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## A Business Value Modeling Tool Set for Exploring the Value of RFID in a Supply Chain

**Ying Tat Leung**

IBM Research Division  
Almaden Research Center  
650 Harry Road  
San Jose, CA 95120-6099

**Feng Cheng, Young M. Lee**

IBM Research Division  
Thomas J. Watson Research Center  
P.O. Box 218  
Yorktown Heights, NY 10598

**James J. Hennessy**

IBM Business Consulting Services



Research Division

Almaden - Austin - Beijing - Haifa - India - T. J. Watson - Tokyo - Zurich

# A Business Value Modeling Tool Set for Exploring the Value of RFID in a Supply Chain

Ying Tat Leung<sup>1\*</sup>, Feng Cheng<sup>2</sup>, Young M. Lee<sup>2</sup>, James J. Hennessy<sup>3</sup>

<sup>1</sup> IBM Almaden Research Center

<sup>2</sup> IBM Thomas J. Watson Research Center

<sup>3</sup> IBM Business Consulting Services

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## Abstract

In recent years, Radio Frequency Identification (RFID) technology has emerged as an important technology to facilitate the management of a supply chain. Because the technology is expensive and time consuming to implement in a large scale, most enterprises require a relatively rigorous business case to be developed to support the decision of whether or when to adopt the technology. To facilitate the development of such business cases, we developed a tool set to show clearly the business value of RFID to different parties in a manufacturing-retail supply chain. The tool set consists of two tools which are linked: a business value model, implemented as an in-house developed application using commercial spreadsheet software, and a business process model, implemented using a commercial discrete-event simulation package. The business process model computes and provides certain supply chain performance metrics to the

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\* Corresponding author: Ying Tat Leung, IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120. [ytl@us.ibm.com](mailto:ytl@us.ibm.com)

business value model, which are otherwise very difficult to obtain. Because the potential benefits of RFID are sometimes not straightforward, it is necessary to use two different types of decision support tools (spreadsheets and computer simulation) in a coordinated fashion to capture the full range of potential benefits.

## 1. Introduction

In the last few years, Radio Frequency Identification (RFID) technology has become commercially viable as a means for automatic identification of physical materials. The physical size and the manufacturing cost of a simple (e.g., passive, read-only) RFID tag has decreased to a point where large scale applications in both the enterprise and consumer space are possible even today. As of 2004, a simple RFID tag costs in the range of US\$0.25. It is still too expensive for most consumer packaged goods but is already feasible for “large ticket” items such as white goods. Ongoing efforts by vendors are aiming to reduce the cost to US\$0.05. At the same time, international standards on the physical characteristics of RFID (such as frequency and coding schemes) are well under way (including ISO 18000 by the International Standards Organization, EPC by EPCglobal Inc.) RFID has become a major topic in the automatic identification community; industry-academia research consortia were set up (e.g., the global RFID consortium at MIT that led to the formation of EPCglobal Inc.); and a number of publications and web sites dedicated to this subject have been launched, including the RFID Journal ([www.RFIDjournal.com](http://www.RFIDjournal.com)), RFID Gazette ([www.RFIDgazette.org](http://www.RFIDgazette.org)), RFID News ([www.RFIDnews.org](http://www.RFIDnews.org)) among others.

Many commercial and industrial enterprises are seriously investigating the feasibility of applying RFID in their business. Most notably, few large retailers such as Wal\*Mart and Target, are in the process of pilot studies or selected application phases of

using RFID tags in their supply chains. As the industry have now learned, using RFID tags simply as a high-tech version of bar codes is economically not very attractive due to the price premium over paper-based bar codes. (Regardless of how fast the cost of RFID tags will decrease due to mass production, we can safely predict that they will be more expensive than bar code labels in the foreseeable future.) To make RFID commercially attractive, we would like to take advantage of its unique technical characteristics and derive business value from them. Building such a business case for RFID is not as easy as it may seem, because at this time it is not widely known how we can exploit the technical advantages of RFID tags in a commercial environment. So, rather than a straightforward application of financial analysis alone, building a business case involves also an element of exploration and innovation.

The supply chain has been widely identified as one key business application of RFID technology. Hence we focus on this area, and more specifically on manufacturer-retailer supply chains. To help build a business case for RFID in such supply chains, we have developed a tool set, consisting of a spreadsheet based Business Value Model (BVM), and a simulation based Business Process Model (BPM). The spreadsheet based BVM serves to calculate the direct benefits that can be captured by traditional financial analysis and also serves as a master model to receive the output from the simulation model. The simulation model calculates indirect benefits that will be hard to captured otherwise. With the tool set we can explore how RFID can be applied so that its technical advantages are exploited to give business value.

This chapter describes the business value modeling tool set. We first discuss the how RFID can be applied in a supply chain and point out what bodies of research literature

are relevant. Then we briefly discuss the subject of business value modeling. In Section 2, we describe our business value modeling tool set in detail, by each module and their linkage. Section 3 discusses how the value modeling tool set can be applied in practice and Section 4 contains a hypothetical example to illustrate its use. We offer some guidelines for practitioners of RFID in Section 5.

Using our tool set, interesting insights on where and how RFID provides business value have been derived for a typical manufacturer-retailer supply chain. They are reported elsewhere (Lee et al. 2005).

### **1.1. Application of RFID in Supply Chains**

RFID, having emerged as one of the most promising automatic identification technology since bar codes, offers the potential of enabling real collaboration across intelligent supply chains. For asset tagging and tracking, RFID tags allow for tracking of capital equipment and container, pallet, or item-level tracking of consumer and industrial goods. Enterprises can potentially streamline operations with reduced logistics and inventory management costs using this technology at various stages throughout the entire supply chain.

Which of these promises will prove true, and which will be revealed as hype? As companies started to apply RFID in complex business settings, some of the fundamental questions on how exactly RFID would benefit a supply chain and what applications could be developed still remain unanswered. Most of the published materials on benefits of RFID in supply chains are qualitative studies on RFID deployments. For example, IBM Business Consulting Services have published a series of papers (e.g. Alexander et al. 2003) on discussing the impact of RFID technology on supply chain performance with a focus on

consumer goods and retail value chains. Other reports of a similar nature include Agarwal (2001) and Kambil and Brooks (2002).

A number of CPG Manufacturers commissioned business case studies, some with key retail customers to get a better understanding of the overall benefits of the technology. Such work has resulted in the publication of several business-case focused white papers by industry groups, most recently by a consortium consisting of FMI, GMA, and NACDS (A.T. Kearney and Kurt Salmon Associates 2004), and by GCI (Global Commerce Initiative and IBM 2005).

Model based quantitative studies are sparse today, but have drawn increasing attention. They usually focus on some specific aspects of RFID benefits and develop analytical or simulation models to address the aspects in question. For example, Fleisch and Tellkamp (2005) quantifies the direct benefits (mostly) of RFID using a simulation model; Gaukler et al. (2004) developed an analytical model to study and compare the scenarios of a centralized and a decentralized supply chain under a possible range of store operating efficiencies (with the most efficient case being the one using item-level RFID tagging); Joshi (2000) used a simulation approach to evaluate the value of information visibility through the use of RFID. Lee et al. (2005) provided a more comprehensive study of RFID benefits, identified where existing works in different technical literatures may be applied to study the benefits, and, using a simulation model, developed some insights on benefits that have not been investigated quantitatively in the past. For example, results of the simulation demonstrate that in some situations a supplier can significantly reduce the warehouse inventory level and customer back orders simultaneously because of process

transformations enabled by the visibility of inventory levels at the retailer's warehouse and store.

In a recent effort to explore the potential benefits of RFID deployment, Wal-Mart Stores commissioned a study to examine the impact of RFID on out-of-stock (Wal-Mart 2005). From February 14 to September 12, 2005, out-of-stocks were examined daily in 24 Wal-Mart stores (12 RFID-enabled stores, 12 control stores) representing all store formats. Preliminary results presented in a research report published by a University of Arkansas team (Hardgrave et al. 2005) suggest that RFID is making a difference: it has helped the selected stores increase revenue by reducing out-of-stock merchandise by 16% in the past year, and RFID-tagged items can be restocked three times as fast as non-tagged items.

## **1.2. Business Value Modeling**

Business value modeling has a long history in business and finance. It usually falls under the subject of investment analysis, which is basically a valuation process that assesses the combined effect of positive and negative cash flow patterns over time (See, e.g., Helfert 2001, Chapter 8). Negative cash flows are those generated by the need to invest resources and positive cash flows represent the benefits obtained as a result of the investments. The negative cash flow items, i.e., the investments are usually the easier ones to estimate, except in cases of exploratory research where the total investment (and time) from ideation to productization is highly uncertain. The positive cash flow items are sometimes not so straightforward, as the benefits provided by a technology investment, say, may be difficult to quantify. An illustrative example of such benefits is the flexibility to perform certain things. Measuring and quantifying flexibility has been a research issue since the days of flexible manufacturing systems; most recently new models based on real

option analysis have been proposed (Nembhard et al. 2005). In practice today, such benefits are known as “soft” or “strategic” benefits and are typically ignored in the quantitative analysis. Inevitably however, increasingly more business cases will be dependent on these “strategic” benefits, as enterprises are becoming automated and investments that provide simple labor savings through automation are mostly complete.

Once the positive and negative cash flow items are calculated, we need to combine their effects over time. A typical way to analyze the combined effects is to treat the cash flows as deterministic and then apply well known calculations such as net present value, return-on-investment, internal rate of return, or payback period to obtain summary measures for insights and comparisons among alternative investments. Spreadsheet software is the tool of choice, with many of these summary measures as built-in functions.

In reality, the cash flows, especially those that represent the benefits, are uncertain and techniques have been developed to model the uncertainty. These techniques include scenario analysis (also called what-if analysis) using a deterministic model, or more advanced models that take into account uncertainty such as decision trees and, more recently, financial or real options based models. Scenario analysis is by far the most commonly used in practice, and is especially well supported by spreadsheet software. Decision trees is a formal way of doing scenario analysis with specified probabilities of each scenario, so that expected measures, such as expected return, can be calculated. Options based modeling recently has become more popular as a tool for valuation of technology investments. Not only does it take into account uncertainty, it also models the possibility of deferring parts of the investment decisions later on, pending the outcome of the initial activities. This setting matches well with that of technology or product



development. For example, an options based model has been used by NASA to assess the value of different technologies (Shishko et al. 2004).

When there are multiple investments available simultaneously, one can form a new asset by investing in a combination of the available assets. This is then a portfolio and specialized techniques have been developed for portfolio analysis, such as the well known mean-variance analysis (see, e.g., Luenberger 1998, Chapter 6). Other specialized techniques have also been developed for specific types of investments such as security derivatives. These are beyond the scope of this chapter.

In this chapter we focus on evaluating the investment of a single technology, namely RFID, in a specific application area, the supply chain. As we shall see, we will apply a combination of traditional value modeling with simulation. Neither approach is new, but the combination to perform value modeling has not appeared elsewhere.

## **2. The RFID Business Value Modeling Tool Set**

### **2.1. The Business Value Model**

Since deploying RFID technology in an enterprise is a business decision, cost-benefit analysis is a key component of the decision making. Based on the analysis, the business owner can make a go/no-go decision, structure the project in a way to capture immediate benefits first, or even modify the scope of the project to maximize benefits. Many factors play a role in determining RFID technology's costs and benefits. For example, costs can be fixed, such as investment in new tools and processes to install and test tags, or recurring, such as the cost of RFID tags or the cost associated with applying them on cases and testing them. Benefits can be direct, such as reduction in shrinkage and buffer stock, or

indirect, such as better customer service due to more detailed and accurate understanding of ship time and date of arrival. Clearly, building business cases for an RFID deployment based on realistic cost-benefit analysis is an important and complex task.

To enable a rigorous cost-benefit analysis, we apply a business value modeling approach that we have developed in the last few years (Grey et al. 2003a, b). This approach goes beyond traditional Return On Investment (ROI) analysis to consider non-financial aspects of an investment, such as improved customer satisfaction or shortened customer response times, translating such operational impacts into financial value. By augmenting traditional ROI analysis, it helps provide more complete and more objective information on the value of an investment. A second feature of this approach is that it considers the impact of the investment at the enterprise level, in addition to calculating returns of that particular investment treated singly. The performance of a business enterprise is characterized by its profit and loss statement and balance sheet. So our approach calculates any differences in the profit and loss statement and balance sheet as a result of the investment.

The business value model consists of three key parts: the benefit model, the cost model, and the data sets as input to the benefit and cost models. There are two data sets required, representing the scenarios before and after the investment has been implemented. The cost model represents the necessary financial investment over the planning horizon to install operate, and maintain the RFID technology. The investment items depend on the configuration of the supply chain and the volume of the business, but are relatively easy to estimate.

Developing the benefit model is the most challenging and critical part of the value modeling exercise. Ideally all impacts of the investment, no matter how indirect they might be, have to be captured at an appropriate level of detail such that their consequences are clearly seen and yet their data requirements are practical in a real life setting. Direct benefits are relatively straightforward to calculate, while indirect benefits may not be obtained using closed form equations. In some cases we may not even understand fully what indirect benefits there might be. The latter is especially true for RFID in a supply chain; Lee et al. 2005 explores this issue in detail.

For RFID business value modeling, the benefit model is based on a hierarchical decomposition or “tree” of key performance measures (KPI’s) of a business, starting from the top level P&L items for the business in question – revenue and major cost items such as cost of goods sold (COGS), selling, general and administrative expenses (SG&A), research and development expenses (R&D), etc. An investment will impact a subset of these KPI’s within this tree, the effects of which are then propagated upwards to the root of the tree using the mathematical relationships defined in the model. Fig. 1 provides a simple illustration for such a decomposition for RFID business value modeling.

On the right-most side of the value tree structure in Fig. 1, we have a list of benefits that are potentially going to be realized by RFID deployment. Each benefit is characterized by a set of performance measures. The values of the performance measures after RFID is deployed is estimated by an expert user from experience or from published studies, or is an output of another model or analysis (such as our process model). These changes in performance measures are then propagated up to the root of the tree by translating the measures into one of the major cost items or revenue. The translation is done through a set

of equations custom built for the context, the supply chain in this case. Many, but not all, of these equations are relatively straightforward. Section 2.1.1 below discusses the list of benefits provided by RFID and Section 2.1.2 gives an example of the propagation calculation.

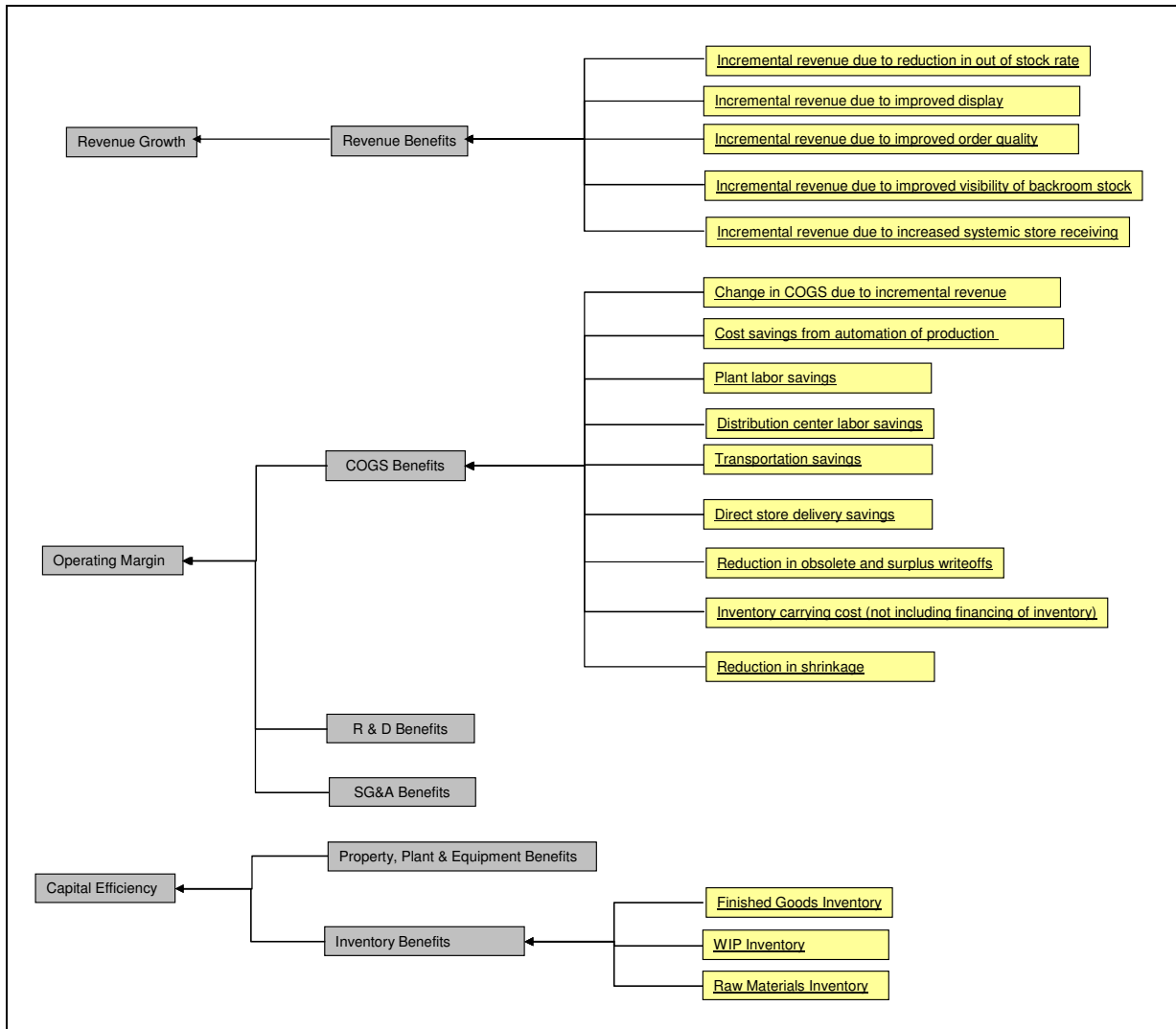


Figure 1. Value decomposition or value tree for RFID

We use the BVM to analyze three possible initiatives in RFID investment:

1. Pallet-level tagging,
2. Case-level tagging, and
3. Item-level tagging.

Each initiative is characterized by its own set of benefits which are in turn specified by the performance measures impacted by RFID. Generally speaking, item level tagging can cover all benefits provided by case level tagging which in turn can cover all benefits provided by pallet level tagging.

### **2.1.1. Direct Benefits of RFID in a Supply Chain**

RFID tags, at their basic level, provide several technical advantages over the most commonly used automatic identification technology today, bar codes. The most important advantages are that RFID tags can be read with no human operation, with practically zero delay, and at little to no variable cost any time when a reader is present, they rely less on the environment (e.g., line of sight or surface condition of the label) for reading accurately, many tags can be read simultaneously, a larger data capacity than bar codes. (Further, more advanced tags present the possibility of writing additional information onto the tag over time, which we will not delve into.) We exploit these advantages to develop the following set of direct benefits.

If bar codes are manually scanned at different points in a supply chain (e.g., the shipping and receiving docks of warehouses and stores) at present, the application of RFID will provide a *direct benefit* of eliminating those labor costs. Computation of such labor savings is relatively straightforward – the average time spent in each relevant manual operation can be collected and the average number of such operations can be estimated from the movement volume of the supply chain and the procedures used in handling the

physical goods. In the BVM, we include a list of common, manual operations that can potentially be saved (at least partially) by using RFID as an automation device, as follows:

1. Production reporting at the end of production lines
2. Shipping of pallets, cases, or items at the factory and distribution center
3. Receiving of pallets, cases, or items at the distribution center and retailer
4. Handling of inventory flow-through or cross-docking
5. Physical or cycle counting
6. Inventory auditing
7. Printing and handling of pallet license plates and case labels, or manual entry of information on labels
8. Inventory reconciliation of damaged products
9. Reconciliation and handling, at the factory and distribution center, of returned products, shipment errors, and subsequent claims

The ability to be automatically read without delay will reduce the cycle time in the movement of goods. Such time reduction will result in, besides labor savings described above:

1. Reduced loading/unloading time reduces trailer detention and carrier costs
2. Reduced delays in shipping and receiving reduces the supply lead times, directly decreasing the stock one has to carry while waiting for delivery.
3. The promotional product component of DC inventory can be reduced as delivery can be phased closer to the promotional event, allowing for a reduction of inventory.

Another important advantage of an automation device captured in the BVM is data accuracy. Today's bar codes have extremely good read accuracy in a laboratory environment and very good accuracy in normal use. The only key advantages of RFID over bar codes in read accuracy is that bar codes can get dirty or damaged relatively easily and that bar code reading needs a clear line of sight (and some minor orientation requirements). If an enterprise faces significant issues because of these reasons, RFID will be one (but not the only) potential solution. The *direct benefits* due to a reduction in inventory read errors include:

1. The inventory value, the inventory carrying and handling costs to cover extra stock in the supply chain because of such errors (a fraction of the inventory is in fact not usable because their record is incorrect, so the supply chain in time will carry extra inventory in order to satisfy customer service level requirements);
2. A reduction in shortage claims by the retailer and less overages shipped (and kept) by the retailer;
3. A reduction in retailer charge-back because of better delivery compliance;
4. A reduction in transportation costs by reducing the transfer of stocks to cover those that are shipped or received in error;
5. An increase in claims recovery from the carriers.

RFID can carry more information than a bar code, such as a serial number. The direct benefit of the presence of a serial number is as follows.

1. Often, the actual selling price of a returned item is unknown so a "default price" is assumed when crediting the customer. Discrepancies between

retailer and manufacturer counts for returned merchandise can lead to unnecessary deductions for the manufacturer and the labor on both the manufacturer and retailer sides to manage the deductions.

2. Visibility of product by serial number through the supply chain will allow manufacturers and retailers to better control the winding down of discontinued or about-to-expire products, reducing price mark downs.
3. It will aid in managing recalls of products, saving time and labor. Recalls are rare but are very labor intensive when they happen.

Another advantage of RFID captured by the BVM is the ability to detect the presence or absence of the tags very frequently at almost no marginal cost. The consequences are:

1. We can detect where and when (up to a certain resolution in space and time) material losses are incurred. We can then investigate the sources of such losses and devise action plans to remedy them. In this way, RFID can prevent shrinkages, even though they themselves do not prevent breakages or thefts. The *direct benefits* are similar to those of inventory read accuracy discussed above.
2. Actual store inventory can be reduced as a result of eliminating the practice of zeroing out of inventory that cannot be found.

Typically the direct losses in inventory related costs due to data accuracy are relatively small, in the order of 1% of total inventory. (While this may still amount to significant monetary value in high-volume supply chains, there are usually opportunities of higher orders of magnitude.) However, the important impacts of RFID lie in the indirect



consequences of the improved inventory accuracy. The dynamic effects of such small changes tend to have far more significant impact than the direct savings. Estimating the impact of those dynamic effects is usually not straightforward. However, with the simulation capability provided by the *RFID Business Process Modeling* tool (see next section), the user can estimate the impact of those more complicated factors using simulation, and then feed the results back to the Business Value Modeling tool to compute the overall financial impact. An interactive use of both tools enables essential inputs of the business process modeling tool to be drawn from the business value modeling tool, and selected outputs of the business process modeling tool to be fed back into the business value modeling tool.

Related to shrinkage and theft, the use of RFID tags at the item level will eliminate fixtures, tags, and labor associated with theft prevention. In addition, eliminating some defensive merchandising strategies, such as holding product in locked display cases, can increase sales.

Because of the electronic nature of RFID, future encryption capability, and audit trails, it is virtually impossible to duplicate the tags. They can be used to distinguish between legitimate and counterfeit products. This can potentially recover significant lost revenue of the manufacturer.

### **2.1.2. BVM Benefit Calculations**

Here we provide two examples of the calculations carried out in the BVM to illustrate how direct effects and indirect effects of RFID are captured and computed.

*Direct effect of inventory shrinkage* is calculated as the sum of shrinkages due to various causes, including theft, process failure, damage, non-sellable allowance, and others.

Each type of shrinkage is specified in terms of a percentage of sales. As-is values can be estimated from the store's historical data. To-be values are estimated by an expert user based on experience or published information. The reduction in the total shrinkage is then translated to either a decrease in COGS, assuming that sales remain the same, or in some cases, an increase in sales, assuming that the goods that were recovered from shrinkage will be sold (with COGS remaining the same). The latter may be true for seasonal items where the supply is purposely planned to be below the estimated demand.

On the other hand, the impact of *indirect effects of inventory shrinkage* cannot be calculated in a straightforward manner. Inventory shrinkage causes a discrepancy between the actual quantity of the physical inventory and the inventory quantity recorded in the computer system. Without RFID, this discrepancy can only be reconciled when a physical inventory count occurs. In between two consecutive inventory counts, the system inventory is not accurate but is the basis for reordering. In this case, the target stock-out rate set in the inventory replenishment policy will not be realized. Calculating this effect is not trivial; we have chosen to use a simulation based process model. It turns out that when the system inventory data are accurate, an inventory reduction can be achieved with the same target stock-out rate; Section 4 contains a further discussion of this effect. The percentage of inventory reduction is calculated by the simulation model and then brought to the value model (manually) which will calculate the associated reduction in inventory carrying cost and other inventory related measures such as inventory turns.

### **2.1.3. BVM Cost Calculations**

The investment cost of RFID in a supply chain is rather substantial. We illustrate the costs using an example from a case study. Major system costs are associated with

establishing the reader network and the variable cost of the tags themselves. In most cases, pallet and case tagging scenarios require readers at the same points in the supply chain so the infrastructure cost is the same for both. Item tagging requires more readers, mostly in the store, to take advantage of item level information.

Though much of the benefit opportunity is associated with labor savings, there is a new labor cost incurred as a result of deploying the system. This relates to the requirement to apply and verify tags on pallets and cases. In some instances, however, additional labor is not required for case level tagging if automated in line application in the packaging process will be used.

Costs per annum for tags will depend on the level of tagging and the volume of goods flowing through the supply chain. In addition, the cost per tag is expected to decrease in the next 10 years as the tag manufacturers learn in mass producing them. This variable unit cost per tag over time has to be taken into account in the value model.

Once installed, maintenance and operational support for the reader network generate additional costs estimated to be 10% -15% of the initial capital investment.

## **2.2. The Business Process Model**

There are two types of benefits of using RFID. The first types of benefits are the *direct benefits* as those given by the automation aspect of RFID. Just like any automation device, RFID reduces total costs by reducing labor and error. These kinds of benefits are quantified by the business value model in a rather straight forward manner as described in the previous section.

The other types of benefits are *indirect benefits*. There are two sources of indirect benefits. The first kind of indirect benefits are those resulting from dynamic effects of

small changes brought about by RFID in one area of the supply chain. Because a supply chain is a complex set of activities connected with each other and connected in time, small changes in one area may lead to unpredictable and/or significant consequences elsewhere in the supply chain or later in time. The well known “bullwhip effect”, first studied by Forrester (1958) and later by Lee et al. (1997) and many others, is an example of small changes propagated and amplified through the dynamic behavior of a supply chain. In our tool set, for example, the direct loss due to inventory shrinkage is just the value of the unaccounted inventory itself, and it is easily quantified by the BVM. The indirect loss of inventory shrinkage may include losses from stock-outs as the result of poor replenishment due to inventory inaccuracy (caused by the unaccounted shrinkage). This indirect benefit cannot be easily estimated in the spreadsheet computation in the BVM; therefore, it is estimated by carefully simulating the involved supply chain environment in the Business Process Model (BPM). The benefit simulated is communicated back to the appropriate benefit section of the BVM.

The second source of *indirect benefits* that might be overlooked by a traditional ROI analysis, as in our BVM, is the need for a business process transformation to take advantage of the information now available from the RFID tags. A simple example is the commonly used, periodic inventory replenishment process – most retailers replenish their stores once a week based on a predetermined decision-making cycle for each product. To take full advantage of the potential real-time inventory information provided by RFID, this periodic replenishment process needs to be redesigned – perhaps as simple as reducing the cycle to a day rather than a week, if other considerations (such as the workload of the planners) allow. Such a change, simple it may seem, may have significant impact on the

performance of the enterprise. However, the impact cannot be easily estimated in the spreadsheet computation in the BVM. Therefore, the BPM is instead used in computing the impact of process transformation by carefully simulating the involved supply chain, and the quantified impact is communicated back to the BVM.

Other indirect benefits identified by our BPM are:

1. Visibility of inventory information across the supply chain – When inventory data across the supply chain are used in decision making in production and inventory planning, substantial benefits can be gained in terms of average inventory in the supply chain and customer service level in the form of out of stock performance. A numerical comparison of three scenarios using or not using inventory data in supply chain planning is contained in Lee et al. 2005.
2. Time delay of inventory data – RFID can potentially eliminate the time delay in updating the inventory data in the information system. There are two types of delays: delay in updating the system after the physical goods changed their place, e.g., after they are received into a distribution center or a store, delay in using the data to make a decision after data have been collected, e.g., point-of-sale data are uploaded to a central database at midnight and the buyer use the data to make a purchase order decision the following afternoon. A more detailed discussion is contained in Lee et al. 2005.

The BPM we developed is limited in scope to the logistics of the supply chain. Although more specialized to individual business situations, RFID can potentially bring benefits to product management and other areas, including:

Enhanced quality control within facilities - Each tagged container of raw material or case of finished goods can provide important information about the code life of individual products. Visibility to code life as the product is stored and moved between facilities will allow product life to be managed more effectively and potential quality issues to be addressed, before product is moved further in the supply chain. This capability will enhance both quality assurance and product FIFO management.

Improved recall capabilities - The ability to track discrete cases (through the use of a serial number in the tag) of product both within the manufacturing locations and externally at customer locations would facilitate a much more effective recall process. While the incidence of recalls is relatively low, the cost can be substantial. In addition, given the visibility and importance of any consumer product, the ability to conduct quick, precise recalls can be vital in limiting any negative exposure.

Improved Market Intelligence - The ability to have visibility to cases of product at customer locations will provide a level of insight into product performance only possible today through external data gathering agencies. In the future, the cost of gathering market intelligence is significantly reduced as tagged case movement is automatically captured by business partner RFID networks and accessed by manufacturer's systems.

### **2.3. The Value Model – Process Model Linkage**

In the consumer products business we investigated using our tool set, the indirect benefits captured by the process model manifest themselves in a reduction in average

inventory carried in the supply chain and an improved customer service level in the form of a lower out-of-stock rate. These two performance measures are then used as input to the BVM. In the BVM, reduction in average inventory results in a lower inventory carrying cost, decreasing the SG&A cost in the P&L statement. It will also impact all the inventory-related measures such as inventory turns. An improved out-of-stock rate will reduce the backordering cost (assuming that the customer will take backorders), decreasing the SG&A cost, or increase the revenue if we assume that a potential sale will be lost if the item is out of stock.

In other industries, other indirect benefits may realize, but eventually all indirect benefits will get translated into cost reduction or revenue increase in the BVM. For example, in a service industry, the availability of real time data may decrease the total time a customer experiences in obtaining service. This improvement in customer experience may increase revenue because the enterprise can now serve more customers with the same resources, or because the customer will bring more business either through more frequent visits or by bringing new customers through word of mouth. Clearly, some of these consequences are not trivial to quantify. The capacity increase can be estimated through queueing or simulation models; the improved revenue will be even more difficult to estimate, and is an entire subject in itself. Once these models are built, their results can be incorporated into the BVM similar to those of the BPM in our study.

### **3. Application of the Business Value Modeling Tool Set**

The business value modeling methodology developed has been deployed in multiple business case engagements for leading manufacturers and retailers to investigate whether RFID technology should be adopted in their particular business. We consider the

one time cost of installation and ongoing tag and reader costs for maintenance and replacement balanced against a number of one time and ongoing benefits. Data inputs required cover metrics such as labor costs, locations (facilities and the number of discrete locations within facilities), transportation, inventory levels, shrink statistics, and product volumes, as required by the cost and benefit calculations described above. All costs and business benefits identified are validated with process experts and functional heads within the client organization, and the projected size of the expected benefits are adjusted if necessary to accommodate any assumptions or simplifications made.

For each business case, the existing framework of benefit opportunities identified in previous studies are used to enable comparison between our output summary and that of the industry level findings published by the FMI/GMA/NACDS and GCI, among others. Where benefits require retailer changes, we assume that appropriate processes were in place to enable realization of these benefits. Benefits are phased over a ten-year timeframe in relation to the anticipated rate of retail adoption. Quantification of downstream benefits (within the retailer supply chain and store operations) was in part based on documented industry assumptions. For example, the benefit opportunity related to a reduction in out-of-stocks leveraged industry studies on the relationship between product availability at the retail shelf and consumer behavior.

Most business cases have a planning horizon of multiple years; for RFID this is particularly important. First, implementing RFID in a supply chain is not a trivial task, so the implementation or adoption time will be several years. The benefits have to be scaled based on the implementation rate. Scaling factors can be estimated using simple but reasonable assumptions, such as, that the benefits are directly proportional to the



implementation rate in terms of the volume of products using RFID. Second, as the industry climbs the learning curve of producing RFID infrastructure items (tags, readers, etc.), the cost of purchasing these items will decrease significantly in the next several years. Such variable unit costs are directly taken into account in the investment input of the BVM.

Our experience indicates that the whether there is a business case for RFID depends on the type of business and the products, the level of tagging (item, case, or pallet), the current operational efficiency of the supply chain, the business volume, and the rate of trading partner adoption. It is possible that, while easier to estimate, direct benefits alone may not provide adequate benefits to offset the investment cost. Indirect benefits are more complex and may involve changing certain business processes or decision making logic. They are also not widely understood and are therefore a barrier to RFID adoption at present.

One critical factor in all the business cases is the cost of the RFID tags. While the unit tag cost is expected to continually decrease in the future, the rate of decrease is uncertain. A useful application of the business value model is to analyze what rate of cost decrease will enable the investment to break even in the planning horizon (i.e., with a net present value of zero over the horizon). By approximating the rate of decrease with a constant rate (representing the average rate), we can find the break even rate using a simple search (e.g. bisection search). Comparing this break even rate to historical cost decrease rates of other technologies, we can gain insights on the chance of having a positive return on our RFID investment at different tagging levels.

## **4. An Illustrative Example**

In this section we provide a hypothetical example to illustrate the use of the tool set to explore financial feasibility of RFID in a supply chain. This hypothetical example

considers a simple manufacturer-retailer supply chain in the Consumer Products (CP) business, which was also used to identify indirect RFID benefits in Lee et al. 2005.

The supply chain consists of three echelons: a manufacturer, a distribution center (DC, that belongs to the manufacturer), and a retail store. (See Fig. 2.) The application of RFID technology is modeled in each of echelon in the supply chain. In the manufacturer, we modeled RFID tag reading at the points of production completion and shipping. In the DC, we modeled tag reading at the receiving and shipping docks. In the retailer, we modeled tag reading at receiving, the backroom and the shelf in the store. Various simplifications and assumptions are made to capture the essence of the supply chain behavior without making the model unnecessarily complicated.

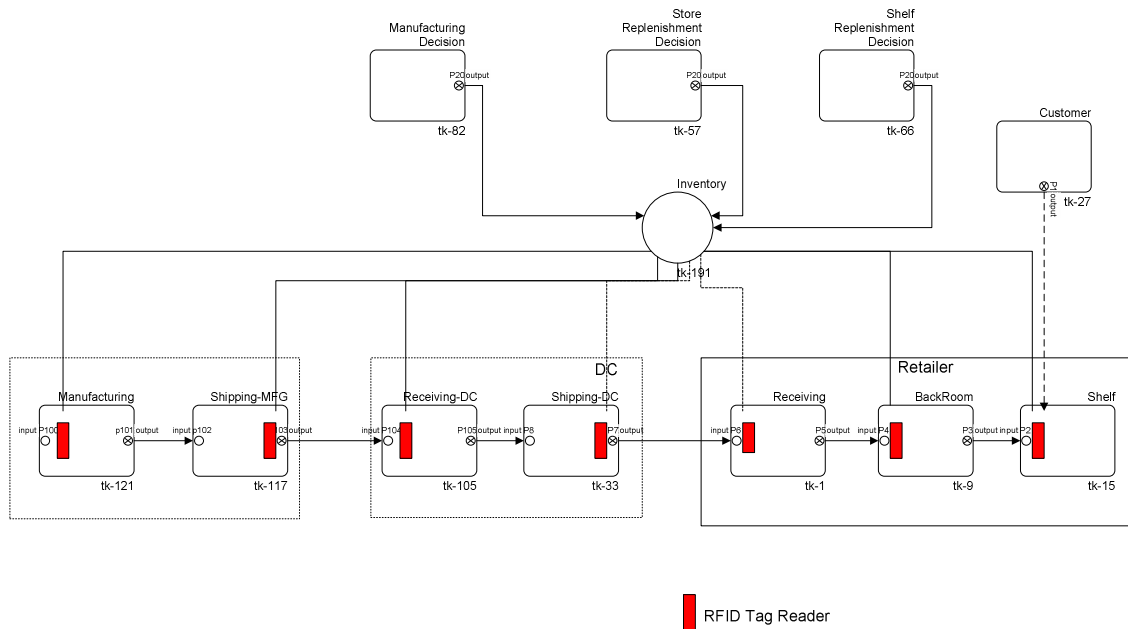


Figure 2. Three Echelon Supply Chain Model for a CP Retail Business

For the retail store, we modeled four products which are sold to customers with equal probability. Customers arrive with an inter-arrival time characterized by a log-normal distribution, and their purchase quantity on each purchase occasion is assumed to be uniformly distributed between 1 and 3. The store replenishment is based on an (s, S) policy: re-order point, s, and target inventory, S. Shelf replenishment is also based on an (s, S) policy.

For the manufacturer, we assumed that the daily production quantity for each product is decided based on a certain policy, and is shipped to the DC once a day. Several different production policies are simulated. The lead time for shipment from manufacturer to DC is one day. For the DC, the products are pulled from the retailer based on the retailer's replenishment policy and decision frequency. The lead time for shipment from the DC to the retailer is one day.

The business value model was implemented in Microsoft Excel and the simulation model was implemented using the simulation engine of IBM WBI Modeler<sup>®</sup> (IBM Corporation). Details of the simulation model are described in Lee et al. (2006).

In this hypothetical example, we assume that the retailer is interested in exploring the value of RFID tags at the item level. The revenue and major costs (before RFID implementation) of the retailer are shown in Figure 3.

| RFID - All Service Areas  | Data Source  | Manual Entry |
|---|--------------|--------------|
| <b>Financial</b>  | Manual Entry |              |
| Net Revenue (\$K)   | Manual Entry | 1,000,000    |
| Research and Development expense (\$K)                          | Manual Entry | 35,000       |
| COGS (\$K)  | Manual Entry | 500,000      |
| SG&A (\$K)  | Manual Entry | 105,000      |
| Depreciation and amortization expense (\$K)                     | Manual Entry | 22,000       |
| Effective tax rate (%)  | Manual Entry | 39%          |
| Pre-tax interest expense (\$K)                                  | Manual Entry | 7,000        |
| Cash and Marketable Securities (\$K)                            | Manual Entry | 110,000      |
| Accounts Receivable (\$K)                                       | Manual Entry | 100,000      |
| Finished goods inventory (\$K)                                  | Manual Entry | 8,000        |
| WIP inventory (\$K)   | Manual Entry | 3,000        |
| Raw materials inventory (\$K)                                   | Manual Entry | 30,000       |
| Accounts Payable (\$K)  | Manual Entry | 80,000       |
| Property, Plant and Equipment (\$K)                             | Manual Entry | 800,000      |
| Other Income or loss (\$K)                                      | Manual Entry | 10,000       |
| Other current assets (\$K)                                      | Manual Entry | 11,000       |
| Other fixed assets (\$K)  | Manual Entry | 12,000       |
| Other long-term liabilities (\$K)                               | Manual Entry | 9,000        |
| Other current liabilities (\$K)                                 | Manual Entry | 7,500        |
| Long-term debt (\$K)  | Manual Entry | 100,000      |
| No. of Employees  | Manual Entry | 10           |
| Weighted Average Cost of Capital (%)                            | Manual Entry | 11%          |
| Inventory carrying cost (%/year) (not including financing cost) | Manual Entry | 12%          |
| <b>Obsolescence and Surplus Write-offs</b>                      | Manual Entry |              |
| Annual cost of expired product write-offs (\$K)                 | Manual Entry | 1,458        |
| Annual cost of seasonal product obsolescence (\$K)              | Manual Entry | 2,562        |
| Annual cost of new product launch write-offs (\$K)              | Manual Entry | 2,304        |
| Annual cost of surplus writeoffs (\$K)                          | Manual Entry | 2,268        |
| <b>Direct Store Delivery</b>                                    | Manual Entry |              |
| Annual cost of check-in and invoice reconciliation (\$K)        | Manual Entry | 3,000        |

Figure 3. Partial list of input data items for the Business Value Model

In this setting, RFID can contribute to the following benefits:

- Reduction in labor due to elimination of scanning and counting
- Elimination of scanning and manual keying of data
- Reduction in labor to manage returns
- Reduction in labor to perform physicals/cycle counting
- Increased margin from reduction in diversion
- Reduced labor to manage shortage/deduction claims
- Increased margin due to improved visibility, order quality & store receiving

- Improved cash flow - reduced deductions
- Reduced shortage/deduction write-offs
- Reduced returns as a result of accurate shipments
- Reduction in transportation due to reduction in inventory
- Reduced receiving time at retail DC
- Reduction in Non-sellable/Swell Allowance
- Shrink - Reduction in paper shrinkage
- Reduction in Expired product write offs
- Reduced safety stock from increased inventory accuracy
- Reduced FG inventory due to improved demand signal
- Reduced FG carrying costs
- Elimination of fixed assets; bar code scanners- handheld and conveyors

The direct benefits are mostly straightforward to calculate. For brevity, we will not go through the computation details for every benefit item. Instead we discuss an indirect benefit related to inventory shrinkage in more detail.

Nowadays a retailer's replenishment decisions are based on inventory information kept in a computer system (system inventory), which is often assumed to be accurate. However, system inventory and the actual inventory count (of the physical inventory) are seldom synchronized due to causes such as shrinkage or stock loss, transaction error, inaccessible inventory, and incorrect product identification. The error between the system inventory and physical inventory accumulates over time and is not corrected until a physical inventory counting takes place, which happens infrequently (typically few times a year) due to its labor-intensive nature.

We focus on a particular reason for inventory inaccuracy: inventory inaccuracy caused by product shrinkage due to damaged or lost goods. Further, we observe that RFID will not prevent damages and may not be effective against theft, but will enable the

system inventory to reflect accurately what is still physically there. By identifying where goods have been lost, it is potentially easier to prevent future losses. Here we make a simplified assumption that shrinkage will continue to occur, but the system inventory information now takes into account the goods that are lost. Using the BPM, we can calculate the savings, if any, resulting from the visibility of shrinkage, which can then be communicated back to the BVM. As we shall see below, the economic consequence of inventory shrinkage is potentially far beyond the loss in monetary value of the product shrinkage.

In this example, we assume that shrinkage at the retailer occurs at a rate of 1.6%. This shrinkage rate was used since it seems representative of what a typical U.S. retailer faces (Kang and Koh, 2002). We simulated a scenario where RFID technology is not deployed, and two scenarios where RFID technology is deployed. Without RFID, the inventory reduction due to shrinkage is not known, and the retailer's replenishment decision is made based on the inaccurate inventory information. With RFID, shrinkage occurs as before, but the replenishment decision is expected to improve due to the more accurate inventory information to reflect what is physically in stock.

In the first scenario, we simulated the quality of replenishment decisions due to shrinkage at the retail store where RFID technology is not deployed. In this setting, physical inventory tracking is done only once every 3 months at the store (using cycle counting), and the inaccuracy of inventory in the retailer's information system accumulates over time until a physical inventory is carried out, at which time system inventory is synchronized with physical inventory. The retail store's replenishment policy we used is a continuous review (s, S) policy, with the reorder point (s) of 36 and the target inventory (S)

of 48, based on the system inventory, not on the physical inventory. Because physical inventory is in fact less than what the system thinks, we can expect that the customer service level will be lower than the target, even though all technical assumptions of the inventory replenishment policy are satisfied.

In the second scenario, we simulated that RFID is now deployed in the business. With the RFID deployment, inventory is tracked more accurately and in real-time, and better replenishment decisions can be made. To clearly illustrate this effect, we assumed that the accuracy of RFID is 100% and the system inventory is same as the physical inventory. Simulation results indicated that the backorder quantity decreased to 1% of that in scenario one, the average inventory became 20% higher but the fluctuation of inventory is much smaller than that in scenario one. This presented an opportunity to decrease the inventory by modifying the replenishment policy; e.g. lowering the re-order point (s), and target inventory (S), without sacrificing customer service; e.g., back order quantity. We showed one such case in the third scenario, with the re-order point decreased to 26 from 36, and lowered the target inventory to 38 from 48. The back order quantity showed a 22% reduction from the first scenario and the average inventory was reduced by 16%.

Table 2 below illustrates the computation of the benefits described above in BVM. The first section of the table shows the computation related to the direct benefit of RFID with inventory shrinkage, which is the reduction of the shrinkage itself. The second section computes the reduction of handling cost for backorder due to improved visibility to inventory shrinkage. The last part of the table shows the reduction of finished goods inventory which is also the result of improved inventory visibility. Note that the

highlighted numbers (in the light blue background) are the parameters obtained from the simulation analysis using BPM.

| Benefit Description   | Driver/Input Description   | "As-is" case     | Case Level RFID  | Impact         | Financial Metric         |
|---|--|------------------|------------------|----------------|--------------------------|
| <b>Incremental revenue due to reduced shrinkage</b>                                 |  | <b>1,000,000</b> | <b>1,005,000</b> | <b>5,000</b>   | <b>Revenue Benefit</b>   |
|   | Shrinkage due to process failure as % of sales                           | 1.0%             | 0.50%            |                |                          |
|   | Shrinkage due to theft as % of sales                                     | 1.0%             | 1.0%             |                |                          |
|   | Shrinkage due to product damage as % of sales                            | 1.0%             | 1.0%             |                |                          |
|   | Shrinkage due to reasons other than above as % of sales                  | 1.0%             | 1.0%             |                |                          |
|   | Shrinkage as % of sales  | 5.0%             | 4.5%             |                |                          |
|   | Net Revenue (\$K)  | 1,000,000        | 1,000,000        |                |                          |
|   | Increase in sales  |                  |                  | 5,000          |                          |
|   | Net revenue accounting for increase due to improved order quality        | 1,000,000        | 1,005,000        |                |                          |
| <b>Reduction of backorder handling cost due to improved visibility of shrinkage</b> |  | <b>9,375</b>     | <b>7,313</b>     | <b>(2,063)</b> | <b>SG&amp;A Benefit</b>  |
|   | Customer backorders as % of sales  | 10.0%            | 7.80%            |                |                          |
|   | % reduction in customer backorders due to improved tracking of shrinkage |                  | 22%              |                |                          |
|   | Annual number of backorders  | 2,500,000        | 1,950,000        |                |                          |
|   | Net Revenue (\$K)  | 1,000,000        | 1,000,000        |                |                          |
|   | Average order quantity per order   | 2                | 2                |                |                          |
|   | Average price per item (\$)  | 20               | 20               |                |                          |
|   | Annual number of orders  | 25,000,000       | 25,000,000       |                |                          |
|   | Annual cost for handling backorders                                      | 9,375            | 7,313            |                |                          |
|   | Average processing time for backorders (hours)                           | 0.25             | 0.25             |                |                          |
|   | Hourly labor rate  | 15               | 15               |                |                          |
| <b>FGI Inventory</b>  |  | <b>8,000</b>     | <b>6,720</b>     | <b>(1,280)</b> | <b>Inventory Benefit</b> |
|   | % decrease in FGI due to reduction of shrinkage                          | -                | 16%              |                |                          |
|   | Finished goods inventory (\$K)   | 8,000            | 6,720            |                |                          |

Table 2. Computation details of benefits related to RFID's impact on inventory shrinkage

Other benefit items are also computed similarly. Most of the direct benefit items are computed based on estimated relative improvements provided by experts or the results of pilot programs. The indirect benefit items are usually computed based on the estimates obtained through the simulation study using BPM. BVM also collects the investment cost data for the RFID initiative. The investment costs include both one time investment cost and recurring costs over the planning horizon. Table 3 below shows the investment data we used in the example for the RFID initiative with a planning horizon of eight years, with an initial pilot program conducted during the first year and the full implementation to be completed by the end of the third year.



| Name                                    | Category | Investment Type | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   |
|---|----------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b>Hardware (\$K)</b>                   |          |                 |        |        |        |        |        |        |        |        |
| Workstations and Servers                | Hardware | Capital         | 456    | 72     | 3,866  | 82     | 84     | 88     | 92     | 92     |
| Tags and Readers                        | Hardware | Capital         | 310    | 250    | 250    | 250    | 250    | 250    | 250    | 250    |
| RFID / Label Printer                    | Hardware | Capital         | 600    | 600    | 1,200  | -      | -      | -      | -      | -      |
| Networking Infrastructure test          | Hardware | Capital         | 100    | 100    | 400    | -      | -      | -      | -      | -      |
| <b>Total Hardware Costs</b>             |          |                 | 1,466  | 1,022  | 5,716  | 332    | 334    | 338    | 342    | 342    |
| <b>Software (\$K)</b>                   |          |                 |        |        |        |        |        |        |        |        |
| Software License Fees                   | Software | Capital         | 800    | 400    | 1,200  | -      | -      | -      | -      | -      |
| Software Maintenance Fees               | Software | Expense         | 100    | 100    | 100    | 100    | 100    | 100    | 100    | 100    |
| <b>Total Software Costs</b>             |          |                 | 900    | 500    | 1,300  | 100    | 100    | 100    | 100    | 100    |
| <b>Total Hardware / Software</b>        |          |                 | 2,366  | 1,522  | 7,016  | 432    | 434    | 438    | 442    | 442    |
| <b>Services (\$K)</b>                   |          |                 |        |        |        |        |        |        |        |        |
| Professional Service Costs              |          |                 |        |        |        |        |        |        |        |        |
| Software Installation and Configuration | Services | Capital         | 500    | 500    | 500    | 500    | 400    | 400    | 400    | 400    |
| Hardware Installation and Configuration | Services | Capital         | 200    | 200    | 200    | 200    | 200    | 200    | 200    | 200    |
| Tagging                                 | Services | Capital         | 400    | 400    | 300    | 300    | 300    | 300    | 300    | 300    |
| Pilot and Phase-in                      | Services | Capital         | 500    | -      | -      | -      | -      | -      | -      | -      |
| <b>Total Services</b>                   |          |                 | 1,600  | 1,100  | 1,000  | 1,000  | 900    | 900    | 900    | 900    |
| <b>Others (\$K)</b>                     |          |                 |        |        |        |        |        |        |        |        |
| Other RFID Costs                        | Others   | Expense         | 400    | 400    | 400    | 400    | 400    | 400    | 400    | 400    |
| <b>Total Others</b>                     |          |                 | 400    | 400    | 400    | 400    | 400    | 400    | 400    | 400    |
| <b>Total Implementation Costs</b>       |          |                 | 43,660 | 30,220 | 84,160 | 18,320 | 17,340 | 17,380 | 17,420 | 17,420 |

Table 3. Illustrative data of investment costs for an RFID initiative.

Based on the costs and benefits defined and computed, the BVM provides a high-level summary of the business impact of the RFID initiative. It includes a pie chart showing key sources of benefit and a graph of cash flow projections (Figures 4 and 5). BVM also reports standard ROI metrics such as Net Present Value (NPV), Payback Period, and Internal Rate of Return (IRR).

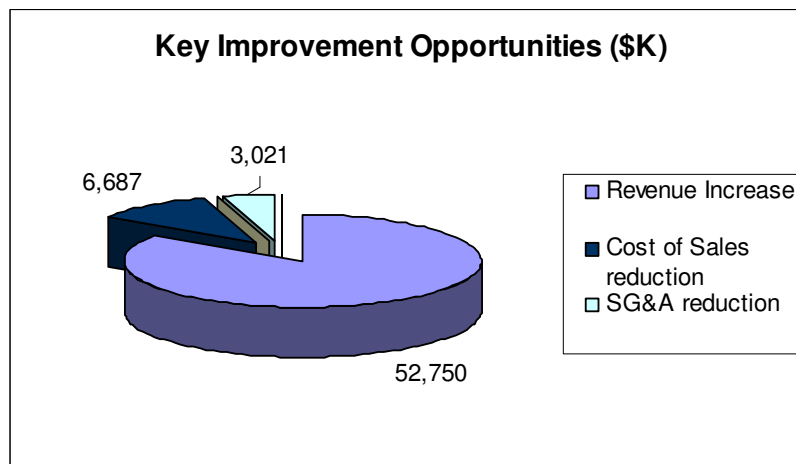


Figure 4. BVM chart: Key Improvement Opportunities

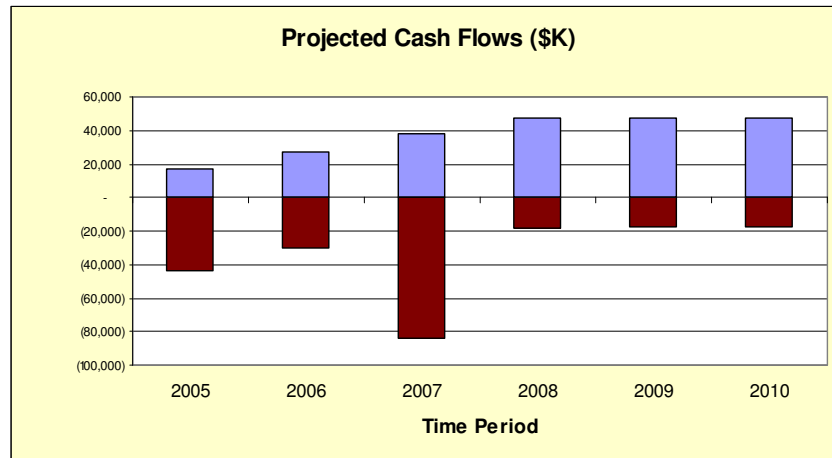


Figure 5. BVM chart: Projected Cash Flows

There are many other useful functions provided by BVM. For example, it allows users to define “what-if” scenarios and perform the comparison analysis of projected financial performance for different scenarios. This capability enables users to understand each initiative’s likelihood of success in a dynamic business environment with uncertainties. Another advantage of using BVM for RFID business value modeling is its ability to link financial performance metrics with business value drivers directly using the decomposition approach described earlier in Section 2.1. A user can always find out the relative impact of a particular value driver, for example, the impact of continuous replenishment policy enabled by RFID, on the overall financial performance of the supply chain.

## 5. Guidelines to Practitioners

In this chapter, we presented a business value modeling tool set, consisting of a spreadsheet based value model and a simulation based process model, to help analyze the business value of RFID technology in a supply chain. Because the benefits of RFID

include both direct and indirect ones, the entire tool set is necessary to cover all potential gains. As we have learned, accounting for a subset of the benefits, for example only the direct benefits which can be more easily calculated in a spreadsheet, is not adequate and may lead to an unwise decision. Indirect benefits are sometimes not obvious to identify; Lee et al. 2005 gives suggestions on areas to look for in a practical situation. In order to realize some of these indirect benefits, significant changes to business processes or decision making logic may have to be made, far beyond a straightforward replacement of a existing automatic identification method such as bar coding. One may argue that such process improvements enabled by RFID are the in fact the pinnacle of what RFID can offer. But it is important to realize that significant effort is required to design and deploy the improvements beyond the mechanical replacement of bar coding.

Because modeling the indirect benefits using simulation takes significant time and effort, we recommend the application of the tool set in two stages. First, the direct benefits are analyzed using the spreadsheet based business value model alone. If a positive business case can be built, there is no need to go further. Otherwise, another study has to be launched to explore where RFID can provide value for that particular business setting, using a simulation model to help design and analyze associated changes. Such a two stage process will reflect a typical roadmap for RFID implementation: first as a direct replacement of bar coding, then redesign the business processes to take advantage of what RFID can provide.

Even though our focus has been on the evaluation of RFID technology, our value modeling tool set is applicable for other new technologies as well. It is increasingly

important to focus on indirect benefits, as automation gains wide adoption and labor savings will have minimal effect on the total cost.

As we have mentioned in Section 2, our process model is limited to the logistics of the supply chain. Other aspects such as market intelligence which will lead to better decision making in how to sell the products or how to respond to market signals quickly can be influenced by the presence of RFID. These indirect benefits are even more difficult to quantify, but can be very important in some businesses. More research is needed in the evaluation of “soft” or “strategic” benefits. These benefits are real and will eventually translate into tangible financial gains, but we do not yet know how to put a value on them. Recent research in estimating the value of flexibility in a supply chain using real options modeling (e.g., Nembhard et al. 2005) is along this line of thought. Once a method is devised to model the benefit, its results can be incorporated into the overall business value model, similar to those of the simulation model described here.

We have limited our scope to analyzing the benefits of RFID tags applied to finished products. Tags can be used for raw materials or sub-assemblies as well. More advanced tags can be written with appropriate information as the material is transformed into the final product. The tool set will be applicable in that situation, although some benefits will be very different from what we have discussed.

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