

Chapter 2

The Cost–Benefit Models for RFID Investments

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Abstract RFID technology does not require line of sight and provides fast and accurate reading from a great distance without human intervention. Albeit RFID is superior to other identification systems, such as barcode, complicated cost and benefit structure inhibits worldwide adoption. As a response, there is a wide range of cost–benefit models used by both industry and academy. The aim of this chapter is to review RFID cost and benefit factors and provide a comprehensive overview of RFID cost–benefit models. Besides hardware and middleware cost, service cost factors, including compliance cost, training cost, and transition cost makes up for the total RFID system cost structure. Benefit factors are more complex than cost factors as the limited pilot studies or studies from other application areas are unable to reveal the full set of benefits. Also, intangible benefit factors such as increased customer satisfaction or increased supply chain collaboration are not easily quantifiable. RFID cost–benefit models are classified as conventional models, uncertainty-based models, and decision-making models. Conventional models include return on investment models, break-even models, internal rate of return and net present value analysis. Although practical enough to help during the initial stages of investment analysis, these models are static, rely on oversimplifying assumptions, and ignore the variability of the system. Uncertainty-based models, such as simulation or real options models generate more accurate results, but require extensive modeling and data gathering effort. Decision-making models, on the other hand, facilitate selection among alternatives or help to visualize the underlying structure of decision-making process of RFID investment. Considering

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the limitations of each model, analysts should take caution when introducing a single type of model and rather utilize a group of different models together.

2.1 Introduction

Manufacturing and delivery of commercial goods no longer stay on the limits of single and self-sufficient corporate structures or local markets. Costly manual reading technologies do not suffice the today's cost-competitive business environment. RFID fulfills the quest for cure-all identification technology. Much advertised by its advocates, RFID provides fast and continuous reading with almost error-free accuracy and less human intervention. Yet, economic feasibility issues inhibit the widespread implementation.

From simple "slap and ship" type of implementations to complete supply chain-wide adoptions, the question is whether the cost performance capability of RFID suffices the efforts. Academic studies and industrial reports provide a series of theoretical and empirical research. Besides "success stories" and "road maps", these papers present a wide range of approaches and techniques but in a disordered manner and in segmented RFID projects. The aim of this chapter is to provide a comprehensive guide to cost-benefit models of RFID. Cost and benefit factors and their mutual relations will be discussed in detail. The cost-benefit models will be presented based on the parameters involved and the level of uncertainty.

2.2 RFID Cost Elements

A general classification suggests three cost categories as follows; (i) Hardware cost, (ii) Middleware cost, and (iii) Service cost. Hardware cost category covers the costs of tangible elements of RFID system, such as tags and readers. Hardware cost is considered usually in the preliminary planning stages and it is important to note that economic models should also consider other cost categories. Justification of hardware costs is not sufficient for implementation decision, although hardware vendors may suggest otherwise. Service cost, such business process redesign cost, and configuration cost, require an elaborate study on the firm and supply chain specific requirements. A whole range of cost elements may emerge depending on the context. For a pioneer application in a certain field, development and initiation cost may be overwhelming. On the other hand, for supply chain-wide adoption, for example, in the case of DoD or Wal-Mart, compliance cost will be dominant. Middleware cost is the cost of software and infrastructure that supports and simplifies RFID-related operations. Determining and investing on the right software architecture is crucial to make the best of RFID system and erroneous or incomplete software will most probably be the bottleneck to realize the expected benefits.

2.2.1 Hardware Cost

Tag cost and reader cost make up to hardware cost. The price of tags is the major obstacle toward widespread implementation (Angeles 2005). Chip cost and assembly cost constitutes the tag cost and as the manufacturing volume increases chip cost decreases, but economies of scale do not necessarily apply to assembly cost (Wu et al. 2006). Supply chain-wide adoptions help to accumulate necessary demand to pull the tag cost down to a reasonable level which may encourage more firms to take the first step toward implementation (Rundh 2008).

Reusable RFID tags, incorporated with reverse logistics, premises to satisfy desired cost target through multiple use but it is also important to note that reusable tags require more durable material and an extra cost of rewriting (Ustundag et al. 2007). Also, as a rule of thumb, more detailed level of tagging provide more benefits but also results at higher cost (Ilie-Zudor et al. 2011). The contribution of tag price on the general cost structure of RFID investment leads supply chain members to develop various sharing models. Interested readers may also refer to Part A Chap. 6 for a more comprehensive discussion on tagging cost sharing.

Reader cost, together with tag cost make up the hardware cost of an RFID system. Reader and related infrastructure cost are often regarded as fixed cost in contrast to tag cost which is variable (Gauklerw and Seifert 2007). Beside cost/distance tradeoff, operations environment and performance expectations are other system design parameters regarding readers (Wu et al. 2006).

2.2.2 Middleware Cost

RFID middleware fills the gap between enterprise resource planning platform and RFID hardware. It connects software and services, administrates hardware, and processes tag data. Middleware also determines the usability of the data, by securing reader connectivity, by routing, filtering, and aggregating data (Leaver 2004). The cost of middleware depends on the complexity of applications, forms of data storage, and the level of maturity of the technology for the given system.

2.2.3 Service Cost

Service Cost includes system design, customization, and configuration cost. For supply chain-wide adoption processes that are usually led by retailers like Wal-Mart or Metro group, service cost also includes compliance cost. High compliance cost often prohibits suppliers to adopt RFID and take advantage of becoming a member of these supply chains (Rundh 2008).

Service cost is directly affected by the maturity of the system. In the beginning or through the early stages, service cost takes the form of development cost and direct implementation cost. But later as the technology matures, service cost is incurred in the form of initiation cost and holistic direct implementation cost (Bunduchi et al. 2011). Furthermore, a full integration of existing operations and RFID applications is obligatory (Curtin et al. 2007). The cost of all the efforts to balance former and novel systems and manage a smooth transition is considered under the category of switching cost (Al-kassab and Rumsch 2008). Finally, to realize potential benefits beyond tracking goods, costs associated with business process redesign and organizational restructuring is also included in the service cost category.

2.3 RFID Benefit Elements

RFID overcomes the limitations of line-of-sight scanning of barcode systems (Véronneau and Roy 2009). This eliminates the need for human intervention in various stages of supply chain (Ilie-Zudor et al. 2011). Automatic reading and recording reduce handling and boost accuracy and visibility. Theft and obsolescence are the primary reasons for shrinkage (Delanuay et al. 2007). Security and visibility leads to less shrinkage as the risk of goods getting damaged, stolen (Rekik et al. 2008) or expired (Çakıcı et al. 2011) is minimized. Even if it happens, faster recovery of items or well-organized recalls are possible (Zhou 2009). In general, increased product availability helps to reduce average inventory level and lost sales quantity. Hence, inventory cost is significantly reduced (Bagchi et al. 2007). In the long run, increased visibility helps to flatten the bullwhip effect and increase smooth material flow through the supply chain (Bottani and Rizzi 2008; Sarac et al. 2010). A comprehensive model of benefit factors is given in Fig. 2.1.

2.4 Cost–Benefit Models

RFID economic justification models cover a wide range of approaches. We group these approaches into three categories; (i) Conventional models, (ii) Uncertainty-based models, (iii) Decision-making models. Net Present Value calculation is a basic example of conventional models. Break-even analysis and engineering economy-based calculations such as net present value and internal rate of return are all considered under the same group. Conventional models are often criticized as being static, overly simplistic, and incapable of capturing the full set of RFID benefit factors. Uncertainty-based models include real options, markov chain models, simulation and system dynamics. These models facilitate net present value analysis with stochastic parameters and economic order quantity-based analysis

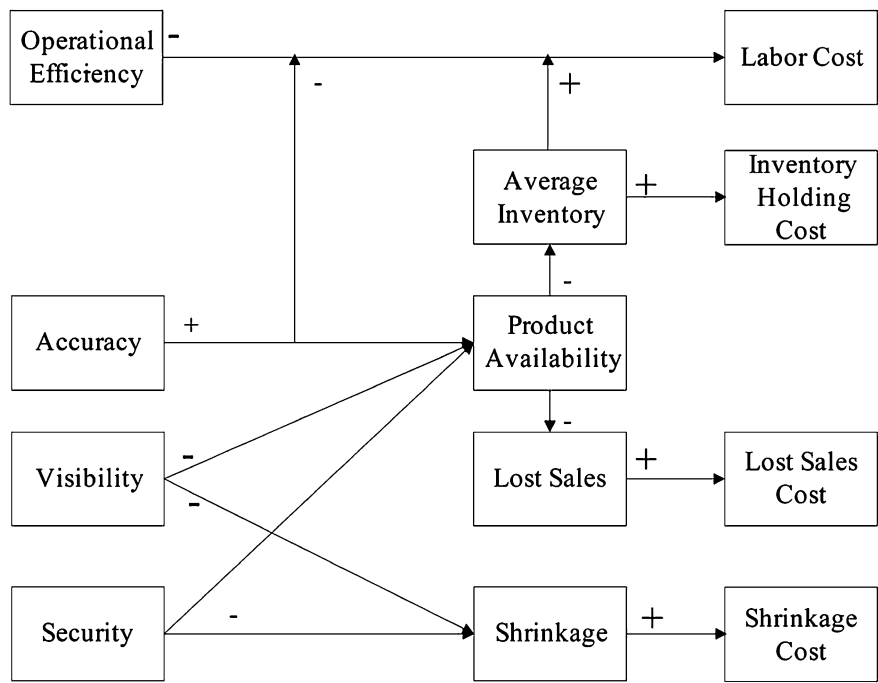


Fig. 2.1 RFID benefit factors

helps to determine the parameter levels. Although it is not always easy to collect necessary data to use uncertainty-based models or validate them, they are known to capture real life more accurately and generate more realistic results. The third category includes decision-making models. Analytical Hierarchy Process (AHP) is the most popular decision-making tool among others but even AHP models for RFID system evaluation is scarce.

2.4.1 Conventional Models

Return on investment is the financial ratio of net returns divided by total expenditure. ROI gives a positive result for profitable projects and higher value means more profits. Although ROI is widely accepted by industry and academy, several challenges should be considered while adopting an ROI-based model. First of all, RFID is a fairly new technology and apart from few application areas such as retail and manufacturing, cost and benefits information is limited for other enterprises (Chao et al. 2007). Especially considering the long term, intangible benefits, increased customer satisfaction or improved inter organizational communication,

ROI analyses lack the required option-based evaluation. Option valuation methods should be preferred to overcome this limitation (Brown 2007).

Break-even analysis is a standard investment tool that presents basically how soon a certain investment will amortize itself. In other words, from an investor's point of view, break-even analysis shows when the expenditures will be repaid. Unlike ROI, break-even analysis does not provide any information about the overall profit but it can be used for sensitivity analysis, together with parameter variation analysis (Hansen and Gillert 2008).

Although that is far less comprehensive than a feasibility study, break-even price of a tag can be the starting point. Comparing two different settings of the same system, (i) operating with RFID and therefore all the cost and benefit factors of RFID, (ii) operating without RFID and therefore keeping the cost and benefit factors unaltered, a break-even price for a tag can be calculated (de Kok et al. 2008).

Internal rate of return and net present value analysis are employed to analyze the cost and benefit structure of RFID investments from an engineering management standpoint (Jones et al. 2007).

2.4.2 Uncertainty-Based Models

Various factors are subject to uncertainty in a supply chain. Although by increased accuracy and elimination of human intervention, RFID systems are known to decrease the variability to a certain extent, manufacturing lead times, delivery times, demand frequency still tend to be uncertain. Besides these inherent variability sources, RFID benefit factors realize in an evolutionary fashion. Promised cost savings and increased collaboration among parties involve a level of uncertainty. RFID operations also comprise a certain level of variability. Most important of all, false positive or false negative readings should be considered when performing a feasibility study.

There is a wide range of models that are aimed to deal with uncertainty. One approach is to employ option valuation techniques to consider intangible, long-term benefits and new business opportunities. Another approach, in simple terms, is to mimic the system behavior by incorporating the probabilistic nature of system variables.

Real Options Analysis (ROA) is a key technique in investment evaluation. Options such as, option to switch, option to wait, or option to abandon, are considered. Managerial decisions with high inherent flexibility are most suitable for real options analysis. Real options models proved to be superior to other investment valuation techniques as they not only determine a satisfactory strategy but also provide corresponding net present value (Wu et al. 2009). In probabilistic real options analysis, net present value and cost are expressed by a single crisp number. On the other, fuzzy real options provides an extension to this application

by using fuzzy numbers and generates a more realistic analysis for investment evaluation of RFID systems (Lee and Lee 2011).

Analytical models of RFID are limited to simplifying assumptions and often incapable of handling complexities of real life cost and benefit structures. Real life applications are difficult to replicate and limited to certain operations. Simulation resolves this problem by imitating the system and provides responses for the given setting. Although it requires excessive data gathering and statistical analysis, together with validation and verification efforts, simulation still proves to be a superior tool for practical reasons. For example, even for the highly complicated case of evaluating the compatibility of a network standard in a given environment, simulation proved to be much useful than any other evaluation tool (Jakkhupan et al. 2011). Focused studies on RFID benefit elements, such as on increased visibility and accuracy, service level improvement can also be performed by simulation (Fleisch and Tellkamp 2005; Lee and Cheng 2004). Complicated RFID-enabled supply chains are evaluated by simulation in terms of visualizing the effect of RFID on work-in-process and bullwhip effect (Wang et al. 2008). System dynamics is also useful to support simulation models as a conceptual modeling tool (De Marco et al. 2011).

Nevertheless, simulation models should be treated as a “black-box” that is incapable of exposing the underlying general relations between system parameters. Therefore, to derive general conclusions simulation models may only assist to theoretical models.

In addition to simulation and real option analysis, a wide range of conventional approaches such as net present value analysis are incorporated with stochastic parameters to reflect the random nature of the system. Often, underlying principles of simple economic order quantity formulation helps to determine the parameter levels.

2.4.3 Decision-Making Models

Decision-making models aim to conceptualize the process of identifying a set of actions among alternatives and aid the decision maker. The process may include several decision makers and various criteria about a predetermined set of alternatives. Preferences and weights of criteria may both be objective or subjective and outcomes may take any form of representation.

AHP is the one of the most popular Multi-Criteria Decision-Making (MCDM) techniques. In the case of RFID investment evaluation, AHP fulfills the requirement of quantifying premised non-cost benefits. Doerr et al. (2006) employed AHP to measure intangible benefits together with ROI analysis and simulation. MCDM models also expose the underlying relations between different factors and criteria. Lin (2009) composed a five-level, 24-factor fuzzy AHP model to present the integrated framework of RFID development in Taiwanese companies.

The literature on applications of decision-making models on RFID investment is scarce. Decision-making models can be used to select an investment strategy among others but are incapable of generating a single profit or loss figure in terms of investment analysis.

2.5 Conclusion

RFID provides a fast and continuous tracking of goods with minimum human intervention. Increased visibility and accuracy help to reduce labor and inventory cost significantly. Besides these quantifiable cost factors, intangible benefits including increased interorganizational coordination and customer satisfaction demands advanced models for RFID investment analysis. Conventional models, including ROI, break-even analysis and IRR and NPV models provide a relatively simple toolset for preliminary analysis. But conventional models are static in nature and ignore the inherent variability of the system. Uncertainty-based models emerge to respond to this deficiency. Real option models provide an option-based evaluation and expose the long-term benefits and new business opportunities and simulation models help to observe system parameters when the analytical models are too complex. Decision-making models, on the other hand, prove to be handy when selecting among multiple alternatives and also describe the core relations between factors affecting the decision-making process.

The diverse nature of RFID cost and benefit factors obligates researchers to employ a variety of cost–benefit models. Conventional models are appropriate for preliminary analysis or can be used with uncertainty-based models which counts for the corrupting influence of variability. Decision-making models on the other hand should be used as a supplementary tool for selecting among multiple alternative tracking technologies or system settings, as well as to generate a hierarchical structure of elements that affect the investment decision.

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