ADOPTION AND DIFFUSION OF DATA WAREHOUSING TECHNOLOGY: A SYSTEM DYNAMICS APPROACH

By

Arunee Intrapairot
E-mail: intrapairota@cbs.curtin.edu.au

Mohammed Quaddus
E-mail: Quaddusm@gsb.curtin.edu.au

The Graduate School of Business
Curtin University of Technology, GPO Box U 1987
Perth 6845, Western Australia

ABSTRACT

This study initially employs multiple criteria decision making (MCDM) to evaluate and prioritise technological alternatives with the potential to fulfil the vision and objectives of one of the largest banks in Thailand. The study results reveal that the predominant preferred technology is data warehouse (i.e. a central source of data that has been extracted, standardised and integrated from various operational databases in support of management's decision-making processes). Subsequently, system dynamics (SD) is employed to elaborate the diffusion model of data warehouse. The model is developed to identify the present state and the constraints of this technology. Then, strategic policies are proposed to detect those that may diffuse the technology most fruitfully and productively. The five main factors that drive the diffusion rate are: training as an instrument in creating knowledge workers; the co-operation between IT departments and key users; decrease in perceived complexity; top management support and increased positive features of technology.

1. Introduction

Banks are under pressure to adopt new technologies and make changes in existing technologies. Bank investment in technologies aims at providing increased benefits to customers (e.g. convenience, security improvements, better access to information and an alternative to cash) while concurrently anticipating direct and indirect returns from such investment (e.g. increasing profit, achieving a sustainable competitive advantage, creating new business opportunities, enhancing business performance and trimming costs).

When new technologies are adopted, bank managers have to put in great effort to diffuse them quickly, enterprise-wide or throughout customers, to avoid prohibitive costs due to the high obsolescence rate of evolving technology. Since technologies are available in plenty for banks to adopt, careful planning is vital for the success of technology adoption and diffusion. Without an appropriate plan, technologies may be under-utilised, wrongly utilised or may totally fail (Quaddus, 1995).

This study initially employs multiple criteria decision making (MCDM) to prioritise technological alternatives in one of the largest banks in Thailand (i.e. the Siam Commercial Bank, Pcl – SCB). Then, system dynamics (SD) is incorporated with MCDM to create a

dynamic approach to the problems and interrelationships among variables regarding technology diffusion. These two decision tools are considered useful in helping decision-makers select and make use of technology effectively.

2. Technological Adoption

Banking technologies have been in effect since 1980 in the form of electronic banking and home banking services. Electronic banking authorises customers to make financial transactions via ATMs and EFTPOS (i.e. Electronic Fund Transfer at Point of Sales), whereas home banking services allow customers to get access to the banks via communication devices (The Australian Government Publishing Service, 1995).

Currently, bank managers consider that numerous advantages are to be gained from technological investment and development of integrated technological infrastructure. However, it is also clear that, given risk factors, not all banking technologies bring about a good return on investment. Therefore, many banks have begun to integrate their IT strategic planning with business and market plans in order to maximise utility of invested technologies (Earl, 1987; Manross & Rice, 1986).

Multiple criteria decision making (MCDM) is suitable to be employed in the technology adoption phase because it helps decision-makers evaluate and prioritise competitive technological alternatives that can enhance the achievement of the business goals of an organisation.

MCDM is an approach that takes explicit account of multiple, conflicting criteria in decision making. It helps decision-makers understand a problematic situation, and thus make appropriate judgements leading to better decisions (Belton, 1990).

Building a multiple-criteria model requires two main fundamental stages; structuring a problem and eliciting information and values (Visual Thinking, 1995).

Structuring a problem: At this stage, decision-makers initially set an objective (or problems) that they try to achieve or resolve. Then, all alternatives that can be a potential solution are proposed to evaluate under a set of certain criteria. For example, the Siam Commercial Bank, Pcl. (i.e. SCB) has the vision of being "*the best managed bank with sustainable excellent performance*" as its main objective. The bank deploys many progressive technologies such as smart cards, data warehousing, video-conferencing, Internet/Intranet banking and EFTPOS to fulfil its objective. These technological alternatives have been evaluated, for the purposes of this research, under the same criteria.

The identifying criteria are structured hierarchically into two levels; high and low level criteria. High level criteria involve the main issues that are taken into account whenever the bank adopts new technology. These criteria may comprise relative advantages, features of technology, bank environments, customer behaviour and economic situation of the nation. On the other hand, low level criteria include specific issues detailed from those main criteria. For example, relative advantages are elaborated into increased sales, increased market share, more accurate and timely information and improved decision making, for instance. All the criteria are structured in hierarchy as indicated in Figure1.

Figure 1: The hierarchical criteria for technology adoption
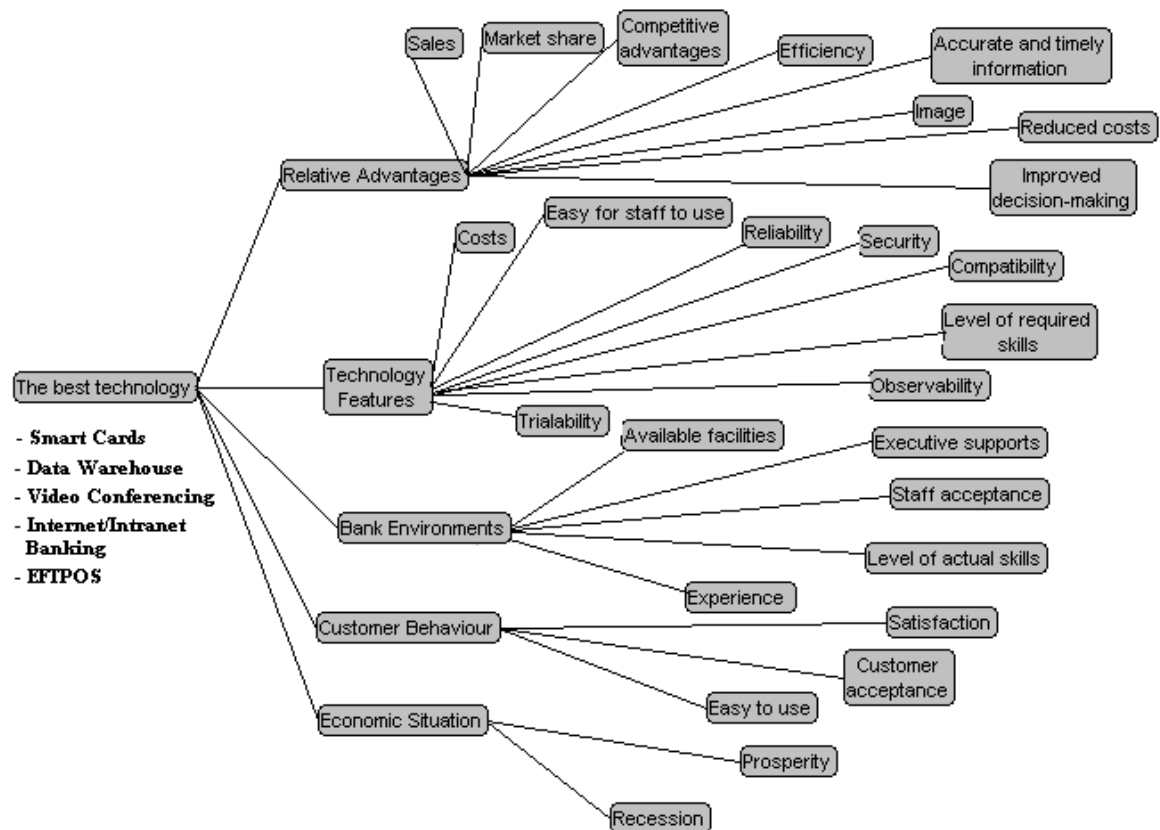
Eliciting information and values: This stage is to determine the "relative importance" of the specified criteria (i.e. weighting) and then to evaluate the performance of alternatives against each criterion (i.e. scoring).

Initially, the bank respondents weighted both the high and low level criteria in order to indicate the level of importance of each criterion. Then, all the alternatives were scored against the specified consecutive criteria. The scores are entered on a 0 to 100 scale, where a higher value represents a more preferred outcome. For example, based on a criterion of increased sales, if Internet banking is determined to be the best technology a score of 100 is assigned. On the other hand, video conferencing, which does least well, is assigned a score of 0. All other alternatives are given intermediate scores, which reflect their performance relative to these two end points.

Finally, MCDM using the V.I.S.A. software application (Visual Thinking, 1995) prioritises alternatives, revealing data warehouse to be the dominant preferred technology.

3. Data Warehouse

A data warehouse (DW) is a central source of data that has been extracted, standardised and integrated from the various operational and management databases of an organisation. It is designed as a subject-oriented (i.e. customer, product oriented), integrated, time-variant, and non-volatile collection of data in support of management's decision-making process (Inmon & Hackathorn, 1994; O'Brien, 1996).

Intense competitiveness is the key factor that triggers investment in this technology. Organisations require DW because data from operational applications are not suitable for providing information for decision support system (DSS) processing. The use of DW provides greater accuracy data through elimination of redundancy, improves efficiency through timely access to information and enhances more effective decision making. Additionally, DW supported by pattern analysis and query tools may reveal a hidden structure in a massive pool of data of an organisation, which in turn can be used for mass customisation and detecting business opportunities (Lambert, 1996).

The SCB has introduced and implemented the data warehouse based on a customer management system since 1995 and expects completion in 1998. Data are integrated from banking operational environments and many disparate bank databases. Many advantages are anticipated, such as improved internal banking processes (paperless), minimised costs and time, increased sales through effective customer segmentation, targets and product strategies, more effective decision making and capturing of business opportunities. These will lead to increased competitive advantages and sustainable growth (The Siam Commercial Bank, 1995; The Siam Commercial Bank's Staff, 1998).

However, the potential benefits from DW are still considered low, intangible and inconclusive, and projects take longer than expected. Furthermore, many DW projects fail even before full implementation. The failures are viewed as a huge resource-consuming project lacking any significant economic returns (Horrock, 1996; The Siam Commercial Bank's Staff, 1998).

Therefore, to promote a better understanding, a diffusion model using a system dynamics (SD) approach is proposed to identify the present state, detect constraints and test strategic policies, thus facilitating diffusion of technology more fruitfully and productively.

4. The conceptual model of data warehousing technology

The development of the conceptual model is based on the qualitative system dynamics approach. The model is divided into four stages: basic concept, present state, identified constraints and the redesign of strategic policies (Coyle, 1996; Wolstenholme, 1994).

The basic concept in Figure 2 depicts the main simple core concepts of data warehousing technology for the purpose of promoting a better understanding and facilitate communication with the bank executives who have little backgrounds in system dynamics. The present and defined constraints illustrate the combined ideas, perceptions and explanations of the bank staff and those of previous literature reviews (Inmon & Hackathorn, 1994; Kelly, 1994; Maier, 1996; Saeed, 1990). Strategic policies are proposed by capturing the highlighted policies suggested by the SCB's executive staff.
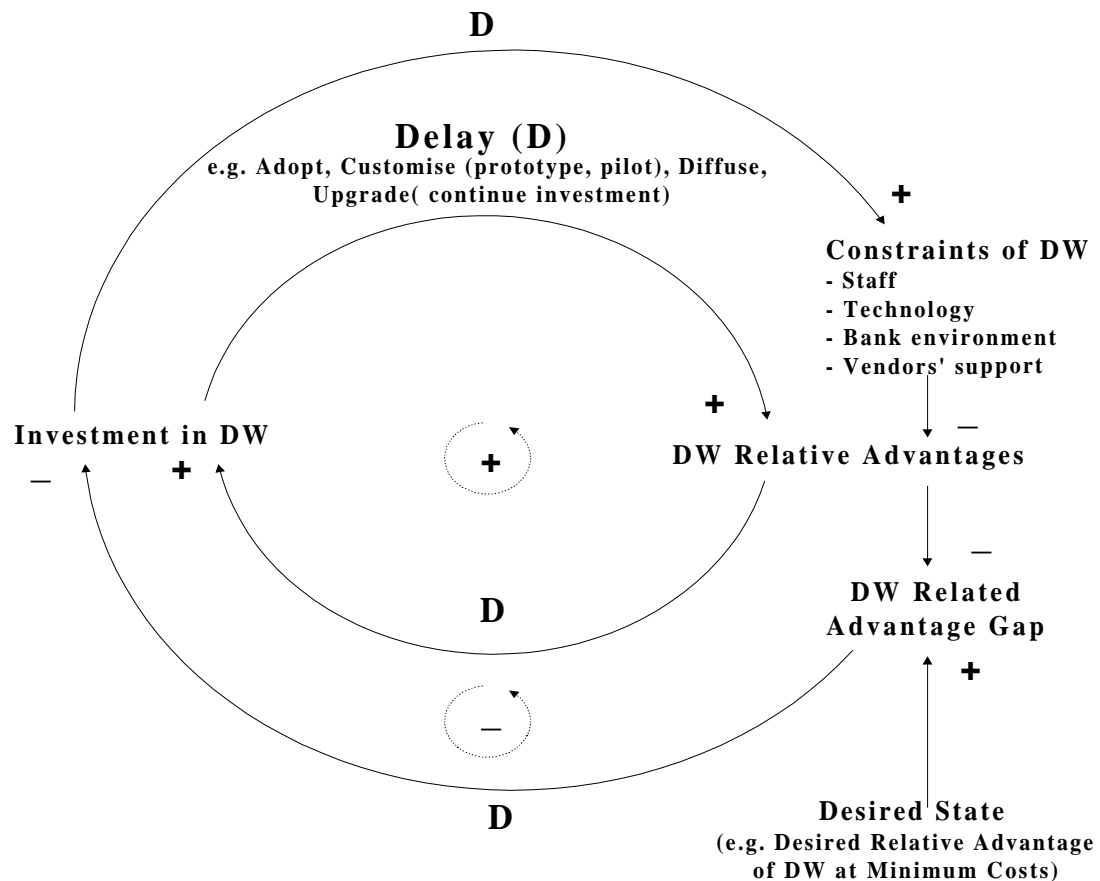
4.1 Basic Concept

The basic conceptual model of the data warehouse is presented in Figure 2. The bank has invested in DW to gain relative advantages. The identified advantages are accurate and timely information, more effective decision making, increased performance efficiency, improved access to information (for loan underwriting, for internal management and for strategic planning), capitalising on business opportunities and mass customisation. These benefits tempt the bank to enlarge its technological investment. However, concurrently, the bank is confronted with constraints, either from the technology itself or its own readiness (e.g. levels of

knowledge of bank staff, limitations of technology, and insufficient support from vendors). The constraints drain relative advantages and expand the gap between the desired and actual advantages, leading to decrease in additional investment.

Two main loops (positive and negative) are depicted. The variables in the negative loop represent the impediments to the bank in obtaining high leverage from its investment.
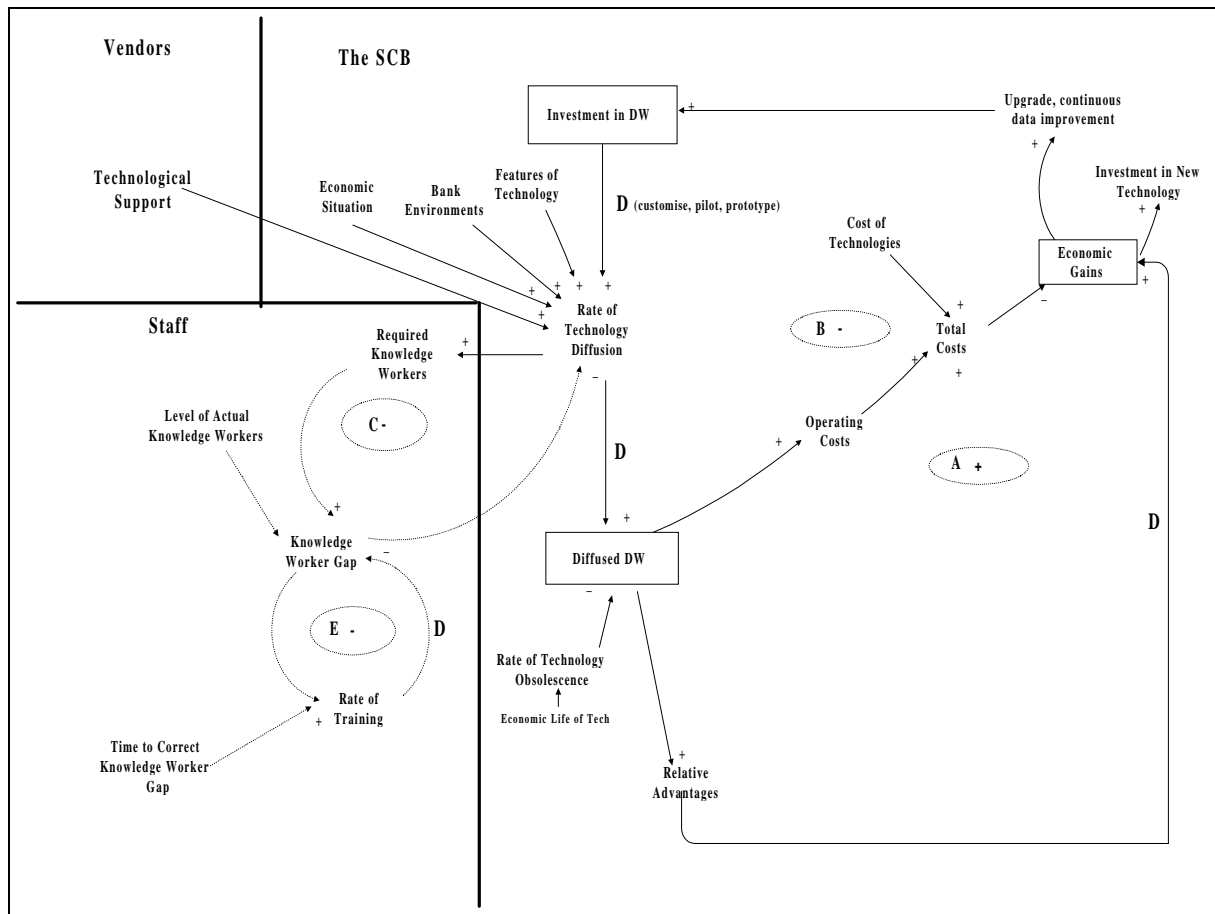
Figure 2: The Basic Conceptual Model of Data Warehouse

4.2 Present State

The model divides organisational boundaries into three sub-sectors (i.e. the bank- technology group as agent of change, bank staff, and vendors) and elaborates the basic concept upon four feedback loops (as illustrated in Figure 3).

Figure 3: The Present State of Data Warehouse

Positive feedback loop A: Investment in data warehousing technology impels the bank to enhance the usage of this technology throughout the organisation in order to maximise relative advantages leading to economic gains. Economic gains induce additional technological investment.

Negative feedback loop B: Adopting and diffusing technology consume excessive resources for purchase and operation. The costs of DW lessen the prospective gains from this technology.

Negative feedback loop C and E: Diffusing DW requires an increase in the number of knowledge workers and subsequently widens the gap between actual knowledge workers and those required. Since the gap hinders the diffusing process, the bank has to provide training or educational programs to bridge the gap.

4.3 Identified Constraints

Based on the literature reviews and personal communication with the bank staff, the present state of the conceptual model is expanded to identify constraints and capture additional feedback loops. The details are illustrated in Figure 4.

Figure 4: Identified Constraints of Data Warehouse
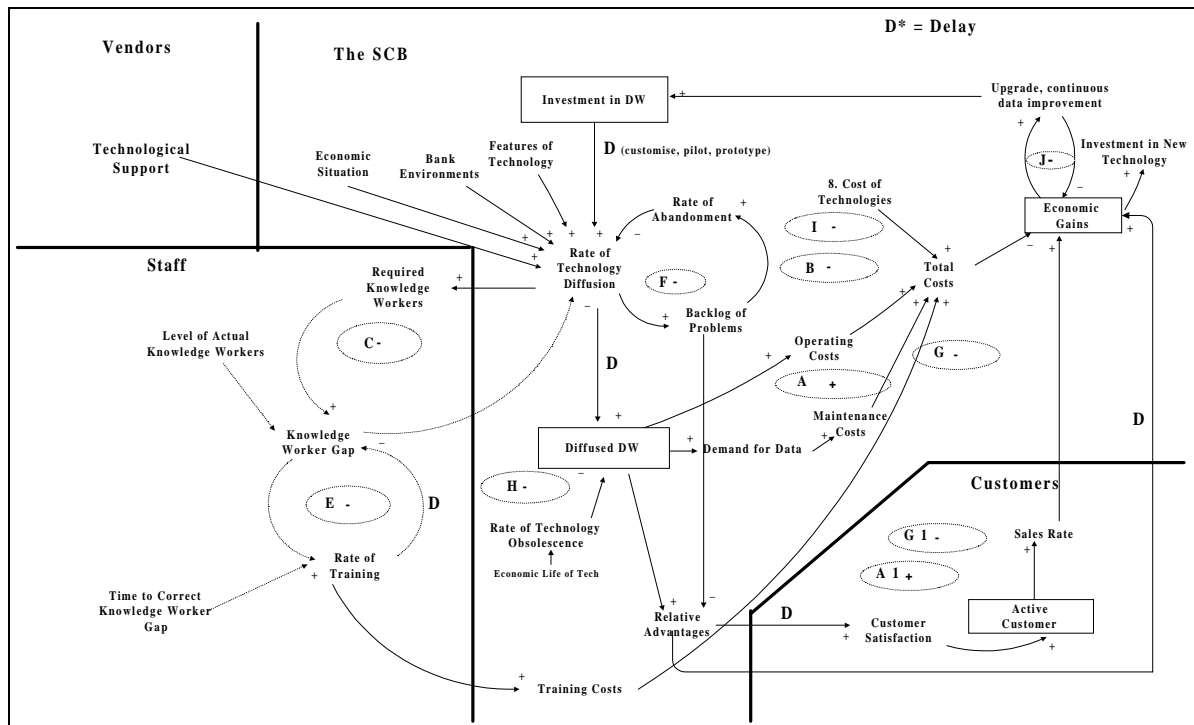
Positive feedback loop A1: Although currently the bank does not highlight the direct effects of DW on customers, optimistically speaking, diffused DW ultimately promotes customer satisfaction leading to increase in active customers and sales rates, respectively. Sales rates, economic gains and additional investment in technology are related in a positive direction.

Negative feedback loop F: Data warehouse has the potential to increase the backlog of problems. First, incomplete integrity of data provides incorrect information, which leads to unreliability among users and customers. Second, excessive storage of data reduces the speed of response time, enlarges costs for data maintenance, demands higher capacity of hardware and requires rapid changes to update data. Third, the more the user involvement, the wider the range of issues that may occur (e.g. abused information and frauds, increase in requirements for technological assistance, and possibly incessant requirements by staff for different and extended data and tools). Forth, data protection legislation (e.g. invasion of privacy of customers) and security may become serious issues (Datawarehousing Information Center, 1997; Kelly, 1994; Paller, 1997; The Siam Commercial Bank's Staff, 1998). These problems may cause abandonment of that technology and subsequently demote the diffusing process.

Negative feedback loop G and G1: Once problems from technology are accumulated, they exert negative impacts on both relative advantages (Loop A.) and customer satisfaction (Loop A1.).

Negative feedback loop H: Upgrading the quality and quantity of knowledge workers via training may result in increasing costs and decreasing economic gains.

Negative feedback loop I: The more the technology is diffused the higher and more various are the costs involved (i.e. cost of technology, training costs, operating costs and maintenance costs).

Negative feedback loop J: The variables in this loop indicate that excessive technological investment may decrease economic gains of an organisation.

In conclusion, numerous constraints have the tendency to obstruct the rate of technology diffusion and mitigate against the expected economic gains. First, abundant problems are entangled (e.g. security, reliability, time and resources consuming) during the diffusion process which may dilute the diffusion of technology and cause people to abandon that technology use. Second, costs for technology implementation, operation and maintenance are explicit and prohibitive whereas the benefits are implicit. Third, training is vital to enhance the level of understanding of knowledge workers, however, end users though be trained may never or seldom apply their training. The lack of understanding and insubstantial usage lessen customer satisfaction and other relative advantages.

4.4. Redesign of Strategic Policies

The strategic policies to diffuse data warehousing technology involve endogenous factors such as staff and bank environments. The bank considers bank staff as the direct customers of this technology. The real customers of the bank are not taken into account because the mutual impacts are not concurrently conceived.

The main strategic policies to drive the diffusion rate, detected from interviewing and questionnaire data, are training, the co-operation between information technology (IT) departments and knowledge workers, decreased perceived complexity, top management support and increased positive features of technology.

a. **Training support:** Bank staff reveal that the major supportive factor in learning and using DW is training. As training is an instrument in creating knowledge workers and enhancing their levels of understanding, bank staff require many types of training including that of the basic concept of DW, basic knowledge of databases, business analysis and the usage of software applications. Gaining relative advantages and increasing customer satisfaction relies very much on understanding and substantial effective usage of this technology. That is, such advantages cannot be obtained directly from the provision of the actual physical technology.

   As well as training, it is important to effect change in the attitudes and vision of knowledge workers, especially middle and top managers, towards an informed, flexible, rational, and eager to learn mind-set. Providing training without changing users' attitudes is ineffective in convincing them in regular use of the technology.

b. **Co-operation between IT and users:** Co-operation between IT departments and key users will enhance effectiveness in diffusing and utilising technology. Since DW technology is perceived as complicated, requiring versatile knowledge and tailor-made tools, end users tend to depend heavily upon IT people. Therefore, technological assistance, involvement in technological development, close communication and follow up are strongly required.

c. **Decreased perceived complexity:** Currently, DW appears difficult to use. To decrease difficulties, the bank installs user friendly software applications to extract required data, perform queries and create reports. Additionally, a data catalogue is designed to illustrate available data. Users can use the data catalogue indexing for data that might meet their requirements. It is believed that once end users know how to get access to their required data easily they will use DW regularly and develop their learning skills to maximise advantages from the available data.

d. **Top management support:** Given the hierarchical nature of Thai society, and the conservative culture of the SCB, subordinate staff may be generally unwilling or indifferent in accepting innovation in technology use. Thus, top management support and firm direction is vital in convincing bank staff to increase efficiency in technology use.

e. **Increased positive features of technology:** Bank staff are involved in considering many technological issues of DW. First, since data are initially stored in many legacy databases, when loading the data into DW, problems regarding data integrity, incompleteness, redundancy and non-updatedness are hard to avoid. These problems lead to unreliability of the data and the system. Second, as there are a lot of data to retrieve, extract or transfer, the response time is slow due to traffic jams in limited communication lines. Third, regarding security, the bank protects the system from misuse by unauthorised people by adding security procedures. High security may reduce the convenience of usage or increase the complexity of the system. Thus, increased positive features of DW technology, such as increased reliability, decreased response time and intensified security without added complexity are vital for diffusing DW.

Figure 5: Redesigned Strategic Policies of Data Warehouse

9
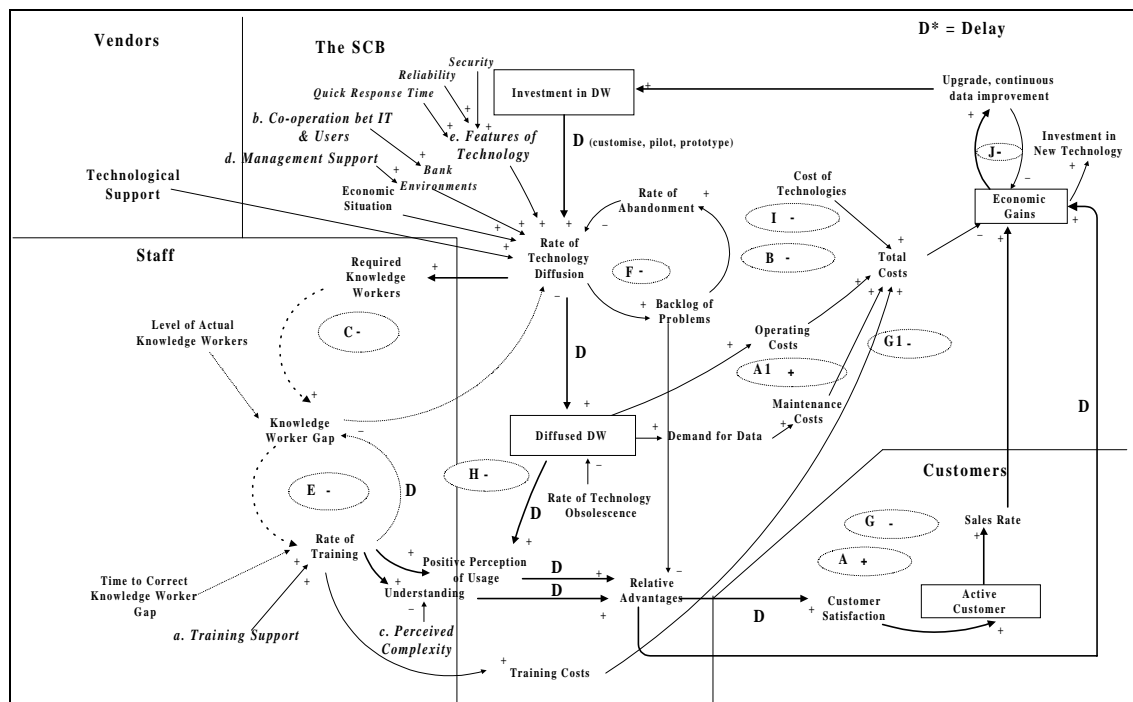
The model is redesigned by changing the flow diagram and by exerting the strategic variables into the defined constraint state.

First, relative advantages were changed from deriving directly from diffused data warehouse to understanding and positive perception of usage because those advantages cannot be gained unless knowledge workers use data warehouse comprehensively and substantially.

On the one hand, the level of understanding is promoted by training with the support of two strategic variables (i.e. *training support* and *decrease in perceived complexity*). On the other hand, positive perception of usage derives from providing training and the endowment of DW. That is, if users, who are supported by sufficient and effective training, use the available technology, the work performances of those with the help of data warehouse and those without may be differentiated. Once positive aspects in using the technology are perceived, usage will accumulate.

In effect, understanding and positive perception towards using this technology would encourage the bank staff to use the technology effectively and substantially. Thus, relative advantages and sales rates may be subsequently increased.

Second, the five mentioned strategic policies are exerted with an expectation that they will enhance technology diffusion and successively have a positive impact on economic gains. However, given the limitation of evaluation based on the qualitative approach, the final outcomes of each or combined policies cannot be perceived precisely and conclusively because the determined policy not only gives the positive intended impacts in one loop but also creates negative unintended impacts on other loops. The positive and negative impacts may cancel out each other or one may have more influence than the others. For example, if the bank promotes the training support policy, increased positive economic gains both from sales rates and other relative advantages may be intuited. However, tracing through the entire loops in the model, this policy will increase training costs, and demand for sophisticated and various data, which ultimately reduces economic gains. Additionally, the more staff use this technology, the more problems are accumulated. Certainly, the problems decrease both staff and customer satisfaction.

Consequently, model analysis based on the qualitative system dynamics approach has a shortcoming regarding the provision of conclusive end results of the modified feedback loops and policy exertion because of the interrelationship of variables and asynchronous impacts of each variable.

In ongoing research, these strategic policies will be simulated and quantified based on the quantitative system dynamics approach to find the most effective policy that helps the bank diffuse this technology productively. The strategic policies from external sectors such as vendors and customers will be detailed in future research.

6. Conclusion

This study employs two decision-making tools (i.e. MCDM and SD) to develop a model for adoption and diffusion of technology in one of the largest banks in Thailand. The MCDM approach is used for the technology adoption phase whereas the SD approach is expanded for the diffusion phase. Bank officials participated in the development and calibration of the MCDM model and the subsequent SD model.

The results of the study reveal that the predominant technology, in assisting the bank to achieve its mission of excellence and good-management is data warehousing technology.

The qualitative system dynamics approach identifies the present state and detects constraints of this technology in the bank. Then the model is redesigned to incorporate strategic policies that are vital for the bank to diffuse this technology fruitfully. Since the critical success factors of data warehouse require understanding of knowledge workers and substantial usage, the proposed strategic policies are: training support, co-operation between IT people and knowledge workers, decreased perceived complexity, top management support and increased positive features of technology. These policies have been identified by interviewing the bank executives. While qualitative SD exposes the first degree impacts of the policies it, however, fails to analyse the higher degree impacts of interacting feedback loops. A quantitative simulation of the SD model is, therefore, necessary.

References

Belton, V. (1990). *Multiple criteria decision analysis- Practically the only way to choose*. Birmingham: Working paper 90/10.

Coyle, R. G. (1996). *System dynamics modelling A practical approach*. London: Chapman & Hall.

Datawarehousing Information Center. (1997). Data Warehousing Gotches. http://www.starnetinc.com/larryg/gotchas.html

Earl, M. J. (1987). *Information systems strategy formulation*. Chichester: John Wiley & Sons Ltd.

Horrock, C. (1996). Making the warehouse work. http://www.computerworld.com/sear - htm1/9606/960624DW1SL96dw10.html

Inmon, W. H., & Hackathorn, R. D. (1994). *Using the data warehouse*. New York: John Willey & Sons.

Kelly, S. (1994). *Data Warehousing: The route to mass customisation*. Chichester: John Wiley & Sons.

Lambert, B. (1996). Data warehousing fundamentals: What you need to know to succeeded. *http://www.data-warehouse.com/resource/articles/lamb8.htm*.

Maier, F. H. (1996a). Substitution among successive product generations: An almost neglected problem in innovation diffusion models.

Manross, G. G., & Rice, R. E. (1986). Don't hang up organisational diffusion of the intelligent telephone. *Information & Management, 10*, 161-175.

O'Brien, J. A. (1996). *Management information systems: Managing information technology in the networked enterprise*. (3 ed.). Chicago: Irwin.

Paller, A. (1997). Top 10 Complaints Of Data-Warehousing Managers. http://techweb.cmp.com/iw/605/05olwa1.htm

Quaddus, M. A. (1995). *Diffusion of information technology: A review of static and dynamic models* (Working Paper). Curtin University of Technology, Perth, Western Australia.

Saeed, K. (1990). Managing technology for development a systems perspective. *Socio Economic Planning Science, 24*(3), 217-228.

The Australian Government Publishing Service. (1995). *A cashless society?: Electronic banking and the consumer*.

The Siam Commercial Bank, P. (1995). *Toward Intelligent Banking*. Bangkok: Pikkanet Printing Center, Ltd.

The Siam Commercial Bank's Staff. (1998). Personal Communication.

Visual Thinking. (1995). *V.I.S.A. for Windows: User Guide*. Glasgow, UK: Visual Thinking International Limited.

Wolstenholme, E. F. (1994). *System enquiry: A system dynamics approach*. Chichester: John Wiley & Sons.