International Journal of Innovative Computing, Information and Control
Volume **3**, Number **1**, February **2007**

ICIC International ©2007 ISSN 1349-4198
pp. **31-39**

THE DYNAMIC ASSESSMENT OF INFORMATION TECHNOLOGY INVESTMENT

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Received May 2006; revised October 2006

Abstract. *Evaluating the effectiveness of Information Technology (IT) investment has always been an elusive but important goal of IS researchers. The purpose of this paper is to present new dynamic approaches in the IT benefits evaluation. We use essential financial indicators to measure the impact of sample entities which performed IT investment before December 31, 2004 in China and Taiwan. From the field study we find that both in China and Taiwan, the IT investment make a negative impact. However, from the Taiwan experience, most entITrises will meet the temporary decline situation after implementing the IT investment, but in the long-term, about 4 years, it will make a significant financial progress. While in China after IT investment, it always keeps a negatively related performance.*
Keywords: Information technologies, Fuzzy theory, Performance evaluation

1. **Introduction.** Investments by firms in information technologies (IT) have increased rapidly over the past three decades. IT investment decisions have the potential to either improve a firm's competitive position or to allow the firm to become more vulnerable to competitive forces. Recent evidence indicates that IT investments have been a very important contributor to productivity [2,5,6]. These literatures suggest that IT investment has a significant impact on firm performance and, therefore, is of value to the firm.

Unfortunately, empirical support for these claims consists almost exclusively of individual case studies [8-10,20]. As a result, there is some doubt about whether the claimed impacts can be generalized from the individual cases to all firms. A number of recent empirical studies have suggested that IT investment do not benefit firms as much as the case studies might lead one to expect [3,14,15,18].

People have concluded from their own study and studies conducted by others, that IT investment have not resulted in significant productivity gains [2-4]. These studies cast doubt as to the real value of IT investment to firms. Determining whether IT investment

can increase firm value poses many problems that are widely discussed in the information systems (IS) literature [7,13,16,19].

In front with the important business project, there are many companies performing the IT investment without examining its economic gains. One of the reasons is that it is not easy to set up an appropriate IT performance evaluation. Precisely quantifying the performance of IT is still problematic since many other factors such as economics, politics or transportation will affect the result.

However, there are many approaches in detecting or testing procedures for IT investment performance evaluation. Among them the t-test or event study method for evaluating the performance of IT are the mostly frequency used [2,5,6,10,12]. These procedures, although easy to implement, have several disadvantages. The main reason for the decimal cost/benefit comparison comes from that measuring IT investment benefits are not immediately evident, but implementation costs can be readily identified ex post [12]. Moreover, the absence of an explicit statistical model for the structure changes makes it difficult to investigate statistical properties of the models and to make forecasts.

In this research we present an integrated testing procedure for IT investment performance evaluation. It contains a single financial factor effect and a single company's performance evaluation. Fuzzy rule base about IT impacts of time and impact of company size are suggested for the testing hypothesis of IT investment impacts. Finally an empirical study about IT investment impacts for China and Taiwan are demonstrated.

2. **Research Design.**

2.1. **Previous methods and factors analysis.**

IT investment is expected to help firms improve their productivity and profitability [12,17]. Much research has supported IT spending and operational improvements, such as lower growth in operating expense [11], improved cost efficiency [1], and higher return on assets, sales growth and nonproduction labor productivity [21]. Hence in this paper we summarize the factors and features for each factors follows: 1. Analysis of operation: (1a) Accounts Receivable Turnover (1b) Inventory turnover; 2. Analysis of profitability: (2a) Pretax profit to sales (2b) Gross profit ratio; 3. Analysis of investment return: (3a) Return on total assets (3b) Return on common equity; 4. Analysis of growth rate: (4a) Sales Growth Rate (4b) Gross Profit Growth Rate, as our financial performance evaluation indicators, the relationship of factors and elements. See Table1.

Given the all-encompassing entITrise-wide nature of IT investment, effects should be large enough to reflect in financial statement values. Prior research has indicated that a time lag is necessary for capturing the performance improvements from information technology [4].

2.2. **Designs of performance evaluations.**

By observing the financial index with n_t companies, we measure the IT performance with fuzzy logic system. In this study, the degree of financial linguistic fluctuation is set to be {plunge (very non-efficient) = [-1,-0.5], down (non-efficient) = [-0.5, -0.1], unchanged (medium) = [-0.1, 0.1], up (efficient) = (0.1, 0.5), and soar (very efficient) = (0.5, 1). The following procedure demonstrates the evaluation decision.

Algorithm for a single factor's evaluation procedure.

Step 1. *Let $n_t$be the number of companies at time t, x_{ijt} : be the i^{th}standardize financial feature of j^{th}company at the t year, i=1,2,. . . ,m, be the numbers of features. j=1,2,. . . ,n_t. Calculate $\Delta x_{ijt} = x_{ijt} - x_{ij0}$, and $R_{it} = \underset{1\le j\le n_t}{median} |\Delta x_{ijt}|$.*

Step 2. *Calculated $l(\Delta x_{ijt})$ the i^{th} financial linguistic variable of j^{th} company at the t year*

$$l(\Delta x_{ijt}) = \begin{cases} 1, & if \quad 1.3R_{it} < \Delta x_{ijt}; \\ 0.5, & if \quad 1.1R_{it} < \Delta x_{ijt} \le 1.3R_{it} \\ 0, & if \quad -1.1R_{it} \le \Delta x_{ijt} \le 1.1R_{it}; \\ -0.5, & if \quad -1.3R_{it} \le \Delta x_{ijt} < -1.1R_{it}; \\ -1, & if \quad \Delta x_{ijt} < -1.3R_{it}. \end{cases}$$

Step 3. *Calculate$\bar{x}_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} l(\Delta x_{ijt})$, the financial linguistic value for the average of n_t company, i=1,2,. . . ,m.*

Step 4. *Find $x_t = \sum_{i=1}^{m} s_i \bar{x}_{it}$, the weighted IT performance of a factor, where s_i is the weight of the i^{th} feature, $\sum s_i = 1$.*

Step 5. *Output the result according to the fuzzy rule base:*

If $0.5 < x_t$, then IT performance of the factor is very efficient up to year t;
If $0.1 \le x_t < 0.5$, then IT performance of the factor is efficient up to year t;
If $-0.1 < x_t \le 0.1$, then IT performance of the factor is no change up to year t;
If $-0.5 \le x_t < -0.1$, then IT performance of the factor is non-efficient up to year t;
If $x_t < -0.5$, then IT performance of the factor is very non-efficient up to year t.

Algorithm for macro evaluation procedure.

Step 1. *Let X_{it} be the weighted IT performance of the i^{th} factor, i=1,2,. . . ,n, the number of factors.*

Step 2. *Find the weighted performance of the macro-IT.*

$X_t = \sum_{i=1}^{n} FW_i X_{it}$, *where FW_i is the weight of the i^{th} financial factor, $\sum FW_i = 1$.*

Step 3. *Output the result according to the fuzzy rule base:*

If $0.5 < X_t$, then macro-IT performance is very efficient up to year t;
If $0.1 \le X_t < 0.5$, then macro-IT performance is efficient up to year t;
If -0.1 $< X_t \le 0.1$, then macro-IT performance is no change up to year t;
If $-0.5 \le X_t < -0.1$, then macro-IT performance is non- efficient up to year t;
If $X_t < -0.5$, then macro-IT performance is very non-efficient up to year t.

2.3. **Decision of the fuzzy weight.** In the evaluation process, people usually treat each factor with the equal weight. That is, we assume that the factors have the same contribution to the universe domain. However, in order to get a more accurate evaluation, we had better use different weights, according to their contributions to the object, for different factors. Since then, the macro-performance evaluation will reflect the real world situation.

To investigate the fuzzy weight of each factor, we may use the fuzzy set theory and sampling survey technique. By fuzzy memberships and multiple values assignment, we

can get an appropriate fuzzy weight for the object. Hence, we give a brief definition about fuzzy weight.

Definition 1. *Fuzzy weight (data with multiple values)*

Let U be a finite set (a discussion domain), $L = \{L_1, L_2, \cdots, L_k\}$ be a set of k-linguistic factors on U, and $\{FS_i = \frac{m_{i1}}{L_1} + \frac{m_{i2}}{L_2} + ... + \frac{m_{ik}}{L_k}, i = 1, 2, ..., n\}$ be a sequence of random fuzzy sample on $U, m_{ij}(\sum_{j=1}^{k} m_{ij} = 1)$ is the membership with respect to L_j. Then, the fuzzy weight was defined as $FW = \frac{\frac{1}{n}\sum_{i=1}^{n} m_{i1}}{L_1} + \frac{\frac{1}{n}\sum_{i=1}^{n} m_{i2}}{L_{i2}} + ... + \frac{\frac{1}{n}\sum_{i=1}^{n} m_{ik}}{L_k}$.

Example 2.1. *Let the universe set U= {factor 1, factor 2, factor 3, factor 4}. In a sampling survey with 7 experts, we get the following fuzzy sample for 4 factors:*

TABLE 1. Fuzzy sample for 4 factors

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*
F_1	0.4	0.1	0.2	0.3
F_2	0.2	0.1	0.2	0.5
F_3	0.3	0.2	0.3	0.2
F_4	0.3	0.2	0.4	0.1
F_5	0.3	0.1	0.2	0.4
F_6	0.2	0.2	0.4	0.2
F_7	0.5	0.1	0.3	0.1
Total	3.2	1	2	1.8
weight	0.41	0.14	0.19	0.26

The fuzzy weight for factors of the universe set is $FW = \frac{0.41}{1} + \frac{0.14}{2} + \frac{0.19}{3} + \frac{0.26}{4}$

3. Empirical Study.

3.1. **Sample selection procedure.** The samples are selected by identifying listed firms that publicly disclosed their IT investment before December 31, 2004. Because not all firms have relevant data available in the TEJ (Taiwan Economic Journal) database for measuring their characteristics; therefore, the sample size is further reduced. Finally, IT investment announcements leave a usable sample of 87 for Taiwan and 52 for China.

The distribution of IT investment by firms, in implementation year, is presented in Table 2. Of the Taiwan sample firms, 88% (82 of 87) of the firms have finished the implementation for more than 2 years, and 44% (38 of 87) for more than 5 years. As compared to Taiwan samples, the average time needed for implementation by China firms is shorter. Of the China sample firms, 75% (39 of 52) have finished the implementation for more than 2 years and 61% (32 of 52) for more than 3 years. But only 29% (15 of 52) have finished the implementation for more than 5 years. The survey sampling is performed both in Taiwan and China by choosing the companies that have publicly disclosed IT investment before December 31, 2004. The data was assessed from the internet and the literatures data base.

TABLE 2. Distribution of sample firms in IT investment year

	Taiwan		China	
	Number	Percent	Number	Percent
More than 1 year	87	*100%*	52	*100%*
More than 2 year	72	*83%*	39	*75%*
More than 3 year	62	*71%*	32	*61%*
More than 4 year	54	*62%*	16	*31%*
More than 5 year	38	*44%*	15	*29%*

3.2. **Main results.**

3.2.1. *Analysis of operation.* Two financial features of operation are Inventory turnover and Accounts Receivable Turnover. The dynamic evaluation is illustrated at Table 3.

TABLE 3. Operation after IT investment

Operation performance		$T=1$	$T=2$	$T=3$	$T=4$	$T=5$
Inventory turnover	China ($\bar{x}_{it}$)	-0.138	-0.111	-0.171	-0.133	
	Taiwan ($\bar{x}_{it}$)	-0.089	-0.063	-0.03	0.134	0.207
Accounts Receivable Turnover	China ($\bar{x}_{it}$)	-0.431	-0.259	0.333	0.250	
	Taiwan ($\bar{x}_{it}$)	-0.273	-0.264	-0.33	0.175	0.339
Factor 1:Operation	China(x_t)	-0.285	-0.185	0.081	0.058	
	Taiwan(x_t)	-0.181	-0.164	-0.18	0.156	0.273

1: $\bar{x}_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} l(\Delta x_{ijt})$, the financial linguistic value for the average of n_t companies, $i = 1, 2, \ldots, m$.

2: $x_t = \sum_{i=1}^{m} s_i \bar{x}_{it}$, the weighted IT performance of a factor, where s_i is the weight of the i^{th} feature.

It can be seen that in China, the dynamic performance of the feature Inventory turnover $\bar{x}_{it}$ is not efficient($\bar{x}_{i1} = 0.138$ $\bar{x}_{i2} = -0.111$ $\bar{x}_{i3} = 0.171$ $\bar{x}_{i4} = -0.133$). While the dynamic performance of Accounts Receivable Turnover is efficient after two years' non-efficiency($\bar{x}_{i1} = -0.431$ $\bar{x}_{i2} = -0.259$). The result of operation performance, IT is not efficient during the first two years. Then the performance moves from negative to positive, while the change is not so steep, the following years its measure is not significant change with the financial performance.

As for the case in Taiwan, the performance of the feature Inventory turnover $\bar{x}_{it}$ at the three years is no change ($\bar{x}_{i1} = -0.089$ $\bar{x}_{i2} = -0.063$ $\bar{x}_{i3} = -0.03$). Then the performance becomes efficient year after year. While the Accounts Receivable Turnover becomes efficient after two years' of non-efficiency. In general, the operation performance is not efficient during the first three years. Then the performance moves from negative to positive and at the fifth year the performance becomes efficient.

3.2.2. *Analysis of profitability.* Two financial features of profitability are Gross profit ratio and pretax profit to sales. The dynamic evaluation is illustrated at Table 4.

It can be seen that in China, after the first year of IT investment, the performance of the feature Gross profit ratio $\bar{x}_{it}$ is no change, while it becomes worse after the succeeding

years, the IT performance is non-efficient. While the dynamic performance of Pretax profit to sales is no change after two years' non-efficient. The result of profitability performance of IT is no change.

As for the case in Taiwan, the performance of the feature Gross profit ratio sales at the first three years is non-efficient. Then the performance turns out efficient ($\bar{x}_{i4} = 0.35$ $\bar{x}_{i5} = 0.339$) while the Pretax profit to sales is worse year after year. In general, the profitability performance is non-efficient during the first two years. Then the performance moves from negative to positive, the performance remains unchanged.

TABLE 4. Profitability after IT investment

Profitability performance		$T=1$	$T=2$	$T=3$	$T=4$	$T=5$
Gross profit ratio	China ($\bar{x}_{it}$)	-0.069	-0.214	-0.159	-0.133	
	Taiwan ($\bar{x}_{it}$)	-0.246	-0.173	-0.214	0.35	0.339
Pretax profit to sales	China ($\bar{x}_{it}$)	-0.093	-0.135	-0.100	0.000	
	Taiwan ($\bar{x}_{it}$)	-0.097	-0.132	-0.265	-0.281	-0.276
Factor 2: Profitability	China(x_t)	-0.081	-0.175	-0.130	-0.067	
	Taiwan(x_t)	-0.172	-0.153	-0.24	0.035	0.032

1: $\bar{x}_{it} = \frac{1}{n_t} \sum_{j=1}^{n_t} l(\Delta x_{ijt})$, the financial linguistic value for the average of n_t companies, $i = 1, 2, \ldots, m$.

2 : $x_t = \sum_{i=1}^{m} s_i \bar{x}_{it}$, the weighted IT performance of a factor, where s_i is the weight of the i^{th} feature.

3.2.3. *Analysis of investment return.* Two financial features of investment return are Return on common equity and Return on total assets. The dynamic evaluation is illustrated at Table 5.

It can be seen that in China, after IT investment, both the performance of the feature Return on common equity and Return on total assets is non-efficient. The result of investment return after the IT investment is non-efficient.

As for the case in Taiwan, after IT investment, both the performance of the features Return on common equity and that of Return on total assets is non-efficient. The result of investment return after the IT investment is non-efficient. In general, the investment return exhibits a negative benefit both in China and Taiwan. And there is no inclination to change the situation.

3.2.4. *Analysis of growth rate.* Two financial features of growth rate are Sales Growth Rate and Gross Profit Growth Rate. The dynamic evaluation is illustrated at Table 6.

It can be seen that in China, after IT implementation, both of the performance of the feature Return on common equity and Return on total assets is non-efficient. The result of investment return after the IT implementation is non-efficient.

As for the case in Taiwan, after IT implementation, both of the performance of the feature Return on common equity and Return on total assets is non-efficient. The result of investment return after the IT implementation is non-efficient. In general, the investment return exhibits a negative benefit both in China and Taiwan. And there is no inclination to change the situation.

TABLE 5. Investment return after IT investment

Investment return performance		$T=1$	$T=2$	$T=3$	$T=4$	$T=5$
Return on common equity	China ($\bar{x}_{it}$)	-0.367	-0.429	-0.409	-0.267	
	Taiwan ($\bar{x}_{it}$)	-0.281	-0.281	-0.382	-0.439	-0.379
Return on total assets	China ($\bar{x}_{it}$)	-0.333	-0.429	-0.364	-0.367	
	Taiwan ($\bar{x}_{it}$)	-0.316	-0.316	-0.373	-0.402	-0.397
Factor 3: Investment return	China(x_t)	-0.350	-0.429	-0.387	-0.317	
	Taiwan(x_t)	-0.299	-0.299	-0.378	-0.421	-0.388

1: $\bar{x}_{it} = \frac{1}{n_t}\sum_{j=1}^{n_t} l(\Delta x_{ijt})$, the financial linguistic value for the average of n_t company, $i = 1, 2, \ldots, m$.

2: $x_t = \sum_{i=1}^{m} s_i \bar{x}_{it}$, the weighted IT performance of a factor, where s_i is the weight of the i^{th} feature.

3.2.5. *The macro IT performance.* In this section we will examine the macro IT performance via above four financial factors. According to the method of Section 3.2, we ask for 7 experts' opinion, and find the fuzzy weight is $FW = \frac{0.41}{1} + \frac{0.14}{2} + \frac{0.19}{3} + \frac{0.26}{4}$. The results of macro-IT performance are illustrated at Table 7.

TABLE 6. Growth rate after IT investment

Investment return performance		$T=1$	$T=2$	$T=3$	$T=4$	$T=5$
Return on common equity	China ($\bar{x}_{it}$)	-0.367	-0.429	-0.409	-0.267	
	Taiwan ($\bar{x}_{it}$)	-0.281	-0.281	-0.382	-0.439	-0.379
Return on total assets	China ($\bar{x}_{it}$)	-0.333	-0.429	-0.364	-0.367	
	Taiwan ($\bar{x}_{it}$)	-0.316	-0.316	-0.373	-0.402	-0.397
Factor 3: Investment return	China(x_t)	-0.350	-0.429	-0.387	-0.317	
	Taiwan(x_t)	-0.299	-0.299	-0.378	-0.421	-0.388

1: $\bar{x}_{it} = \frac{1}{n_t}\sum_{j=1}^{n_t} l(\Delta x_{ijt})$, the financial linguistic value for the average of n_t company, $i = 1, 2, \ldots, m$.

2: $x_t = \sum_{i=1}^{m} s_i \bar{x}_{it}$, the weighted IT performance of a factor, where s_i is the weight of the i^{th} feature.

It is interesting to find that the IT performance in China exhibits an optimistic progress, from non-efficient to the third year no change. Though the IT investment does not meet the expected achievement, we may see from the dynamic trend that as the time goes by it may get the positive benefits.

The same situation can be found in Taiwan, the macro-IT performance is no change.

4. **Conclusion.** In this research, we present new dynamic approaches in IT investment evaluation for Taiwan and China before December 31, 2004. We use four financial factors with each factor has two features, to evaluate IT performance. We applied the fuzzy rule base decision rule to examine the benefit of IT investment. From the single feature of evaluation of IT, we can see that in China only Accounts Receivable Turnover exhibits positive improvement, the others are getting worse. While in Taiwan, the Inventory turnover, Accounts Receivable Turnover and Cross profit ratios getting better as the year goes. As for the impact of the four factors evaluation of IT: IT performance in China, the

TABLE 7. Results of macro-IT performance

		T=1	T=2	T=3	T=4	T=5
China	Factor 1:Operation	0.29	−.185	0.09	0.06	
	Factor 2: Profitability	0.09	0.18	0.13	0.07	
	Factor 3: Investment return	0.35	0.43	0.39	0.32	
	Factor4: Growth rate	0.24	0.22	0.11	0.05	
	Macro IT performance	0.16	0.28	0.18	0.12	
Taiwan	Factor 1:Operation	0.18	0.16	0.18	0.16	0.27
	Factor 2: Profitability	0.17	0.15	0.2	0.04	0.03
	Factor 3: Investment return	0.30	0.30	0.38	0.42	0.39
	Factor4: Growth rate	0.25	0.29	0.32	0.24	0.24
	Macro IT performance	0.13	0.25	0.29	0.23	0.19

$X_t = \sum_{i=1}^{n} FW_i X_{it}$,where FW_i is the weight of the i^{th} financial factor, $\sum FW_i = 1$

IT performance of operation, the growth rate and the profitability is no change. But the investment return factor becomes worse than after the IT investment. While in Taiwan, the best performance is operation, it exhibits a positive trend, from negative measurement to positive. The IT performances for other factors are no change.

Suggestions to the China side: many entITrises are public; the western economic administration system is not well constructed. Hence they may reform their administration concept, promote the management system before they invest the IT. Suggestions to the Taiwan side: After IT investment, at the first several years it may be non-efficient or no change, but in the long run (about four years) it is improving. As for the other financial factors, though IT investment makes no change during the short run, we believe, in long run it will improve, say after 4 years.

REFERENCES

[1] Bender, D. H., Financial impact of information processing, *Journal of Management Information Systems,* vol.3, no.2, pp.232-238, 1986.

[2] Bharadwaj A. S., A resource-based perspective on information technology capability and firm performance: An empirical investigation, *MIS Quart,* vol.24, no.1, pp.169-96, 2000.

[3] Bresnahan, T. and S. M. Greenstein, The competitive crash in large scale computing, in *The Mosaic of Economic Growth*, Landau, Taylor and Wright (eds.), Stanford, CA, Stanford University Press, 1996.

[4] Brynjolfsson, E. and L. M. Hitt, Computers and economic growth firm level evidence, Unpublished manuscript, MIT Sloan School Cambridge, MA, 1993.

[5] Brynjolfsson, E. and L. M. Hitt, Paradox lost? Firm level evidence on the returns to information technology spending, *Management Science,* vol.42, no.4, pp.541-558, 1996.

[6] Brynjolfsson, E. and S. Yang, The intangible benefits and costs of computer investments evidence from the financial markets, *Proc. of the 18th International Conference on Information Systems*, Atlanta, GA, pp.147-166, 1997.

[7] DeLone, W. H. and E. R. McLean, Information systems success: The quest for the dependent variable, *Information Systems Res.*, vol.3, no.1, pp. 60-95, 1992.

[8] Dos Santos, B. L., Justifying investments in new information technologies, *J. Management Information Systems*, vol.1, no.4, pp.71-89, 1991.

[9] Dos Santos, B. L. and K. Peffers, Rewards to investors in innovative information technology applications: A study of first movers and early followers in ATMs, *Working Paper*, Krannert Graduate School of Management, Purdue University, West Lafayette, IN 47907, 1992.

[10] Dos Santos, B. L. and K. Peffers, Firm level performance effects: A framework for information technology evaluation research, in *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage*, R. D. Banker, R. J. Kauffman and M. A. Mahmood (eds.), Idea Group Publishing, Harrisburg, PA, pp.515-546, 1993.

[11] Harris, S. Y. and H. L. Katz, Organizational performance and information technology investment intensity in the insurance industry, *Organization Science,* vol.2, no.3, pp.263-295, 1991.

[12] Im, K. S., K. E. Dow and V. Grover, Research report: A reexamination of IT investment and the market value of the firm-an event study methodology, *Information Systems Research,* vol.12, no.1, pp.103-117, 2001.

[13] Kauffman, R. J. and C. H. Kriebel, Measuring and modeling the business value of IT, in *Measuring Business Value of Information Technologies*, ICIT Research Study Team #2 (ed.), ICIT Press, Washington, D.C., pp.93-120, 1988.

[14] Loveman, G. W., An assessment of the productivity impact of information technologies, *Working Paper*, Department of Economics, Massachusetts Institute of Technology, Cambridge, MA, June, 1988.

[15] Osterman, P., The impact of computers on the employment of clerks and managers *Industrial and Labor Relations Review*, vol.39, no.2, pp.175-186, 1986.

[16] Porter, M. E. and V. E. Millar, How information gives you competitive advantage, *Harvard Business,* pp.149-160, 1985.

[17] Rao, S. S., EntITrise resource planning: Business needs and technologies, *Industrial Management & Data Systems*, vol.100, no.2, pp.81-88, 2000.

[18] Roach, S. S., *America's Technology Dilemma: A Profile of the Information Economy*, Special Economic Study, Morgan Stanley and Co., 1987.

[19] Strassmann, P. A., Management productivity as an IT measure, in *Measuring Business Value of Information Technologies*, ICIT Research Study Team #2 (ed.), ICIT Press, Washington D.C., pp.93-120, 1988.

[20] Stoddard, D. Otisline, *Harvard Business School Case Study*, #9-186-304, Cambridge, MA, 1988.

[21] Weill, P., The relationship between investment in information technology and firm performance: A study of the valve manufacturing sector, *Information Systems Research*, vol.3, no.4, pp.307-333, 1992.