

The Relationship Analysis of RFID Adoption and Organizational Performance

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Abstract—The goal of this study is to determine factors influencing the adoption of RFID and its effects on organizational performance. In the research model used in this study, factors influencing the adoption of RFID were examined under a TOE (Technology, Organization, Environment) framework, with a series of hypotheses set up accordingly, and organizational performance was measured using a BSC (Balanced Scorecard). The data were collected from organizations currently using RFID, and the research model and hypotheses were tested through structural equation modeling. The analysis showed that technology competence, technology compatibility, top management support, RFID related cost, competitive pressure, and government support had an influence on the adoption of RFID, and the adoption of it impacted on organizational performance. And policy implications were derived from the results and strategies for stimulating demand for RFID.

Keywords—RFID; RFID adoption; Balanced scorecard; Organizational performance; Structural equation modeling.

I. INTRODUCTION

Counted among the top 10 technologies of the 21st century [1], RFID is a highly promising technology used in a wide-ranging area, from distribution and logistics to manufacturing, transportation and defense. RFID is a non-contact sensor technology using RF signals. A RFID system is composed of a tag with an integrated chip and antenna and a reader for the processing and transmission of stored data [2]. The global RFID market, estimated at US\$ 5.6 billion in 2010, is expected to grow to US\$ 24.1 billion in 2021. By region, the RFID market is predicted to reach the largest size in East Asia, in part on the back of a lively growth in the Chinese market [3].

RFID is one of the technology policy focuses in major countries around the world where it is perceived as a next-generation engine for future economic growth, and related R&D is actively underway. In the US, R&D activities in RFID are led by the NITRD (Networking and Information Technology R&D) program. The diffusion of RFID is steadily widening, thanks, in part, to the rule making its use mandatory in key government agencies, including the Department of Defense, FDA and the Department of Homeland Security. In Europe, the use of RFID is actively encouraged as part of the effort to build an intelligent society. RFID is currently piloted in various fields, in

Europe, including distribution and logistics, and manufacturing. In Japan, its Ministry of Economy, Trade and Industry started a RFID project, called the “5-yen Tag” project, in 2006. The Japanese Ministry of Internal Affairs and Communications, meanwhile, is carrying out projects to build infrastructure necessary for the broad use of RFID tags. In China, RFID has been selected as one of the key technology tasks for the 11th 5-year plan by its government, and the government is providing extensive support for fostering this industry. Efforts are also underway in China, to establish RFID-related standards [4]. In Korea, RFID has been included in ‘new IT,’ one of the six fields selected as the next-generation engines for economic growth (which otherwise include energy/environmental technology, IT-based new converged industries, bio-industry, transportation systems and knowledge services) [4].

RFID is increasingly receiving attention from the research community as well, in recent years, with research being actively conducted especially on adoption behavior. However, most studies remain attempts to identifying factors influencing the adoption of RFID by certain organizations, and not its massive take-up or the industry-wide level of adoption. Creating a large enough demand is, needless to say, a vital requirement for the viable growth of the RFID industry. Meanwhile, it is also important to understand, for the long-term prospect of the RFID industry, whether and to what extent the adoption of RFID directly influences organizational performance. This study distinguishes itself from previous research on the adoption of RFID in that it is an empirical attempt to comprehensively investigate whether its adoption has a direct impact on organizational performance. The goal of this study is, therefore, to determine factors influencing the adoption of RFID by organizations and how its adoption influences organizational performance so as to develop strategies for stimulating demand for this technology.

This paper is organized as follows. First, in introduction, background, necessity, and objectives were described. Secondly, in literature review, the factors influencing the adoption of RFID were examined through existing literatures by means of a TOE framework. In addition, BSC methodology was considered to measure organizational performance. Thirdly, on the basis of existing literatures, research model and hypotheses were set up. Fourthly,

research model and hypotheses were tested with structural equation modeling. Finally, implications were derived from the analysis, and significance and research direction in the future were presented.

II. LITERATURE REVIEW

A. TOE Framework

In this study, we explore factors influencing the adoption of RFID using the well-known TOE (Technology, Organization, Environment) framework. The TOE framework has been widely used to determine factors influencing the adoption of a new technology or system from a technological, organization and environmental perspective. Noteworthy studies conducted using the TOE framework include Kuan & Chau [5], investigating influence factors for the adoption of electronic data interchange (EDI), and Xu et al. [6] and Zhu et al. [7]-[9], determining factors influencing the adoption of e-business. Joo & Kim [10] used the TOE framework to discover influence factors for the adoption of e-marketplace, and Soares-Aguiar & Palma-dos-Reis [11], to discover determinants of the adoption of e-procurement systems. Finally Wang et al. [12] explored determinants of the adoption of RFID, utilizing the TOE framework.

B. Balanced Scorecard(BSC)

The Balanced Scorecard (BSC), proposed by Kaplan & Norton [13]-[15], is a technique for measuring organizational performance. Under this technique, the performance of an organization is not just measured through financial indicators, but is comprehensively evaluated by looking also at non-financial aspects; hence, a balanced measurement method. Aside from general organizational performance, The BSC is also frequently utilized to measure the effects of the introduction of a new system or information technology on organizational performance. The BSC considers four perspectives, namely, financial, internal business process, learning and growth, and customer that are derived from an organization’s vision and strategy.

Examples of studies using the BSC for measuring organizational performance are numerous and are from widely-varying research fields. Papalexandris et al. [16], for instance, measured performance among Greek software companies, using the four perspectives from the original BSC proposed by Kaplan & Norton, unmodified. As for Michalska [17], he used the BSC in this measurement of corporate performance in the Polish metallurgic industry, but replaced the learning and growth perspective, one of the original four perspectives, with the development perspective, and derived appropriate performance indicators for the readapted perspectives. Gumbus & Lyons [18] measured the performance of Philips, employing a BSC comprising the financial, process, customer and the capacity perspective.

Olson and Slater [19], in their measurement of performance among service and manufacturing companies, used a BSC framework consisting in the customer, internal business process, innovation and growth, and the financial

perspective. Chand et al. [20], meanwhile, analyzed the effects of the introduction of an ERP system on organizational performance, employing a BSC framework consisting of a process, customer, financial, and a learning and innovation perspective. Bhagwat & Sharma [21] investigated the impact of supply chain management on organizational performance, using a BSC framework comprising a financial, customer, internal business and an innovation and learning perspective. As for Fang & Lin [22], they used a financial, customer, internal, and an innovation and learning perspective to analyze how the introduction of an ERP system affected organizational performance.

III. RESEARCH MODEL AND HYPOTHESES

The research model for determining factors influencing the adoption of RFID under the TOE framework and measuring the effects of the adoption of RFID on organizational performance was designed, as shown in (Figure 1). In this study, we assumed that technology factors such as technology competence, technology compatibility and technology complexity; organizational factors such as support from company leadership, the size of organization and the cost of implementing a RFID system; and environmental factors such as competitive pressure and government support influence the adoption of RFID. We, further, assumed that the adoption of RFID will have an influence on organizational performance.

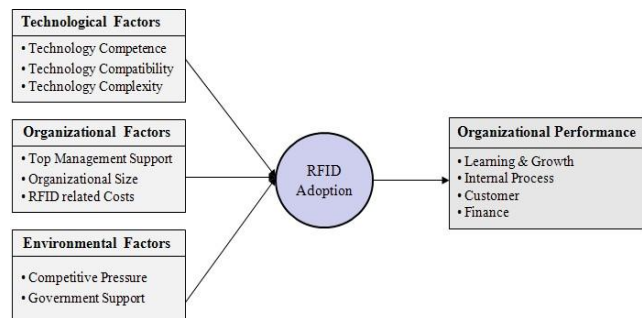


Figure 1. Research model

Concerning technology factors influencing the adoption of a new technology by organizations, quite an important number of previous studies suggested that technological competence, technological compatibility and technological complexity were among the key factors. Kuan & Chau [5] empirically confirmed the impact of technological competence on the adoption of EDI (Electronic Data Interchange), and Xu et al. [6] and Zhu et al. [7] reported that technological competence was a critical influence factor for the adoption of e-business. Kim & Garrison [23] found that technological knowledge was positively associated with the adoption of RFID for supply chain management. Ramamutrthy et al. [24], meanwhile, reported that the adoption of EDI was positively influenced by technological compatibility. Chang et al. [25] and Tsai et al. [26] confirmed through empirical data that technological

complexity was a major influence factor which inhibited the adoption of RFID. Brown & Russell [27] and Wang et al. [12] found that both technological compatibility and complexity importantly influenced the adoption of RFID. Drawing on findings from these previous studies, we set up the following three hypotheses on the relationship between technology factors and the adoption of RFID:

- H1. The technology competence has a positive effect on RFID adoption
- H2. The technology compatibility has a positive effect on RFID adoption
- H3. The technology complexity has a negative effect on RFID adoption

Several studies have reported that organizational factors such as support from company leadership, the size of organization and the cost of implementation were critical factors influencing the adoption of a new technology. Huang et al. [28], in an empirical study on internet-based EDI, found that the adoption of EDI was positively associated with support from company leadership. Joo & Kim [29] stated that the size of an organization was a major influence factor on the adoption of e-marketplace, while AL-Qirim [30] found a positive association between the size of an organization and the adoption of e-commerce. Wang et al. [12] reported, in their empirical study, that the size of an organization had a positive influence on the adoption of RFID. Wymer & Regan [31] suggested that costs played an important role in the adoption of e-commerce. This view was corroborated by Kim & Garrison [23] who also found that financial resources had a measurable influence on the adoption of e-commerce. Brown & Russell [27] reported that the attitude of the management and the size of an organization had a positive impact on the adoption of RFID, and the cost of implementation, a negative impact. Drawing on the existing literature, discussed above, we formulated the following two hypotheses on the relationship between organizational factors and the adoption of RFID:

- H4. The top management support has a positive effect on RFID adoption
- H5. The organizational size has a positive effect on RFID adoption
- H6. The RFID related costs have a negative effect on RFID adoption

A large number of previous studies showed that environmental factors such as competitive pressure and government support had an influence on the adoption of a new technology. Huang et al. [28] suggested that competitive pressure had a positive impact on the adoption of EDI, and Zhu et al. [7] found that it was positively associated with the adoption of e-business. Wang et al. [12] and Brown & Russell [27] stated that competitive pressure was a critical influence factor for the adoption of RFID. Xu

et al. [6], meanwhile, advanced that government support in the form of incentive or legal and regulatory support positively influenced companies' adoption of e-business. According to Chang et al. [32], government support would also have an important influence on the adoption of electronic sign-off. In this study, we, therefore, set up the following two hypotheses on the relationship between government support and the adoption of RFID:

- H7. The competitive pressure has a positive effect on RFID adoption
- H8. The government support has a positive effect on RFID adoption

That organizational performance is positively affected by the adoption of new technologies is a well-known fact. Fang [33] and Fang et al. [34] empirically established that corporate performance is influenced by the adoption of e-business. Chang & Wong [35], meanwhile, showed how the adoption of e-procurement and e-marketplace had an impact on corporate performance. In this study, the influence of the adoption of RFID on organizational performance is measured using a BSC framework, as has been said earlier. Improvements in organization performance under the effect of the adoption of RFID will be, therefore, measured from four perspectives, including learning and growth, internal process, customer and financial. We, therefore, set up the following four hypotheses on the relationship between the adoption of RFID and each of the four BSC perspectives:

- H9. The RFID adoption has a positive effect on performance of learning and growth
- H10. RFID adoption has a positive effect on performance of internal process
- H11. The RFID adoption has a positive effect on performance of customer
- H12. The RFID adoption has a positive effect on performance of finance

IV. METHODOLOGY

C. Factors and Data Collection

To identify factors influencing the adoption of RFID and understand whether and to what extent the use of RFID affects organizational performance, we developed a series of measurement items, drawing on the existing literature, as shown in Table 1. All items were measured using a 7-point likert scale.

The data were collected through direct interview of companies currently using RFID by contacting them by phone or through email. Of 130 total responses returned, 103 were retained for analysis, after discarding random or otherwise invalid responses. The demographics of the sample were as follows (see Table 2). An overwhelming majority of 82.5% of respondents were men, and people in their 30s represented 50.5%.

TABLE 1. FACTORS AND MEASUREMENT ITEMS

Factor		Measurement Item	
Technological Factors	Technology Competence (A)	A1	Amount of IT infrastructure related to the deployment of RFID
		A2	Familiarity with RFID technology
		A3	Level of employees' knowledge about RFID
	Technology Compatibility (B)	B1	Compatibility between RFID and existing equipment and facilities
		B2	Compatibility of RFID with routine tasks performed in the company
		B3	Appropriateness of RFID to organizational goals, values, beliefs or strategies
	Technology Complexity (C)	C1	RFID is perceived as complicated to use in our organization.
		C2	Developing RFID is considered a complicated process in our organization.
		C3	Implementing and using a RFID is considered a process requiring a great deal of efforts in our organization.
Organizational Factors	Support from Management (D)	D1	The degree to which the management considers RFID important and supports its use.
		D2	The degree to which the management considers the deployment of RFID as an important issue.
		D3	The extent to which the management will be willing to communicate with staff and participate in the process.
	Size of Organization (E)	E1	Our company's capital is larger than most companies' in the same business sector.
		E2	Our company's profit is higher than most companies' in the same business sector.
		E3	The number of employees in our company is larger than that in most companies in the same business sector.
	RFID-related Costs (F)	F1	The cost of implementing the RFID system is high.
		F2	The cost of providing education and training on RFID is high.
		F3	The cost of using and servicing the RFID system is high.
Environmental Factors	Competitive Pressure (G)	G1	Commensurate with the number of competitors having a RFID system
		G2	Commensurate with the number of companies in the same sector having a RFID system
		G3	Commensurate with the number of companies in the same sector, successfully using a RFID system
	Government Support (H)	H1	Whether the government provides incentives for the introduction of RFID
		H2	The extent to which the government supplies information related to the implementation of RFID
		H3	The extent to which the government makes efforts toward the improvement of laws related to RFID
Adoption of RFID(I)		I1	The extent to which the implementation of RFID
Organizational Performance	Learning & Growth (J)	J1	Enhancement of employees' work satisfaction attributable to RFID
		J2	Increase in the stock of knowledge about RFID
		J3	Improvement in employees' RFID-related skills and proficiency
	Internal Process (K)	K1	Increase in the rate of timely delivery of products and services attributable to RFID
		K2	Increase in the efficiency of inventory management attributable to RFID
		K3	Shortening of work processes and task handling time attributable to RFID
	Customer (L)	L1	Enhancement in customer satisfaction attributable to RFID
		L2	Enhancement of the company image attributable to RFID
		L3	Enhancement in customer loyalty attributable to RFID
	Finance (M)	M1	Cost reduction attributable to RFID
		M2	Sales increase attributable to RFID
		M3	Increase in return on investment attributable to RFID

In terms of education level, college graduates accounted for the largest share of 65.0%. In terms of number of years in service, less than 10 years represented 50.5% of total respondents. Meanwhile, in terms of organizational characteristics, as shown in Table 3, most were manufacturing and ICT companies, representing respectively 30.1% and 20.4% of total respondents. In terms of number of employees, 1,000 or more accounted for the largest share of 41.8%. As for three-year average sales, the greatest number of companies declined to answer this question, but among those providing an answer, 100 billion won to 500 billion won represented the largest share of 23.3%.

D. Structural Equation Modeling

In this study, the research model is tested against the data using structural equation modeling. Structural equation

modeling is a technique widely used for evaluating causal relationships between constructs. For the purpose of this study, we used PLS (Partial Least Squares) based structural equation modeling, which helps minimize endogenous variable errors and provides a greater level of explanatory power.

The reliability of constructs, when using PLS analytical tools, is determined by the value of internal consistency (IC) between the constructs. As a general rule, a value of 0.7 or greater indicates the existence of reliability [36][37]:

The validity of constructs is judged based on the value of their AVE (Average Variance Extracted. When the AVE is 0.5 or greater, this is considered an indication of the existence of convergent validity. Meanwhile, when the square root of the AVE is larger than the correlation coefficient between each of the factors, this is considered to indicate the existence of discriminatory validity [36][38].

TABLE 2. DEMOGRAPHIC PROFILE

Demographic Profile		Frequency	%
Gender	Male	85	82.5
	Female	18	17.5
Age(years)	20-29	11	10.7
	30-39	52	50.5
	40-49	33	32.0
	Over 50	7	6.8
Education level	College graduates	67	65.0
	Master/Doctor	36	35.0
Years in current position	Less than 5 years	24	23.3
	5 to 9 years	28	27.2
	10 to 14 years	23	22.3
	15 to 19 years	15	14.6
	20 years or more	13	12.6
Total		103	100.0

V. RESULTS

The reliability analysis performed on the factors used in this study revealed that the IC value was greater than the threshold of 0.7 for all factors, suggesting a good level of reliability. The AVE also proved to exceed the threshold value of 0.5 for all factors, attesting to their convergent validity. All factors were tested satisfactorily for discriminant validity as well.

When the research model was tested using the structural equation modeling technique, all hypotheses, except H3, H5 and H12, were accepted (see Figure 2). Among the technology factors, technology competence and technology compatibility proved to have a strong influence on the adoption of RFID. Technology complexity, on the other hand, showed no significant influence on the adoption of RFID. What these results point to is the importance of organizational capacities such as knowledge about RFID and infrastructure necessary for the deployment of RFID for an organization’s adoption of RFID. The results also confirm that whether RFID is compatible with an organization’s strategy or the situation it is currently facing and whether it is compatible with tasks routinely carried out in an organization are important determinants of its adoption.

Among organizational factors, analysis revealed that the adoption of RFID was measurably influenced by support from company leadership and the cost of implanting and using RFID. The results indicated, meanwhile, that the size of an organization had no real influence on the adoption of RFID. These results, therefore, attest to the importance of interest and awareness at the level of leadership within a company for its adoption of RFID. Also, the higher the cost of implementing RFID, the lower the probability of an organization’s adoption of RFID proved to be. Hence, to broaden the adoption of RFID, it is necessary to find ways of reducing the cost of introducing RFID.

TABLE 3. ORGANIZATIONAL CHARACTERISTICS

Organizational Characteristics		Frequency	%
Industry Sector	Manufacturing	31	30.1
	Information & communications	21	20.4
	Financial and insurance	10	9.7
	Distribution/ logistics	11	10.7
	Service	13	12.6
	Construction	11	10.7
	Other	6	5.8
Number of employees	Less than 100	18	17.5
	100 to 499	26	25.2
	500 to 999	16	15.5
	1,000 or more	43	41.8
Sales (3 year average)	Less than KRW 10 billion	14	13.6
	10 billion to - KRW 100 billion	9	8.7
	100 billion - KRW 500 billion	24	23.3
	KRW 500 billion or more	18	17.5
	No answer	38	36.9
Total		103	100.0

Among environmental factors, the results confirmed that the adoption of RFID was affected by competitive pressure and government support. What this says is that the higher the level of adoption of RFID among competitors in the same business sector, the more willing a company is to adopt RFID in its turn. Equally important is government support, in the form of a tax break or legal and regulatory improvement to incline a company toward the adoption of RFID.

The results of analyzing causal relationships between the adoption of RFID and organizational performance showed that learning and growth, internal process and customer performance were strongly affected by the adoption of RFID. Meanwhile, the adoption of RFID did not appear to influence the financial performance of a company. The results, therefore, point to important contributions by RFID to corporate performance, in terms of learning and growth, internal process and customer performance. But, the use of RFID is yet to produce an impact on the financial performance of companies. The detailed results of hypothesis testing are given in Table 4.

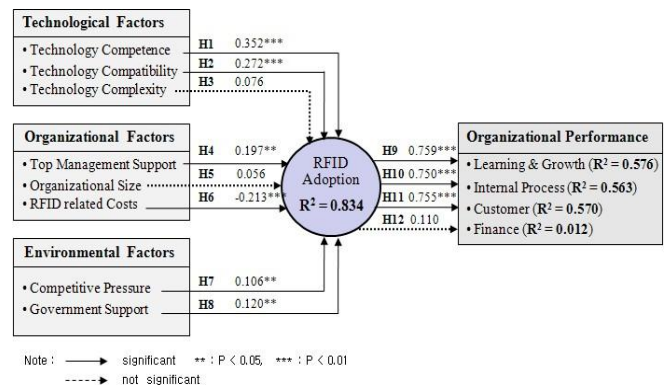


Figure 2. Results of Structural Equation Model Testing

TABLE 4. RESULTS OF RESEARCH HYPOTHESIS (H1-H12) TESTING

Path	Hypothesis	Estimate	S.E.	t value.	Results
Technology competence→ RFID adoption	H1	0.352***	0.095	3.8062	Accept
Technology compatibility→ RFID adoption	H2	0.272***	0.0982	2.7695	Accept
Technology complexity→ RFID adoption	H3	0.076	0.0486	1.5627	Reject
Top management support→ RFID adoption	H4	0.197**	0.0843	2.3370	Accept
Organizational size→ RFID adoption	H5	0.056	0.0437	1.2823	Reject
RFID related costs→ RFID adoption	H6	-0.213***	0.0598	3.5634	Accept
Competitive pressure→ RFID adoption	H7	0.106**	0.0532	1.9925	Accept
Government support→ RFID adoption	H8	0.120**	0.0486	2.4700	Accept
RFID adoption→ Learning and growth	H9	0.759***	0.0518	14.6640	Accept
RFID adoption→ Internal process	H10	0.750***	0.0547	13.7082	Accept
RFID adoption→ Customer	H11	0.755***	0.0574	13.1616	Accept
RFID adoption→ Finance	H12	0.110	0.1096	1.0040	Reject

VI. CONCLUSION AND IMPLICATIONS

This study has been an empirical attempt to understand technology, organizational and environmental factors influencing the adoption of RFID and measure its effects on organizational performance of companies. From the results obtained in this study, we derived the following policy and practical implications for stimulating demand for RFID and accelerating its diffusion:

First, there is a need for policy-level support for the technology factors that were found to influence the adoption of RFID. For example, education and training programs to help companies improve their understanding of, and proficiency with, RFID could be very useful. Also useful would be an onsite technical consulting program to assist companies in determining whether RFID is compatible with their existing systems and tasks they carry out routinely.

Second, this study found that support from company leadership positively influences the adoption of RFID. Therefore, programs to kindle interest in RFID among corporate executives could effectively help promote its adoption. Programs for sharing cases of successful implementation and use of RFID and concrete examples of benefits resulting from the use of RFID with CEOs would be particularly useful for raising interest in this technology and encouraging companies to adopt it.

Third, as emerged from this study, the high cost of setting up a RFID system is a factor making companies hesitant about its adoption. Hence, financial support from the government to assist with initial costs associated with setting up a RFID system could help toward an early adoption of this technology by companies. SMEs in strong need of RFID, but hesitant about actually introducing it due to financial burden could particularly benefit from such support.

Fourth, our study found that external environmental factors such as competitive pressure from within their own business sector and government support played a critical

role in their decision to adopt RFID. It may, therefore, be useful to publicize sector-specific cases of successful implementation and use of RFID and details of benefits gained from RFID to kindle interest in this technology. Tax breaks and other forms of incentive for companies introducing RFID will be also effective means for encouraging its adoption, along with legislative and regulatory improvement to facilitate the process.

Fifth, concerning the effects of the adoption of RFID on organizational performance, its influence proved particularly strong on learning and growth, internal process and customer performance. These are positive findings about the beneficial effects of RFID on organizational performance. However, we found no concrete effect of RFID on financial performance. This, therefore, points to a need for further efforts to improve the performance-effects of this technology so that its use can also enhance the financial performance of companies.

This study is significant in that it proposes strategies for promoting and accelerating the adoption of RFID by companies, based on the analysis of influence factors for its adoption and the effects of its use on organizational performance. Future research can improve on this study by developing an objective model for directly evaluating the performance-enhancing effects of RFID and by presenting strategies for promoting its adoption based on concrete performance data. This study found that the use of RFID is yet to produce a measurable effect on the financial performance of companies. Future research, therefore, also needs to investigate factors that can directly influence financial performance.

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