

Center for

eBusiness@MIT

<http://ebusiness.mit.edu>



A research and education initiative at the MIT Sloan School of Management

**What is RFID Worth to Your Company?
Measuring Performance at the Activity Level
Paper 223**

January 2006

**Robert Laubacher
S.P. Kothari
Thomas W. Malone
Brian Subirana**

For more information,

please visit our website at <http://ebusiness.mit.edu>

or contact the Center directly at ebusiness@mit.edu or 617-253-7054



What is RFID worth to your company?

Measuring performance at the activity level

Robert Laubacher, S. P. Kothari, Thomas W. Malone, Brian Subirana

MIT Sloan School of Management

December 2005

Draft—Not for circulation or attribution

Leading global retailers like WalMart, Target and Metro have launched initiatives requiring their major suppliers to implement radio frequency identification (RFID) technology. RFID tags are in line to become the bar codes of the 21st century, allowing manufacturers and retailers to track items moving through the supply chain more quickly, cheaply and reliably (for an overview of this technology, see “What RFID can do”). Bar codes came into widespread usage in the 1980s and by 1997 were generating over \$15 billion in annual benefits for the \$300 billion U.S. grocery industry.¹ RFID has the potential to spur an even broader and deeper revolution in supply chain practices.

The road to realizing these benefits, however, promises to be neither straight nor smooth. Much of the value of RFID will not be generated within the four walls of the warehouse or store, but instead, will depend on close cooperation between supply chain partners. Managers who must decide today on whether and how to implement RFID face large up-front investments, with payoffs that look small in the short term and uncertain in out years. In addition, the range of possible approaches is bewildering: Should firms launch pilots at a small number of key sites? Tag only shipments bound for retailers that require RFID? Or pursue rapid, broad implementation to gain a lead on competitors?

Managers considering RFID investments could use a reliable way to measure the potential costs and benefits of their various options. A new tool we are developing—Activity Based Performance Measurement, or ABPM—can help. ABPM can assess business performance at the activity level and then aggregate these fine-grained metrics

upward to the business unit and firm level. ABPM is more flexible and leverages insights gained during the measurement effort more effectively than traditional, project-based return-on-investment approaches. It also offers greater visibility into where in the supply chain benefits will be achieved, thus providing guidance for managing the implementation and negotiating with supply chain partners. The RFID investment decision, with its complexity and high stakes, is a problem well-suited for ABPM.

What RFID can do

Radio frequency identification (RFID) does all the things bar codes do, but with three key differences: RFID tags have no line-of-sight requirement; can be rewritten from a distance; and hold a number, the Electronic Product Code (EPC), that contains enough information to provide a unique identifier for every atom in the universe.

RFID technology is over fifty years old, with many applications in use today. Automated toll systems rely on RFID tags that can be read at long range and high speeds. Recently a large group of companies, working through the MIT Auto-ID Center, have defined a new set of standards that promise inexpensive, battery-less RFID tags. Cheap RFID tags are expected to have a major impact in many areas of the economy; one of the sectors likely to be most deeply affected is retail. The key functionality of RFID in retail is that it enables the *counting* of tagged items present at key junctures in a supply chain with less work (essentially effortless), with greater accuracy (conceivably 100%), and in less time (less than a second for a full pallet) than can be accomplished by prior methods, such as manual counting or bar code scanning. At short ranges, RFID technology also enables easier and faster *finding* of tagged items.

In a retail supply chain, RFID tags can be applied to individual *items* that are sold to consumers (“eaches” as they are known in the industry); *inner packs* containing

multiple items; *cases* of multiple dozens of items aggregated for shipping; *pallets* comprised of multiple cases; or *shipments* comprised of multiple pallets.

This article focuses on an implementation where tags are applied to cases of goods at a consumer goods manufacturer's factory. Implementations like this are expected to be the most common type during the first wave of RFID adoption. Item level tagging is expected to come later, after the price of tags drops significantly, except when a case corresponds to a single item, as with a computer printer, or when the high cost of individual items warrants the use of more expensive tags, as with certain luxury goods.

Key insights behind ABPM

ABPM is based on two insights. The first is that costs come mainly from an activity's parts, while benefits usually result from how an activity affects other activities. As a result, measuring costs is relatively easy, but measuring benefits is hard. The second insight is that there are common patterns in the types of benefits associated with activities that have similar underlying characteristics. We call these common patterns family resemblances.

Costs from parts, benefits from effect on other activities. The discipline of accounting has over the centuries developed a good set of methods for measuring costs. Calculating the costs of an activity is a matter of decomposing it into constituent parts, determining the cost of each part, and aggregating those costs. Issues can arise over how to parcel out the costs of activities that touch many areas within an organization, such as R&D spending or salaries of senior corporate managers, but these problems have proven tractable, and broadly accepted practices for allocating these kinds of costs have emerged.

The benefits of an activity usually arise, by contrast, from how it affects other activities in the value chain. For example, quality programs reduce product defects and

so reduce costs associated with factory rework and staffing customer service units. Higher quality can also increase future sales, due to greater customer satisfaction and enhanced firm reputation.

Costs typically lend themselves to more precise measurement in “hard dollar” terms, while measurement of benefits usually involves less exact “soft dollar” estimates. For example, the costs associated with a quality program could be measured based on the costs of employee time dedicated to activities that reduce defects. But benefits would have to be estimated more approximately, based on such factors as the extent to which costs associated with rework or customer service staffing would be reduced, the probability of sales increases resulting from greater customer satisfaction, or price premiums that could be charged based on an enhanced reputation.

Family resemblances—Common patterns in the kinds of benefits associated with similar activities. It is difficult to consider all the possible benefits that an activity can generate and develop systematic approaches for estimating those benefits in every instance. ABPM seeks to gain leverage on this problem by taking advantage of the underlying similarities that exist among many activities that take place in business. For example, checking the quantity of goods is an activity that occurs at many places in the retail supply chain. Quantity checks of this sort are done at the receiving dock of the manufacturer’s warehouse, when shipments arrive from the factory; at the manufacturer’s loading dock, when shipments are placed on trucks for transportation to the retailer; at the retailer’s distribution center, when the truck arrives; and so on, all the way to the point where the consumer makes a store purchase, and the clerk checks the quantity of each item in the shopper’s cart. The underlying similarities between these different specific activities allow us to create a family tree, whose root is the general activity “check quantity” and whose branches include ever more specific instances (see figure 1). When RFID is implemented across the supply chain, we find that it creates similar kinds of

benefits across all these instances of “check quantity.” As a result, the benefits associated with RFID do not have to be estimated anew in each case where this activity occurs; instead, a standard approach can be developed to calculate the benefits associated with RFID for the entire family tree.

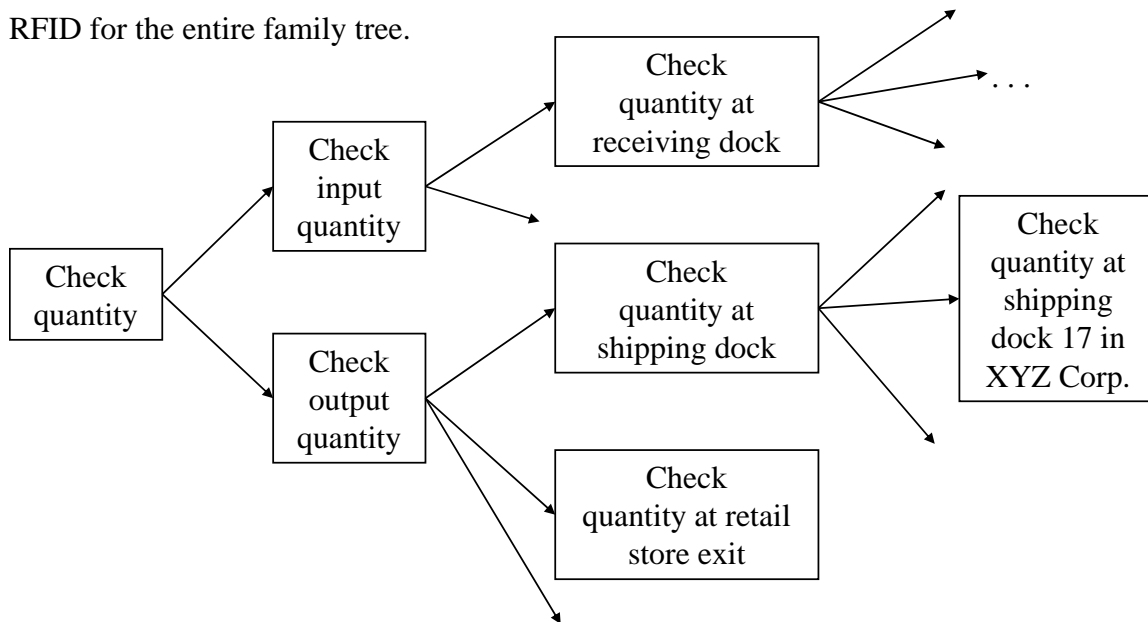


Figure 1: Family Tree of Activities—Check quantity

How ABPM works

Managers can use ABPM to assess the impact of a new technology, such as RFID, or a management intervention of any sort. ABPM can help in estimating the potential costs and benefits to make pre-implementation decisions, and it can also provide post-implementation measurements of actual benefits achieved. Using ABPM to assess the impact of a new technology like RFID involves four primary steps:

1. Develop potential post-implementation scenarios.
 This step involves deciding how the activities in question could operate if enabled by the new technology. Some managers may wish to focus on a single implementation scenario; others will want to consider many.
2. Identify activities affected by the new technology.
 This step starts with a high level activity map. Top level activities are then decomposed to identify sub-activities affected by the technology.

3. Map the activities with vs. without the new technology.

This step involves mapping the activities prior to implementation and then as they will be executed post-implementation.

4. Measure benefits and costs by comparing differences in outcomes of pre- vs. post-implementation activities.

This step involves finding instances where the new technology results in changes in the firm's costs or revenues.

The steps described above can be used when analyzing the costs and benefits of a new technology for the first time. But when similar ABPM analyses have already been done, exploiting the concept of family resemblances can often reduce or eliminate the work needed to complete some of the steps. For instance, leveraging the results described in this article can substantially reduce the amount of work needed to estimate the costs and benefits of RFID in other supply chains.

We will now go through the steps outlined above to show how ABPM can be used to assess the impact of RFID.

Developing post-implementation scenarios

This article examines a single, straight-forward scenario, with RFID enabled counting replacing bar-code scanning. More radical scenarios, such as randomized warehousing or major restructuring of the supply chain, which have larger potential payoffs and greater risks, could also be considered but are not addressed here.

Identifying activities affected by RFID

To estimate the costs and benefits of a case level RFID implementation, we start with a high level map of the retail supply chain, then decompose the high level activities until all instances of the activities that could be affected by RFID have been identified. The typical retail supply chain starts with goods moving from a manufacturer's factory to its warehouse. They then get shipped from the warehouse to a retailer's distribution

center. From the distribution center they go to the store, where they are initially placed in the back room. Clerks then move them from the back room to the store shelf, where they can be selected by consumers for purchase (see Figure 2).

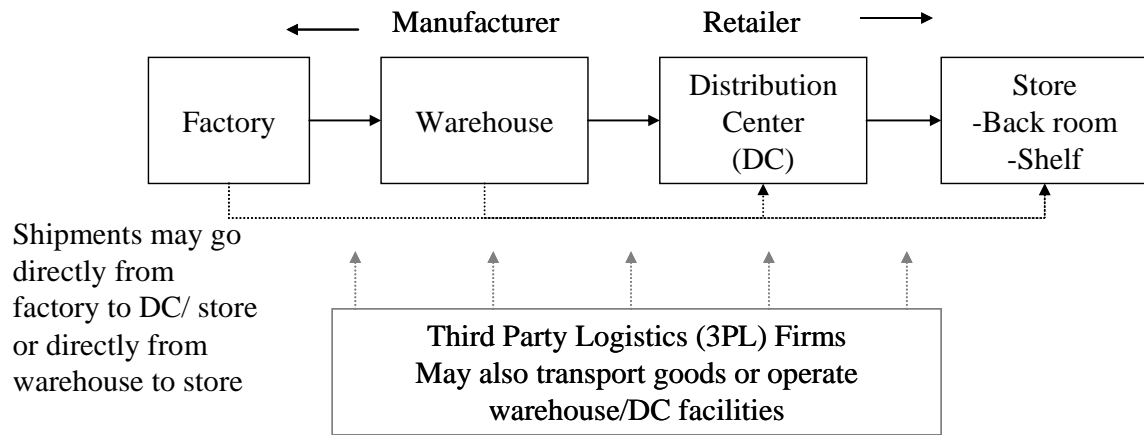


Figure 2: High level map of retail supply chain

At each stage, an intermediate destination may at times be skipped. For example, factory shipments sometimes go directly to DCs or stores, and shipments may move from the manufacturer’s warehouse straight to stores as well. Or items that are in high demand may get placed on the shelf as soon as they arrive at the store, without a stopover in the back room. In addition, third party logistics (3PL) companies sometimes provide outsourced transportation or warehouse/distribution center management services to manufacturers or retailers. For the sake of simplicity, we will refer to a supply chain that involves only a manufacturer and retailer in the discussion that follows.

To identify activities that will be affected by RFID, we start in the manufacturer’s warehouse and look at potential benefits of RFID. We then proceed to subsequent stages in the supply chain—the retailer’s distribution center, the store back room, and the store shelf—and look at potential benefits there. After examining potential benefits for the entire supply chain, we then turn to costs. Our findings are based on extensive field work undertaken at a leading U.S. consumer goods manufacturer. This firm is planning a case-

level RFID implementation, with tags to be affixed at its factories, before goods are shipped to its warehouses.

Three primary activities occur inside the warehouse—receiving goods, storing goods, and fulfilling orders (see Figure 3). When we decompose these activities to the next level, we can identify four sub-activities that will be affected by RFID.²



Figure 3: Primary activities in manufacturer’s warehouse

The first of these occurs at the receiving dock, when shipments arrive from the factory. Before accepting a shipment, warehouse personnel check the number of cases in the shipment against the number promised in the accompanying documentation, which may be paper or electronic.³ This checking is now typically done by scanning bar code labels on the cases. After the implementation, RFID tags will be affixed to cases of goods at the factory. Checking at the warehouse receiving dock will be done by antennae installed around the entrance automatically detecting the RFID tags on the cases as they pass through (see “Accept Shipment” activity in Figure 4).

The second activity affected by RFID is the periodic inventory taking that occurs inside the warehouse. Warehouse managers keep track of receipts and shipments that flow into and out of their facility, thereby maintaining an ongoing estimate of the inventory held. But errors creep in, so warehouse personnel also periodically undertake an actual count of the cases held in inventory. Today, this is done by scanning the barcodes of cases on the shelves. RFID will enable this process to be undertaken by remote readers installed at fixed points in the warehouse or by workers moving through the warehouse with portable readers (see “Manage count” activity in Figure 4).

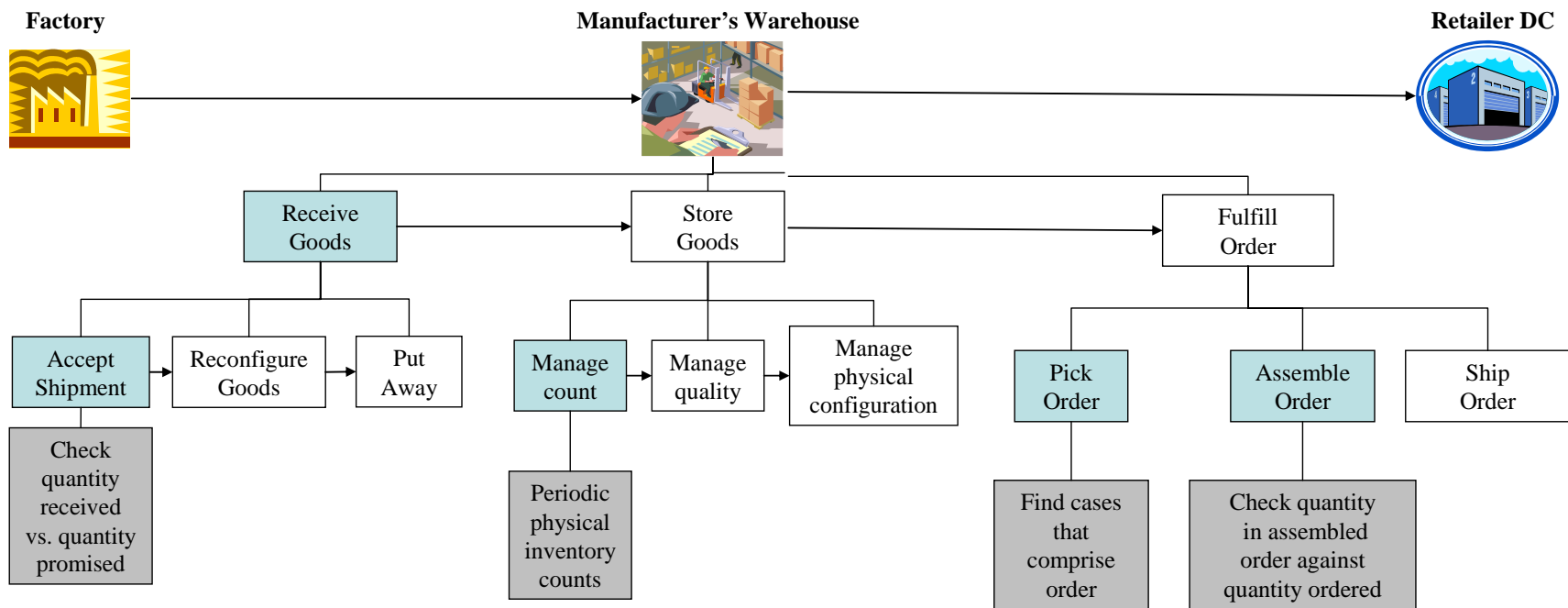


Figure 4: Activities in manufacturer's warehouse affected by RFID

The third activity that will be affected by RFID is picking, or taking cases down from the shelf, which occurs in the course of fulfilling an order. Today, warehouse management software keeps track of what goods are stored on each shelf and tells forklift truck drivers where to go to find the cases they need. But cases are often misplaced, and workers must hunt around to find the right goods. Forklift-mounted or handheld RFID readers can help workers to find goods more quickly and with less effort (see “Pick Order” activity Figure 4).⁴

The final activity that will be affected by RFID is order assembly. Warehouse workers bring together all the cases that make up an order and place them on pallets. Before the pallet goes on the truck to be shipped, the selection and number of items on the pallet is checked against the documentation to ensure that the physical order and purchase order agree. Today this checking is done by bar code scanning. In an RFID-fitted warehouse, antennae fitted around the shipping dock doors will check the contents of outgoing order automatically (see “Assemble Order” activity in Figure 4).

Mapping key activities before and after RFID implementation

The next step compares how activities affected by RFID are carried out before and after the implementation. Figure 5 compares pre- and post-RFID receiving at the manufacturer’s warehouse. RFID-enabled receiving requires less labor, is completed more quickly, and provides more accurate counts. These differences can be quantified by showing the differentials in labor required, in time needed for completion of the process, and in error rate of the count. At our field site, RFID is expected to reduce receiving time from 180 to 40 seconds per pallet, which will accordingly lower labor costs and increase throughput. The error rate is initially expected to go from 0.05 percent to 0.02 percent and approach zero as technology improves. Similar changes are projected for the other warehouse activities affected by RFID—undertaking inventory counts, picking cases from the shelves and checking the quantity of cases in outgoing orders prior to shipment.

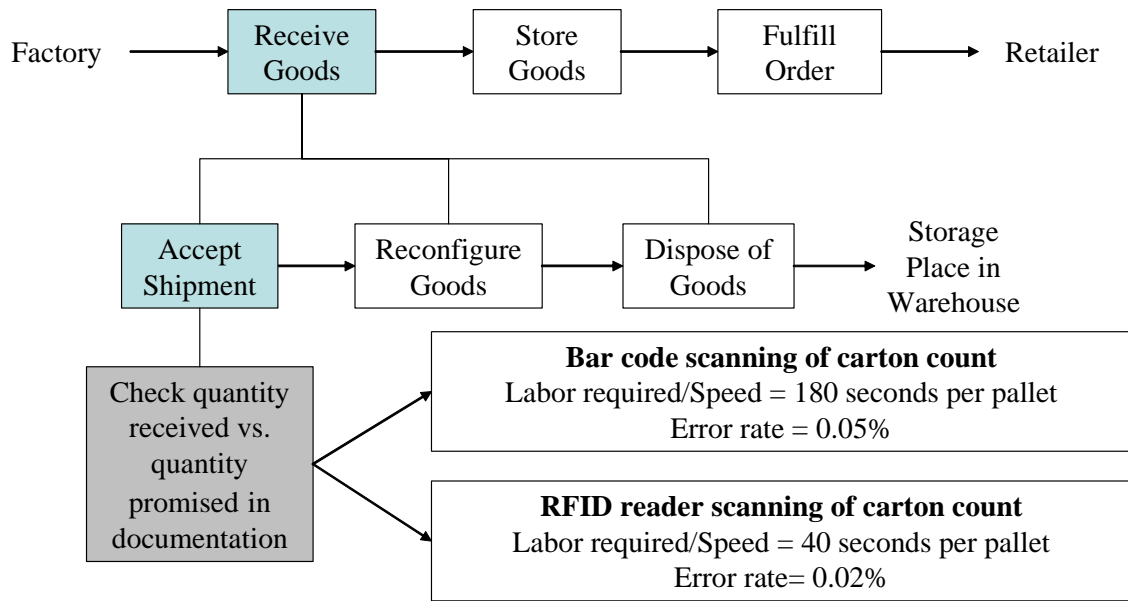


Figure 5: Current vs. RFID-enabled activities—Receiving

Measuring benefits of RFID—In the manufacturer’s warehouse

The next step measures benefits by comparing differences in outcomes of pre- vs. the post-implementation activities. We use three approaches to identify potential benefits. First, we brainstormed within our research team about likely benefits, based on knowledge of retail supply chain practices and RFID technology’s capabilities gained from our fieldwork. Second, we interviewed executives in a wide range of functional groups at the consumer goods company where we undertook our field work. Lastly, we consulted studies by other researchers that examined the potential impact of RFID.⁵

The benefits of RFID identified at our field site were based on two features of the technology. The first was RFID’s ability to count the number of cases of goods passing through a portal or to find a particular case with little or no labor input from workers. The second was the reduced error rate enabled by RFID, which provided more accurate data about the quantity of goods present at key places in the warehouse.⁶ At our field site, little or no benefit was anticipated from the third key feature of RFID, increased

speed. But in supply chains with fast cycle times or featuring high value items, RFID-enabled increases in speed could potentially generate additional benefits.

A new technology, or a management intervention of any sort, has the potential to create benefits in two basic ways: by lowering costs or by increasing revenues. RFID has the potential to reduce costs in five primary ways and increase revenues in two:⁷

- Ways that RFID can lower costs
 - Labor savings in counting
 - Reduction of theft
 - Reduction of disputes with trading partners
 - Reduction of excess inventory
 - Reduction of spoilage/obsolescence
- Ways that RFID can increase revenues
 - Reduction of out-of-stocks
 - Greater responsiveness to customer

Ways that RFID can lower costs. The first way RFID can lower costs is through labor savings resulting from automation. Warehouse personnel no longer need to scan bar codes on cases; instead, RF antennae detect the presence of ID tags automatically. In the warehouse, automation will touch all four activities affected by RFID—checking quantity during receiving, taking of physical inventory, picking, and checking quantity prior to shipping.

The second way RFID can lower costs is by reducing theft, or shrinkage, as it is called in the retail supply chain. Theft occurs both within the warehouse and when goods are being shipped to and from the warehouse. Today, errors creep into the counts generated by bar code scanning. As a result, when shortages occur in shipments or in inventory counts, warehouse managers cannot know for certain whether they are the

result of theft or human errors. The improved read accuracy enabled by RFID will allow theft to be more readily detected and thus serve as a strong deterrent.

The next way RFID can lower costs is by reducing the disputes that occur when there is a disagreement between supply chain partners over the quantity of goods in a shipment. For example, a manufacturer will claim to have sent fifty cases, while the retailer contends that only forty-eight arrived. More accurate RFID-enabled counting can reduce the number of instances when such disagreements occur. For the manufacturer, this means a reduction in double shipments and penalty payments. Fewer disputes also mean less administrative time is needed to research and negotiate customer claims concerning under-shipments. In addition, more accurate counting will reduce over-shipments that favor the customer but go unreported.

The next way RFID can lower costs in the manufacturer's warehouse is through reduction of excess inventory. The errors that creep into counts today mean manufacturers must carry additional inventory, both in the warehouse and the factory. The more accurate count enabled by RFID will allow the manufacturer to wring out this excess, both in its finished goods inventories at the warehouse and in its raw material and work-in-progress inventories at the factory.

Better data on what inventory is on hand can also enable warehouse managers to make sure they are holding the *right* inventory, which can, in turn, reduce write-offs caused by spoilage or obsolescence of products. This is a particular problem for goods that have short shelf lives, like perishable foods, or rapid product cycles, like consumer electronics. It is also a problem for manufacturers with revenues that fluctuate seasonally or that make extensive use of promotions.

Ways that RFID can increase revenues. The first way RFID can increase revenues is by reducing the number of instances when needed items are out-of-stock. Out-of-stocks most often result from simple failure to recognize that the supply of an item is running

low, which leads to late reordering. Ordering errors and shipping errors can also lead to out-of-stocks. Any of these can result in items being out-of-stock on the store shelf, which results in incremental lost sales for the retailer, and by extension, the manufacturer. The more accurate inventory count enabled by RFID can significantly reduce sales lost in all these ways.

The second way RFID can increase revenues is by enhancing customer responsiveness. In the extreme case, when a large customer, such as WalMart, mandates RFID, implementing the new technology allows a manufacturer to maintain and potentially improve the existing relationship with that customer. Failing to adopt RFID could result in losing a portion of or even all sales to that customer. To calculate the benefits of RFID in such a scenario, the manufacturer would need to take into account the future sales levels that could be attained with adoption vs. the potential fall-off that could occur due to non- or slow adoption.

An RFID mandate from a major customer is akin to an exogenous shock to the business system, such as a major regulatory change or the emergence of a disruptive new technology. Management at manufacturers facing such mandates will need to weigh their situation carefully, assessing the balance of power between customers and suppliers in the industry, and the likely stance of major competitors, before deciding whether playing under the new set of rules is worthwhile.

In instances where mandates are not involved, RFID can still enhance relationships with customers. RFID adoption by manufacturers has the potential to generate substantial internal benefits for retailers. For example, fewer shipping disputes means lower administrative costs for the retailer, and RFID tags on cases will deter theft within the retailers distribution center and between the DC and stores. Other factors being equal, a manufacturer that adopts RFID and competes against other suppliers that do not will likely win orders from customers that are equipped to capture RFID-enabled benefits.

Measuring the potential benefits of enhanced customer relationships requires a deep understanding of the underlying market and competitive dynamics in the sector. Much of this can be gleaned by polling experienced executives, but there may also be a need to collect new kinds of data and undertake new kinds of analysis.

An additional strategic factor that managers must consider is that the lower cost structure and enhanced market position RFID can provide may allow early adopters new kinds of flexibility that slower adopting competitors will not enjoy. The early adopter might choose to leverage its lower cost position to reduce prices and gain market share. Or it could maintain existing pricing levels but use the higher margins it earns to invest in next-generation products. The larger point is that managers need to think about RFID from a perspective that goes beyond supply chain optimization and takes into account strategic questions about the future evolution of relationships with key customers and likely actions of leading competitors.

Localized vs. distant benefits. When examining the benefits associated with RFID, we find that some are tied directly to the activities affected by RFID. For example, costs savings associated with automation result from changes that occur in the affected activities themselves, specifically, elimination of the need for workers to scan bar codes. We refer to such benefits as *localized*. Veterans of the retail supply chain speak of such benefits as being achievable “inside the four walls” of the facility.

Other benefits, by contrast, involve connections between activities directly affected by RFID and activities that occur within other units of the firm or even within outside firms. For example, the more accurate counts that RFID enables by gathering better data during receiving, inventory taking, and order assembly are only one part of what allows spoilage/obsolescence to be reduced. For warehouse managers to make headway against spoilage/obsolescence, they also need real-time data on sales from downstream retail stores and close coordination with their firm’s marketing and sales

group, to adjust pricing or promotion policy, and with their factory, to ramp production rates up or down. We thus speak of spoilage/obsolescence reduction as being a *distant* benefit, since it involves not only the activities immediately reshaped by the RFID technology, but other, linked activities in the supply chain.

The distinction between localized and distant benefits is important because it shapes the extent to which a firm or business unit implementing RFID has direct control over achieving the full benefits of the technology. When most of the benefits are localized, the group implementing the new technology has a high degree of control over whether or not it achieves the benefits. But when many of the benefits are of the distant kind, the implementing group must rely on other business units or supply chain partners to achieve the full potential of RFID.

For manufacturers, only one RFID benefit—automation—is exclusively localized; all the others are distant benefits in part or all. For manufacturers to achieve the full potential value of RFID thus requires high levels of cooperation across their business units and with their supply chain partners. Since distant benefits are main means by which manufacturers can generate value from RFID, they must must complex organizational collaboration to take full advantage of the technology.

Measuring RFID benefits—At the retailer’s DC, back room, and store shelf

When we undertake an analysis of potential benefits of RFID at the retailer, we find a striking parallel between activities at the manufacturer’s warehouse and those that occur at the DC, store back room, and store shelf (See Figure 6). At the manufacturer’s warehouse and each of the retailer’s locations, goods are received from an upstream part of the supply chain, are stored, and then are provided to a party that has a downstream position in the chain. To describe the underlying commonality between these activities, we can speak of the activities that take place at each of these junctures in the supply chain as specific examples of a more generic activity, one we can call “Hold inventory.”⁸

The sub-activities that are parts of “hold inventory” remain the same in most of the specific cases. For example, the “Store” sub-activity is basically the same at all four locations. In some instances, however, the sub-activities differ. For example, when shipments are sent from the retailer’s distribution center to a store, clerks typically do not check the quantity of goods received, but instead, simply accept on faith that the quantities promised and those shipped are the same. These quantities often do not match, however, and errors creep into the store’s inventory records, leading to out-of-stocks. RFID will allow easy checking at the store receiving dock, thus eliminating errors at this juncture and the problems associated with them.

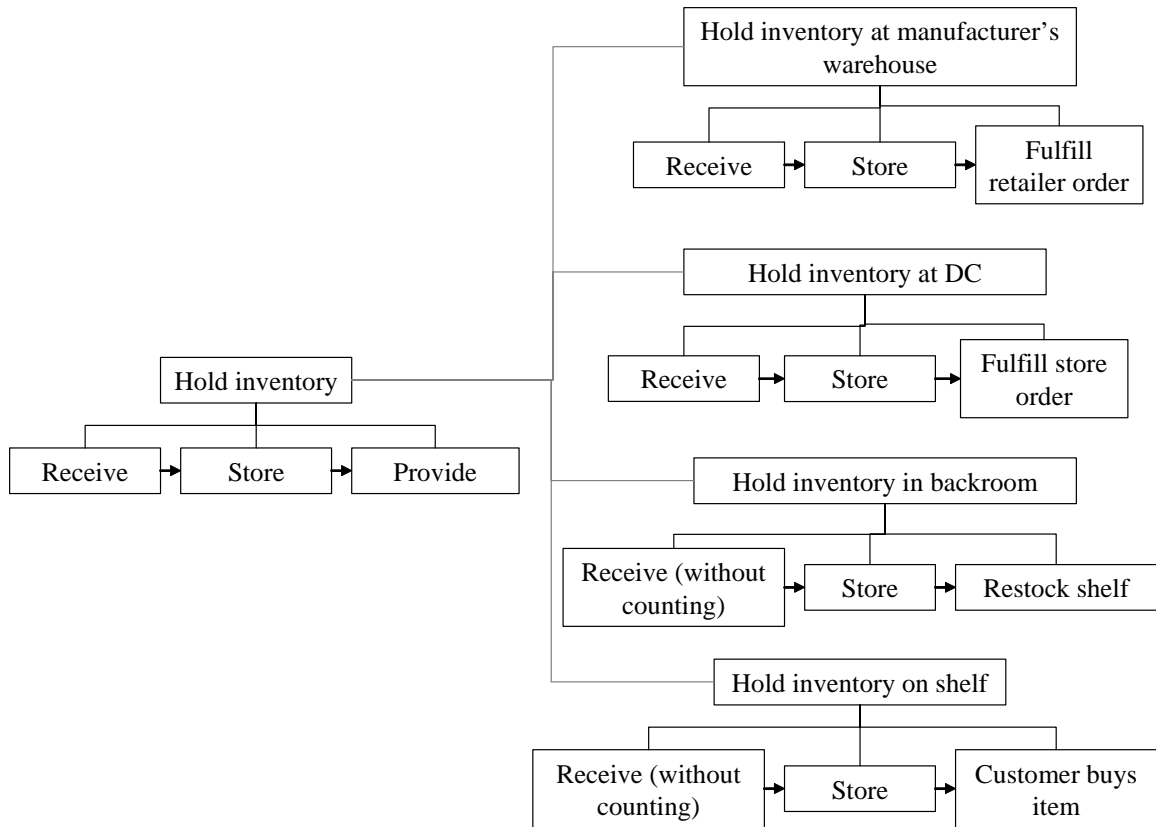


Figure 6: Examples of “Hold inventory” in the retail supply chain

Given the basic underlying similarity in this entire class of activities, we expect the RFID implementation to affect “hold inventory” in similar ways throughout the

supply chain—from the manufacturer’s warehouse all the way through to the store shelf. In particular, RFID can thus be expected to generate benefits at each of the key junctures where the retailer holds inventory that are similar to the benefits identified in prior analysis of the manufacturer’s warehouse. Benefits achieved by the retailer will not be exactly the same at each of its facilities as those attained at the manufacturer’s warehouse, since, as noted above, activities are sometimes executed in slightly different ways at various junctures in the supply chain. But the benefits identified in field work at the manufacturer’s warehouse can provide a solid framework to begin considering likely benefits of RFID at the retailer’s facilities.

Family trees of benefits. Constructing “family trees” that classify similarities and differences in how a particular benefit can be achieved at each key location allows us to consider in a systematic way the entire range of potential benefits of RFID throughout the supply chain. Consider the family tree for the benefit “Reduce disputes with trading partners” (see Figure 7).

We first distinguish between internal vs. external transaction. RFID can reduce disputes with both external firms and with other internal business units within the same firm. Within the class of external transactions, we can distinguish between the benefits of reducing under-shipments vs. over-shipments. Finally, within the category of under-shipments, we can distinguish between the benefits of reducing double shipments and penalties vs. reduction in the administrative costs associated with researching and negotiating over disputes. Similar family trees can be constructed for the other six kinds of benefits identified.

The advantage of this approach is that once a manager or assessment team gains an understanding of the benefits RFID can generate among one cluster of activities, this knowledge can provide a systematic framework for considering potential benefits

connected with similar classes of activities going forward. Prior knowledge gives guidelines on where to look for similarities and where to detect differences.

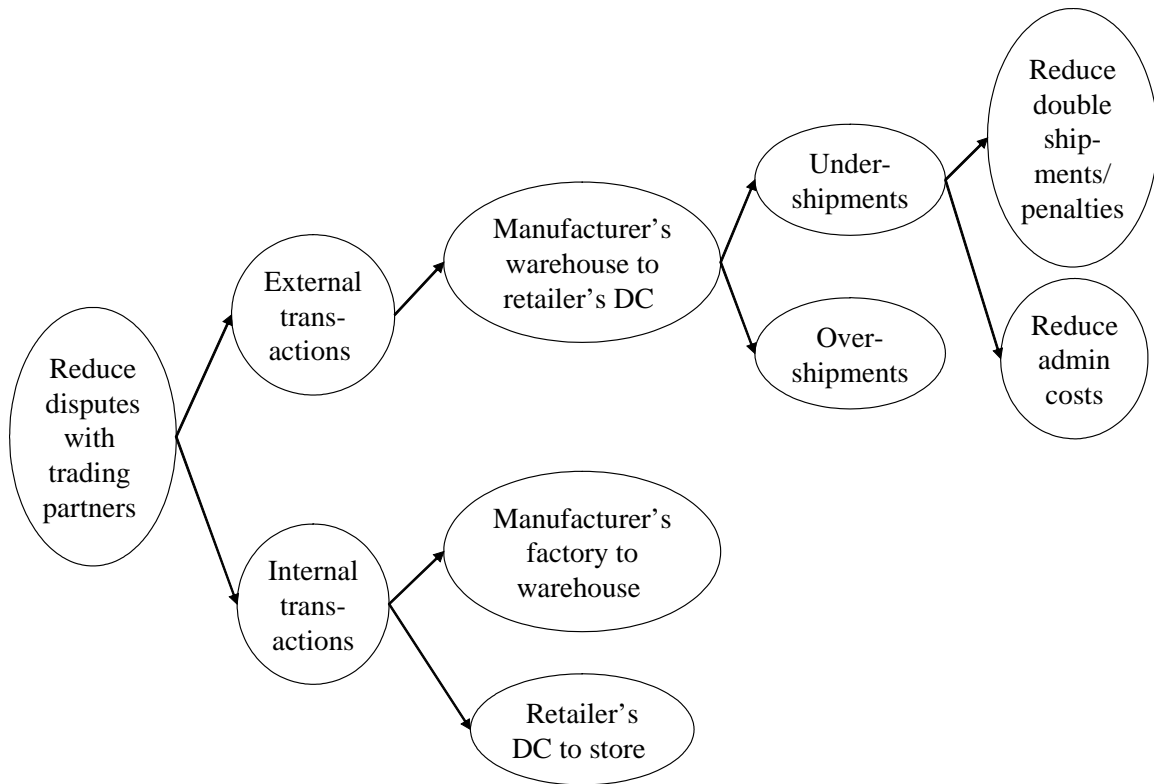


Figure 7: Family tree of benefits—Reduce disputes with trading partners

Sometimes the parallels between similar activities are so great that calculating RFID benefits for the two similar activities is simply a matter of plugging in slightly different empirical values into the same basic equation. For example, measuring theft at various locations in the supply chain simply involves taking into account differences between the volumes of theft and the amounts that RFID can be expected to reduce it at each point. In other cases, it may be necessary to recognize that a benefit does not carry over from one setting to another. For example, case level tagging can reduce theft that occurs inside the manufacturer's warehouse and retailer's distribution center and during shipment to and from those facilities. But because most theft in stores occurs after items

have been unpacked from their cases, case-level tagging will have very limited impact on store-level theft.

Knowledge about the types of benefits the RFID generates can carry over across similar activities being considered within the same RFID implementation, as described here. But such knowledge can also carry over between activities that have similar characteristics across different implementations. Thus knowledge about RFID’s impact on a particular class of activities can accumulate.

In fact, family trees of activities can be used to organize numerical values from prior studies of benefits. Figure 8 shows the benefits of reducing out-of-stocks at the manufacturer’s warehouse vs. the retailer’s distribution center vs. in the store. More than 85 percent of out-of-stocks occur in the store, and Figure 8 shows the actual magnitude of benefits from out-of-stock reduction in the store, based on four case studies.

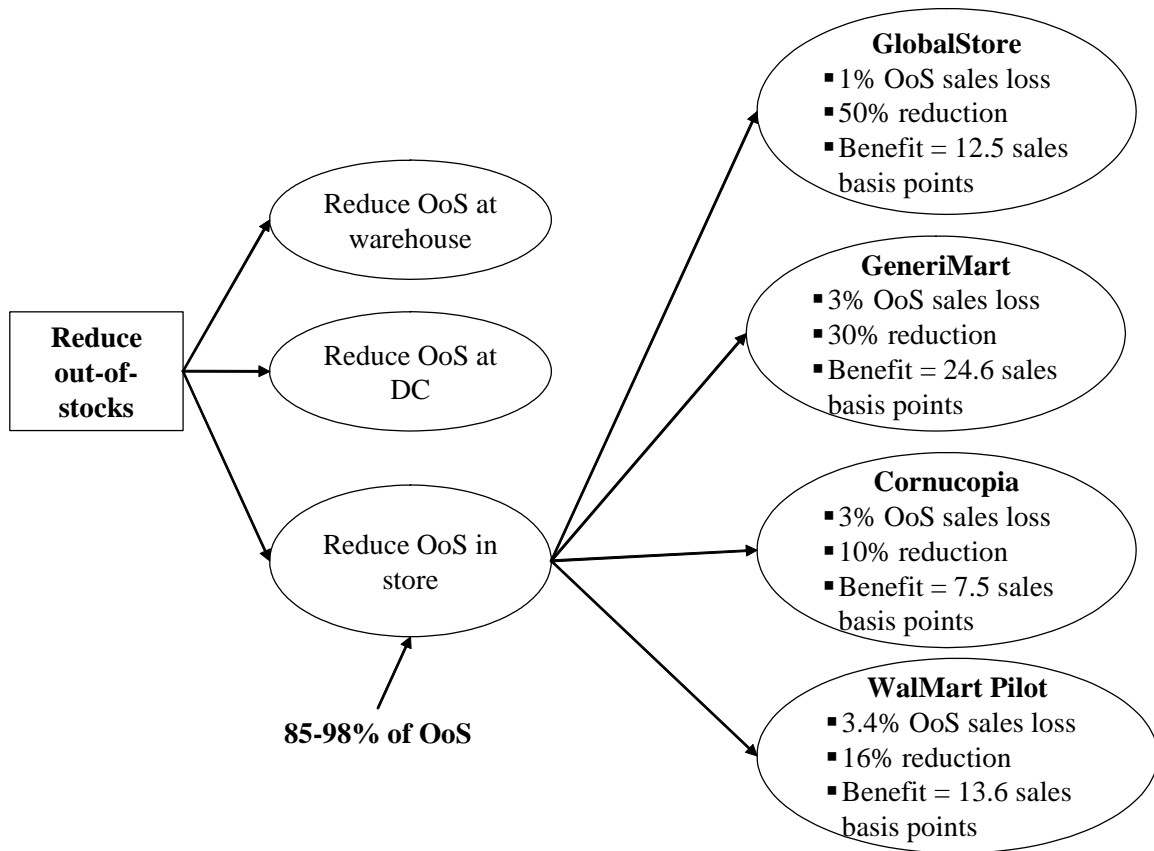


Figure 8: Family tree of benefits—Reduce out-of-stocks⁹

In each example, the key variables are the existing level of lost sales due to out-of-stocks and the extent to which RFID can be expected to reduce out-of-stocks. The potential gain in the four case studies ranges from 7.5 to nearly 25 sales basis points. Leveraging the common properties of classes of activities and mapping family trees of benefits can significantly reduce the work involved in assessing a technology's benefits and is one of the major advantages of ABPM. Keeping track of groups of similar activities and family trees of benefits in a systematic way, however, can be a challenge. MIT's Process Handbook provides a conceptual framework and software tools that enable gathering and storing of this sort of knowledge in a structured, on-line form.¹⁰

Measuring RFID costs

Three types of costs are associated with any RFID implementation:

- Enterprise wide.
Middleware and database applications, with associated hardware upgrades, to link to existing IT infrastructure. Costs associated with reengineering enterprise-wide business processes must also be included.
- Facility-specific.
Readers, antennae and local computing required to generate data from RFID tags and tie it into the enterprise's IT systems. Costs associated with reengineering facility's business processes must also be included.
- Variable.
Cost of RFID tags and equipment/labor needed to affix them.

Costs can be parsed out to each key point in the supply chain by aggregating facility-specific costs for each site and allocating enterprise-wide and variable costs across the sites. Family trees of RFID costs can be constructed in much the same way as family trees of RFID benefits.

Tags will constitute a major portion of the overall costs of any RFID implementation, at least until the unit price of tags drops significantly below today's levels (even the cheapest tags are currently priced at approximately 10 cents each).

Under the mandates recently put into place by large retailers, manufacturers are expected to bear this cost. Manufacturers are seeking to spread out the burden, for example, by passing on some costs to packaging manufacturers and some to their other suppliers.

Case example of RFID benefits and costs—Gillette

To demonstrate how ABPM can help managers facing RFID investment decisions, we present findings from analysis of the anticipated benefits and costs of a case-level implementation at Gillette. This case study estimates the benefits and costs of a broad, firm-wide implementation. But our approach could readily be adapted to consider other scenarios, such as a small pilot or an implementation confined only to those retailers that require RFID tags. Our analysis is based on data from our field work at the manufacturer's warehouse and from external studies undertaken by other academics, consulting firms and trade associations.

In this article, we have slightly altered the findings from our field study to make the results broadly applicable and to avoid revealing proprietary information. In the calculations presented here, the manufacturer's revenues are normalized to \$5 billion in 2004 and are projected to grow at 4 percent annually. The cost of capital is assumed to be 9 percent, with benefits and costs projected seven years out into the future. Another important assumption is that the benefits achieved through RFID are initially translated into higher margins and revenues, but over time, we these benefits are competed away and get converted into consumer surplus.¹¹ The figures for revenue growth, cost of capital, and rate at which benefits are converted into consumer surplus are all generic assumptions, not specific to Gillette. We adjusted the results calculations that were based on our field study to avoid revealing the exact magnitude of specific benefits for Gillette. These adjustments were done so that the relative magnitude of each benefit, as a percentage of the total, remained roughly the same as at the field site.¹²

To assess the overall impact of the RFID implementation, we undertook a detailed analysis of all benefits and the costs. To assess the potential benefits from labor savings, we estimated the amount of labor time RFID can be expected to save in each of the activities where it will have an impact—receiving, taking physical inventory, picking, and order assembly. Figure 9 shows detailed analysis of RFID’s expected impact on one of these activities, checking quantity at the receiving dock.¹³

Assumptions							
1.40	Labor time saved per pallet at field site (minutes)						
4,000	Pallets per week						
4%	Sales growth						
\$21	Hourly cost of fork operator						
\$2	Hourly cost of fork truck						
6	Barcode labels per pallet						
\$0.0175	Unit cost of barcode label						
10,000,000	Number of bar code labels required at field site in year 1						
18%	Field site share of enterprise turnover						
80%	Share of potential benefits actually achieved						
2	Time to achieve full benefits (years)						
10	Time after implementation for benefits to be competed away (years)						
33%	Income tax rate						
Forecasted benefits							
<i>Potential benefits</i>	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Min saved/week	5,600	5,824	6,057	6,299	6,551	6,813	7,086
Hours saved/year	4,853	5,047	5,249	5,459	5,678	5,905	6,141
Labor savings/year	\$101,920	\$105,997	\$110,237	\$114,646	\$119,232	\$124,001	\$128,961
Fork truck savings/year	\$9,707	\$10,095	\$10,499	\$10,919	\$11,355	\$11,810	\$12,282
Bar code savings	\$21,840	\$22,714	\$23,622	\$24,567	\$25,550	\$26,572	\$27,635
Field site total savings	\$138,320	\$143,853	\$149,607	\$155,591	\$161,815	\$168,287	\$175,019
Enterprise total (\$m)	\$0.768	\$0.799	\$0.831	\$0.864	\$0.899	\$0.935	\$0.972
<i>Projected benefits</i>							
With ramp-up (\$m)	\$0.307	\$0.639	\$0.665	\$0.692	\$0.719	\$0.748	\$0.778
With competition (\$m)	\$0.307	\$0.639	\$0.598	\$0.553	\$0.503	\$0.449	\$0.389
After tax benefits (\$m)	\$0.205	\$0.426	\$0.399	\$0.369	\$0.336	\$0.299	\$0.259

Figure 9: Labor saving benefits at receiving dock

We undertook similar analysis for the other three activities where labor savings could generate benefits and then went on to undertake similar analysis for five of the remaining six benefits. We used expert judgments from knowledgeable people at our field site to estimate the key parameters needed for the analysis of each benefit. We did not have sufficiently detailed data on the market and competitive situation to venture a reasonable estimate of the benefits of RFID’s ability to enhance customer relationships. It is worth

noting, however, that this benefit potentially dwarves all the others. Failure to comply with RFID mandates from large retailers could lead a manufacturer to lose part or even all of its business with its largest customers.

Once the analysis of benefits was complete, we undertook a similar analysis of costs. We then summed up the benefits and compared this sum against costs to show the yearly net cash flows (see Figure 10)¹⁴.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
<i>Cost savings</i>							
Labor savings	\$0.9	\$1.9	\$1.8	\$1.6	\$1.5	\$1.3	\$1.2
Theft reduction	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0
Claims reduction	\$1.8	\$1.9	\$1.8	\$1.7	\$1.5	\$1.3	\$1.2
Excess inventory reduction	\$1.1	\$2.2	\$3.5	\$4.9	\$6.3	\$7.1	\$7.7
Spoilage/obsolescence reduction	\$0.8	\$1.7	\$2.7	\$3.7	\$4.9	\$4.6	\$4.2
<i>Sales increases</i>							
Out of stock reduction	\$0.7	\$1.4	\$2.1	\$3.0	\$3.9	\$4.8	\$5.8
Total benefits (\$m)	\$5.3	\$9.2	\$11.9	\$14.9	\$18.0	\$19.1	\$20.0
Present value benefits (\$m)	\$66.4						
<i>Costs (\$m)</i>							
Costs (\$m)	-\$3.6	-\$4.2	-\$4.3	-\$2.6	-\$2.7	-\$2.8	-\$2.9
Present value costs (\$m)	-\$16.9						
Benefits less costs (\$m)	\$1.7	\$5.0	\$7.6	\$12.3	\$15.3	\$16.4	\$17.2
Net present value (\$m)	\$49.4						

Figure 10: Case example—After tax costs and benefits of RFID implementation

We then translated these cash flows into present values. The present value of the anticipated benefits is \$66 million, while the PV of the costs is projected to be \$17 million, resulting in an NPV of just under \$50 million. The analysis also shows that three benefits—reduction of disputes with trading partners, reductions of excess inventory, and reduction of out-of-stocks—account for nearly three-quarters of the expected benefits. Analysis of this sort can help to identify where the big wins from RFID may be and so guide managers during the implementation.

We undertook a similar analysis of RFID benefits at a large retailer. For a retailer with comparable revenues to the manufacturer we examined, the PV of RFID costs was \$22 million and PV of anticipated benefits was \$90 million (see figure 10).¹⁵ An important finding from this analysis was that all of the benefits for the retailer were tied

to activities over which the retailer had full control, or, as is said in the parlance of the retail sector, benefits that were “inside the four walls” of the retailer’s facilities. By contrast, the vast majority of the benefits for manufacturers required cooperation from the retailer. In the absence of these collaborative benefits, RFID is at best a break-even proposition for manufacturers.

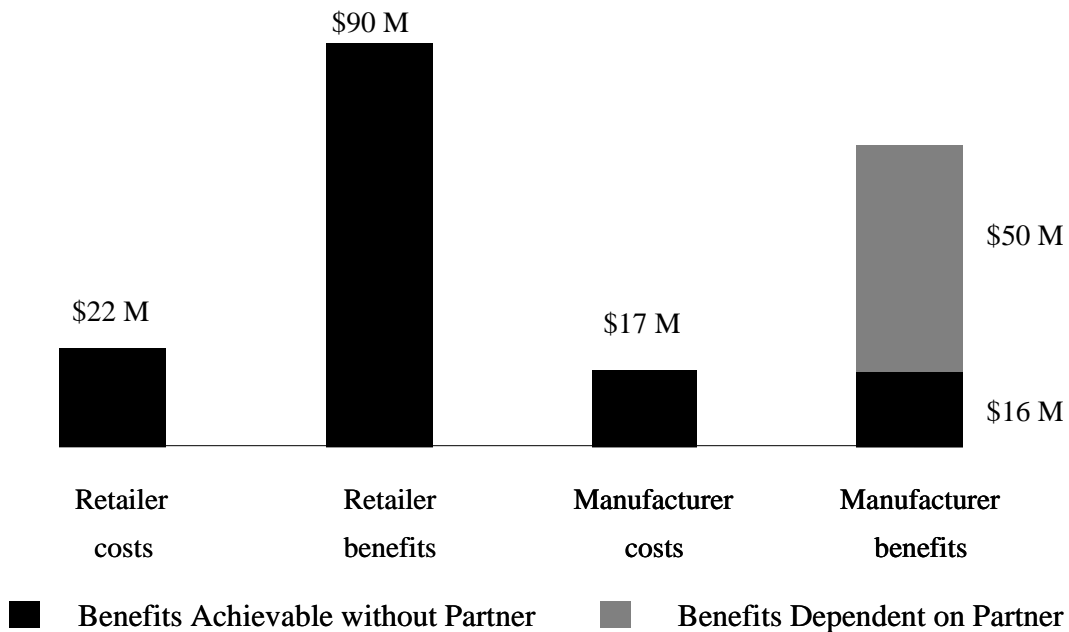


Figure 10: RFID costs/benefits for \$5 billion manufacturer and retailer
 (Present value, \$ million)

This fact may explain the reluctance of many consumer goods manufacturers to jump into RFID implementations.

Implications for firms considering RFID investments

The greatest opportunities for manufacturers to create value with RFID—reducing disputes between trading partners wringing out excess inventory, cutting down on out-of-stocks—are the ones that require tightest synchronization of the supply chain. Because achieving these benefits involves complex interaction between disparate units, it is

difficult to assess them with traditional measurement methods, which are at their best when they are trained on tightly focused organizational groups, where the firm has full control, and traditional “hard” accounting metrics can be gathered and analyzed closely. Such methods reduce risks by favoring investments where the firm has greater control. But they can also paint managers into a corner by creating the misperception that certain types of benefits are more “real” simply because they are better suited to existing measuring tools.

The truth is that there are a range of potential benefits that can be achieved with RFID technology, each with their attendant uncertainties. The best approach is to examine the entire landscape of possible opportunities, scoping out the magnitude of potential gains, understanding risks, noting instances where supply chain partners’ interests are aligned—and where they aren’t. This wider view will allow managers to follow implementation paths that capture quickly achievable benefits in areas where their firm has control, thereby generating early wins that can provide staying power to capture the larger, but more difficult to achieve, prizes down the road.

Implications for measuring performance at the activity level

A key feature of ABPM is that it focuses on *where* and *how* within a chain of activities a new technology creates value. By estimating the potential size of each type of benefit and by locating where those benefits will be achieved, ABPM allows managers to focus attention during the implementation on the most important opportunities to create value.

ABPM also allows managers to accumulate knowledge gained in the course of their measurement efforts. Once a firm has assessed the benefits of a technology on a particular group of activities, it can use that prior experience to think systematically about the likely benefits on similar groups of activities. Drawing up family trees of benefits

that describe how technologies affect a class of activities can save time by preventing managers from continually re-inventing the wheel.

For instance, catalogs that detail the benefits and costs generated by technologies in different parts of organizations can be created inside firms or more broadly, by industry associations or by professional groups that bring together experts in functional areas such as marketing or product development. In the long run, we hope such catalogs, and the ABPM methodology described in this article, will provide the foundation for a new generation of management accounting and decision-support tools.

Endnotes

¹ Benefits of bar codes from Alan L Haberman, ed., *Twenty-Five Years Behind Bars: The Proceedings of the Twenty-fifth anniversary of the U.P.C. at the Smithsonian Institution, September 30, 1999* (Cambridge, Mass. and London: Harvard University Press, 2001), 13-19, 150-151. Other studies that examine the effects of bar codes are Stephen A. Brown, *Revolution at the Checkout Counter* (Cambridge, Mass. and London: Harvard University Press, 1997) and Frederick H. Abernathy, John T. Dunlop, Janice H. Hammond, and David Weil, *A Stitch in Time: Lean Retailing and the Transformation of Manufacturing—Lessons from the Apparel and Textile Industries* (New York and Oxford: Oxford University Press, 1999).

² The activity decomposition in this section is based on George Herman, Thomas W. Malone, Brian Subirana, Michael Barrett, Humberto Moran, and Karl Prince, *Reference Framework for a Generic Receiving Process, Draft Working Paper*, MIT Center for Coordination Science, 2005. The paper is based on field work at one large U.S. and one large European consumer goods company and describes in detail the flows of physical goods and information in a warehouse setting.

³ Even though this transaction takes place between two units within the same firm, at the firm where we did our field work, the factory and warehouse had their own accounting and incentive systems for managers. Checking quantity at the receiving dock ensures that the warehouse will not be wrongly “charged” by the factory for cases of goods it does not in fact receive.

⁴ The ability to find goods on the shelves more readily during picking can also enable new approaches to storing goods. Relaxing the need to store goods in rigidly demarcated spots can allow maximization of variables such as forklift travel or picking time, which have heretofore been subsumed to the need to maintain orderly storage practices.

⁵ Of particular value were studies undertaken by IBM Consulting (some under the name of Price Waterhouse Coopers Consulting) and Accenture on behalf of the MIT Auto ID Center. These studies are available on the global Web site of the Auto ID Labs at <http://www.autoidlabs.org>. Also useful was work undertaken as part of the Future Store Initiative under the sponsorship of the German retailer, Metro. For more see <http://www.future-store.org>.

⁶ RFID enables greater accuracy through two features of the technology. First, the automated counting undertaken by RFID readers can eliminate the human errors that occur when warehouse and store personnel count by scanning bar codes. Second, RFID can reduce misplacement of inventory, that is, instances where cases of goods gets placed in the wrong location in a warehouse or store backroom. This latter problem is particularly acute in store backrooms.

⁷ In addition to these seven types of benefits, which are common to almost all manufacturers in the retail supply chain, RFID can generate other kinds of benefits for manufacturers with products possessing particular characteristics. For example, manufacturers whose products are shipped in containers that have value in their own right, such as brewers' kegs, can benefit from RFID tagging of the containers. Manufacturers of products that may be counterfeited or smuggled, such as luxury goods or pharmaceuticals, can benefit from RFID tagging to prevent fraud. And finally, companies with complex product lines or batch manufacturing processes requiring careful planning can optimize their factory scheduling in new ways, thanks to the improved data provided by RFID. We did not examine these benefits in our field study, but evidence from other case studies indicates that they can be sizeable. See, for example, Gert Assmus and Carsten Wiese, How to Address the Gray Market Threat Using Price Coordination, *Sloan Management Review* 36, 3 (Spring 1995), 31-41.

⁸ In the language of coordination science, a field that studies the underlying properties of and interrelationships between business activities, all of these activities are *specializations*, or specific embodiments, of the more general activity, "Hold inventory." For more on coordination science, see Thomas W. Malone, Kevin Crowston, Jintae Lee, Brian Pentland, Chrysanthos Dellarocas, George Wyner, John Quimby, Abraham Bernstein, George Herman, Mark Klein, Charles S. Osborn, and Elisa O'Donnell, *Tools for Inventing Organizations: Toward a Handbook of Organizational Processes*, *Management Science* 45, 3 (March 1999), 425-443 and Thomas W. Malone, Kevin Crowston, and George A. Herman, *Organizing Business Knowledge: The MIT Process Handbook* (Cambridge, Mass.: MIT Press), 2003.

⁹ The first three examples in the benefits tree are from a case study undertaken by the German retailer Metro and from MIT Auto ID Center working papers. For GlobalStore, see Metro Group, Future Store Initiative, RFID: Uncovering the Value—Applying RFID within the Retail and Consumer Package Good Value Chain, 2004. On GeneriMart, see PWC Consulting, Focus on Retail: Applying Auto-ID to Improve Product Availability at the Retail Shelf, MIT Auto ID Center Working Paper, IBM BC-

001, 2002. On Cornucopia, see Accenture, Auto-ID in the Box: The Value of Auto-ID Technology in Retail Stores, MIT Auto ID Center Working paper ACN BC-006, 2003. The WalMart example is from Bill C. Hardgrave, Matthew Waller, Robert Miller, Does RFID Reduce Out of Stocks? A Preliminary Analysis, Information Technology Research Institute Working Paper, Sam M Walton College of Business, University of Arkansas, November 2005, <http://itri.uark.edu>.

¹⁰ For more on the Process Handbook, see Malone et al., 1999, and Malone, Crowston and Herman, 2003. A public version of the Process Handbook is available for viewing at <http://ccs.mit.edu/ph>.

¹¹ We assume that benefits are competed away in a linear fashion over a ten-year period after the implementation is complete.

¹² We took margins of errors into account in many of our analyses, but have not included them here, opting instead to use a set of conservative assumptions.

¹³ For process-based examination of how RFID generates benefits by automation in a manufacturer's warehouse, see Brian Subirana, Chad Eckes, George Herman, Sanjay Sarma and Michael Barrett, Measuring the Impact of Information Technology on Value and Productivity using a Process-Based Approach: The case for RFID Technologies, Working Paper 4450-03, MIT Sloan School of Management, 2003.

¹⁴ Spreadsheets which contain the detailed benefit and cost calculations are posted at <http://ccs.mit.edu>.

¹⁵ Spreadsheets providing detailed calculations of benefits and costs at the retailer are also available at <http://ccs.mit.edu>.

6732 words (7742 words with endnotes)