A Decision Support System Framework for RFID Technology Adoption

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Abstract

In recent years, companies have started to consider if they should adopt RFID technology to boost their business performances. Yet, they have many concerns, such as costs, RFID performance, company situation, actual benefits, etc. A study also showed that many senior executives lacked of the necessary financial skills to evaluate IT investments. Many companies defer the RFID adoption as they find it difficult to assess its benefits. To assist managers, a Decision Support System (DSS) framework is proposed to quantify the benefits of RFID technology adoption for various industries. The DSS is designed with a multi-criteria decision model, with integration of the essence of cost of quality, cost of benefit analysis, activity based costing methods. The objective is to quantify the benefit of RFID adoption based on individual company needs and circumstances, in order to provide managers a clear and comprehensive view.

1. Introduction

In today's rapidly changing business environment, companies must continually improve their operational efficiency to maintain their competitive advantages. Many companies have been adopting various information technologies and systems, such as Enterprise Resource Planning (ERP), Electronic Data Interchange (EDI), Warehouse Management System (WMS) etc, to maintain or improve their efficiencies. In the past ten years, Radio Frequency Identification (RFID) technology has a fast development and the price of RFID tags has dropped significantly. Large enterprises, such as Wal-Mart adopted this technology, with estimated savings of US$6.7 billion in reduced labor costs, US$600 million in out-of-stock supply chain cost reduction, US$575 million in theft reduction, $300 million in improved tracking through warehousing and distribution centers, US$180 million in reduced inventory holding and carrying costs (Asif and Mandviwalla, 2005).

Many companies are considering if they should adopt RFID technology to boost their business performances. In which, they are concerning many factors, such as direct and in-direct costs, RFID performance and risks, current company situation, the efforts for initial implementation and adoption in a long-run, etc. Managers want to see if their own company is suitable to adopt RFID and the estimated cost and benefits of such implementation. Most companies still doubt about the benefits brought by RFID, given the need for a huge investment up front and the uncertain return on investment (ROI) (Bhattacharya et al. 2010). Although there were studies discussing the general pros and cons of RFID, or providing successful examples of adopting RFID in a particular business sector, managers are still skeptical if RFID fits the unique situation of their companies. In addition, a study surveyed 130 senior executives from companies with average $230 million in annual IT spending and showed that : 51% of respondents had no process to evaluate IT investments against business strategy; 74% did not track financial metrics after making an investment decision; and 80% lack the necessary financial skills (Chabrow, 2003). Due to the insufficiency in systematically evaluating the effects brought by RFID, many companies delay decision on RFID adoption. This may significantly influence companies' competitiveness in both local and global supply chain businesses.

In viewing of current situation, we believe a Decision Support System (DSS) should be developed to quantify the benefits of RFID technology adoption for various industries, so as to allow managers understanding the appropriateness and effects of this adoption. In this paper, we

first study current RFID applications and to generalize the pros and cons of RFID technology for various industries. Then we analyze the costs and benefits of RFID technology implementations. With the analysis, we can identify what kind of company, in terms of size and industry, process flow, is suitable for adopting RFID technology. A decision support system is proposed to help each manager designing if his/her company should adopt RFID technology based on individual needs and circumstances.

In the following sections, we first review studies in RFID and barcode. Section 3 describes RFID application in different industries and summarizes the pros and cons of RFID. In-depth analysis of the successful cases of adopting RFID technology across different industries is presented. In which, relevant data are collected as the benchmark to estimate the average performance for RFID adoption in various industries. Section 4 elucidates the research methods, including cost of quality, cost benefit and activity based costing (ABC). Section 5 designs and proposes the decision support system framework. Lastly, section 6 provides suggestions for future studies.

2. Literature Review

In this section, we review RFID literature with a focus on the papers that are most relevant to the supply chain. Comparison is made between RFID and barcode, a common tagging technology in current supply chain. Lastly, the costing models in supply chain are reviewed to assess their suitability to be incorporated into the decision support system.

2.1 RFID History and Development

RFID is an auto-ID technology that uses radio frequencies to identify, track and trace objects or products. The roots of RFID technology can be traced back to World War II when British planes were installed with radio frequency transmitters to identify objects on the ground (Landt 2005; Miles 2005). Commercial applications began in the early 1980s, which were used to identify asset inside a single location (Reyes, 2011). Today, applications of RFID are applied in a wide range of industries such as retail, logistics and manufacturing. There are many benefits of adopting RFID technology in the supply chain, such as easy integration of RFID and Internet technologies, accurate and instant information of the products recording and transmission across the supply chain. These benefits can enhance the efficiency and diminish the chances of waste and error, which are very important concerns for supply chain performance. In addition,

improving traceability can reduce the costs to downstream parties – such as retailers or processors monitor the raw material supply of upstream parties (Sarac et al. 2010).

Currently, RFID technology plays a key role in supply chain management in some retailers such as Wal-Mart, Marks & Spencer, Proctor & Gamble (P&G). It can improve warehouse logistics efficiency by ensuring that goods can be traced through the chain so as to reduce out-of-stock rates and enhance replenishment efficiency. In view of these successful cases, it is perceived that adopting RFID technology can significantly improve business process, enhance organizational performance and increase competitiveness.

2.2 A Comparison of RFID and Barcode Technologies

Despite RFID technology can provide numerous expected benefits over bar code systems, many companies are still unwilling to switch to RFID tags. Barcode is the current and the most common method of product tracking in many industries. It is a mature auto identification technology and has been used in supply chain management for many years. It is viewed as a reliable, inexpensive and easy-to-operate system. However, there are many limitations for barcode system. The first one is the fixed labeling – once the barcode is being printed on a label, it cannot be changed or rewritten. The second one is limited identification – it cannot uniquely identify all items because barcode system cannot create a unique number for each item. The third one readability problem, a line of vision scan is required to read a barcode once at a time, and many environmental factors, such as moisture and physical damage affect readability. Lastly, barcode may not be an appropriate technology in meeting high security standard, since barcode-based identification cards can be duplicated easily (White et al. 2007).

In contrast, RFID does not have any of these limitations. Yet, when RFID technology was first launched to the market, many companies have already put significant investment in barcode system. They worry if they switch to RFID technology, it will incur a huge large amount of initial investment again. In addition, in comparison with RFID technology, the variable cost of barcode is much cheaper. This may be true when the direct and in-direct costs, such as efficiency, out-of-stock risk, security and goodwill brought by the above limitations are not calculated. Some companies also concern the customer privacy issue in RFID, as RFID tags can be tagged on item level rather than boxes or pallets. Customers using the products with RFID tags can be traced easily - nearby readers may easily read the ID number or the Electronic Product Code (EPC) stored in the tag. To address this problem, several security measures have

been proposed. For retail industry, the simplest method is the "Kill Tag" approach which the tag is electronically deactivated after the item is sold; or the tag can also be removed from the product for recycle before being sold (Sitlia et al. 2009).

2.3. Research Methodologies

To develop the decision support system, we need to formulate the model for analyzing RFID implementations in terms of their costs, benefits and performances. The common investment methods used in decision making are real options analysis, cost benefits analysis, cost of quality, activity based costing (ABC) and payback period or return on investment (ROI). After discussing their characteristics, we analyze their appropriateness for the DSS model.

2.3.1 Available Methodologies

A. Real options analysis (ROA) is a key management technique for estimating the value of investment. ROA is related to the concept of net present value (NPV), which does not account for changes in risk over a project's life cycle. With ROA, the uncertainty inherent in investment projects is usually accounted for by risk-adjusting probabilities. Cash flow can then be discounted at the risk free rate. (Bowman and Moskowitz, 2001; Benaroch, 2002). There are five common real options: 1.Waiting to invest options; 2.Growth options; 3.Flexibility options; 4.Exit options; and 5. Innovation and learning options.

B. Cost benefit analysis clarifies the trade-offs between initial costs and operating costs. It is computed by dividing the annual benefit by the annual cost. It can provide an economic assessment of the extent to which a project or program may achieve its ultimate goal of reducing the number or severity of crashes (Engel, 2006). It ultimately provides a method of selecting the most cost-effective countermeasure for any projects.

C. Cost of quality (COQ) is a financial measure of the quality performance of an organization, so as to allow a company continuing meeting customers' expectations. It serves as an essential indicator for the cost of bad quality. The costs associated with quality are divided into two categories: costs due to poor quality (internal and external failure costs) and costs associated with improving quality (prevention and appraisal costs) (Kaner, 1996). Prevention costs and appraisal costs are incurred in an effort to keep defective products from falling into the hands of customers. Failure costs are incurred because defects are produced despite the efforts made for prevention. Prevention and appraisal costs have a

positive correlation with quality conformance, while failure costs have a negative correlation with quality conformance.

D. Activity based costing (ABC) is a costing method which provides managers with cost information for strategic and other decisions that potentially affect capacity and fixed cost (Cleverley et al. 2007). Its aim is to understand overhead and the profitability of products and customers. It is different from traditional cost accounting systems, which objective is to value inventories and cost of goods sold for external financial reports in accordance with the generally accepted accounting principles (GAAP). It identifies activities that consume resources and the cost drivers associated with each activity.

E. Return on investment is a performance measurement used to evaluate the efficiency of an investment. The step of calculating ROI is subtracting the cost of investment from the gain from investment, and divided by the cost of the investment. Next, payback period is defined as the time period needed to compensate for the initial investment expenditure using the money flow that is produced by the investment, with a rate equal to zero. (Apostolopoulos and Pramataris, 1997)

2.3.2 Suitable Methodologies

Based on the above analysis, we summarize their appropriateness as follow. First, the real option analysis may not be suitable for this study. Options are valuable when there is uncertainty, however many innovative projects do not conform to the same capital market assumptions underlying option models. ROI or payback period are regard as imperfect criteria, too. They ignore any benefits and profits that arise after the payback period and they also ignores the time value of money. On the other hand, the cost-benefit analysis will be useful to evaluate all potential costs and revenues that may be generated from RFID implementation. Cost of quality (COQ) and activity based costing (ABC) can be useful to quantify benefits on quality performance and activity savings.

Every method has its pros and cons and if the DSS just adopts one investment calculation method, the result may be incomprehensive to reveal the whole picture and inflexible to adjust according every company's needs. Thus, it is risky for a company to make RFID investment decision based on one particularly method. We have to combine investment methods to provide a strategic and comprehensive view on profitability and quality. Therefore, an integrated decision

making model, consisting of cost of quality, cost of benefit and activity based costing methods will be proposed in section 5.

3 RFID Applications in Different Industries

To allow the DSS supporting RFID implementation decision across different industries, we have to review the current developments, benefits and concerns of RFID applications in various industries. RFID has a growing range of potential uses throughout industries, and it has been implemented in different areas such as jewelry management, food supply chain management, retail, transportation and baggage handling in airport. Successful implementation cases can be found in different industries and they are briefly described in Appendix A.

From these studies, we found that the main driver for the adoption of this technology is the capability to identify and track the movement of products through supply chains. For example, the major benefit of RFID adoption in jewelry management is enabling more accurate and faster inventory tracking in order to increase security standard. In food supply chain management, RFID guarantees the freshness and food safety. This benefits increase restaurants goodwill and reduce legal liability risk. For retail sector, RFID technology enables end-to-end traceability which helps company reduce out-of-stocks cases and safety stock levels. For example, by placing a removable RFID tag on product that can be read by a hand-held scanner, staff can quickly find out which size of jacket is missing. Reduce out of stocks can reduce loses of sales – according to Proctor & Gamble (P&G), manufacturers and retailers can enjoy 20 percent more sales just by ensuring that displays and promotional products arrive on the sales floor on time (Motorola, 2010).

Beside retailers, other parties involved in the supply chains also can gain benefits in different ways. For suppliers and manufacturers, collecting product demands from retailer real-time allow suppliers to plan production more efficiently. In transport and logistics sector, it helps the airport to reach quicker reconciliation of baggage and reduces manpower costs. The use of the RFID ticket (Octopus Card) brings great convenience to users with shorter transaction time due to the improved integration of different public transport systems. This also brings benefits to transportation service providers, as it replaces the manual ticket-checking process, improves crowd management at stations and prevents fake tickets.

In short, there are common advantages and disadvantages for RFID applications in various industries. Advantages include improvements in information accuracy, security, traceability, reliability, response time and cost reduction. Disadvantages include costly investment, privacy concern and data protection. As shown in Table 1, all applications can enjoy most of the benefits and face mainly the cost problems, which we will discuss further in next section. Privacy concern and data protection should not be the major hindrances for some industries. With more adoption of RFID technology globally, the cost of RFID technology has decreased significantly. It is estimated that the cost of RFID technology will be close to barcode after three to five years.

Table 1: Common pros and cons of RFID applications

		Advantages					Disadvantages		
Application	**Information Accuracy**	**Security**	**Traceability**	**Reliability**	**Response time**	**Cost Reduction**	**Costly Investment**	**Privacy concern**	**Data protection**
Jewellery	√	√	√	√	√	√	×	√	√
Food SCM	√	√	√	√	√	√	√	×	×
Retail	√	√	√	√	√	√	√	√	√
HK International Airport	√	√	√	√	√	√	√	×	×
Octopus Card	√	√	√	√	√	√	√	√	√
RFID Train Ticket	√	√	√	√	√	√	√	×	×
RFID in Logistics	√	√	√	√	√	√	√	√	√

4. RFID Costing

The major concern of most companies is the cost of implementing RFID system, which cost depends on the application, size of the installation, type of readers and the volume of RFID tags. In this section, a cost comparison between barcodes and RFID is conducted, and the RFID implementation cost is discussed.

4.1. Cost Comparisons: Barcodes v. RFID

Compared with RFID, barcodes are much cheaper. Thus, they are adopted by most of the companies and many company owners are unwilling to establish the RFID system. In fact, the RFID tag price decreases every year, and in 2011, the tag price has decreased to US$0.25. While for barcodes, its unit tag price is US $0.05. It is believed that RFID tag price will be comparable with barcode by 2016 (Das & Harrop, 2008). Despite, RFID tag price is still 5 times of barcode

tag price, companies should take into account that RFID tag can be re-used but barcode tag is one time use. RFID is a more cost effective choice, since the tag can be used for 10-20 years. While for reader price, RFID reader price is mostly between US $1000 – US $3000 and the barcode reader price is between US $300 and US $1000 (Source: www.nextag.com). In considering barcodes have several disadvantages mentioned in section 2.2, we believe the total cost of barcodes and RFID should be similar in the long-run. That means if the owner set up the RFID system, the additional revenues gained will compensate the initial cost, and this has proofed by many cases depicted in section 3.

4.2 Adoption and Implementation

There are three costs for RFID implementation: training cost, hardware and software cost and additional labor cost. To utilize RFID technology effectively and efficiently, sufficient trainings must be provided to employees. According to some RFID implementation solution providers, a four days RFID training course is around US$500 per person. Second, the middleware cost, including reader, tag and enterprise software is around US$180,000 on average. Lastly, the cost for hiring more IT staff to maintain the system is around $US443,000, in which US$128,000 for consulting and US$315,000 for internal project team (RFIDjournal.com, 2005). Though there are significant costs in middleware and labor, adopting RFID can significantly reduce the labor cost for manual checking and monitoring processes. In addition, RFID technology can bring additional cost savings and revenue in sales, which can be in billions of dollars.

5. Decision Support System Framework for RFID Adoption

A decision support system (DSS) is a system providing solutions by combining with different methods for organizational decision-making activities. In this study, we design a decision support system for company to answer three questions: 1. Should they should adopt RFID technology? 2. If yes, to what extent should they adopt this technology? 3. What are the expected benefits brought by this adoption? As an initial design of the DSS, it focuses on three sectors which are the most common industries in Hong Kong: manufacturing, logistics and retail. To provide valid solutions, this DSS must understand the current processes, situations, and environmental factors of the company. Decision makers using this system must fill-in a questionnaire which covers different aspects of company, with two focuses: the current

performance of the company without RFID technology and the expected benefits get from the technology. Then, the system will combine cost of quality, cost of benefits and ABC to calculate the costs as well as the benefits, in terms of profit and quality. Lastly, suggestions will be provided on RFID technology adoption (Figure 1).

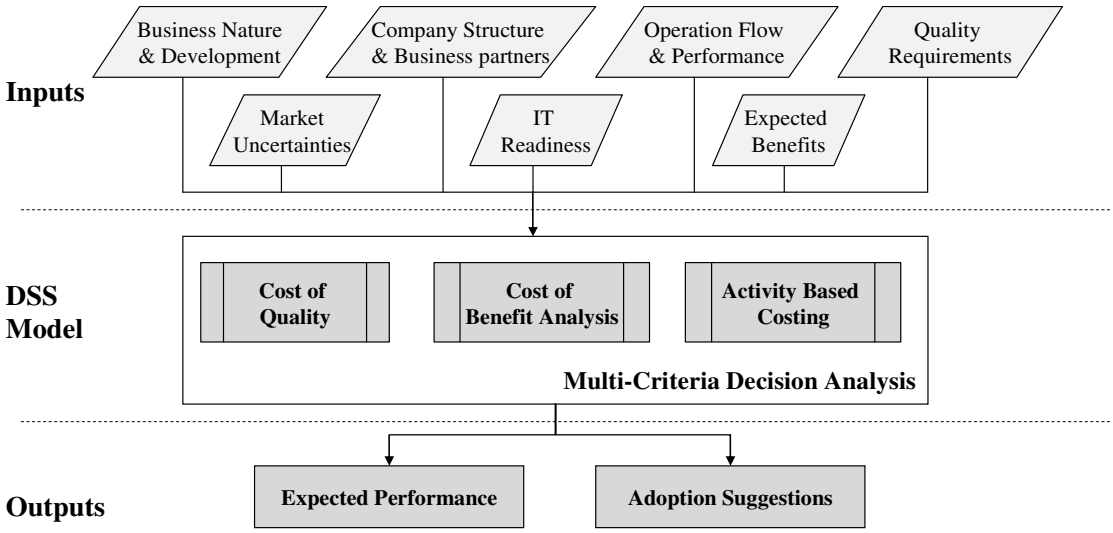

Figure 1. Decision Support System Framework

5.1 The Input to DSS

The justification of IT adoption can be a complex issue as it involves five aspects of considerations: strategic, tactical, operational, intangibles and tangible. The corresponding factors include performance indicators, data migration, system integration, quality improvement, goodwill, product cost, lead-time, etc, and according to Gunasekaran, there were 40 factors (2001). Due to the uniqueness of each factor, it is impossible to evaluate or estimate them using a single system. This DSS tries to cover the concerns from each of the five aspects by incorporating some of their important factors: such as internal operating performance, external environment, nature of business, IT readiness, quality standard, expected benefits from RFID adoption are considered. If the company is currently using barcode, there are also some questions to understand the reason why the company seeks for RFID. Appendix B shows a portion of the survey as an example. The survey will be further revised for different industries.

5.2 DSS Formulation

As mentioned in Section 2.3.2, this DSS is based on three models. For Cost of quality analysis model, the potential quality benefits of implementing RFID are less rework time and less rework cost. To estimate the cost of benefits after implementation, the system uses information collected from companies of the same industry which have adopted RFID technology. For the activity based costing part, common operating costs are identified as the bases of the model. As the DSS combines three models (cost of quality analysis, cost benefit analysis and Activity Based Costing), the importance of these three models for each industry is different. Based on the company's conditions and preferences, as well as the industry nature, different weightings will be assigned in the multi-criteria model to reflect the importance of these three models.

5.2.1 Cost of Quality

For four quality costs, the respective parameters to be considered in the decision support system are identified in Table 2. Similar to other COQ models, our system will be based on the prevention-appraisal-failure (P-A-F) classification.

Table 2: Different costs associated in Cost of Quality

Prevention cost	● Costs of training ● Cost of new product review ● Cost of testing ● Costs of process capability evaluations		**Failure costs**	a. Internal Failure Costs ● Cost of scrap ● Cost of rework ● Cost of re-inspection ● Cost of retesting ● Cost of material review and downgrading
Appraisal cost	● Cost of in-process and final inspection or test ● Cost of incoming and source inspection or test of purchased material			b. External Failure Costs ● Cost of processing customer complaints ● Cost of customer returns ● Costs of warranty claims ● Cost of product recalls

This method is used to compare the difference in cost of quality for the company before and after RFID adoption. Equation (1) sums various costs together to find the total cost of quality. The reduction of in costs will regard as the benefit of RFID adoption.

$$\sum_{i=1}^{4} P_i \quad \text{where } P_i = X_i / TC \tag{1}$$

where

X_i: Various types of cost under cost of quality, X_1: Prevention Cost; X_2: Internal Failure Costs; X_3: External Failure Costs; X_4: Appraisal Cost

TC: Total Cost

5.2.2 Cost of Benefit Analysis

Cost benefit analysis is used to determine the performance of RFID adoption. Benefits can be represented as a reduction in costs Cj or an increase in revenue Rj of a particular industry j. The implementation cost of RFID technology can be classified as two parts: direct costs and indirect costs. Direct implementation costs include investments in readers, initial hardware and software cost and the ongoing costs associated with tags. Indirect implementation costs include maintenance cost and technology uncertainty cost.

Equation (2) represents the percentage reduction in costs after RFID adoption:

$$D_j = \frac{C_{j1} - C_{j2}}{C_{j1}} \tag{2}$$

where C_{j1} : Sum of four major operating costs, inventory cost, employee cost, product defect cost and others cost in the last year

C_{j2}: Cost in this year (assuming with RFID implementation)

Equation (3) represents percentage increase in revenue:

$$F_j = \frac{R_{j2} - R_{j1}}{R_{j1}} \tag{3}$$

R_{j1}: Revenue in last year (before adopting RFID technology)

R_{j2}: Revenue in this year (assuming with RFID implementation)

Dj and Fj are common ratios which represent industry cost and revenue performances after adopting RFID. Using these ratios, the system can estimate the cost C_{j2} and revenue R_{j2} of a company after adopting RFID technology. For companies who have adopted RFID technology, we collect the relevant information from their annual reports and websites in order to estimate the performance before and after implementing RFID technology.

Lastly, the formulas of cost benefit analysis are :

$$(C_{j1} - C_{j2}) / (Y_1 + Y_2) \tag{4}$$

$$(R_{j2} - R_{j1}) / (Y_1 + Y_2) \tag{5}$$

where

Υ_1: Direct implementation cost of RFID, including readers, hardware and software implementation and ongoing costs associated with tags

Υ_2: Indirect implementation cost of RFID

The value of Υ_1 and Υ_2 can be calculated based on company sizes, product types, process complexity, service requirements and uncertainty level.

5.2.3 Activity Based Costing (ABC)

For the activity based costing model, we find that several common operating costs can be reduced by RFID technology adoption. These operating costs include cost of inventories sold, employee expenses, provision for slow moving inventories and stock shrinking. On the other hand, there may be increase in maintenance and equipment costs. Maintenance cost refers to the estimated cost of maintaining the RFID every month or every year whereas equipment cost includes the cost from RFID technology adoption such as RFID readers, tags etc.

The activity based costing model is as follow:

$$\sum_{k=1}^{N} \mu_{jk}' \quad where\ \mu_{jk'} = (1-s_{jk})\,\mu_{jk} \tag{6}$$

Where μ_{jk} : Cost of particular activity or attribute k under Activity Based Costing

μ_{jk} : Cost of particular activity or attribute k after adopting RFID technology

s_{jk} : percentage of savings for similar industry for activity or attribute k.

According to studies in ABC analysis, performance metrics (Kleijnen and Smits, 2003) and Supply Chain Operations Reference (SCOR) model (Huan et al. 2004), the activity or attribute k is defined as follow. The total number of k will only be confirmed after pilot tests on few companies are completed.

k =1: cost of inventories sold;

k =2: employee expenses;

k = 3: provision for slow moving inventories and stock shrinking;

k = 4: maintenance cost;

k =5: cost of work in process (WIP)

k =6: cost of delay

k = 7: cost of waste disposal.

k = 8: cost of acquisition,

k = 9: cost of distribution, etc

Different industry may have different savings with better information management and inventory control. Table 3 summarizes part of the findings from past studies. The DSS will store a set of percentage of savings for every industry.

Table 3. Cost savings for different activities in different companies

Activity/Attribute	Findings	Source
Sales	Manufacturers and retailers can enjoy **20 percent** more sales just by ensuring that displays and promotional products arrive on the sales floor on time.	Motorola, 2010
Profits	Misplaced items reduced profits by 25%.	Raman et al., 2001
Profits	Eliminating the bullwhip effect can increase profits by an average of 15–30%.	Raman et al., 2001
Out-of-stocks	Wal-Mart succeeded in adopting the RFID technology and reduced out-of-stocks by 16%	Bottani and Rizzi, 2008 Bentonville, 2005.
Reading time	Mark & Spencer gained 83% reduction in reading time with RFID adoption	Wilding and Delgado, 2004
Reduction in shrinkage	Mark & Spencer have 15% reduction in shrinkage	Sarac et al. 2010
Losses during transit	Mark & Spencer decreased losses during transit by 11–14%,	Sarac et al. 2010
Cost in merchandise	Mark & Spencer reduced costs in merchandise distribution centers by 11%	Sarac et al. 2010
Inventory cost	RFID reduces transaction errors, which equivalent to 5.9 % of inventory cost	Lee and Ozer, 2007

5.2.4. Market uncertainty

Apart from internal operation, external environment also affects the future performance of a company. Thus, market uncertainty factors should also be taken into consideration. Three questions are designed to estimate the impact of company's business under uncertain environment, and a scoring method is applied to evaluate how market uncertainty affects a company's performance. These three questions related to area of distribution coverage, prediction of future economic environment and the extent of company's business affected future economy.

For the distribution coverage, we believe the effects of RFID will be more effective in local market as compared to global market, as the distribution is mainly controlled by few partners or

companies. Also, there can be lots of unpredictable factors affecting the global market, and thus the risk of business loss is high. In contrast, the uncertainty of local market is easier to predict and tend to be more stable. Therefore, the weighting of global distribution area is lowest, followed by regional market, with the local market being the highest. Next, the company is requested to predict the future economic environment of its industry by ranking among three choices: "poor", "fair" and "good". "Fair" means the company assumes the future economic environment is similar to this year with stable sales. We assume this "fair" view will not affect the company's intention of adopting RFID technology. If the company chooses "poor", it means the company has a pessimistic or conservative view of future business performance, and this will affect their intention to invest in new technology. On the other hand, if the company chooses "good", it means the company has an optimistic view on their future business performance, and the company is more likely to be willing to invest in new technology. The last part is about the extent of company's business which is affected by future economy. Four choices are designed: "seriously affected", "medium affected", "slightly affected" and "no effect" for the company to choose. Together with prediction of future economic environment, there are twelve combinations. Table 4 summarizes all the weightings of external environment.

Table 4. Factors related to external environment

Distribution coverage	Global	Regional	Local
Weighting	0.7	1	1.3
Future economic environment	Good	Fair	Poor
Weighting	1.3	1	0.7
Business affected by future economy	Future Economic Environment		
	Good	**Fair**	**Poor**
Seriously Affected	1.5	1.1	0.5
Medium Affected	1.2	1.1	0.7
Slightly Affected	1.1	1	0.9
No Effect	1	1	1

5.2.5 Multi-Criteria Decision Analysis

With the discussion on section 3, we know different companies have different expectations and concerns in adopting RFID technology. To customize the suggestion fitting various companies' concern, a multi-criteria analysis approach is adopted. A question is designed for companies to rank the importance of expected benefits brought by RFID technology adoption.

These benefits include increase quality, increase reputation, reduce error rate, reduce cost and increase revenue, etc. As shown in Appendix B, question (33), weightings indicate the level of importance for each parameter, and it ranges from "1": not important to "7": extremely important. The company is required to set the weights for each criterion to reflect its importance. As this DSS adopts three costing models, model which is highly related to a particular benefit will have the highest grade of "5". For example, the benefit of "reduce error rate" is highly related to cost of quality, and its grade will be "5", while the grades for cost benefit analysis and ABC are "1". The DSS then multiply the weighting and grade for each of the model to obtain the overall score. Model with the highest overall score means it is the most important one. According to overall score, a factor A_m will be assigned to each model m, where m = 1 to 3, Table 5 shows the value of A_m for each result.

Table 5. The index of (A) for each result

Result	**Factor A_m**
The highest overall score	1.9
Second highest score	1.5
The lowest score	1

Based on the above information and calculation, the DSS will estimate the cost and savings from RFID adoption, together with implementation suggestions. There are four alternative suggestions: A: fully adopt RFID technology immediately; B: Adopt RFID technology partially and gradually; C: Wait and adopt the technology later; D: there is no need to adopt RFID technology.

6. Conclusion and Future Research Agenda

Advanced technology plays a crucial role in changing people's life, improving peoples' living standard and generating revenues for business corporations. The innovation of barcode and Radio Frequency Identification (RFID) technology are the breakthroughs to improve the supply chain performance. RFID technology has become prevalent in recent years with the successful adoption cases by companies from different sectors. However, majority of the companies postpone such adoption, as the cost of implementing RFID technology is perceived as high and the actual benefits brought by this technology in uncertain. In this study, a decision support system is proposed to estimate costs and benefits for RFID adoption for each company.

By quantifying the costs and benefits, it helps managers understanding the expected performance and removing some concerns for their RFID adoption.

To ensure the validity of the DSS model, it will be tested using data of the companies before and after launching RFID technology. Next, a study will be conducted next by selecting one company from each part of the supply chain to predict their performance after the RFID adoption. Based on these results, the DSS input and modeling will be further improved.

To increase the accuracy for DSS prediction, more relevant data for RFID adoption, especially for small and medium enterprises (SME) will be collected. In the current study, we only use a single average ratio or percentage for companies belong to the same industry, which may not be an accurate estimation. For example, Wal-Mart serves as an industry indicator for retail industry , but the product nature, scale, target market of the company being studied may significantly different from Wal- Mart. Take Sa Sa (Sa Sa, 2011), a regional cosmetic chain-store, and Wal-Mart as examples, despite both are in the retail industries, their product nature, positioning, scale, and target market can be quite different. Thus, the values *Dj, Fj* and s_{jk} should be fine-tuned according to the above parameters. Lastly, a data warehouse should be developed to support the decision support system, which will be programmed as a software package.

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Appendix A

A.1 Jewelry Management

In Hong Kong, RFID has been used for wholesales, inventory checking and internal logistics operations in jewelry Industry. In particular, it is useful for large-scale jewelry tradeshows like Hong Kong Jewelry & Watch Trade Fair. Also, it has been adopted in many jewelry stores or warehouses for jewels identification, inventory checking, information collection and data transfer. It serves as the real-time monitoring and security system (Hong Kong RFID, 2008).

A.2 Food Supply Chain Management

RFID tags are used to track food products during distribution and storage. With RFID tagged pallets and carton boxes, the goods in each container can be registered and the goods in transit between suppliers and overseas destinations can be monitored in real-time. Examples are Sushi restaurants, food supply chains.

RFID technology ensures the freshness and hygiene of sushi in the self-help sushi chain system. For example, the Japanese Sushi Bar Sen-Ryo has been using RFID tags to monitor the quality of sushi. To ensure the freshness of sushi, sushi chain will scan every tagged plate to measure how long each sushi plate of sushi has stayed in the conveyor belt. The system automatically identifies sushi which has stayed beyond the defined period of time and takes it out from the conveyor belt to keep all sushi fresh. Besides, it also improves the accuracy and response time of the charging system. Traditionally, sushi bar uses plates with different color to distinguish different price categories. When customers finish their meals, waiters have to count the number of the plates for each color. With RFID, waiters can sum up the bills immediately by reading all the sushi plates via a RFID reader. This saves time significantly and prevents calculation mistakes. In turn, it improves the turn-around frequency and sales of restaurants. Customer's satisfaction will also be enhanced with the guarantee of food quality and service efficiency.

The vegetable and fish supply chain contains cultivation, processing, storage, transportation and retailing. In China, starting from 2007, all fish tanks carrying live fish from Guangdong to Hong Kong are sealed with RFID technology to trace the place of origin. Eggs and eggs by-products must carry RFID labels showing details of their farms and companies, production dates and batches for tracking purposes; all are required to bear health certificates. (China Technology News, 2007, Thompson and Hu 2007).

In short, adopting RFID technology in food supply chain can ensure the freshness and food safety, enable end-to-end traceability and reduce the labor cost by cancelling the manual checking steps (Mai et al, 2010). However, for most of the daily food supply chain, the cost is relative significant.

A.3 Retail Industry

A.3.1 Walt- Mart

Wal-Mart launched its RFID initiative on June 11, 2003. She required its top 100 suppliers to begin tagging pallets of merchandises by January 2005 and all suppliers begin tagging pallets of customer goods with Electronic Product Code (EPC) by January 2006. Wal-Mart has been using EPC to improve the inventory accuracy and shelf availability to customers as well as to drive sales through better shelf in-stock. According to the study by Hunt et al. 2007, a typical retailer (without RFID technology) loses about 4% of sales due to out-of stock situations. Improved product in-stock, enabled through RFID, will lower these costs. Theft prevention, lower shrink, and automated checkout are several other potential store benefits.

After adopting RFID technology, Wal-Mart resulted in a 30 percent reduction in chance of out-of-stocks and excess inventory in the supply chain. It attains 63 percent more effective in replenishing out-of-stocks, and manual orders placed by stores were reduced by approximately 10 percent. Proctor & Gamble (P&G), a major supplier to Wal-Mart, estimated that it could increase annual sales by $1.2 billion via RFID technology by reducing the frequency of out-of-stock items in stores.

A.3.2 Prada

In December 2002 Prada installed a RFID-based Smart Retail System (SRS) in new stores. Unlike Wal-Mart, which has many stock-keeping units, it is relatively easy for Prada to keep track of out of stock products. Thus, reducing costs or increasing supply chain efficiency were

not their main drive of adopting RFID. Instead, SRS offers smart dressing mirror for customers. All clothing, shoes, dressing rooms and customers' cards were tagged with RFID. This can shorten the waiting time for fitting room as SRS offers real-time mix-and-match style advice to customers. When customers select a particular cloth, salesperson can instantly read its detailed information, such as color, fabric and name of the designer, current stock status to provide better service to customers.

A.3.3 Marks & Spencer

Like most retailers, Marks & Spencer (M&S) operates a point of sale solution. However, the stock accuracy had been poor, in that clothes have not been ordered and replenished in store on time, resulting in clothing being out of stocks and low level of customers' satisfaction. M&S started using RFID technology item-level tagging (Intelligent Labeling) in six clothing departments in 42 stores. Despite major investment, M&S believes this system supports the future growth of the business and improves the customer's shopping experience in store (Marks & Spencer, 2006). After the implementation, the inventory time of clothing for men and women has shortened from eight hours to one hour, which equivalent to an 88 percent increase in efficiency. Besides, RFID has been implemented in M&S food business. As 70% of its food is refrigerated fresh foods, the reaction and sensitivity to stock in supply chain is crucial and the actions must be swift. RFID tags can monitor temperature of products during the delivery process so that sellers can confirm if the products are properly shipped. Distributors and retailers can quickly determine which pallets should be rejected, accepted, or sold first among the accepted ones to ensure safety and freshness and minimize waste that incur.

In short, adopting RFID technology in retail industry can reduce out-of-stocks chances, safety stock level, and improve order forecasts and service level. However, customer privacy concern is one major issue that retailers should carefully address.

A.4 Transport and Logistics

RFID technology has also been widely applied in transportation and logistics, such as airport, mass transit system and integrators.

A.4.1 Hong Kong International Airport

In 2005, HKIA became the world's first airport implementing an end-to-end RFID sorting and reconciliation system for all departing baggage. The objective to adopt RFID technology is to reduce employees cost and shorten the travelers' waiting time for baggage. It led to quicker reconciliation of baggage on departing aircraft and fewer misdirected bags. The initial investment of RFID Project cost around HK$ 50 million including infrastructure and computer system. HKIA's baggage handling capacity grows from 9,000 in 2008/09 to 16,000 bags per hour in 2010 (HKIA Annual Report 2008/09). At the HKIA, a reduction in handling cost from $7 to $4 per bag attributed to the implementation of RFID tracking. In addition, the service performance of HKIA had improved significantly after adopting the RFID technology. For example, the first bag delivered to baggage reclaim within 20 minutes significantly increased from 93.1% (2008/09) to 97% (2009/10). Also, the number of complaints against the lost of baggage significantly reduced. As shown in Figure A.1, in Year 2005/06, after HKIA started to implement RFID technology for baggage tracking, the number of complaints dramatically dropped to 3.89 per million passengers. Apart from HKIA, Las Vegas McCarran International Airport has recorded great improvement in service with RFID adoption, by reducing lost baggage by 40 percent. The International Air Transport Association (IATA) predicts that Worldwide implementation of RFID-based baggage handling could result in annual savings of US$760 million for the industry.

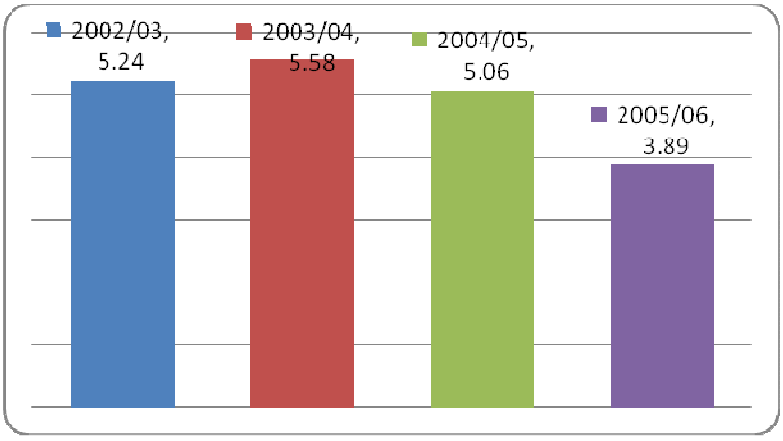

Figure A. 1 Number of Complaints per Million Passengers form 2002/03 to 2005/06

(Source: HKIA Annual Report 2005/06)

A.4.2 Octopus Card

Octopus Card is an electronic payment system based on a wireless RFID technology launched and developed in Hong Kong in September 1997. Similar to London's Oyster Card and Japan's Cutting Edge Suica Card, users simply hold their contactless smartcards over an electronic reader and the payment is deducted from the card automatically. In Hong Kong, application of Octopus card has been expanded from transportation industry to retail industry (Lam, 2011).

A.4.3 Rail System

Train movement and location can be automatically captured in real time by utilizing RFID Railway Train Tracking System (TTS) with RFID readers and tags. The tracking and location information is available to railroad operators for asset management and other purposes. Trains are equipped with RFID readers. When a train arrives at a particular train station, the readers interrogate tags placed at the station. The unique ID on the station's tag is sent to a central database together with the exact arrival time of the vehicle. Transport officials use the information to reduce congestion and keep passengers well informed of delays. The system provides accurate and reliable information about where a train is located. Besides, Guangshen Railway Company (GSH) is the first operator in China to switch from traditional barcode tickets to RFID tickets which can reduce losses caused by fake tickets.

A.4.4 Logistics

In the logistics industry, big integrators, such as UPS and DHL have adopted RFID technology since 2005. UPS adopted RFID technology and its revenue in 2006 had increased by 11.7% (DHL, 2005-2007, UPS, 2004 – 2006).

To summarize, adopting RFID technology in transportation and logistics industries can improve accuracy and customer service level, shorten processing and transaction time, enhance visibility, traceability and asset management, reduce errors and manpower costs (Baars et al, 2009). Yet, many companies are still facing the difficulties on standardization and integration with companies around the world.

Appendix B

The Decision Support System for RFID Technology Adoption
Questionnaire Sample (Partial)

Part 1

(1) What is the nature of your business?
___Retail ___Manufacturing ___Service ___Logistics

(2) When did your company start the business?
0- 3 4- 6 7- 9 10- 15 Above 15 (years ago)

(3) Number of employees: 1-20 20-40 40-60 60-100
100-150 150-200
200-300 300-500 above 500

(4) Distribution area: ___Local ___Regional ___Global

(5) Turnover in last year: _____

(6) How much was the business operating costs? _____

(7) What are the major costs of your business? (Please specify the percentage)
___Inventory Cost
___Employee Cost
___Product Defect Cost
___Other, please specify:

(9) What is the Cost/revenue Ratio of your business? _____

(10) What is the proportion of fixed costs and variable costs of your business?

(11) Is your company using barcode system?
Yes No
If yes, please answer Q12 to Q15

(12) How many inventory damage due to instable accuracy of the barcode system?

(13) Estimate the error rate of the barcode system.

(14) How much of the profit lost due to instable accuracy of the barcode system?

(15) Estimate the savings you company has from barcode system per year.

(16) How many different types of products?

(17) How many stock keeping units (SKU)?

(18) What is the price range of your products?

(19) How many percent of goods/inventory was lost in last year?

(20) How many percent goods/inventory is expired last year?

(21) What is the defect rate of the company products? (In percentage)

Part 2- Environment

(22) What is your expectation of future economic environment?
Good Fair Poor
(23) To what extent the future economic environment will affect your business?
Seriously Affect Medium Affect Slightly Affect No Affect

(24) Estimated business performance in the coming year
Optimistic Neutral Conservative

(25) How many suppliers always work with you?

(26) Dose your partner use or will use RFID? (If yes, please specify the number)
Yes _____ Unknown
(27) How many types of parties involved in your supply chain?

(28) What are the supply chain strategies that your company is adopting?
___JIT
___Few suppliers
___any suppliers
___Close partnership with suppliers
___Subcontracting
___Close partnership with customers
___Outsourcing
___Third parties logistics
___Other, please specify _____

Part 3- IT complexity
(29) What types of systems are currently being used in your company?
___Electronic Data Interchange (EDI)
___Material Requirements Planning (MRP)
___Warehouse Management System (WMS)
___Customer Relationships Management (CRM)
___Supplier Relationships Management (SRM)
___Bar code
___Enterprise Resource Planning (ERP)
___Other, please specify:

(30) How much do you benefit from using these systems?
(Please mark 1 to 5: 1, not at all; 2, little; 3, average; 4, greatly; 5, a lot)
___Better quality information
___Reduced inventory level

___Reduced lead time
___Cost saving
___Increased sales
___Resource planning
___Increased coordination between departments
___Better operational efficiency

(31) Problems when using these systems:
(Please mark 1 to 5: 1, no problem at all; 2, little problem; 3, some problem; 4, significant problem; 5, serious problem.)
___Resistance to change from employees
___Resource shortages
___Skill shortages
___Insufficient vendor support
___Integration with existing systems
___Integration with partner's systems

(32) How much do you spend on these IT systems annually?

(33) What are your desire results of RFID adoption?
Please rank the following parameters in order of their importance to you:
(7 = Extremely important, 1 = Not important at all)
___Reduce Cost
___Improve efficiency
___Increase security level
___Increase revenue
___Increase reputation
___Improve inventory control
___Increase quality
___Reduce error rate