A Cognitive Approach to IS Requirement Analysis: Mental Model Building from Case Study

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***Abstract*—Determination of requirements is critical for development of a new information system prior to the IS design. A good system design not only fulfills user needs, but is also a required concern for specific and future development in industry. Past researches show many tools have been introduced to generate information system requirements; however, they lack cause-effect relationships among factors. The purpose of this study is to identify system requirements and their cause-effect relationship determination process to serve emerging needs. The goal of this study is to assess potential organization needs in order to get a better foundation for system development and effectiveness. Case study and mental models approach were used to demonstrate the relationships between the requirements for a new system. The results indicate leading vendor effect, management support, and user needs are important for system development. These findings should heighten organization information systems selecting and investment decisions.**

***Index Terms*— System requirements determination, System development, Case study, System effect, Mental models**

I. INTRODUCTION

In a competitive environment, organizations have been permeated information investments (IS) to create their productivity and increase competition advantage. The contribution of IS is as competitive weapon to increase organizational effectiveness and efficiency [1]. It has been reported that more than 50% IS executives believed IS could increase their work performance [2] because they realized the benefits of IS and expected to have a good return from IS [3, 4]

However, since then the role of IS has changed from merely a tool of process data and recall transaction, in turn to affect firms' services and internal processes, reduced workforce, provides resource control, and supports decision making to create business value, increase profitability, and enlarge the competitive advantage [5]. Thus, it is important for organizations to meet the challenges of IS and understand their system objectives.

American firms spend nearly $1.8 trillion on software, hardware, and telecommunications equipment, although only 35 percent of software projects are categorized as successful in satisfying user system requirement [6]. Numerous researchers have suggested that system failures are due to lack of clear and specific information requirements; insufficient, inaccurate, and outdated information [7]. Therefore, it is vital to understand an organization's objective in order to determine correct and complete IS requirements determination prior to IS design.

IS requirement specification is used to understand an enterprise's needs for internal and external environment for system implementation [8]. If organizations have a clear and unambiguous understanding of IS requirement and design, then these organizations can better utilize resources dedicated to the relevant process to increase their performance and competition. Essentially, a complete and accurate specification of IS requirements analysis is the critical ingredient process to serve emerging needs. Besides, correct information requirement understanding can enhance organizational capabilities with suppliers, customers, and rivals, resulting in improved quality and customer satisfaction.

IS requirements analysis has received special attention from MIS researchers. There are many techniques used to get information requirements determination [9]. Unfortunately, most requirements determination methods only focus on technical concerns and produce a "standard" system [10]. Thus, the task will become formidable when requirement analysis is under routine and well-structured system design [11].

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TABLE I.
Time – Event Array of MYT System Development History

Time period				
	Jan, 1992- Dec, 1995	Jan, 1995 – Dec, 1997	Jan, 1998 – Oct, 2006	After Oct, 2006
Entire company	✧ Company Established ✧ Paper work ✧ No information system ✧ Traditional business thinking	✧ Demand analysis ✧ From paper work to computerize ✧ Newly thinking of business	✧ All of the business computerize ✧ Business increasing ✧ Simplify workflow ✧ Joint B university Incubation Center ✧ Industry-Academy cooperation ✧ Planning a new Integrated IS system	✧ Attempt create new international market ✧ Attempt to reform the closed industry ✧ Accept new thinking ✧ Integrated IS system ✧ Data transfer and management from Internet
Department of Information		✧ Employ a new IS analyst ✧ Analysis industry needs ✧ Developing IS	✧ Create new IS ✧ IS Analyst resigned ✧ No one develop IS stopped	✧ Planning development IS by their self to replace an old one ✧ Integrate heterogeneity database system
System user		✧ Education Training ✧ Start using IS	✧ User modified original system	

A good system design not only satisfies user needs in a given environment, but also needs to consider future development to pit against uncertainties as to its actual value. Many tools were developed to elicit information requirement in IS literature research [11]. However, they all lack an overall view of IS requirement factors relationship representation.

The goal of this study is to establish an understanding of organizational information processing needs, in order to achieve the objective of the organization. We seek to go beyond the normative model produced. Instead, we focus on individual perceptions of how requirements determination is found. Specially, the study proposes a combination of a real-life case and uses a mental model approach to demonstrate the linkage of organizational environment change when an old system is insufficient, and which stimulates the need for an integrated IS.

II. Literature Review

The development of IS should consider customer needs. Mental models focus on the "user view" of functional requirements [12] and non-functional requirements, such as the interoperability with other systems or the viability of the vendor [13]. In fact, non-Functional Requirements are rarely treated as ''first-class" elements as Functional Requirements in software development [14]. However, non-functional requirements play a critical role when software architects need to make efficiency, usability, portability, or integrity determination decisions. As previously, mental models that best satisfy both the functional and non-functional requirements.

Norman [15] defined mental models as "what people really have in their heads and what guides their use of things". Mental models have substantial support in the cognitive psychology literature [16]. Furthermore, mental models are conceptual model and the main theory for understanding how humans reason deductively with given information through construction, combination, and elimination [17]. Most importantly, mental models represent the causal relationships between various factors or events, as the representations of a system [18], and a "picture-like representations" [16]. Thus, a mental model is a sort of "mental diagram" that contains "mental images" [19].

In view of cognitive psychology, a mental model is a cognitive phenomenon [16] and an internal scale-model to build knowledge from prior experience, schema segments, perception, and problem-solving strategies to make decisions in novel circumstances [20]. From this elicitation technique, we can understand users' innate information processing activities and decision processing [9].

Users' mental models are a combination of users' beliefs and their perception of how system works. Norman suggests an interface designer had better include users' mental models and conceal the system model to guide a user from novice- to expert status. Davidson's [20] study proposes that mental models play as an important role in human-computer interaction (HCI), especially in improving users' usability.

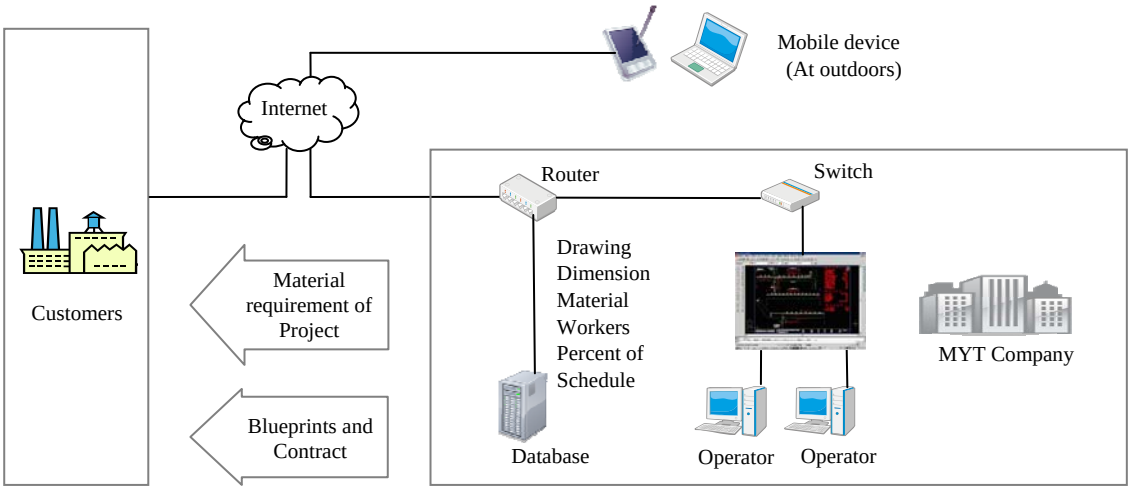

Figure 1. MYT Proposed Integrated System Process

Mental models have been successfully applied in IS [21] and HCI [22]. Davidson et al. [20] propose that mental models play as an important role in HIC, especially in improving usability. Mental model diagrams are a network of associations between domain concepts that lead people through reasoning problems [23]. For example, Vandenbosch and Higgins [24] study used mental models to investigate the relationship between information acquisition and learning in executive support systems (ESS). Many studies note mental models are constrained by people's background and previous experiences with similar systems, which in turn, continue to enforce or change to form workable results.

III. Research Methodology

Case study is a well-accepted approach to understand complex phenomena of technology implementation in organizations [25]. In addition, the case study method provides rich information and good insight into phenomenon, to discover causal links or reasons.

In this study, we adopted a real case to present an overall understanding of the past system use and new system requirements analysis decision. Furthermore, we also draw out a mental model to represent the interrelationship among IS requirement factors.

A. Case Study Background

The research study reported in this paper was conducted at MYT Company (a pseudonym), a telecommunication engineering company in Taiwan that was founded in 1992. At the time of study, there were approximately 100 employees. The company offers a variety of services in telecom wire-line construction engineering, wireless communication engineering, and surveillance transmission systems, etc. Formosa Telecom Incorporation (FTI) (another pseudonym) is their biggest business customer.

The company has individually developed a Telecom Engineering Graphing-Aiding system using AutoCAD at its core. The Graphing-Aiding system can directly calculate the items of different works and quantities of used materials, after the engineering wiring diagram design has been completed. By providing a speedy estimation of engineering materials–in-use and cost, it can enhance the efficiency of the case-taking capability of the company.

However, since business was growing fast, intense competition, and the result of market changes, a data integration problem emerged. The existing system cannot accommodate other Internet-relevant functions, network, or relational data structures. Moreover, the company continues to grow and various engineering constructions are always taking place at more than 10 work sites simultaneously. Therefore, MYT needs a single integrated data structure to meet its varied needs. It is necessary to have a new IS to increase working efficiency.

In order to control adequately the engineering progress and quality at different work sites, MYT managers want to build up an integrated enterprise system (see Figure 1). In 2003, MYT was allied with a university in Yunlin County (Taiwan) to provide education training for their employees. The purpose of the university–industry collaboration was to enhance employees' ability to use global networks and databases.

The managers hope the new integrated system can concurrently integrate the project data across different sites and have real time control, accurate, and well-integrated data to increase organization's competitive advantage.

B. Data collection

Our data gathering included three processes: (1) interview, (2) coding, and (3) triangulation analysis to conduct theoretical propositions [26]. In this case study, we used interviews and documentary materials as the primary source of data [27]. Interviewees were asked to respond on MYT' system use history, current events at MYT, and their involvement in the integrated IS

TABLE II.
Axial Codes And Open Codes

No	Axial codes	Open codes (illustrated some examples)	
1	User needs (UN)	(1) Our work need graphing –aiding system (2) Need online (3) Project control	(4) Ability to automatically processing (5) Control workflow (6) Integration
2	Integrated Platform (IP)	(1) A integrated framework (2) Ability to integrate data with Accounting department	(3) Databases integration problems
3	Management Support (MS)	(1) Top manager support (2) To solve business problems and develop appropriate IS	(3) Electronics business
4	Enterprise Vision (EV)	(1) To enlarge market shares (2) To have a database center	(3) Build up a data management center
5	Leading Vendor Effect (LVE)	(1) Our biggest business customer (2) Any change because Formosa Telecom Incorporation requirement	(3) Cooperation with Formosa Telecom Incorporation
6	Industrial Character (IC)	(1) Domain knowledge (2) Industry specific	(3) Specify industry needs in information system
7	Information Technology (IT)	(1) Auto LISP/Auto CAD (2) Visual Lisp	(3) Accounting system, Telecom system, and other application system must be compatible with FTI
8	System Development (SD)	(1) Three big sub-system (2) Planning (3) Outsourcing	(4) System life cycle management (5) Design (6) Cooperation with university
9	Education Training (ET)	(1) Education training (2) Two weeks can train a novice employee	(3) One month training (4) University-industry collaboration in training
10	System Effects (SE)	(1) Save time (2) Increasing efficiency (3) It is helpful of computerization	(4) Can deal with more work loads (5) Easy to accomplish assignments

requirements decision. The interviews were audio taped and transcribed to preserve details of language use.

We conducted private interviews with each of the four informants, including one executive manager, two system users, and one system manager. All interviews were taped and transcribed verbatim. One of system users had 15 years experience of IS implementation in the company. The executive manager and system manager both had university degrees.

The interviews questions were a semi-structured protocol and started with *"What requirements you think are important and will affect the new system design development in your organization?"* Furthermore, we used the principles of methodological triangulation to prevent the researcher's biases from blocking important data. Thus, data collections process was from multiple sources and accompanies with a time-event matrix chart in Table I. Therefore, our data collection was geared toward understanding under what circumstances a new system adoption occurs.

C. Data Analysis Methodology

Following Yin [26] and the grounded theory approach, our data analysis began by coding data which responded to the interview questions. Grounded theory is an important method in qualitative research and is an iterative process that included the following steps: (1) open coding, (2) theoretical coding, (3) selective coding [28].

Coding is the major sorting strategy and its purpose is to break up the data and re-categorize the data for comparison between different categories [28]. Consequently, it helps to develop theoretical concepts. During the coding process, specific key points are identified as "*open coding*". Second, these same semantic notions of codes are grouped together to form a category, named theoretical coding step, as "*axial coding*". Simultaneously, tentative relationships are developed between these axial codes. As relationships emerge, theoretical propositions are designated as "*selective coding*".

D. Reliability and Validity

Validity and reliability are more difficult to address in qualitative studies than in quantitative studies [29]. In this study, we used multiple sources of company documents and interviewed key informants as validity concerns [26]. Case descriptions were written and reviewed by all informants to reduce any errors and biases.

All that data collection was from different sources and places, methods, and researchers. As Guba and Lincoln [30] stress Triangulation method is the only possible way to exclude the possibility for misunderstanding participants' intentions or viewpoints.

E. Principles of Methodological Triangulation

The principles of methodological triangulation are a popular qualitative research method [31]. Triangulation has risen as an important methodology in qualitative approaches to control bias and establishing valid propositions [32]. The Triangulation method requires

TABLE III.
Proposition table

	Proposition	Example
1	***Leading Vendor*** has influence on ***Industrial Character***	"Generally speaking, we are doing most of business related to FTI."
2	***System Development*** has influence on ***System Effects***	"Like before, the geographical information system developed by university students, which sensuously is relatively superficial from the sales point of view, does not really meet the requirements." "…doing analysis, these outcomes are really what we need."
3	***Education & Training*** has influence on ***System Effects***	"After the training class, people are able to begin operation; however, people need to fumble about by themselves. After two or three days of training, people can on the production line. … In fact, we become busier and boss is happy…"
4	***System Development*** has a positive effect on ***Integrated Platform***	"There is room for improvement and analysis…..After the direction has been set, we plan a framework that could be brought into system integration"
5	***User needs*** have a positive effect on ***Integrated Platform***	"We mainly expect to do the integration of our systems through this plan, and, to tie in with the network communication to achieve the remote control effect; integrating the sales business like wire lines, installation, conduits etc. As for the overhauling….."
6	***Industrial Character*** has influence on ***System Development***	"….From our point of view, we do the analysis…" "The type of thought process that we use is to understand first, then to go forward with the analysis, because our (business) belongs to a relatively professional territory."
7	***Information Technology*** has a positive effect on ***System Development***	"…Auto List, honestly speaking, this is a technology of very old days, if with relatively new thinking, we use VISIOLISP to plug in. However, the problem is that they have been using the system for so many years, so it is difficult to go for an overhaul."
8	***User needs*** have influence on ***System Development***	"Understanding the system requirements, to make an analysis of the positives or negatives of the original system…."
9	***Enterprise Vision*** has influence on ***System Development***	"….is the cooperative mode of university-industry collaboration. It is benefit to students because it could become a way leading to students' future career. In the future, what I want to build up a data management center; it will be of a network type. We expect to take up more of the sales business from FET (Fareast Tone) etc. As a matter of fact, we have already undertaken quite a bit of their sales business. '
10	***Leading Vendor Effect*** has influence on ***System Development***	"The reason why we make a change is mostly to respond to customers' demands. So if FTI makes any changes, we will have to do a revision." "Sometimes the ways we use to process the business is more time-saving and labor-saving. However, because of the (working) pattern due to customers' original system, we must work coherently with those more sluggish ways to process the business…."
11	***Management Support*** has influence on ***System Development***	"Our structure demands are just like this. It depends on what type of skills or scientific technology we adopt, or if we are making a trial move; we are willing to go for a trial."
12	***Management Support*** has influence on ***Enterprise Vision***	"….In this way, we also expect to work out a system framework that could make a system processing to exploit sales market."

researchers complement varied methods to gather data in order to avoid researcher's bias.

In this research, Triangulation method was performed to enhance the reliability and validity for research analysis. Triangulation method includes (1) method triangulation (2) data triangulation (3) analysis triangulation [33].

1. *Method triangulation*: During the process of this research various and different data collection methods were used (e.g. interview, observation, and documentation) for cross validation to confirm consistency.

2. *Data triangulation*: Two system users and manager were interviewed at different times to understand relevant problems through different interviews.

3. *Researchers triangulation*: A reliability test was done as follows: We had four people doing coding of the interview. If two or more of the four people came out with the same coding, then we used the codes with common recognition. However, if only one person came out with coding which proved different from others, then it was used as independent unique coding. This independent coding should be discussed whether it should be added to the coding.

IV. Analysis and Results

According to the data analysis, four coders agreed on 123 of the 159 participant responses, to give a reliability of 77.4%. The agreed codes were used in the subsequent analysis. There were 36 independent unique codes. It is worth noting that when we refer to relevant concepts, different people may have not really have used the same primitive wording. Thus, in order to build up the consensus among different people, modification of coding was made in the course of validating.

This research has gone through full discussion and been modified by removing the researcher's own independent unique codes in order to reach a consensus.

Using the approach described above, all open codes were categorized into 10 axial codes. The data analysis has gone through the process of categorizing into ten axial codes: *User needs, Integrated Platform, Management Support, Enterprise Vision, Leading Vendor Effect, Industrial Character, Information Technology, System Development, Education Training, and System Effects* (Table II). According to the verbatim transcript we conduct 12 propositions (Table III) and draw up a proposition relationship matrix (Table IV). In the case study, we draw on a visual diagram to make sense from contextual information and to ascertain the IS requirements determination (Figure 2).

Obviously, we can see from Fig. 2 that *system effects* are influenced by *system development* and *education training*, and the system development is influenced by another six factors (*user needs, management support, enterprise vision, leading vendor effect, industrial character, and information technology*). However, *user needs*, *management support*, and *leading vender effect* not only directly influence *system development*, but also influence other factors. From a management perspective, these factors are major influences on *system effects*, thus, these factors are more dominant than others in IS management. For example: *user needs* not only influence *system development*, but also influence *integrated platform.* In addition, *management support* influences *enterprise vision*, and *leading vender effect* influences *industrial character.*

TABLE IV.
Proposition relationship Matrix

→	SD	SE	LVE	IC	MS	EV	IT	UN	IP	ET
SD		●							●	
SE										
LVE	●			●						
IC	●									
MS	●					●				
EV	●									
IT	●									
UN	●								●	
IP										
ET		●								

Note: → means direction

Information requirements determination is the most crucial phase in information system development in any successful IS implementation. Moreover, end-user satisfaction is a critical success factor for application development in any successful software implementation [34]. Based on an analysis of the case descriptions, *user needs* is the drive to influence *system development* to meet users' requirement and expectation. This finding is consistent with Smart and Whiting [35], increasing complexity of technology requires an awareness of customer need and their interaction with the system. In this case, system users need an integrated system instead; therefore, system development will focus on this concern.

Our case study results indicate *management support* has influence on *system development which*, in turn, influences *system effects*. *Education training* also influences *system effects* (Figure 2). Organizations provide employees with training geared toward their specific perspectives and objective. Some researchers propose that training and management support are critical strategies of system development [36]. In addition, Alter [37] classified obtaining management support and meeting user needs as basic system development strategy.

Organizational environments are not homogeneous but have differing degrees of uncertainty. Our results show that the leading vendor has an impact on the IS design and development. In addition, FTI is the biggest business customer of MYT, and tasks must be in cooperation with FTI to fulfill their requirements. Therefore, MYT's system development must take these into their system

requirement concerns in order to reach system effectiveness.

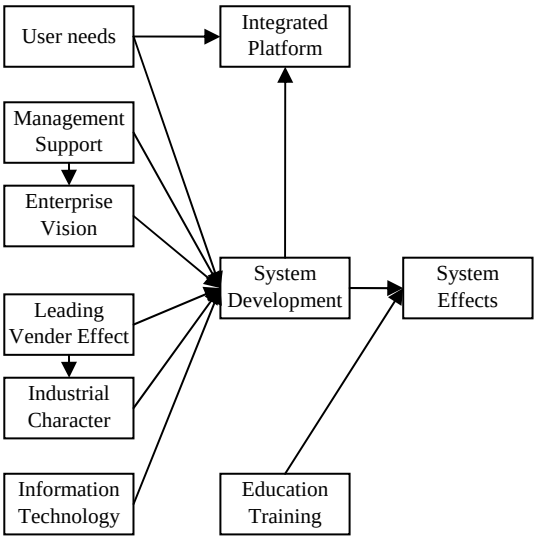

Figure 2. Association Chart of Axial Propositions

In today's competitive business environment, organization should have a whole *enterprise vision*. In the enterprise vision, managers should provide a large amount of planning information, industrial specific and future-oriented trend. Consequently, enterprise information technology must manage and cope with the integration and collaboration within and across functions to increase system efficiency.

FTI is MYT's dominant buyer, but it is also the leading vendor in the Telecom industry. Therefore, a successful and unique customer-vendor relationship is necessary depending upon organization goals. Furthermore, the new IS must also reflect the needs of the leading vendor to maintain organization development. This has important implications for managers in terms of determining an appropriate system decision.

V. Conclusion

Information requirement determination is an important step in MYT's new system development processes. Effective IS requirement analysis thorough user information is needed prior to IS design and implementation. This article presented a case study as an initial elicitation step to gain domain concepts for adopting a new system decision. After that, a mental models approach was used to acquire conceptual structures to identify cause-effect relationships of IS requirement. A good qualitative study can help to understand a situation to be neither enigmatic nor confusing.

There are ten factors influencing the development of the company's system design requirement and a clear cause-effect factors interrelationship is associated. The study results show combining case study and a mental model approach to draw on the diagram of information requirement decision processing can get a better insight of users' concerns and find a more objective way of arriving at a decision. From the case results, we know IS users' job functionality is the key driver developing IS objectives. Good system efficiency can help system users accomplish their work and get users satisfaction. Users satisfaction will increase organization's net benefits, systems use, and job satisfaction.

From the perspectives of organization development, system replacement and implement is the pillar of strategy. This study provides a high degree of in-depth understanding of system requirement diagnostic decision activities. In addition, the study results indicate that good understanding of usable systems design build IS development and should meet origination's work domain, goals, tasks and need, objective and expectation.

Although this paper proposed the leading vendor role and industrial character effect the new systems requirements development, it is still at an exploratory level of a case study. Further extended research in this paper should be complemented by theoretical advancements and extensive empirical studies.

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