A Diffusion of Innovations Approach to Investigate the RFID Adoption in Taiwan Logistics Industry

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Logistics tasks heavily depend on reliable shipment and accurate tracking information. For this reason, logistics today have evolved into a high-technology industry. Distribution is no longer simply about moving cargo on the road or via air from location A to B, but is a complex process based on intelligent system for sorting, planning, routing, and consolidation that supports faster transportation. [1] The purpose of this study was to investigate how RFID technology was implemented and adopted in Taiwan's logistics industry. Specifically, this study focused on the positive influence of using RFID technology on the industry and the strategical benefits the RFID system had provided to companies, which had accepted and utilized this technology. This study also aimed to determine the concern factors of adopting the RFID system into current company management systems. An integral part of this research was to develop and to empirically test a model of the adoption of RFID in the context of the logistics industry in Taiwan. Based on the concepts of Rogers [2]-- the theory of technology diffusion, this research used a questionnaire to assess Taiwan logistics companies' cognition and perspective of the relative advantage, compatibility, complexity, trialability and observability of the RFID system; as well as to assess their attitudes toward the RFID system and intentions of using the system. Research findings revealed the attributes of innovations mentioned above were significantly positively associated with the adoption of RFID. According to the research results, managerial implications and opportunities for future research were discussed in the final.

***Index Terms*—Radio Frequency Identification; Diffusion of Innovations Theory; Attributes of Innovations; Logistics Industry.**

I. INTRODUCTION

Since June 2003, mass consuming markets had demonstrated a significant shift toward Radio Frequency Identification (RFID) technology. This has occurred not only because of RFID mandates imposed by Wal-Mart and other stores, but also the widely used of RFID by government organizations. Its use has the potential to affect an extremely wide spectrum of the population, from technology adopters to vendors, integrators, and users [3]. For this reason, the adoption of RFID technology is expected to increase rapidly in the current and coming years. In 2006, Chu et al. [4] had even speculated that RFID production will increase 25-fold by 2010. One RFID consumer survey, the RFID Consumer Buzz - Special Report, found that 28 percent of the 7,000 U.S. consumers surveyed were aware of RFID, and that most of them could describe the technology to others [5]. Journalists and researchers [6] have found that a growing number of businesses use RFID in their supply chain or manufacturing processes. In addition, there are hundreds of studies that discuss how Wal-Mart uses RFID to reduce its huge logistics costs and improve supply chain efficiency.

In Taiwan, government departments, the medical and pharmaceutical sectors, and private businesses have followed the RFID trend to take advantage of this new

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technology to enhance their standard operation processes [7] These companies are attracted by the number of potential benefits RFID offers, such as improved supply chain visibility, reduced labor costs, and enhanced process efficiency. This research study investigated the RFID technology adoption and how RFID has been used in Taiwan's logistics industry.

II. THEORETCAL FOUNDATION

A. Innovation Diffusion Theory (IDT)

According to Rogers [2], "diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system". (p.5) In Rogers's definition there are four elements of diffusion that constitute the main idea of diffusion in the innovation process: the innovation, communication channels, time, and the social system. In this study of RFID system adoption, RFID system as the innovation is communicated through certain channels over time among the members. In this study, the social system means Taiwan business environment and the members refer to Taiwan logistics industry.

Regarding to innovation-decision process mentioned above, Rogers explained it is "the process through which an individual (or other decision-making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation and use of the new idea, and to confirmation of this decision". ([2], p.20) There are five main steps in the innovation-decision process: (1) Knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation.

In addition, Rogers mentioned in his book "innovations that are perceived by individuals as having greater relative advantage, compatibility, trialability, and observability and less complexity will be adopted more rapidly than other innovations". (p.16) Innovations with the cluster of opposite characteristics require a longer diffusion period. There are many studies that indicate that these five qualities are the most important characteristics of innovation (attributes of innovations) in explaining the rate of adoption.

Relative advantages—"the degree to which an innovation is perceived as being better than the idea it supersedes. ". ([2], p.212) He explained the degree of relative advantage is often expressed as economic profitability, social prestige, or other benefits. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption will be.

Compatibility—The innovation's consistency with the existing values and norms (social system), past experiences, and the needs of potential adopters. "An idea that is more compatible is less uncertain to the potential adopter, and fits more closely with the individual's life situation". ([2], p.224)

Complexity—The degree to which an innovation is perceived as a difficulty to understand and use.

Trialability—The degree to which an innovation may be experimented on a limited basis. "New ideas that can be tried on the installment plan are generally adopted more rapidly than innovations that are not divisible". ([2], p.243) The higher the trialibility, the more quickly the innovation may be adopted.

Observability—The degree to which the results of an innovation are visible to others. Observability has been discovered to be positively related to adoption of an innovation.

Base on the concepts of Rogers's five steps of innovation-decision process and attributes of innovations, this research used a questionnaire to understand the perceived attributes of innovations and cognitions, decision among Taiwan logistics companies.

B. Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) technology is defined as a "wireless data collection technology that uses electronic tags for storing data and recognizing data" [8], and then uses radio waves to automatically identify any objects that have RFID tags. Sandip Lahiri, an RFID Solution Architect with IBM Global Services, indicated in his *RFID Sourcebook* [3] that "RFID is an example of automatic identification (Auto-ID) technology by which a physical object can be identified automatically." (p. 1)

The use of Radio Frequency Identification (RFID) in tracking and accessing applications first appeared during the 1980s. As the technology has been refined, more pervasive and possibly invasive uses for RFID systems have quickly gained the retail industry's attention because of RFID's ability to track moving objects.

An RFID system is a system that integrates a collection of components that implement an RFID solution. An RFID system may consist of several technology components — such as a tag, an antenna, a reader, and middleware — that can be embedded into a business environment to improve and transform key transaction processes.

The benefits of adopting an RFID system can be vary. They relate to the company or industry's current performance. Kevan [9] mentioned in Frontline solutions magazine ,Michael Dominy, a senior analyst for the Yankee Group, stated that "if you have world-class, leading capabilities in your logistics functions, the amount of benefit you're going to get out of RFID will be very small and incremental," ([9] ¶ 2). This means that if the logistics system the company adopted is a labor-based system company like most of the small and medium enterprises (SMEs) in Taiwan and the company wants to update to an RFID-enabled system, the benefits from adoption will be dramatic. In addition, the technology investment costs will be huge.

The logistics industry can be a major beneficiary of the RFID system because RFID technology dramatically enhances supply chain management, inventory management, and labor cost reduction. Chris Murphy, Senior Executive Editor of Information Week Web, said that "Today, without RFID, we don't know what's in the back room and what's in the front of customers' hands" [10]. In addition, a white paper published by the New Times Company (2006) pointed out that retailers can

expect great inventory savings and labor cost reduction from the adoption of radio frequency identification (RFID) technology. Furthermore, numerous researchers ([11],[3]) and consulting firms (such as A.T. Kearney, Information Week) have reported benefits in several areas, including inventory management, human resources management, and stock and shelf management.

III. Research Questions and Hypotheses

A. Research Questions

Based on the research background and purpose of the study, this investigation attempted to examine various factors of RFID implementation in the logistics industry in Taiwan. The study sought to answer the following research questions:

RQ1: What factors influence RFID technology acceptance attitude in Taiwan's logistics industry?

H1: The Relative Advantage of RFID system positively affects the attitude of RFID adoption in the logistics companies in Taiwan.
H2: The Compatibility of RFID system positively affects the attitude of RFID adoption in the logistics companies in Taiwan.
H3: The Complexity of RFID system negatively affects the attitude of RFID adoption in the logistics companies in Taiwan.
H4: The Trialability of RFID system positively affects the attitude of RFID adoption in the logistics companies in Taiwan.
H5: The Observability of RFID system positively affects the attitude of RFID adoption in the logistics companies in Taiwan.

RQ2: What factors affect RFID implementation intention in Taiwan's logistics industry?
H6: The attitude of using RFID system positively affects the usage intention of RFID adoption in the logistics companies in Taiwan.

RQ3: What are the barriers to RFID adoption in Taiwan's logistics industry?
H7: The logistics environmental factor has amplifies effects on the relationships between attitudes toward RFID adoption and future usage intention.

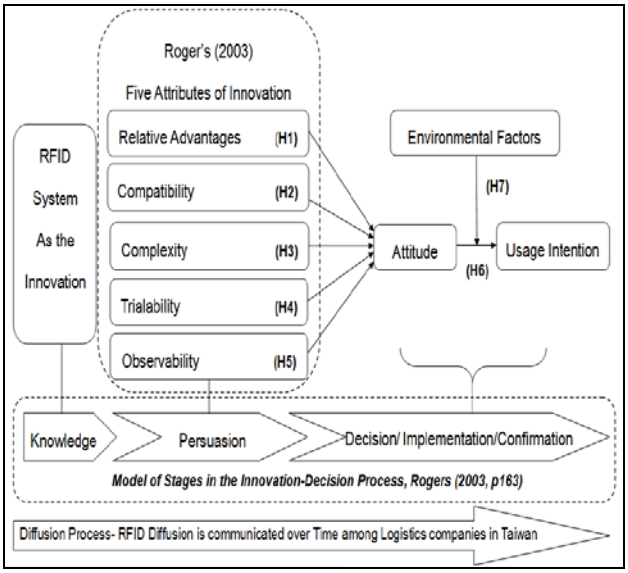

Figure1. Research Framework

IV. Research Instrumentation

A. Description of Questionnaire

The survey used in this study was primarily developed by the author to address unique aspects of this study with academic references, while the questionnaire as the data collection instrument for the context of the Taiwan logistics industry and its adoption of RFID technology.

The questionnaire was designed based on a five-point Likert-type scale which asks respondents to select from five scale options: 1 –Strongly disagree; 2 –Disagree; 3 – Undecided; 4 –Agree; 5 –Strongly Agree. It consisted of two sections. Part A aimed to investigate the basic background of the participating companies. Part B was designed to evaluate responding companies' knowledge and cognition of the relative advantage, compatibility, complexity, trialability, observability, and environmental effects regarding RFID technology.

The measurement variables of part B (Rogers's characteristics of innovation), relevant key questions and references are showed n below:

TABLE 1
MEASUREMENT SCALE QUESTIONS
FOR THE QUESTIONNAIRE PART B OF THIS RESEARCH

Variable	Relevant key questions	References
Relative Advantage	Q1: Efficiency Q2: Operation Performance Q3: Reduce Costs of Operations Management Q4: Profit Capability Q5: Effective	[12],[13], [14] ,[15], [2],[16][17] ,[18],[19], [20]
Compatibility	Q6: Value and belief Q7: Compatible Q8: Accord with the demand Q9: Accord with information system	

Complexity	Q10: Easy to use Q11: Easy to learn Q12: Clear and easy to understand Q13: Complicacy Q14: Difficulty	
Trialability	Q15: Popularization Q16: Assistance Q 17:Training programs Q18: Good product technique Q19: Proper post-sale service Q20: Training course	
Observability	Q21: Management support Q22: Management resource and budget Q23: Management sensed the efficiency Q24: Management encourage	
Environmental Factors	Q25: Competition Q26: Substitute products and services Q27: Barrier to entry Q28: Loss customers if not adopted RFID system Q29: More Competitive if adopt RFID system	
Attitude Toward RFID adoption	Q30: Positive toward RFID Q31: Positive view point of management's RFID adoption Q32: Advocate	[18],[21],[14]
Usage Intention	Q33: will and intention Q34: Rate of Usage Q35:Supply chain integration	[19],[20], [15];[14],[22]

Note. Questionnarie scale questions from this study

V. Data collection and analysis

The research population for this study was the companies list under the logistics-related category "104 Yellow Pages Business Directory" from Taiwan's largest job bank consultant company - 104 Job bank (http://www.104.com.tw) February, 2010, a total of 439 companies were the research population.

A. Validity and Reliability

The instrument of this research was developed with relevant references, key literature reviews and critical theory of Rogers [2] as the fundamental knowledge. Questions are abstracted from the most important points of the fundamental knowledge base. Thus, the questionnaire consisted of valid and crucial questions.

This study used Cronbach's alpha coefficient to examine the reliability of the instrument. There are eight variable factors in questionnaire part B. The reliabilities for those factors ranged from .702 to .923 as listed in Table 2, and the total reliability for part B questions were .931. According to George & Mallery [23, p231], they indicated that Cronbach's alpha reliability coefficient >0.9 means an excellent internal consistency of the questionnaire items. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the questionnaire scale. [28] The smallest value of Cronbach's alpha of this instrument was .702; this explained that this instrument was reliable. [24]

TABLE 2
RELIABLIITY OF CRONBACH ALPHA COEFFICIENT

Variables	Relevant key questions	Cronbach Alpha
Relative Advantage	Q1,Q2,Q3,Q4,Q5	.806
Compatibility	Q6,Q7,Q8,Q9	.812
Complexity	Q10,Q11,Q12,Q13,Q14	.855
Trialability	Q15,Q16,Q17,Q18,Q19,Q20	.779
Observability	Q21,Q22,Q23,Q24	.861
Environmental	Q25,Q26,Q27,Q28,Q29	.702
Attitude	Q30,Q31,Q32	.923
Usage Intention	Q33,Q34,Q35	.905
Total Alpha		.931

Note. [23] provided the following rules of thumb for Cronbach's alpha coefficient): "[alpha] > 0.9--Excellent, [alpha] > 0.8--Good, [alpha] > 0.7--Acceptable, [alpha] > 0.6--Questionable, [alpha] > 0.5--Poor, and [alpha] < 0.5--Unacceptable"

B. Descriptive analysis for participants' background

In this section, a total 439 participated companies' background analyzed by SPSS 16. June 3, 2010 to July 3, 2010 was the mailing survey operation time. After the end of one month survey period, 163 valid questionnaires were returned, yielding a 37.1 percent (37.1%) usable response rate. The background details have shown in the table below: (Table 3)

TABLE 3
PARTICIPATED COMPANY BACKGROUNDS

Background items	Items	Percent
Industry	Logistics Industry	68.10%
	Non-Logistics Industry	31.90%
Participants' Department	Management Dept.	42.41%
	Non-Management Dept.	57.59%
Business operated years	0-10 years	41.10%
	11-20 years	47.85%
	Over 21 years	11.05%
Company's Capitalization	under 51 million	63.19%
	51 million-100 million	20.86%
	Above 100-300 million	15.95%
The usage of Barcode system	Non-Barcode user	62.73%
	Barcode user	37.28%
The usage of RFID system	Non-RFID user	87.04%
	RFID user	12.96%

Note. There were total 163 valid respondent questionnaires.

Table 4-1 below showed the correlation of backgrounds and variables among participating companies (industry, participants' department, age of the firm, company capitalization) and all variables (five attributes of innovations, environmental factors, and attitude and usage intention) were conducted by Pearson correlation analysis. Table 4-1 demonstrated only participant's department has a significant positive correlation with the compatibility and complexity. The correlation coefficients are r =.165 (*) and .248 (**). The statistical result meant the higher working position participants attach the greater importance to the compatibility and complexity of RFID adoption.

TABLE 4-1
CORRELATION BETWEEN
COMPANY BACKGROUNDS AND VARABLES

Variables	Industry	Participant's Department	Business operated years	Company Capitalization
Relative Advantage	.023	.140	-.002	-.018
Compatibility	.024	.165 (*)	.015	.029
Complexity	.139	.248 (**)	-.042	-.051
Trialability	.119	-.004	-.109	-.017
Observability	.101	.065	-.082	-.037
Environmental	-.065	.098	.152	.022
Attitude	-.072	.078	.087	-.005
Usage Intention	.007	.098	-.016	.023

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

For the company background questions, the experience of using barcode system and RFID system was also examined. The relationship between those two system and variables were also conducted. In table 4-2, the Pearson's correlation represented that the usage of barcode system have significant ($p<0.05$) positive correlation with trialability and usage intention. Most importantly, the experiences of using RFID system were significantly related to all those variables.

TABLE 4-2
CORRELATION BETWEEN
BARCODE /RFID EXPERIENCES AND VARABLES

Variables	The usage of Barcode system	The usage of RFID system
Relative Advantage	.118	.265 (**)
Compatibility	.027	.305 (**)
Complexity	-.010	.259 (**)
Trialability	.181 (*)	.383 (**)
Observability	-.035	.258 (**)
Environmental	-.050	.175 (*)
Attitude	.151	.317 (**)
Usage Intention	.168 (*)	.449 (**)

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

C. Relationship between innovation variables/Attitudes; and relationship between innovation variables/usage intentions

As Table 5 illustrated below, the relationships among participating companies' cognition of attributes of innovations toward RFID adoption, environmental factors, attitude toward RFID adoption and future RFID usage intention were examined by Pearson Correlation analysis. All variables had significant ($p<.01$) correlation with each other (from .507 to .669), except the environmental factors. The high coefficients signified that these variables had solid relationships with each other. The strong correlations among all those variables were positive. The statistical analysis confirmed the hypothesis 1 to hypotheses 5 (H1-H5) were accepted. However, the hypothesis 7 has been denied.

TABLE 5
CORRELAITON COEFFICIENT-H1 to H5, H7

Variable	Attitude toward RFID adoption	Usage Intention
Relative Advantage	.581 (**)	.528 (**)
Compatibility	.569 (**)	.540 (**)
Complexity	.361 (**)	.459 (**)
Trialability	.507 (**)	.669 (**)
Observability	.570 (**)	.598(**)
Environmental	.060	.137

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*

D. Relationship between the Attitude toward RFID System and Behavioral Intention

As Table 6 demonstrated below, the Pearson correlation analysis .623 revealed a strong and positive relationship existed between attitude toward RFID system and future usage intention. ($r=.623$**, $p=.000$) The result supported past researches, which indicated a positive association between attitude toward RFID system adoption and behavioral intention. [25], [26], [27] Therefore, the hypothesis 6 was accepted.

TABLE 6
CORRELATION BETWEEN THE ATTITUDE AND USAGE INTENTION

Correlations (H6)			
		Attitude toward RFID	**Usage Intention**
Attitude toward RFID	Pearson Correlation	1	**.623****
	Sig. (2-tailed)		.000

Adoption	Sum of Squares and Cross-products	106.453	75.369
	Covariance	0.657	0.465
	N	163	163
Future usage Intention	Pearson Correlation	**.623****	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	75.369	137.339
	Covariance	0.465	0.848
	N	163	163

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*

D. Tests of the Hypotheses

In this section, the researcher conducted one-way and two-way ANOVA to examine all seven hypotheses of this study. In one-way ANOVA, the five attributes of innovations toward RFID adoption were independent variables while attitude toward RFID adoption served as one independent variable. The statistical results indicated that the F-value of H1 to H5 were all reached the significant level (p<.001); therefore, hypotheses 1 to 5 were accepted. (See Table 7)

Regarding to H6, the purpose of one-way ANOVA was to verify whether there was a significant effect between attitudes toward RFID adoption and RFID usage intention. Attitude was the independent variable and dependent variable was usage intention. The ANOVA was significant for H6 (F=18.842, p=.000); therefore, hypothesis 6 was accepted. (See table 7)

A two-way analysis of variance was conducted to evaluate the relationship between two independent variables. In this case, they were the attitude toward RFID adoption and environmental factors; and the usage intention was the dependent variable. The statistical results indicated the F value was 1.854 and p-value was .011 made the results were not significant, therefore the hypothesis was rejected.

TABLE 7
RESULT OF HYPOTHESIS TESTING

Fixed Factor	Dependant Variable	*F*-value	*P*-value (Sig.)	Hypothesis testing
Relative Advantage	Attitudes toward RFID adoption	8.862	.000	Accepted H1
Compatibility		8.109	.000	Accepted H2
Complexity		5.759	.000	Accepted H3
Trialability		10.327	.000	Accepted H4
Observability		6.882	.000	Accepted H5
Attitudes toward RFID adoption	Usage intention	18.842	.000	Accepted H6
Attitudes toward RFID adoption *Environmental Factor		1.854	.011	Rejected H7

VI. RESULTS AND CONCLUSION

The investigation of this paper served as a feasibility study to determine what factors have influenced RFID future usage intention. To achieve this purpose, the researcher adapted Rogers's [2] innovation diffusion concept and included the following five major variables in the research as a research model of this study: relative advantage, compatibility, complexity, trialability, observability and attitude toward RFID adoption.

The research framework of this study used five steps of Rogers's innovations – decision processes (knowledge, persuasion, decision, implementation, and confirmation), and followed by the main concept of innovation diffusion: an innovation is communicated through certain channels over time among the members of a social system to build up the RFID diffusion model. Using attributes of innovations, environmental factors and attitude toward RFID system as variables to examine potential influence factors toward the RFID future usage intention.

From data collection and analysis section, the researcher took advantage of SPSS 16.0 to analyze the conceptual framework, research questions, and hypotheses of this study. The quantitative research methods involved in this study were described as follow: descriptive statistics, Pearson's correlation, and one-way and two-way ANOVA. Base on the information of the valid questionnaires and the analyzed data, the findings and the conclusion of this study were discussed.

A: Research question 1: What factors influence RFID technology acceptance attitude in Taiwan's logistics industry?

For the research question one (RQ1), not only the Pearson product-moment correlation (Table 5) was chosen to find the relationship between variables and the attitude toward RFID system adoption, but also one-way ANOVA (Table 7) was applied. The results found significant relationships and differences among these independent factors, relative advantages, compatibility, complexity, trialability, and observability, to the dependent variables, the attitude toward RFID system adoption. The results of this study suggested the five attributes of RFID system were conducive to the attitude toward RFID adoption of Taiwan logistics companies. It can be the influential factors toward RFID acceptance attitudes.

B. Research question 2: What factors affect RFID implementation intention in Taiwan's logistics industry?

The relationship between the attitudes toward RFID adoption and RFID usage intention showed significant differences and positive correlated with each other. Base on the results of one-way ANOVA (Table 7) for RQ2, different attitude toward RFID adoption had a different usage intention. Pearson product-moment correlation (Table 6) proved that attitudes toward RFID adoption and RFID usage intention had positive relationship; therefore, attitudes toward RFID adoption affected RFID implementation intention in Taiwan's logistics industry.

C. Research question 3: What are the barriers to RFID adoption in Taiwan's logistics industry?

Base on the two-way ANOVA, the relationship between the attitudes toward RFID adoption and environmental factors showed no significant difference to the RFID usage intention which meant the environmental factors such as competition inside the logistics industry, substitute products and services, entry barrier were not very influential to RFID usage intention.

VII. SUGGESTIONS

The results of this study have demonstrated the value and the feasibility of RFID adoption for Taiwan's logistics industry. The diffusion of innovation model of Rogers in this study also revealed the importance of the attitude toward RFID adoption and usage intension in terms of potential users' perceptions of attributes of RFID system.

Base on the research questions and the findings from the data analysis, the five perceived attributes of RFID system have the most significant predictive power on potential users' intentions of adopting RFID system. According to the research results, the researcher offered the following contributions and suggestions to this study.

The most prominent finding of this study was the five attributes of the innovations - RFID system. RFID provider companies should try their best to promote this technology's attributes of innovations: the relative advantages of RFID system to their potential customers, such as the costs reduction, profit capability and improvement of operation performance, design RFID system more friendly and more compatibility for quick adoption; reduce RFID system's difficulty and make it easy to learn and use. RFID providers can provide a trial-able project toward their potential customers. (Korteweg, et al, 2006) Moreover, the pilot project can identify aspects of important before deciding to totally implement the technology, which improves the observability of the RFID system.

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