A STUDY ON THE PERFORMANCE IMPROVEMENT IN PERSONAL PROPERTY MANAGEMENT THROUGH THE APPLICATION OF RFID TECHNOLOGY

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1. Introduction

RFID (Radio Frequency Identification) technology is, in its narrow application, a technology developed to replace barcodes. In broader application, however, it is one of the core next-generation technologies that can be applied to a broad range of areas including logistics, distribution, supply change management, transportation and environment (Curtin et al., 2007). Currently, the typical application of RFID technology involves attaching a tag, consisting of an antenna and a microchip that uses a radio-wave medium, to a personal property article. The tag, then, wirelessly transmits the information on the article and associated information, allowing the management personnel to read the information using RFID information reader devices. In essence, it can be categorized as a contactless identification technology (Want, 2006) with a broad applicability, as diverse radio frequency ranges can be used for different purposes. It also has the advantage that it can be applied to the industry without much conflict with the existing management schemes and technologies (Sang-seok Kim, 2004).

RFID is a technology that can be applied to various aspects of

public administration directly and without much complication. For instance, the management of government-owned personal properties required for the provision of public services is an important operation that contributes to the efficiency of public administration. The management of government-owned personal properties is one of the five manager components of the national finance, along with those of government real estates, government bond, foreign currency assets, and the national treasury. (Yu-jin Kim & Ki-seon Ku, 2003). Therefore, effective and systematic management of government-owned personal properties contributes to the efficiency of the government's budget operation and serves to improve the government's public services.

In the Republic of Korea, Public Procurement Service (PPS) is responsible for the supervision and coordination of the management of government-owned personal properties being held and used by the central government ministries and their subordinate agencies ("government-owned goods"). The total value of government-owned goods subject to PPS's supervision increased from 3.3 trillion Korean won in 1997 to approximately 8 trillion Korean won in 2009, marking a 2.4 times increase over the period. The total number of articles under PPS's supervision amounted to 12 million in 2009. Compared to the growth of the value and volume of government-owned goods, the advances in the management process were made at a relatively slow pace, and the management revealed inefficiencies in labor, time, and budget execution arising from perfunctory and inefficient processes (Tae-Ryeon Kim, 2009).

Prior to 2006, most of government-owned goods were managed based on manual inspection (at the average number of articles of 3,240 per one management person), and the managerial bookkeeping was done through the government's national budget and

accounting system (D-Brain). As a result, the record on the book often did not accurately reflect the actual inventory. Despite the importance of the task, public entities often treated it as a perfunctory, low-priority task, and staff changes were also frequent Furthermore, government-owned goods management has a low visibility, and public entities often repurchased the articles that they already own and disposed of articles that still maintain good use value. The periodical inventory inspection, which is the fundamental basis for efficient personal property management, took over 20 days, creating inaccuracies in the inventory data. Institutional changes in the government's accounting schemes also rendered it difficult for the traditional management scheme to adequately cope with the new accounting schemes such as the double-entry bookkeeping system and accrual basis accounting.

In order to overcome these difficulties, PPS adopted an RFID-based government-goods management system. After a pilot operation in 2005, PPS began to expand the application of RFID-based Government Goods Management System to all central government agencies on a gradual basis. In this new scheme, an RFID chip containing all the information needed for managerial purposes is attached to the government-owned goods at each agency. These chips, with varying types depending on the type of goods, enable automatic transmission of information which can be read and processed through an RFID reader device.

This study offers a case study on a successful example of applying RFID technology for efficient management of government-owned goods, and analyzes the impact through a multi-dimensional evaluation from the perspective of ITSM. Based on the result of the analysis, this study will also propose directions for further application and development of RFID-based government goods

management system.

2. Theoretical Background

2.1. Basic Concepts in RFID

2.1.1. Definition of RFID

RFID technology refers to the technology that stores information in a microchip-embedded tag, and allows the wireless reading of the stored information through a reader device by means of radio frequency (Yeong-il Song & Jae-hong Lee, 2006). As RFID technology complements the limitations of barcodes and magnetic recognition devices and offers greater user convenience, its application is drastically increasing in logistics management and inventory management. It is being perceived by many as one of the core future technologies (Eun-gon Lee, 2004). The differences between the barcode system and the RFID system are summarized in table 1.

[Table 1] Comparison between RFID System and Barcode System

Category	Bar-code	RFID
Recognition Method	Contactless	Contactless
Recognition Distance	0~50cm	0~27m
Data Writing	Not Possible	Possible (100,000 times)
Memory	1~100byte	64kbyte
Durability	Low	Semi-permanent
Recognition Rate	Less than 95%	Over 99.9%
Multiple Recognition	Not Possible	Possible
Recognition Time	Up to 4 seconds	0.01~0.1 second

Security	Very Low	Very High (impossible to duplicate)
Cost per a Tag	10 Korean won	500~10,000 Korean won
Period of USe	-	100,000 times (60 years)

2.1.2. Composition of an RFID System

An RFID system consists of a tag, an antenna, and a reader. The tag stores data and exchanges data through a protocol, and the antenna wirelessly receives and transmits data through the pre-defined protocol and radio frequency. The reader recognizes and reads the data stored in the tag, as well as writes data onto the tag. The tag plays the core role of RFID, i.e, the storing of data. RFID technology recognizes multiple tags at once via contactless means, allows long distance recognition, and the recognition penetrates objects between the tag and the reader. The tag can be used semi-permanently with a broad range of applicability, allows repetitive re-writing of large data, and the data recognition is faster compared to other media.

2.1.3. Operational Mechanism of an RFID System

The operational mechanism of an RFID system is as following: firstly, the data appropriate for the purpose is stored in a tag composted of a chip and an antenna, which is then attached to the object to be managed, such as boxes, palettes, vehicles, etc. Secondly, a radio frequency generated by the reader installed at an entry gate, a cashier, a toll gate, etc., reaches the tag. Thirdly, the tag reacts to the radio frequency and sends its stored data to the antenna. Fourthly, the antenna transforms the data and transmits it to the reader. Lastly, the reader decodes the data and transfers it to the host computer.

2.1.4 Current Use of RFID Technology

Since RFID instantly identifies multiple objects and the recognition range can be extended depending on the radio frequency used, it can be used flexibly for a variety of purposes. Due to the contactless recognition method, it is also less prone to damages. These properties allow a wide range of applications in areas including logistics management, entry / exit management, library management, courier services, and e-Money (Keun-woo Lee et al, 2008). Table 2 is the summary of the applications of RFID technology by industry sectors.

[Table 2] Application of RFID Technology

Sectors		Applications
Industries	Process Management	− Enables real-time monitoring of performance and defects by each process. − Information on the final marker, production personnel, date, order number, lot number stored in the tag can be used to facilitate A/S.
	SCM	− Enables the identification of products and the monitoring of their current status throughout their transfers from the manufacturer, wholesaler and retailer to the consumer. − Facilitates the management of resources in stock and planning for the future demands.
	Entry / Exit Management	− Enables selective entry/exit control at places that require such control, including companies, apartments, and membership-oriented venues. − Allows an integrated management on a broad range of business managements including the employee's on/off duty schedules, cafeteria operations, and personal PC security among others.
Logistics	Transportation Management	− Logistics management with real time updates using the shipping information stored in the tags.
	Warehouse	− Unmanned warehouse management from

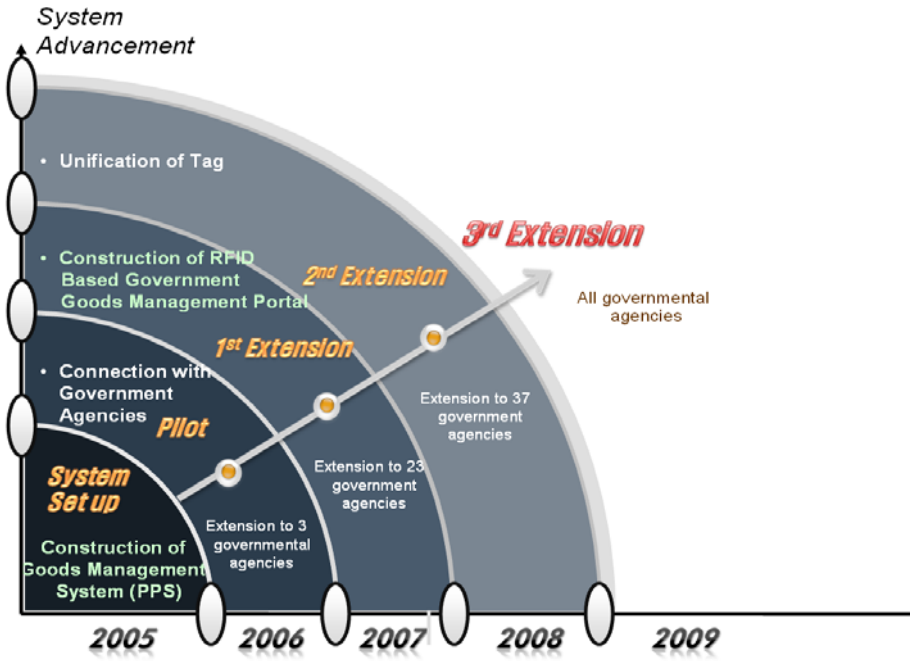
	Inventory Management	stocking to releasing, with automatized information management on the inventory and the stocking locations of the inventory items. − Enhances the efficiency of warehouse management.
	Air Transportation Management	− Real-time monitoring of the itinerary of the goods, current location and condition.
	Large Discount Stores	− Real-time monitoring of the logistics history of goods, inventory management on the goods on display, anti-theft management, and facilitates the casher operations. − Enables an unmanned store management.
Public Facilities	Library Management	− Monitoring on the members and check-out status of books. − Streamlines the check-out and return process
	Parking Lot Management	− Allows non-stop parking lot entry, automated fee clearing, prevention of unauthorized parking. − Automated toll collection for express ways.
	Traffic Fee Collection	− Can be applied to credit cards and public transit cards. − Currently in use for fare collection for buses and the subway. The use can expand to air/waterway transportation, taxis, and express ways.
Other Applications	e-Money	− RFID's high stability, duplicity prevention and privacy protection meets the requirements to be applied to e-Money
	Arboreal / Forest Management	− Can be applied for real time monitoring of the conditions and biographical data of trees.
	Animal Husbandry	− Management of biographical data of the livestock including age, vaccination, disease history, etc.
	Casino Management	− Planted in the chips in Casinos. − Real-time monitoring of the flows of the chips at each table. Prevention of thefts and loss.

3. Application of RFID Technology in Government Goods Management in Korea

3.1 Implementation of RFID-based Government Goods Management System

In Korea, RFID-based in government goods management system began with the implementation of a pilot system in 2005 by Public Procurement Service (PPS). By 2006, 3 additional public entities adopted the pilot system. In 2007, on account of the positive performance outcome, it has been decided that all public entities will adopt RFID-based government goods management. To accomplish this goal, a two-stage adoption plan was established, in which the first stage further divides into three phases. As the first phase adoption, 23 central government entities adopted the system in 2007, and the second phase adoption in 2008 included additional 37 central government entities. By the completion of the third phase in 2009, the system was adopted by all public entities that are subject to the institutional framework for the government goods management, that includes over 2,000 public entities. In the second stage, PPS aims to further advance the system to reach higher stability and to enable life cycle management of goods that expands the system to include post-disposal management to promote recycling (figure 1).

Figure 1. RFID-based Government Goods Management System Implementation Progress



RFID-based government goods management system in Korea reflects a best practice where the implementation has been conducted within the shortest time period under a central plan systematically drafted by the central government goods management authority. After the completion of the second stage implementation, PPS plans to disseminate the best practice worldwide.

In the 2004 pilot implementation, PPS used its own budget for attaching 35,000 RFID tags in 2004 to the goods under its management responsibility. In 2006, the 3 entities that joined the pilot operation individually funded for the attachment of RFID tags to the goods under their own responsibility, totaling 43,000 tags. The expansion roadmap was established in 2006 for the government-wide implementation of the system, and in 2007, one million tags were attached to the goods held by 23 central government entities. In 2008, 2.2 million additional tags were attached, and in 2009, 6.7 million

tags were attached to the items held by over 2,000 public entities, marking the adoption of RFID-based goods management system by the majority of public entities in Korea. The adoption of the system by the remaining minority is scheduled from 2010.

3.2 Overview of RFID-based Government Goods Management System

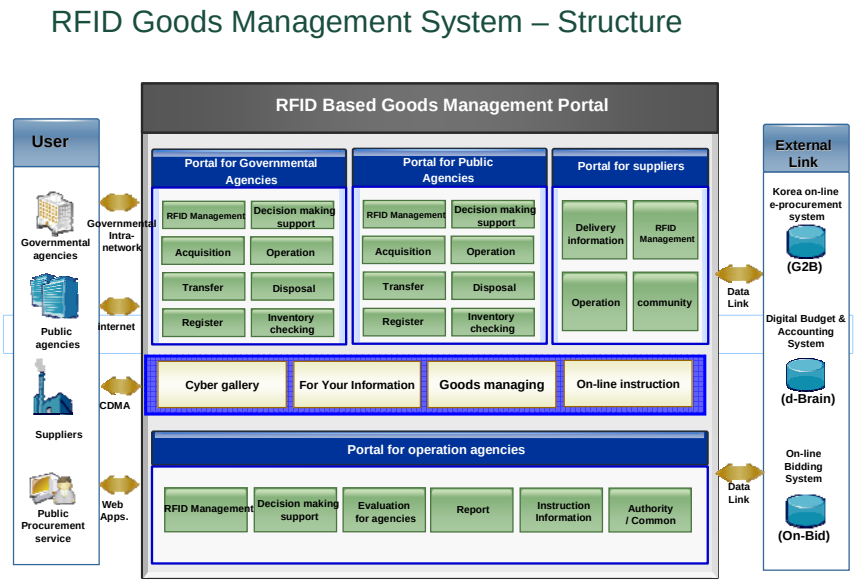
3.2.1 Composition of the System

RFID-based Government Goods Management System consists of 4 modules, each module designed for the corresponding user group: central government entities, other public entities (local governments and independent public entities), suppliers, and the system operator (PPS). While the former 2 modules are similar in that they incorporate RFID technology in the previous goods management process, they partially differ in their functions due to the different governing laws and regulations. The suppliers' module enables the suppliers to register the model number, item number and the price of the goods, and issue RFID tags to be attached to the goods to be supplied to public entities. The system operator's module allows PPS to manage the RFID tag information and provide online training.

One of the most important benefits of PPS's RFID-based government goods management system is that it enables a seamless stream of work process by utilizing various wired/wireless data transmission channels effectively creating a ubiquitous work environment. With the implementation of RFID-based government goods management system, Korea has digitalized all of the five major elements of national finance. The Digital Budget and Accounting System (d-Brain), the Electronic Asset Disposal System

(On-Bid), and the e-Procurement System (KONEPS) share the data on public procurement, inventory management, accounting and disposal on a real-time basis, creating an integrated digital environment for the national budget operation (Figure 2).

Figure 2. Conceptual Diagram of RFID-based Government Goods Management System



3.2.2 Life-cycle Management of Government-owned Goods

RFID-based Government Goods Management System allows the entire life-cycle management of government-owned goods from purchase to disposal.

At the purchasing stage, the product and contract information is transmitted from the government e-Procurement system (KONEPS) to the government goods management system. For

prompt and accurate inspection and take-over of the goods, the government goods management system exchanges data with the digital budget and accounting system (d-Brain). At the take-over stage, the information stored in the tag is compared with the contract information obtained from the government e-Procurement system for improved accuracy. Upon the transfer of goods, the information in the tag allows the monitoring of logistics history, and the use of RFID reader also reduced the time for inventory inspection. Lastly, the system also facilitated the disposal management using the data exchange linkage with the government asset disposal system (On-Bid).

3.2.3 Challenges in the Implementation and Operation

The implementation of RFID-based Government Goods Management System faced a number of technological and managerial challenges.

First of all, there was a challenge related to the issuance and the recognition performance of RFID tags. Initially, the issuance of the tags was centrally handled and managed by a government authority. This approach, however, faced difficulties due to the overwhelming number of goods and the product property information associated therewith. To overcome this challenge, PPS has changed its policy and allowed the tag issuance by each public entity provided that they adhere to the standards and the manual.

Secondly, there were challenges associated with the recognition performance of RFID tags and readers. Initially, the reader was developed in a PDA size for portability and convenience. Due to the limitations of the software and hardware, however, the early readers had unsatisfactory performance in the tag recognition speed and accuracy. Due to the use of multiple types of readers, there also arose compatibility and interoperability issues. In response, PPS

developed a standard module for portable RFID readers (Mobile RFID SDK) to ensure interoperability and improved performance of RFID readers. Recently, UMPCs(Ultra Mobile Personal Computers) have been put into use, allowing more prompt and accurate reading of the tag information.

Lastly, there was a challenge in the work process where public entities checked the product information for each individual item and issued the tag, as the large number of goods created a large workload for the public employees responsible for this process. In addressing this issue, PPS is currently looking into a new policy that requires the suppliers to attach the tags prior to delivery in accordance with the tag issuance information provided by the purchasing entity.

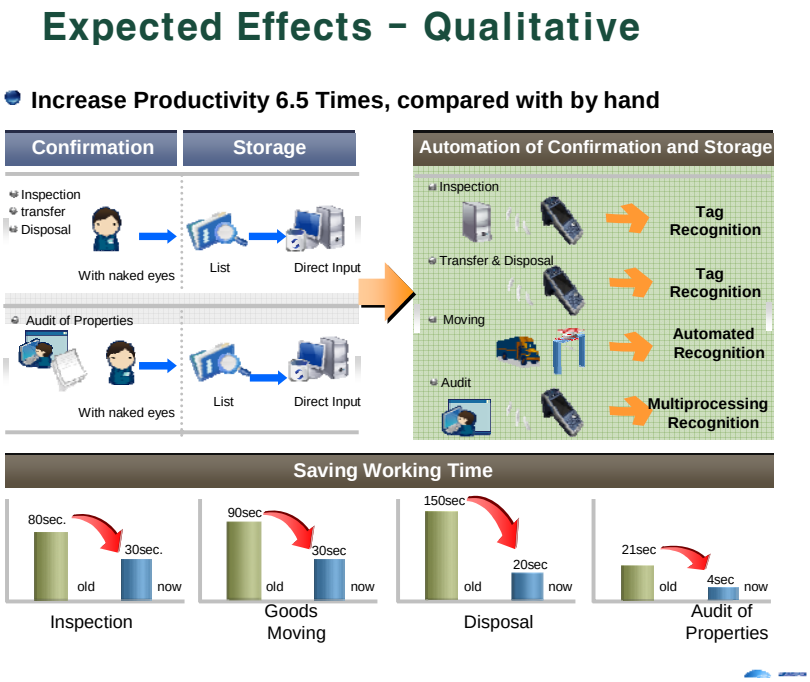
3.2.4. Anticipated Effects

The direct qualitative effects anticipated from the implementation of RFID-based Government Goods Management System are the enhancement of transparency and visibility of government goods management, as well as improved efficiency. Indirectly, PPS also anticipates the effects of job creation, and the revitalization of waste disposal and recycling industry.

Enhanced transparency and the visibility can be achieved through the expansion of RFID-based management system, which increases the accuracy of the government's asset management. The system will also improve the productivity of the government goods management process (acquisition, transfer, disposal and inventory inspection). In particular, real-time monitoring on the goods (service year, purchase price, etc.) can minimize new purchases. The system will also help the standardization of government goods management, which will further enhance the efficiency of government-owned goods management. The development, manufacturing and sales of RFID tags, readers, tag issuers, tag labels, and the operating software constituted a new industry, attracted investment, and lead to the

creation of new employments (Figure 3).

Figure 3. Quantitative Effects of RFID-based Government Goods Management System



The quantitative effects of RFID-based Government Goods Management System was a significant reduction of the process time required in acquisition (inspection), transfer, disposal, and inventory inspection. In the pilot operation in 2005, RFID-based management marked a 6.5 times higher performance compared to the previous manual inspection. Prior to RFID, the work process depended on the visual confirmation of the inventory items, on-site book-keeping and entering the information on the book onto the government budget and accounting system (d-Brain). With RFID-based Government Goods Management System, the inspector uses an RFID reader to read the information stored in the tags attached to inventory items and remotely transmit it to the management system portal. This real-time processing yielded the time savings of 50 seconds per item in

acquisition process, 60 seconds per item in transfer, 120 seconds per item in disposal, and 17 seconds per item in inventory inspection process. Based on a survey conducted on public entities where RFID-based inventory management has been implemented for over 2 years, the economic effect of the time savings is estimated to be 5.7 billion Korean won (Table 3).

Table 3. Time Savings of RFID-based Goods Management System

	Manual (Sec.)	RFID (Sec.)	Time Saving	Time Saving on Error Correction	Number of Items	Labor Cost (Won/hr)	Labor Cost Saving
Inventory Inspection	47.9	2.3	45.6	600	12,800,000	11,939	5,756,189,867

* On empirical basis, the estimated error rate of 15% was used in the estimation. Likewise, 600 seconds was used for the time required for error correction, although the actual time would vary based on the characteristics of the item as well as the circumstances.

The comparison of the 2005 pilot implementation result and the 2010 performance result shows that the effect of the system future increases after a successful settlement phase following the initial implementation. Since it typically takes from 1.5 to 2 years for a large-scale information system to yield visible effects in organizational asset management, in can be inferred that the impact of RFID-based system is best realized in organizations that adopted the system in 2007 and thereafter.

4. Evaluation Model for RFID-Based Government Goods Management System and the Evaluation Results

4.1 Overview of the Evaluation Model

This study adopted a multi-dimensional model in order to evaluate RFID-based Government Goods Management System. In particular, the model took into account the factors used in establishing ITSM (Information Technology Service Management). ITSM is a management that encompasses the entire range of IT services, and is defined as recognizing the IT resources as services, and strategically and systematically managing the IT resources. (Sang-hoon Lee et al, 2007). ITSM aims at optimizing the IT services to meet the business's information requirement and effectively manage the business's IT infrastructure. Recently, ITSM is also expanding into web service architecture (Stern et al., 2004). As RFID-based goods management system provides IT services for inventory and asset management, the factors and values used in ITSM is directly applicable to RFID-based Government Goods Management System. ITSM's goal is to maintain and improve the IT services provided for the organization, and therefore developing the factors for measuring the level of IT services is very important. This study adopted a model that assesses RFID-based goods management system from three aspects: technology, economic benefits, and user-reception.

The multi-dimensional model complements the previous models focusing mainly on economic assessment. Economic assessment methods focuses solely on the economic value of the technology itself, and had limits in assessing the diverse benefits of the services made available from such technology. (O-byeong Kwon, Ji-hun Kim 2006; Mankoff et al., 2004; Riekki et al., 2004). Most related studies, however, appear to technology value assessment, propagation effects analysis based benchmark input-output accounts, and economic feasibility assessment based on financial indices such as ROI and ROA. The credibility of such assessment is limited, as the parameters for the assessment are often based on hypothetical

service scenarios that have not been actualized.

Contrarily, the multi-dimensional assessment model can access the economic benefits by measuring the economic value created from the products and services made available from the technology, and at the same time evaluate the potential for expansion by measuring the user-reception. As a matter of fact, an assessment focusing on the economic benefits may fail to note such problems as the resistance among the users and difficulties in technological quality management that may obstruct the designed effects of the system. In order to measure the feasibility for RFID-based Government Goods Management System's expansion into the private sector, a multi-dimensional assessment that measures both the economic benefits and how well the system serves the organizational needs.

Therefore, this study evaluated RFID-based Government Goods Management System using a comprehensive multi-dimensional evaluation model. This model will evaluate the technological completeness, economic benefits, and the users' willingness to adopt the system.

4.2. Multi-dimensional Evaluation Model and Analysis

In order to evaluate RFID-based Government Goods Management System from the aspects of technology, economic benefits and user reception, this study applied 2-4 measurement factors per each aspect. The technological and economic factors measure the system's feasibility and performance from the perspective of the service provider, while the user-reception reflects the assessment from the service users' viewpoints. The assessment for each factor was conducted through a survey, and the factors were weighed differently in the final value in accordance with their respective importance (Table 4).

Table 4. Multi-dimensional Assessment Results

		Factors	Original Score	Weight	Weighed Score
Service Provider's Perspectives	Technology	System's Functional Quality	75.1	0.3	22.53
		Quality of System Management	77.6	0.2	15.52
		Quality of Inventory Inspection	80.5	0.3	24.15
		Quality of RFID-based Management System Portal	80.4	0.2	16.08
	Sub-total		78.4	1	19.57
	Economic benefits	Inventory Inspection	100	0.4	40
		Acquisition & Inspection	57.1	0.2	11.42
		Transfer	56.7	0.2	11.34
		Disposal	60.5	0.2	12.1
	Sub-total		68.6	1	18.7
User Perspectives	User-reception	System's Utility Value	80.5	0.3	24.15
		Use Increase Rate	81.4	0.7	56.98
	Sub-total		81	1	40.6

In evaluating the quality of technology, this research measured the functional and performance quality of RFID readers, RFID tags, the management portal, and the system's functionality for inventory inspections.

For economic benefits, this study measured the direct economic gains that may be obtained from managing government-owned goods (acquisition, disposal, inventory inspection), converted into monetary value.

User-reception is a criteria on how well the products and services would be received by the users. In this study, this criteria is measured by the user evaluation on the system's utility value, and the use increase rate.

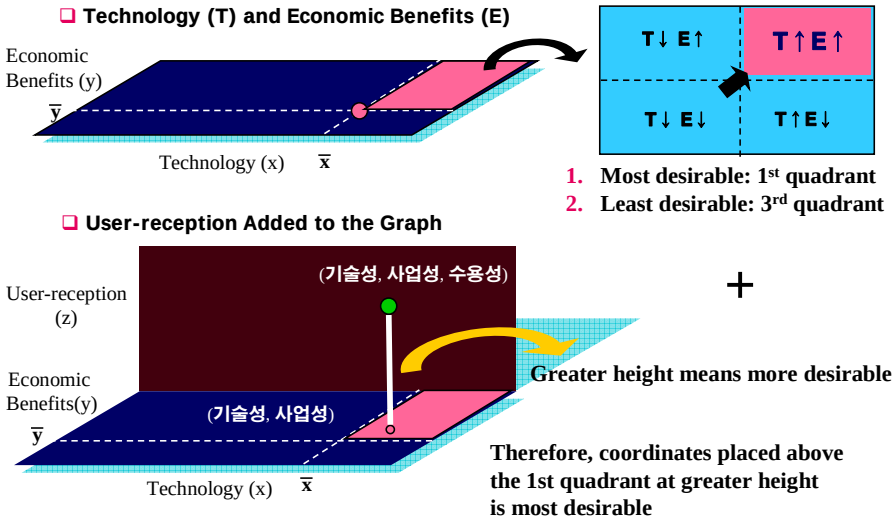


Figure 5. The Evaluation Method and Process

Figure 5 depicts the three dimensional evaluation on the technology, economic benefits and the user-reception. The first stage of the evaluation assesses technology and economic benefits from the service provider's viewpoint, and the second stage measures the user-reception and tri-dimensionally shows the results. The evaluation results on technology and economic benefits are drawn on a two-dimensional plane, and the first quadrant represents good technology and economic benefits. The user reception is represented as the height in the three-dimensional space. In general, a result placed above the 1st quadrant of the horizontal plane represents a good result (greater height represents better user reception).

4.3. Results of Evaluation

The result of the evaluation showed that RFID-based

Government Goods Management System marked the score of 78.4, which is quite high for a one-year-old system. It also scored 68.6 on economic benefits, representing a sustainable economic gain.

More importantly, the analysis yielded a very positive assessment in user-reception. The system scored 80.5 in the utility value, and 81.4 in use increase rate. This result indicates that budget investment for RFID-based Government Goods Management System is sufficiently justified. Figure 6 shows the graphic diagram of the evaluation results.

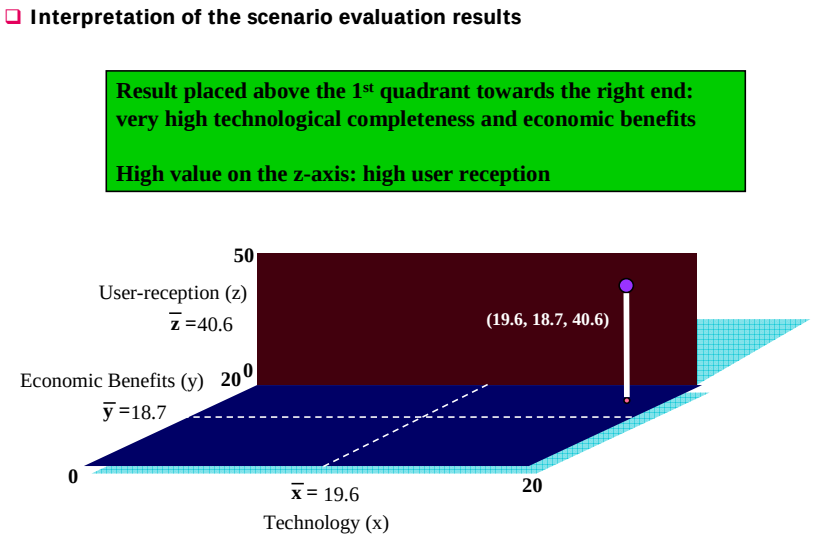


Figure 6. Result of Multi-dimensional Evaluation on RFID-based Government Goods Management System

The technological and economical assessment both yielded very high values, respectively marking 19.6 and 18.7. The coordinate consisting of the three values are placed above the upper right side of

the 1st quadrant, representing a very high feasibility from the perspective of ITSM. The user-reception marked 40.6, close to the highest possible score, representing a very positive reception among the users. These results provides a solid justification for the implementation of RFID-based Government Goods Management Systems or similar other systems.

5. Conclusion

This study confirmed the rationality of adopting RFID technology in government-owned goods management, from the viewpoint of technological readiness, economic benefits and user-reception, through Korea's case. The achievements of Korea's RFID-based Government Goods Management System could be summarized as follows:

Firstly, Korea's adoption of RFID-based Government Goods Management System began with 2007 pilot operation among three organizations, and as of 2010, 2,000 public entities have adopted the system including 69 central government entities. From the qualitative aspect, RFID-based Government Goods Management System enhanced the transparency and visibility of government-owned goods management, and thereby improved the transparency of the national budget operation. Secondly, the system automated the inventory inspection process, and improved the productivity and accuracy of government-owned goods management process. Thirdly, the government-wide expansion of the system created a continuous demand for RFID-related products and services, and served to revitalize the related industry. The public sector initiative also expected to induce private sector adoptions, particularly among the 70,000 suppliers that supply goods and services to the Korean government. Lastly, by exchanging data with other e-government

systems, such as the government e-procurement system, the government budget and accounting system, and On-Bid system, RFID-based Government Goods Management System enabled the life cycle management of government-owned goods and realized an automated e-Inspection process.

Two implications can be drawn from the aforesaid achievements. Firstly, In order to achieve maximal performance improvements, a concentrated mid-to-long term investment is required. As the system is to be adopted by all public entities nationwide, differences in the adoption schedule and the level of the adoption have negative influences on standardization and cause redundancy in investment. Secondly, the scope of the system implementation should also include the integration with related government systems in order to obtain the maximal benefits.

However, there are also limitations arising from a number of problematic issues. For instance, in applying the system for 2,000 public entities in a short time, the system process had to make considerable shifts from the previous government goods management process. A phased implementation is recommendable, in order to overcome the difficulties arising from such shifts. Secondly, there are challenges associated with the performance of RFID tags and readers. In order to minimize inaccurate reading of the tag's data, improvements in the durability of the tags are needed, and the signal interferences need to be reduced. The data reading sensitivity also varies depending on the angle between the tag and the reader, which also needs to be improved in order to minimize hindrances in the work process.

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