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Measuring the Impact of Information Technology on Value and Productivity using a Process-Based Approach: The case for RFID Technologies

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Abstract:

There has been a lot of research addressing the relationship between Information Technology (IT) investments and productivity. Most of the work has been based on firm-level metrics such as total IT investment. We present what we believe is one of the first attempts to create a systematic methodology to assess the impact of IT in business process performance metrics. Our approach builds on the MIT Process Handbook as a basis to both guide the analysis and capture the resulting knowledge for future use. We will present preliminary results on how to use such methodology to analyze the impact of a given IT technology, namely RFID (radio frequency identification devices), in performance metrics of a consumer packaged goods company. We are interested in looking at how IT may impact performance metrics such as productivity, cost and value. We believe our methodology can help CPG companies prioritize their investments. We show results on how the specialization features of the MIT Process Handbook can

[1] The authors would like to mention that this paper would not have been possible without the guidance and insights of Prof. Thomas W. Malone. He was the PI in a CMI research grant that funded most of the work here described. He has contributed a lot of his time while following the research from day one and providing copious detailed comments on various drafts of this paper.

incorporate performance metrics to help assess such investments in RFID.

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1. Introduction

The attention given to radio frequency identification (RFID) has been going up steadily throughout the past years given the remarkable benefits it can provide. In particular, the application of RFID to the consumer packaged goods (CPG) supply chain has been one of the first to capture large scale adoption, with companies like Wal*Mart mandating their top 100 suppliers to begin sending cases and pallets of goods with RFID/EPC (Eletronic Product Code) tags by the year 2005. This mandate will cause these suppliers to invest in new RFID and IT infrastructure. For each supplier there are, in fact, many options to do so: tag cases at the exit doors, tag all cases in the supplier's warehouse entry doors, tag a certain section of the warehouse, etc.

With this challenge in mind, we set out to find a methodology for quantifying the value of RFID for a consumer packaged goods company. Through our summer 2003 study of a major CPG company exploring RFID for one of their warehouses, we were able to come up with a methodology. This paper gives an account of our project and the process-based methodology we've developed.

There has been a lot of research addressing the relationship between Information Technology (IT) investments and productivity. Most of the work has been based on firm-level metrics such as understanding the relationship between total IT investment and productivity. We present what we believe is one of the first attempts to create a systematic methodology to assess the impact of IT in business process performance metrics. Our objective is to develop a conceptual methodology for prioritizing the various options related to IT investments while providing an estimate of the value of the productivity improvements that can be obtained with each option. In IT investment projects, the manager can be faced with the task of quantifying the value of such investments, and insuring their organization that a positive return will be achieved. With technologies as new as RFID, however, this task becomes more difficult: there are no benchmark studies available, and the technology is new and constantly changing. RFID also provides many investment alternatives.

We believe our methodology can be useful to measure the impact of IT in general, and RFID in particular, using process performance metrics. In the case we analyzed, the predictive estimates generated by our methodology suggest that RFID can have a profound impact on business processes, creating significant value – for some processes an 80% savings and over 100% productivity gain – for the organization[2]. In general, our methodology predicted that the potential savings, productivity gains and value generation opportunities may be larger than was initially thought.

[2] Even though our research has shown the gains of over 100% as real estimates in the field site, the rest of the numbers presented throughout the case have been modified to preserve the confidentiality of the data used in the actual field work.

2. Business Process Analysis and the MIT Process Handbook

The starting tool we used in our endeavor was business process analysis. By looking very closely at the processes performed in the company's warehouse, we determined ways in which RFID could clearly improve efficiency and accuracy within material goods handling. Furthermore, we married cost and productivity data to our process analysis, which led us to a concrete financial model that shows the value of RFID for a single business process.

In any business process analysis project, one must utilize a process mapping tool for documenting and understanding processes. In our case, we employed the *MIT Process Handbook*. This tool provided us with a way of thinking about processes that proved quite useful. In particular, the MIT Process Handbook uses the metaphor of a compass, to depict how processes are related to one another, allowing the user to look at decompositions and uses of a process, as is common in most tools, but also enabling the definition of generalizations and specializations[3].

The goal of the MIT Process Handbook[4] is to "develop rich online libraries for sharing and managing many kinds of knowledge about business". Started in 1991, the MIT Process Handbook project has developed one such library. Today, the Handbook is an extensive online knowledge base consisting of over 5000 business activities and a set of software tools for managing this knowledge. The research described here aims to enhance such a project by enabling it to capture various process performance metrics throughout the process hierarchy. The specialization characteristics of the MIT Process Handbook allowed us to capture various types of RFID implementations including different adoption stages. By capturing RFID performance metrics in the MIT Process Handbook, other companies interested in analyzing the possible impact of RFID in their own business processes may be able to use the specialization and part decomposition properties of the Handbook to benefit from our research. Eventually, the Process Handbook could grow to contain information about how different IT applications (not just RFID) impact business process performance metrics. This may be a useful repository to determine which technology should be used to successfully enable a given desired process transformation.

The MIT Process Handbook may be used for other purposes too. For example, the capability of including video and images was highlighted in our field work as a benefit of using the handbook with the potential of using these features for knowledge management when rolling out Auto-ID worldwide. Exploring these other uses of the handbook for RFID deployment requires further work and is beyond the scope of the research presented here.

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[3] Malone, Thomas W., Crowston, Kevin, Lee, Jintae, Pentland, Brian. "Tools for inventing organizations: Toward a handbook of organizational processes." Management Science, March 1999, 45(3), 425-443.

[4] See also http://ccs.mit.edu/ph/ for a more detailed description of the MIT Process Handbook.

3. Methodology for Quantifying the Value and Productivity of IT investments

The methodology we used was composed of ten steps:

1. Determine objective of modeling effort including executive decision to be addressed
2. Analyze MIT Process Handbook data and develop preliminary reference model
3. Study, decompose and document current process in earnest
4. Define the future state of RFID
5. Decompose and document future process
6. Gather current performance metrics for the process
7. Apply metrics to process decompositions
8. Calculate estimates for value and productivity performance metrics of RFID process
9. Create executive report using estimates
10. Include findings in the MIT Process Handbook for future use

To help describe the methodology in more detail, we will use an example based on the real situation we studied this summer, where RFID was being considered by a major consumer packaged goods manufacturer as a possible value-generating IT investment. In particular, we describe a process involving a fork truck operator receiving and moving pallets of goods, and also entering data about the pallet into a warehouse management system, via manual data entry and barcode scanning.

1. ***Determine objective of modeling effort including executive decision to be addressed***

   The first step was to determine the objective of estimating process performance metrics. Part of this first step was to determine what activities we needed to model. This helped scope and guide the effort towards relevant metrics. In our field work with a CPG company, we wanted to address the following question:

   > "To what extent does it make sense to invest in RFID?"

   The context naturally lent us to analyze the warehousing processes given the advancement of RFID applications in this domain. The modeling question also implied we were interested in understanding what some of the cost savings and other value generation opportunities may be. Here we report the work done to measure cost savings and briefly outline how other value generation opportunities may be incorporated using the same methodology.

2. ***Analyze MIT Process Handbook data and develop preliminary reference model***

   Given that the MIT Process Handbook already contains over 5000 activities including some related to supply chain management, we studied the various types of warehousing activities and what some of the essential components of warehousing processes may be.

3. ***Study, decompose and document current process in earnest***

After studying existing entries in the Process Handbook, we turned our attention to studying a real process in a warehouse. In particular, we studied a routine process of receiving pallets into the warehouse, involving a fork truck, a computer terminal and a barcode scanner.

Through observation, reading through training manuals, videotaping, and interviewing fork truck operators and their supervisors, we acquired a deep understanding of the environment and process. For example, we learned how many times the fork truck moves from place to place, how many times a pallet is picked up and put down, and how many data fields an operator must enter into their fork truck's computer terminal. To enhance our understanding even further, two of us (Subirana and Eckes) even went through the one-day training course required for fork truck operators in this warehouse.

Videotaping the process was important for our efforts, as it allowed us to capture the process being performed repetitively, helping us understand which steps in the process were routine, versus which were anomalies. It also allowed us to time the process, as well as recognize how long various steps usually took, and which steps were prone to delays.

After having a deep understanding of the process, we proceeded to decompose the process into parts, as prescribed by the MIT Process Handbook methodology. This entailed defining hierarchical trees of processes, where the top node in the tree, or parent, represented an entire process. The parent was then decomposed into many parts, or children, which in turn were broken into further parts, and so on and so forth (see Figure 1 for example). We used both spreadsheets and the web-version of the MIT Process Handbook to document our process decomposition. Figures 2 and 3 provide examples. (Also see Appendix A for a generic depiction of the "Receive Physical Resource" process.")

This was one of the most time consuming steps of the methodology resulting eventually in several thousand activities. By introducing the process description in the Handbook we saved valuable time (for example different types of the receiving process shared many aspects in common). In fact, we hope that future exercises can vastly reduce their modeling time if there are similar processes already inputted in the handbook[5].

[5] There is an initiative to make the MIT Process Handbook available through an open source licensing agreement. See http://ccs.mit.edu/ophi/ for more information on this initiative.

Figure 1
Sample process decomposition and specialization hierarchy. Note that here *Pick One Pallet* and *Pick Two Pallets* are both specializations of the process *Pick Pallets*

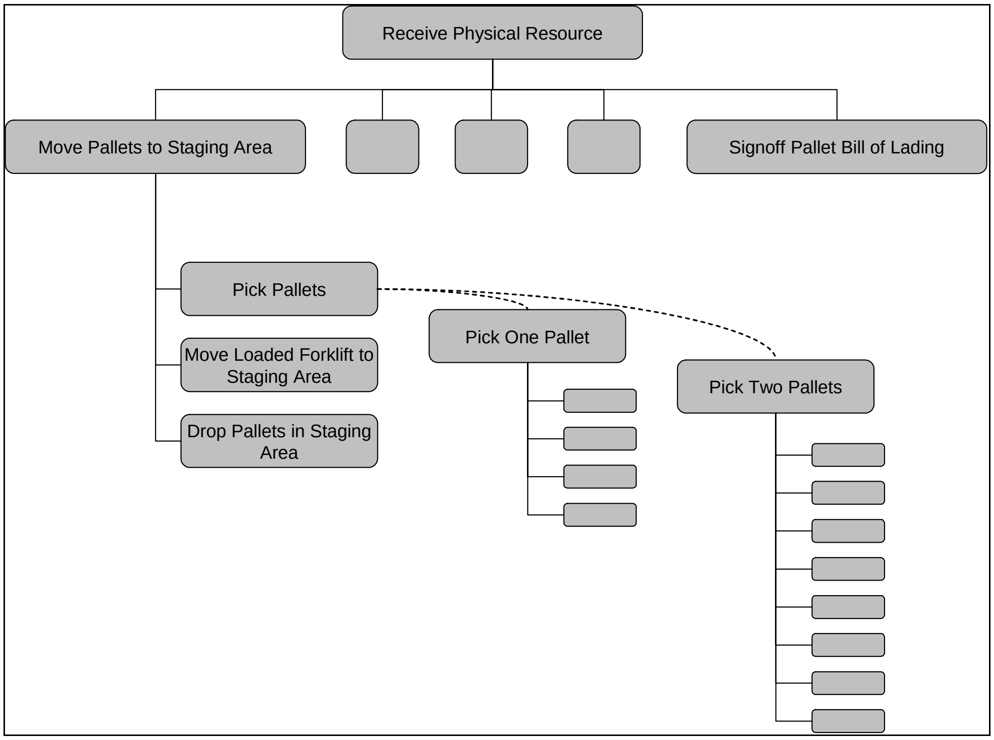

Figure 2: Sample MIT Process Handbook entry

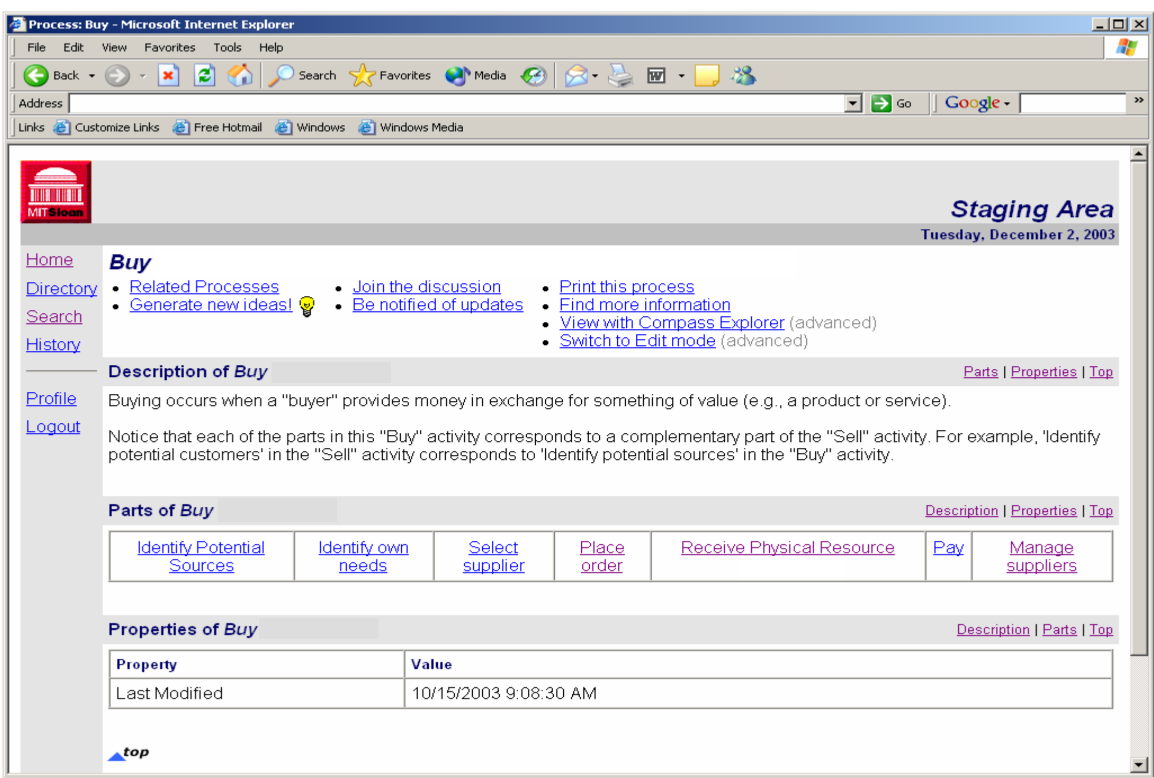

Figure 3

Warehouse Process Decomposition - "As-Is"

Handle Warehouse Inventory
- 1. Buy
  - 1.1 Identify Potential Sources
  - 1.2 Identify Own Needs
  - 1.3 Select Supplier
  - 1.4 Place Order
  - 1.5 Receive Physical Resource
    - 1.5.1 Move Pallets to Staging Area
      - 1.5.1.1 Pick Pallets
        - Pick One Pallet
          - 1.5.1.1.1 Drive Through Portal
          - 1.5.1.1.2 Place forklift into container
          - 1.5.1.1.3 Raise Container
          - 1.5.1.1.4 Backup forktruck into distribution center
        - Pick Two Pallets
          - 1.5.1.1.1 Drive Through Portal
          - 1.5.1.1.2 Place forklift into container
          - 1.5.1.1.3 Raise Container
          - 1.5.1.1.4 Place Container on top of second container
          - 1.5.1.1.5 Backup forktruck
          - 1.5.1.1.6 Place forklift into bottom container
          - 1.5.1.1.7 Raise containers
          - 1.5.1.1.8 Backup forktruck into distribution center
      - 1.5.1.2 Move Loaded Forklift To Staging Area
      - 1.5.1.3 Drop Pallets in Staging Area
    - 1.5.2 Enter Pallet into WMS
      - 1.5.2.1 Login to WMS via reach truck RF terminal
      - 1.5.2.2 Choose Receiving Function in WMS
      - 1.5.2.3 Enter pallet data into WMS
    - 1.5.3 Affix Barcode labels to pallet
      - 1.5.3.1 Get printed barcode labels
      - 1.5.3.2 Affix barcodes to pallets
      - 1.5.3.3 Put label backing in trash
    - 1.5.4 Move Pallet from Staging Area to Storage
    - 1.5.5 Sign off on Pallet Bill of Lading

4. *Define the future state of RFID*

We next needed to envision a future world within the warehouse, where RFID would be utilized and would replace various manual steps within our process. In doing this, we made assumptions about the efficacy of the technology, such as the fact that 100% of case-level tags would be read almost instantaneously when passed within 3 meters of an antenna/reader. The next few steps on our methodology are designed to assess the change in the performance metrics between the original process and the one corresponding to this future world[6].

For our study, we defined the future world to be:
- Case-level tags read with 100% accuracy
- Pallet identification barcode labels replaced by RFID tag

[6] In some cases, it may be desirable to do a comparative analysis between two processes. For example, if company A and company B are both using the same ERP, we may be interested in comparing performance metrics in the order taking process at the two companies to understand how differences in the use of the ERP system may impact such performance metrics.

- RFID replaces manual entry of data into warehouse management system (both hand entries and barcode scans)

In general, it will be desirable to determine not one but a few future states. For example, one can assume that RFID is broadly adopted by the industry or that it is just used within the four walls of the company. Depending on the results of a process performance analysis, one may iterate some of the steps until a satisfactory result is obtained. Here, again, the MIT Process Handbook is useful because it can capture different types of processes while maintaining the relationships between them. Thus, even though we present the steps as a fairly straightforward sequence, the methodology is in fact tentative and iterative. Because we cannot predict the future, it may be more accurate to have a "possible future state" which is always being negotiated.

5. Decompose and document future process

After understanding what RFID "world" we wanted to live in, we proceeded to think about and document what the process would turn into with RFID in place. Again using the spreadsheets and the web-version of the MIT Process Handbook, we documented our process decomposition. In the lingo of the Process Handbook, we created a *specialization* of the original process. This meant that we *inherited* various parts from the original process. In this particular situation, we mostly eliminated parts from the original process, added a couple of new steps, and only inherited a few. Figure 4 shows an example.

Figure 4

Warehouse Process Decomposition - "As-Is"

Handle Warehouse Inventory
- 1. Buy
  - 1.1 Identify Potential Sources
  - 1.2 Identify Own Needs
  - 1.3 Select Supplier
  - 1.4 Place Order
  - 1.5 Receive Physical Resource
    - 1.5.1 Move Pallets to Staging Area
      - 1.5.1.1 Pick Pallets
        - Pick One Pallet
          - 1.5.1.1.1 Drive Through Portal
          - 1.5.1.1.2 Place forklift into container
          - 1.5.1.1.3 Raise Container
          - 1.5.1.1.4 Backup forktruck into distribution center
        - Pick Two Pallets
          - 1.5.1.1.1 Drive Through Portal
          - 1.5.1.1.2 Place forklift into container
          - 1.5.1.1.3 Raise Container
          - 1.5.1.1.4 Place Container on top of second container
          - 1.5.1.1.5 Backup forktruck
          - 1.5.1.1.6 Place forklift into bottom container
          - 1.5.1.1.7 Raise containers
          - 1.5.1.1.8 Backup forktruck into distribution center
      - 1.5.1.2 Move Loaded Forklift To Staging Area
      - 1.5.1.3 Drop Pallets in Staging Area
    - 1.5.2 Enter Pallet into WMS
      - 1.5.2.1 Login to WMS via reach truck RF terminal
      - 1.5.2.2 Choose Receiving Function in WMS
      - 1.5.2.3 Enter pallet data into WMS
    - 1.5.3 Affix Barcode labels to pallet
      - 1.5.3.1 Get printed barcode labels
      - 1.5.3.2 Affix barcodes to pallets
      - 1.5.3.3 Put label backing in trash
    - 1.5.4 Move Pallet from Staging Area to Storage
    - 1.5.5 Sign off on Pallet Bill of Lading

Warehouse Process Decomposition - "To-Be"

Handle Warehouse Inventory
- 1. Buy
  - 1.1 Identify Potential Sources
  - 1.2 Identify Own Needs
  - 1.3 Select Supplier
  - 1.4 Place Order
  - 1.5 Receive Physical Resource
    - 1.5.1 Create inventory in RFID system
      - 1.5.1.1 Read case and pallet EPCs
      - 1.5.1.2 Store case and pallet data in RFID system
    - 1.5.2 Create inventory in WMS
      - 1.5.2.1 Send case and pallet data to WMS
      - 1.5.2.2 Mark inventory as received
      - 1.5.2.3 Assign storage location to pallet
    - 1.5.3 Move Pallets to Storage
      - 1.5.3.1 Pick Pallets
        - Pick One Pallet
          - 1.5.3.1.1 Drive Through Portal
          - 1.5.3.1.2 Place forklift into container
          - 1.5.3.1.3 Raise Container
          - 1.5.3.1.4 Backup fork truck into distribution center
        - Pick Two Pallets
          - 1.5.3.1.1 Drive Through Portal
          - 1.5.3.1.2 Place forklift into container
          - 1.5.3.1.3 Raise Container
          - 1.5.3.1.4 Place Container on top of second container
          - 1.5.3.1.5 Backup fork truck
          - 1.5.3.1.6 Place forklift into bottom container
          - 1.5.3.1.7 Raise containers
          - 1.5.3.1.8 Backup fork truck into distribution center
      - 1.5.3.2 Move Pallet to Storage
    - 1.5.4 Sign off on Pallet Bill of Lading

6. Gather current performance metrics for the process

Having completed our documentation of the "as-is" and "to-be" processes, we set out to find metrics that described the current process. Through collection and study of the very detailed company reports of productivity and costs, we generated the following important metrics:

Metric	Example
Average hourly cost of fork truck operator[7]	$15.00 / hour
Average hourly cost of fork truck maintenance[8]	$2.00 / hour
Average cost per barcode label[9]	$0.0175 / label
Average amount of time it takes for one iteration of the process to be performed[10]	240 seconds / pallet or 15 pallets / hour
Average number of pallets handled per week by the process[11]	6000 pallets / week

7. Apply metrics to process decompositions

Given cost and productivity metrics that represent the "typical" effort and time it takes to perform the process, we then attempted to spread the metrics – in particular, the time it takes for one iteration of the process – across the many steps in the process decomposition. Instead of performing separate timing studies for each step, we used our detailed knowledge of the process to estimate how much time each step took, relative to the other steps in the process. For example, we knew that the step "Scan barcode" was consistently quick. However, a step such as "Apply barcode label to pallet" could vary considerably, based on whether the operator needed to walk a short or long distance to the barcode printer and pallets. Thus, on average, this step took substantially more time.

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[7] The hourly wage of a typical fork truck operator working in the warehouse. The wage accounts for benefits, vacation, and sick leave, but does not account for supervisory and administrative overhead.

[8] The hourly cost of maintaining the particular type of fork truck involved in the process (in this case, a stand-up reach truck). This cost accounts for battery charge time, battery replacement, wheel replacement and mechanic time.

[9] The cost of one printed barcode label, which gets affixed to a pallet in the warehouse. This cost accounts for printers, printer ink, and blank labels.

[10] The amount of time it takes a fork truck operator to perform the process on one pallet. This metric was derived from a manager's report on individual operator productivity, by week, over a 36-week period. The report was based on operators' daily time reports.

[11] The number of pallets handled by all operators performing that process, for an entire week. Again, this metric was derived from a manager's report on individual operator productivity.

To provide an example, Figure 5 shows how the top-level metric of 240 seconds/pallet can be allocated across the many parts of the process.

Figure 5

Warehouse Process Decomposition - "As-Is"	Time (secs)
Handle Warehouse Inventory	
1. Buy	
1.1 Identify Potential Sources	
1.2 Identify Own Needs	
1.3 Select Supplier	
1.4 Place Order	
1.5 Receive Physical Resource	240.00
1.5.1 Move Pallets to Staging Area	104.00
1.5.1.1 Pick Pallets	40.00
Pick One Pallet	40.00
1.5.1.1.1 Drive Through Portal	14.00
1.5.1.1.2 Place forklift into container	8.00
1.5.1.1.3 Raise Container	10.00
1.5.1.1.4 Backup forktruck into distribution center	8.00
Pick Two Pallets	
1.5.1.1.1 Drive Through Portal	
1.5.1.1.2 Place forklift into container	
1.5.1.1.3 Raise Container	
1.5.1.1.4 Place Container on top of second container	
1.5.1.1.5 Backup forktruck	
1.5.1.1.6 Place forklift into bottom container	
1.5.1.1.7 Raise containers	
1.5.1.1.8 Backup forktruck into distribution center	
1.5.1.2 Move Loaded Forklift To Staging Area	44.00
1.5.1.3 Drop Pallets in Staging Area	20.00
1.5.2 Enter Pallet into WMS	50.00
1.5.2.1 Login to WMS via reach truck RF terminal	12.00
1.5.2.2 Choose Receiving Function in WMS	14.00
1.5.2.3 Enter pallet data into WMS	24.00
1.5.3 Affix Barcode labels to pallet	86.00
1.5.3.1 Get printed barcode labels	36.00
1.5.3.2 Affix barcodes to pallets	10.00
1.5.3.3 Put label backing in trash	40.00

After allocating the time across the "as-is" process, we turned our attention to the "to-be" process. This exercise was relatively straightforward, since our "to-be" process only contained a fraction of the original steps from the original process. Moreover, there were very few additional steps that needed to be added. Thus, we simply had to *inherit* the values we had assigned in our "as-is" process, as well as estimate values for the new steps we had added. Figure 6 provides an example.

Figure 6

Warehouse Process Decomposition - "To-Be"	Time (secs)
Handle Warehouse Inventory	
1. Buy	
1.1 Identify Potential Sources	
1.2 Identify Own Needs	
1.3 Select Supplier	
1.4 Place Order	
1.5 Receive Physical Resource	40.00
1.5.1 Create inventory in RFID system	
1.5.1.1 Read case and pallet EPCs	
1.5.1.2 Store case and pallet data in RFID system	
1.5.2 Create inventory in WMS	
1.5.2.1 Send case and pallet data to WMS	
1.5.2.2 Mark inventory as received	
1.5.2.3 Assign storage location to pallet	
1.5.3 Move Pallets to Storage	40.00
1.5.3.1 Pick Pallets	40.00
Pick One Pallet	40.00
1.5.3.1.1 Drive Through Portal	14.00
1.5.3.1.2 Place forklift into container	8.00
1.5.3.1.3 Raise Container	10.00
1.5.3.1.4 Backup fork truck into distribution center	8.00
Pick Two Pallets	
1.5.3.1.1 Drive Through Portal	
1.5.3.1.2 Place forklift into container	
1.5.3.1.3 Raise Container	
1.5.3.1.4 Place Container on top of second container	
1.5.3.1.5 Backup fork truck	
1.5.3.1.6 Place forklift into bottom container	
1.5.3.1.7 Raise containers	
1.5.3.1.8 Backup fork truck into distribution center	

This again illustrates the power of using a specialization tool for measurements. Today, the MIT Process Handbook does not contain such functionality but one of the contributions of our methodology is to specify implicitly how it could be incorporated.

In general, it may be difficult to gather the ideal metrics and it may be more useful to redefine the process to be studied in light of the readily available data. In our field work, we found this to be one of the most challenging aspects. We often had to revise the scope of the studied processes to match the available data. We found it is also important to involve the relevant constituencies within the firm – so that decisions based on the analysis are not questioned because of the integrity of the data.

8. *Calculate estimates for value and productivity performance metrics of RFID process*

Now that we had numbers for the amount of time it would take to perform the process without RFID and with RFID, we could marry those with our cost data, to determine what cost savings RFID would generate. Figure 7 shows how this analysis worked.

Figure 7

Value Generated by RFID - "Receive Physical Resource" Process	**As-Is**	**To-Be**
Process duration (in seconds)	240.00	40.00
Process duration (in minutes)	4.000	0.667
Saved		3.33
% improvement		83.3%
Pallets per hour	15.00	90.00
Pallets per week (constant)	6000.00	
Barcode labels per pallet	2	
Hours per week to perform process	400.00	66.67
Variable Costs		
Cost per hour of fork truck operator	$15.00	
Cost per hour of fork truck	$2.00	
Cost per barcode label	$0.0175	
Cost of process - fork truck and operator		
Per week	$6,800.00	$1,133.33
Per year	$353,600.00	$58,933.33
Cost of process - barcode labels		
Per year	$10,920.00	$0.00
Total cost of process per year	$364,520.00	$58,933.33
Savings per year		$305,586.67

9. *Create executive report using estimates*

Once the value and productivity process performance metrics had been estimated, they could be put to work to support the objectives of the modeling effort. This step, in general, can result in many different analyses reflecting the host of decisions executives make. These may include a productivity analysis of the supply chain, a coordination value analysis of RFID opportunities (as sketched in section 4), etc. It is beyond the scope of this paper to address these in detail. Here we will illustrate how they can be used to determine whether investing in RFID can be justified based on the value generated.

Given the large number of steps eliminated from the "as-is" process, it was no surprise that RFID generated value. What we had to do next was compare that value to the estimated investment required to enable the warehouse with RFID. Thus, we set out to create a value model, which we envisioned as being a 7-year analysis of costs and benefits, discounted back to the present time period, in order to account for the time value of money. In other words, a discounted cash flow (DCF) analysis.

Our modeling effort was broken up into three steps:

Step 1 – Determine input variables

In order to make the model representative of the significant number of unknowns associated with RFID, we created a list of input variables that, when changed, would result in the bottom-line value figure changing. These input variables were broken into two types: constants and year-over-year variants. The following table lists all of the input variables:

Input Variable	Type
Cost of capital	Constant
Sales growth rate	Constant
Tax rate	Constant
Cost of tags	Varies year-over-year
Number of tags purchased	Varies year-over-year
Cost of readers	Varies year-over-year
Number of readers purchased	Varies year-over-year
Cost of antennas	Varies year-over-year
Number of antennas purchased	Varies year-over-year
Cost of systems integration	Varies year-over-year
Cost of maintenance/other	Varies year-over-year
Depreciation rate of fixed assets	Varies year-over-year
Burden rate of systems integration costs	Constant
Burden rate of maintenance and other costs	Constant
Burden rate of tag costs	Constant
Burden rate of reader costs	Constant
Burden rate of antenna costs	Constant

An important set of variables here is the burden rate variables. These represent the percentage of costs a particular process should bear. For example, for the one process we studied, we estimated that it represented 5% of all processes within the company's warehouse operations. Thus, it should burden 5% of the warehouse-wide costs: systems integration, maintenance/other, and tag costs. On the other hand, the burden rate for reader and antenna costs should be 100%, since we can estimate a concrete number of readers and antennas that will be specifically allocated to the single process we studied.

Figure 8 shows a full set of input variables.

Figure 8

Input Variables to ROI Model - "Receive Physical Resource" Process							
Constants							
Cost of Capital	9%						
Sales Growth Rate	4%						
Tax Rate	35%						
Tag Cost Burden	5%						
Systems Integration Cost Burden	5%						
Maintenance/Other Cost Burden	5%						
Reader Cost Burden	100%						
Antenna Cost Burden	100%						
Varying year-over-year							
	Year						
	1	2	3	4	5	6	7
Cost of Tags	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Number of Tags	6,400,000	6,656,000	6,922,240	7,199,130	7,487,095	7,786,579	8,098,042
Cost of Readers	$1,500	$1,500	$1,000	$700	$500	$400	$300
Number of Readers	2	0	0	0	0	0	0
Cost of Antennas	$200	$200	$150	$120	$100	$100	$100
Number of Antennas	4	0	0	0	0	0	0
System Integration Costs	$100,000	$0	$0	$0	$0	$0	$0
Maintenance and Other Costs	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Depreciation Schedule	33%	33%	34%	0%	0%	0%	0%

Step 2 – Create discounted cash flow model

As mentioned above, we decided to measure the value and costs of RFID over a 7-year time horizon. Our first step in creating the DCF model was to input the value created by RFID in year 1 ($100,000), and grow that value annually by the annual sales increase percentage (which was an input variable). Figure 9 shows the value section of the DCF.

Figure 9

Discounted Cash Flow - "Receive Physical Resource" Process							
	Year						
	1	2	3	4	5	6	7
Value							
Receive Physical Resource	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665
Total Value	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665

Next, we input all of the costs. Many of these were dictated by the input variables we setup earlier. Figure 10 shows the cost section added to the DCF.

Figure 10

Discounted Cash Flow - "Receive Physical Resource" Process							
	Year						
	1	2	3	4	5	6	7
Value							
Receive Physical Resource	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665
Total Value	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665
Costs							
Cash Out -- COGS							
Tags	$16,000	$16,640	$17,306	$17,998	$18,718	$19,466	$20,245
Readers	$3,000	$0	$0	$0	$0	$0	$0
Antennas	$800	$0	$0	$0	$0	$0	$0
Maintenance/Other	$500	$500	$500	$500	$500	$500	$500
Total Cash Out -- COGS	$20,300	$17,140	$17,806	$18,498	$19,218	$19,966	$20,745
Cash Out -- Assets							
Systems Integration	$5,000	$0	$0	$0	$0	$0	$0
Total Cash Out -- Assets	$5,000	$0	$0	$0	$0	$0	$0
Cash Out -- Taxes							
COGS	$20,300	$17,140	$17,806	$18,498	$19,218	$19,966	$20,745
Depreciation Expense	$1,650	$1,650	$1,700	$0	$0	$0	$0
Taxes @ 35%	$99,273	$104,657	$108,856	$113,836	$118,396	$123,139	$128,072
Total Cash Out -- Taxes	$99,273	$104,657	$108,856	$113,836	$118,396	$123,139	$128,072
Total Costs	$124,573	$121,797	$126,662	$132,334	$137,614	$143,106	$148,817

As seen in Figure 10, the costs are broken into different categories: Cost of Goods Sold costs (COGS), Fixed Asset costs, and Tax costs. We differentiated the costs this way, since these are the likely classifications of the RFID investment on the company's income statement and balance sheet. Thus, we accounted for depreciation expense and tax expense, which, to us, was a truer way of depicting all of the costs related to RFID.

This category breakdown was done in conjunction with the standard accounting practices and is not essential to the methodology being proposed. What we believe is essential is that the choice of variables and use of the model be done in conjunction with those that are going to make decisions based on it. In some cases, the existing accounting practices may not enable the capture of all the benefits associated to a given technology, within their current cost categories. It will be necessary then to refine those and maybe challenge the firm´s current performance practices.

Note that here we are assuming all cost savings will go directly to the bottom line[12]. In many cases it may be unrealistic to assume that all the potential cost savings would actually be realized in this way. For example, time savings of a person that is already underutilized may not result in the reduction of actual expenses at all. For large warehouses, involving hundreds of employees, this may not be a big issue. In general, more analysis should be done to estimate which portions of the efficiency gains should be counted towards value creation and which ones should not.

Now that the value and cost sections were laid out, we calculated the annual net value (or loss) of the process. We did this for each of the seven years, and then discounted them all

[12] We are also assuming that costs and initial benefits occur in the same year. In some cases a more accurate approach would involve a lag between investment and initial benefits.

back to year 1, which gave us the net present value (NPV) of the overall investment project. From that NPV, then, we could calculate value as the NPV of all benefits and productivity metrics by taking such NPV divided by the discounted sum of all investments. Figure 11 shows the NPV and ROI.

Figure 11

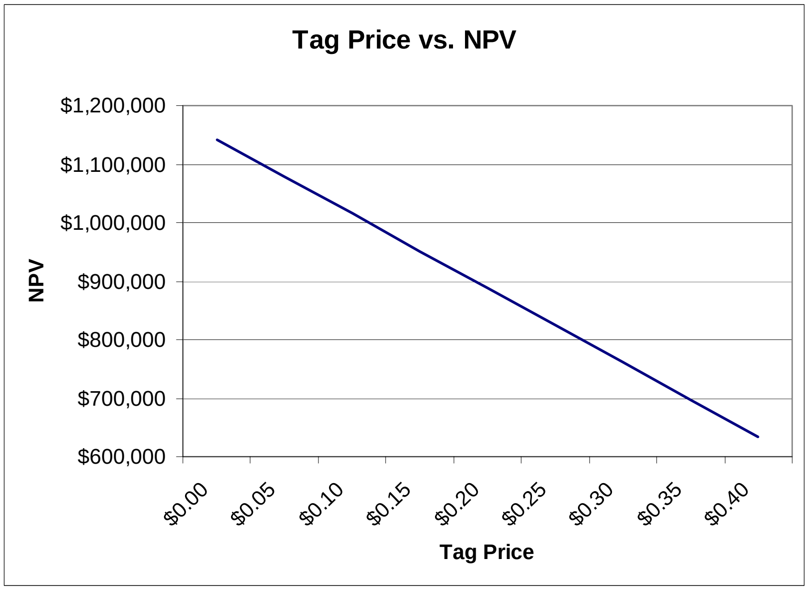
Discounted Cash Flow - "Receive Physical Resource" Process

	Year						
	1	2	3	4	5	6	7
Value							
Receive Physical Resource	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665
Total Value	$305,587	$317,810	$330,523	$343,743	$357,493	$371,793	$386,665
Costs							
Cash Out -- COGS							
Tags	$16,000	$16,640	$17,306	$17,998	$18,718	$19,466	$20,245
Readers	$3,000	$0	$0	$0	$0	$0	$0
Antennas	$800	$0	$0	$0	$0	$0	$0
Maintenance/Other	$500	$500	$500	$500	$500	$500	$500
Total Cash Out -- COGS	$20,300	$17,140	$17,806	$18,498	$19,218	$19,966	$20,745
Cash Out -- Assets							
Systems Integration	$5,000	$0	$0	$0	$0	$0	$0
Total Cash Out -- Assets	$5,000	$0	$0	$0	$0	$0	$0
Cash Out -- Taxes							
COGS	$20,300	$17,140	$17,806	$18,498	$19,218	$19,966	$20,745
Depreciation Expense	$1,650	$1,650	$1,700	$0	$0	$0	$0
Taxes @ 35%	$99,273	$104,657	$108,856	$113,836	$118,396	$123,139	$128,072
Total Cash Out -- Taxes	$99,273	$104,657	$108,856	$113,836	$118,396	$123,139	$128,072
Total Costs	$124,573	$121,797	$126,662	$132,334	$137,614	$143,106	$148,817
Net Value	$181,014	$196,013	$203,861	$211,410	$219,879	$228,687	$237,848
Net Present Value	$181,014	$179,829	$171,586	$163,247	$155,768	$148,631	$141,821
Total NPV	**$1,141,895**						
Total Investment	**$724,341**						
ROI	**158%**						

Step 3 – Run sensitivity analysis

At this point, we were basically done. We had achieved our goal of quantifying the value of RFID. Still, we wanted to show how sensitive the NPV and ROI could be to changes in our input variables. We therefore ran a number of trials with different input variables. In one particular trial, we altered the cost of tags and observed how the NPV changed. A graph of this analysis is shown in Figure 12 which shows how sensitive the NPV value seems to be to tag price.

Figure 12



10. ***Include findings in the MIT Process Handbook for future use***
    The final step in our methodology is to report back to the MIT Process Handbook the results found. Part of the results can be included in the current version of the MIT Process Handbook. For example, the various ways in which RFID can be introduced in the warehouse can be captured within a specialization tree. Other findings will require changes in the code of the MIT Process Handbook if the analysis above is to be conducted and reproduced without the help of a spreadsheet program.

    Eventually, our goal is to capture knowledge about value and productivity performance metrics, so that others can use it to guide their modeling efforts. This has the potential of saving many managerial hours directed at analyzing non-value added activities, by illustrating where the value opportunities have been found by others in the past. It could also help standardize performance metrics. For example, the estimates in the handbook may be validated by independent third party organizations, so that people may justify investing in RFID with little, if any, analysis on the basis of such validated estimates.

4. Other areas of value opportunity enabled by RFID

Our research suggests RFID could create value for one particular process within a warehouse. Moreover, our methodology gives detailed numerical estimates of this value. Throughout our project, we also came across a number of other possible areas, both within the warehouse and beyond, where RFID will likely create value. Though we did not study these processes in detail, we suggest that in many cases, value could be found and quantified using the same methodology.

We found that most of the value RFID generates, when introduced in a process, comes from one of two sources. First, the effect that RFID has in the internal value metrics of the process, such as the time to complete the receiving process, the quality of the shipped orders in the shipping and handling (S/H) processes, or the labor costs of the warehouse processes. Second, the use of RFID in a process can also have an impact in the performance metrics of *other* processes, given the interdependencies between processes. For example: assigning EPC codes to cases and pallets has an impact in the accuracy of the cycle count processes; verifying cases in the receipt process has an impact in the accuracy of the put away process; putting RFID tags in the warehouse permits lowering the costs of the customer's warehouse management processes.[13]

The following list provides some of the sources of value we encountered in our study. We have not done detailed performance metrics estimates of all these sources. In combination, the value they may generate could be vastly larger than the one derived from our analysis.

- Improved efficiency in the warehouse including less time spent on: receiving; put away; picking; checking/counting, shipping; exception handling, returns from other DC's and customers
- Reduced labor and material costs due to improved efficiency
- Reduced transportation costs
- Reduced inventory on hand in the warehouse, and throughout the supply chain
- Reduced shrinkage in the supply chain, due to reductions in: theft, spoilage and product diversion
- Improved sales, due to lower out of stocks

5. Conclusion

We have introduced a methodology to estimate process performance metrics and to quantify the value IT can bring to a given process. The methodology provides a systematic approach that can help companies predict the impact of IT investments in process performance based on their own metrics and eventually those of others, if the MIT Process Handbook is extended to incorporate reference metrics. This may help direct resources to the areas where RFID has the most potential to generate value. In particular, we have shown how the methodology can be applied to estimating the impact of RFID on warehousing management processes.

Our research also corroborates the intuitive notion that RFID can add significant value to CPG companies. Our analysis has been focused to a given process within the four walls

[13] For those familiar with Coordination Theory all of these dependency examples are related to one particular type of dependency, flow dependencies. We have also found that the introduction of RFID in a given process also generates value in other processes by virtue of the fit and sharing dependencies between it and others. The notion that the value of a process can be measured by looking at the impact it has in other processes is a novel insight that we have developed in this research. For an introduction to coordination theory see "Malone, T.W., K. Crowston 1994. The Interdisciplinary study of coordination. ACM Comput. Surveys 26 (1) 87—119"

of a company. Similar analyses could be done for cross-company processes. Further work is needed before we can scope the full potential of RFID technologies.

We have also demonstrated that the MIT Process Handbook can be used for detailed analysis. In our field work, the number of activities in the warehouse, measured by the thousands, is comparable to the whole content developed over the last 10 years and currently present in the handbook. This further builds our confidence that the MIT Process Handbook is a good tool to capture business knowledge of many different types and for many different goals.

6. Appendix A – Generic Depiction of "Receive Physical Resource" Process

Generic Version of "Receive Physical Resource" Process

1. Receive physical resource
    - 1.1 Receive from transporter
        - 1.1.1 Unload transport
    - 1.2 Verify
        - 1.2.1 Verify quantity against need
        - 1.2.2 Verify quality against need
    - 1.3 Acknowledge
        - 1.3.1 Get information about receipt
        - 1.3.2 Configure information for communication about receipt
        - 1.3.3 Send information about receipt
    - 1.4 Move
        - 1.4.1 Prepare for move
            - 1.4.1.1 Reconfigure physically
            - 1.4.1.2 Determine location for putaway
            - 1.4.1.3 Print relevant documentation
            - 1.4.1.4 Assign to resource
        - 1.4.2 Move to location
        - 1.4.3 Verify move

7. Appendix B – Generic Depiction of All Processes within a Warehouse

Generic Version of All Processes in a Warehouse

1. Design
2. Buy
    - 2.1 Identify needs
    - 2.2 Identify supplier
    - 2.3 Select supplier
    - 2.4 Order
    - 2.5 Receive product
        - 2.5.1 Verify count
        - 2.5.2 Prepare for putaway
        - 2.5.3 Putaway
    - 2.6 Pay
    - 2.7 Manage suppliers
3. Make (Storage)
    - 3.1 Cycle count
    - 3.2 Replenish pick fronts
    - 3.3 Consolidate bins
4. Sell
    - 4.1 Identify customer
    - 4.2 Identify customer needs
    - 4.3 Inform customer
    - 4.4 Get order
    - 4.5 Deliver
        - 4.5.1 Pick
        - 4.5.2 Prepare for transport
            - 4.5.2.1 Prepare transportation
                - 4.5.2.1.1 Schedule transportation
                - 4.5.2.1.2 Buy transportation
                - 4.5.2.1.3 Create transportation documentation
            - 4.5.2.2 Pack
                - 4.5.2.2.1 Package order
                - 4.5.2.2.2 Verify case count per pallet
                - 4.5.2.2.3 Create container document
        - 4.5.3 Transport
    - 4.6 Receive payment
    - 4.7 Manage customers
5. Manage