IT Applications in Taiwan Construction Firms

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Abstract: Advances in information technology (IT) are promoting corporations in various industries to improve their business process. Electronic business is also a current trend for the construction industry. Before adopting more new information technologies in a construction firm, the decision maker should know the firm's present conditions of IT applications, evaluate its real needs of IT, and find its driving force. However, so far there is no specific methodology applied to measure the level of computerization for construction firms. The purpose of this paper is to develop a methodology to measure the level of computerization for construction firms and apply the methodology to present findings in Taiwan construction industry. The findings show that construction firms' computerization can be divided into five levels. The evolution of five levels is related to the organizational characteristics. The factors that drive the construction firms to adopt IT in business process are also evaluated in the paper. The results of the paper will offer guidelines for construction firms to push ahead with their works of computerization, provide references for government organizations to formulate related policies, and supply a basis for software producers to adjust their R&D and marketing strategies.

Keywords IT applications, computerization, Information system

1. INTRODUCTION

Since the global competition and managerial needs of Taiwan's construction firms, more new information technologies were applied on our business process. Electronic business, such as World Wide Web (WWW), Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Electronic Knowledge Management (e-KM), is also a current trend for this construction industry. Before adopting these new information technologies into a construction firm, the decision maker should know the firm's present conditions of IT applications, evaluate its real needs of IT, and find its driving forces.

However, our understanding of how IT involved in the construction firm is very limited. There was no such survey or research recently and any significant methodology applied to measure the level of computerization for construction firms. What we want to know eagerly is the real condition of the IT applications in construction firms nowadays. So the major objectives of this research are as follows:

- Suggest the indexes to measure the level of computerization for construction firms
- Develop a framework to describe IT Applications in Taiwan's construction firms of nowadays.
- Investigate the factors that influence the construction company to adopt IT.
- Recommend the potential weakness and managerial challenge for managers.

This research focuses on the survey of construction firms' value activities, which were accounting and financing, employees management, cost estimating, procurement, scheduling and cost control, quality management, contract management and material management.

2.LITERATURE REVIEW

COMPUTERIZATION INDEX

There was a macroscopic computerization index from Taiwan Institute for Information Industry. The whole index included company size, average hardware amount and computerization expenditures etc. Singapore also uses an index, such as software develop ability, database usage and IT application field, to investigate their industry 's IT application.

STAGE HYPOTHESIS FOR IT APPLICATION IN ORGANIZATION

The Nolan stage hypothesis (1973) is the most famous one to describe the IT applications in an organization. Based on the study of expenditures for data processing, a descriptive stage hypothesis is presented. It is suggested that the planning, organizing, and controlling activities associated with managing the computer resource will change in character over a period of time, and will evolve in patterns roughly correlated to four stages of the computer budget: Stage I (computer acquisition), Stage II (intense system development), Stage III (proliferation of controls), and Stage IV (user/service orientation). Each stage is described and related to individual tasks for managing the computer resource.

Venkatraman (1994) use a framework that breaks IT-enabled business transformation into five levels. Describes each level's characteristics and offers guidelines for deriving maximal benefits. He suggests that each organization first determines the level at which the benefits are in line with the costs or efforts of the needed changes. Then proceed to higher levels as the demands of competition and the need to deliver greater value to the customer increases.

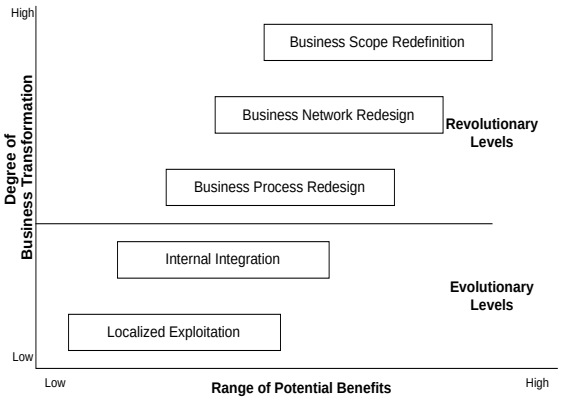


Fig.2-1 Five Levels of IT-Enabled Business Transformation by Venkatraman (1994)

DRIVING FORCES INFLUENCE CONSTRUCTION FIRMS TO ADOPT IT

Mitropoulos and Tatum (2000) investigate the forces that drive construction firms to adopt new information technologies. The investigation identified four forces that drive innovation, which were competitive advantage, process problems, technological opportunity, and institutional requirements. These forces change over time and drive the diffusion of a technology in the industry. The study also found that different organizational characteristics determine a company's sensitivity to each force. They propose a new model of diffusion of new technologies and presents the implications for increasing the rate of innovation in the industry.

SUMMARY AND POINT OF DEPARTURE

The review of the literature resulted in the following observations:

- The macroscopic computerization indexes were only the universal way to evaluate the computer usage. But what we want to know is the level of IT involvement in the organizations.
- Nolan's four stages hypothesis emphasize on the data processing view to evaluate the organization's computerization. Venkatraman's five level framework focuses on the IT enabled not only data processing, but also organizational transformation. Above two are both considered IT application in a company was an accumulated growth and with a sequence.

This research integrated above viewpoints, then developed the index not only reference above indexes, but also considered the IT applied filed and depth in an organization in order to measure

the level of computerization for construction firms on their business process.

3. APPROACHES

The main research activities included the followings:

- Literature review

The first step included an extensive review of the literature on IT applications, stage hypothesis for IT application in company and organization management.

- Data collection

Data was collected by two steps survey through phone and questionnaire (available on request) to identify the level of computerization; interview is also used to find the difficulty when the selected cases adopting IT.

- Data analysis

To identify the level of computerization and each level's characteristic, cluster analysis and chi-square test are used.. There are also lesson-learned from 9 case studies in order to gather more findings.

Cluster analysis is an exploratory data analysis tool for solving classification problems. Its object is to sort cases (people, things, events, etc) into groups, or clusters, so that the degree of association is strong between members of the same cluster and weak between members of different clusters. Group members will share certain properties in common and it is hoped that the resultant classification will provide some insight into research topic. The classification has the effect of reducing the dimensionality of a data table by reducing the number of rows (cases).

- Conclusions and recommendations.

The conclusions summarize the characteristics that managers can use to identify their situation on adopting IT. The recommendations are offered to construction firms, government organizations and software producers.

4. DATA ANALYSIS

Major findings of the survey are summarized in this section. Demographics of samples are discussed first. Then the results are presented next. Through the cluster analysis, all sample construction firms are classified into three computerization levels.

The population of the sampling in the first step is the whole construction firms in Taiwan. 400 firms were selected as samples and surveyed by phone, in which 370 firms responded. The findings show that large construction firms are more involved with IT on their business process. However, most of the small construction firms just use computers on typing documents and have not adopted more IT on their business process.

According to the results of the first step, in the second step 50 large construction firms which were listed on the Top 100 Contractors of Taiwan are furthermore investigated by questionnaire through fax or electronic mailing. 33 firms responded. The response rate (66%) is significantly higher than the 10 to 20% rate usually obtained for this type of survey (Dillon et al. 1994).

DEMOGRAPHICS OF SAMPLES

Fig. 4-1 illustrates a demographic profile of the respondents. Though all the samples are large construction firms, they are still within a wild range in their scope of capital, employees, and business volume.

The operation years of the samples are ranged from 5 to 55 years. As to the computerization experience of these construction firms, 5 to 10 years are the average.

Fig. 4-1 Demographics of Samples

Basic Information	Average	Median	Range
Capital (Unit: NTD)	$1,493,000,000	$565,000,000	0.115~12.761 Billion
Employees	235	193	26~897
Volume (Unit: NTD)	$3,680,000,000	$2,332,000,000	0.30~14.241 Billion
Operating years	28.37	26	5~55
Computerized years	5~10	5~10	0~20

CLUSTER ANALYSIS

11 indexes are applied to identify the level of computerization for 33 respondents. Then a cluster analysis with hierarchical and non-hierarchical techniques is utilized. Through the hierarchical techniques, Ward's method is used, and Euclidean distance is measured. The hierarchical tree shows that the samples could be divided into 3 or 4 clusters. Then when the amalgamation of linkage rule is applied, the result shows that 3 clusters is the best choice to cluster the samples. On the other hand, the analysis by non-hierarchical techniques, K-means method, also separates the samples into 3 clusters. Therefore we got the final result of clustering. The number of each cluster's members and the significant test data were presented as Fig4-2.

Fig. 4-2 The Information of Each Cluster

Computerization Indexes		Cluster1	Cluster2	Cluster3	P-Value[a]
V1	Process Design	3.3125	2.5000	2.4444	0.000**
V2	Computerized Degree	3.2500	4.3750	2.4444	0.000**
V3	Application Level	3.0625	4.2500	2.4444	0.000**
V4	Integration Level	2.2500	3.7500	1.5556	0.000**
V5	Networks Application	2.2500	3.0000	1.4445	0.000**
V6	Operating System	3.5625	4.7500	2.8889	0.000**
V7	Database System	2.2500	2.7500	1.3333	0.000**
V8	Network Hardware	3.6250	5.2500	1.1111	0.000**
V9	Hardware of IT Platform	2.0000	2.5000	1.4444	0.000**
V10	Software developed tools	2.3125	3.3750	1.4444	0.000**
V11	Application Software	2.1875	2.6250	1.7778	0.016*
Members of Cluster		**16**	**8**	**9**	

[a] *=significant,**=very significant

Ducan's significant test is to identify the differences between clusters. The magnitude of the F values from the analysis of variance performed on each dimension indicated how well the respective dimension discriminates between clusters. The test result of Computerization Indexes and 3 clusters is shown on Fig. 4-3. It shows that cluster 2 has the highest scores and cluster 3 has the lowest scores on 11 indexes. We can conclude that there exists a sequence on the level of computerization which was Cluster 2 > Cluster 1 > Cluster 3.

Fig 4-3 Ducan's Significant Test Between Clusters

Computerization Indexes		Duncan Significant Test
V1	Process Design	Cluster 2>Cluster 1>Cluster 3
V2	Computerized Degree	Cluster 2>Cluster 1>Cluster 3
V3	Application Level	Cluster 2>Cluster 1>Cluster 3
V4	Integration Level	Cluster 2>Cluster 1>Cluster 3
V5	Networks Application	Cluster 2>Cluster 1>Cluster 3
V6	Operating System	Cluster 2>Cluster 1,Cluster 3
V7	Database System	Cluster 2,Cluster 1>Cluster 3
V8	Network Hardware	Cluster 2>Cluster 1>Cluster 3
V9	Hardware of IT Platform	Cluster 2>Cluster 1>Cluster 3
V10	Software developed tools	Cluster 2>Cluster 1>Cluster 3
V11	Application Software	Cluster 2,Cluster 1>Cluster 3

THE APPLICATION CONDITIONS ON INVESTIGATED FIELD.

Figs. 4-1 illustrates IT application conditions on nine investigated aspects of the respondents. We could easily find that the accounting and financial affairs are conducted with the most information technologies. The personnel management and cost estimation are conducted second. But on the value activities of construction project management, such as scheduling, cost control and quality management are not conducted with IT very much.

In addition, the results also shows that nowadays the level of IT applications in the value activities of business operation in Taiwan construction firms is between data processing and control, which was illustrated by the average score from the Application Level Index. IT just plays a supporting role in the business process, even has not brought more management functions into the organization yet.

Fig. 4-4 IT Application on Investigated Fields

Investigated field	Computerized Degree	Application Level	Time of Adopting
Accounting and financing	High	High (3.51)	1
Employees management	High	Low (2.28)	2
Cost estimating	High	Middle (2.67)	3
Procurement	Middle	Middle (2.85)	5
Scheduling	Low	Middle (2.41)	6
Cost control	Middle	High (3.14)	4
Quality management	Middle	Low (2.23)	7
Material management	Low	High (2.97)	8
Contract management	Low	Low (2.19)	9

ORGANIZATIONAL CHARACTERISTICS' RELATIONSHIP WITH CLUSTERS

Based on the level of computerization found, the research also identify the relationship between organizational characteristics and clusters. Fig. 4-5 showed the trend of the clusters and characteristics. Company size grows up with the level of computerization. Managers attitudes toward IT also have influence on computerization levels. It seems that when the top manager is more active toward IT application, the higher maturity IT application is whether on the application fields or level. There is also a finding on IT professionals and the level of computerization in departments.

Fig.4-5 Relationship of Organizational Characteristics and Clusters

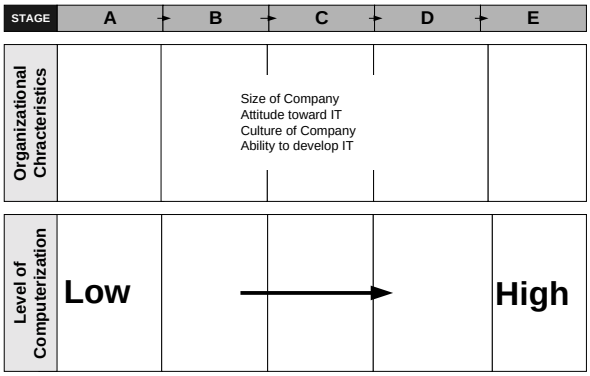
Organizational Characteristics	Cluster 3	Cluster 1	Cluster 2	P-value [a]
Company Size				
Capital	$413,000,000	$791,000,000	$4,025,000,000	0.016*
Employees	108	204	442	0.032*
Volume	$1,358,000,000	$3,245,000,000	$7,028,000,000	0.010**
Attitude Toward IT	Conservative	Active	Reactive	0.001**
IT Professional and Department	None	Just 1~2 Employees	Most have IT Department	0.001**

[a] *=significant,**=very significant

FRAMEWORK SETUP PATTERN

Followed by the statistics results, the research concludes that there is a three-stage development of IT applications through the questionnaire survey in the second step. In addition, there exist a level below the three stages where most small construction firms belong to according to the results of the first step in the survey. Furthermore, for the trend of IT applications in the future, there should exist a higher stage above the three stages. The research proposes a framework as Fig.4-5, in which a five-stage development and evolution of IT applications in Taiwan construction firms is presented. Stage A, B, C, D, E were all concerned with the levels of computerization and organizational characteristics.

Fig.4-6 The Framework of IT Application



CASE STUDY'S LESSON-LEARNED

The research also focuses on nine construction firms to study their development progress of IT applications. Each case could be classified into some stage. Their experience were gathered through lesson-learned and offer helpful guidelines.

5.CONCLUSION

After statistical analysis, and case study, this study concludes the different stages of IT applications in Taiwan construction firms. Table 5.1 shows five groups of distinctive characteristics of contractors: company size, attitude toward IT, application field, process design, and network applications. Table 5.2 shows the major driving forces, potential weaknesses, and management challenges in the different stages of IT applications.

According to the level of computerization as measured and the characteristics as shown, the names were given to each stage, which were Stage A-Initial, Stage B-Supporting, Stage C-Expanding applications, Stage D-Competitive advantage applying, Stage E-Organization revolution.

Major technology management issues in different stages of Taiwan contractors are summarized as:

1. In supporting stage, no standard procedure is the bottleneck of development of information system.

2. In expanding stage, the lack of long-term system planning and uniform data exchange format caused the gap between information system and standard procedures. The efficiency of data exchange is low, too.

3. The competitive advantage stage faces the integration of built information systems of different time. The interdepartmental procedures interfere with independent information system, and duplicated data is stored in different databases.

Most contractors still purchase management software suits as information system for management activities. This research discovers that most software providers design functions based on their own experiences, but the procedures of these management suits did not match the standard procedure of contractors. Therefore, these management suits stay on some basic functions. The major reason of this phenomenon is the short of standard procedure, data exchange standard and uniform material code in Taiwan construction industry.

Most contractors will put knowledge management as their first option in their next software system. In last decade, Taiwan contractors start to put more effort on document management and information exchange. After case data and construction method information is accumulating, how to utilize these documented experiences is the major management issue in Taiwan. Some major contractors start to evaluate the feasibility of Enterprise Resources Planning (ERP), because this new information technology can help contractor to integrate independent information systems inner-organization and to apply on resources planning of different project.

Nowadays most Taiwan contractors still stay on the supporting stage and expanding stage. The standardization of process procedure is low; the benefit of information system is only on information processing, not to help enterprises to integrate the management functions and to enhance the management performance. This drawbacks comes from the construction automation is focus on independent construction activities or single management function, without organization-wide process revolution.

Table 5.1 The Distinctive Characteristics of Contractors in Different Stages

Stages	Distinctive Characteristics				
	Company Size	Attitude Toward IT	Application Field	Process Design	Network Application
A	Small contractors	Passive	Document edited	No standard process.	No network's link.
B	Traditional small contractors	Conservative	Accounting, financing and management of employees support activities.	Ambiguous process	Start to link to internet.
C	Medium contractors (Most part of them are contractors of conglomerates)	Start to be active	Cost estimating, procurement primary activities, which were involved with transactions.	Processes were standardized and parts of them were computerized.	Set up LAN & company's homepage
D	General contractors	Active and search for competitive advantage	Scheduling and cost control primary activities, which were core activities of project management.	IS could reflected part of business process.	LAN was completed and start to develop WAN with project participants
E	Medium and General contractors	Reactive, also search for competitive advantage	IT applied in business process.	Processes were redesigned and all applied with IS.	Integrate LAN, WWW and WAN. Adopt Web-based Project management site and build up enterprise information portal etc.

Table 5.2 The Major Driving Forces, Potential Weaknesses and Management Challenges of Construction Firms in Different Stages

Levels	Major Driving Forces	Potential Weaknesses	Management Challenges
A	Client requirement	Data are hard to reuse	
B	Process Problem Operation needs	Users' resistance of IT	Identify high value areas and process institutionalize
C	Process Problem Management needs	Lack on planning of IS	Focus on business process interdependence and technical interconnectivity.
D	Competitive Advantage	Difficult on integration of IS	Recognize that organizational issues and challenges are far greater than selection of the technology.
E	Competitive Advantage	Communication with participants	Articulation of the firm's strategy for business network redesign.

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