RFID Solutions Center℠ Dayton

Project Summary Report

Preventative Maintenance & Trouble Shooting for Passive RFID Technology: Results of the Procter & Gamble Study

October 2007

1 Background Information

1.1 Acknowledgements

The RFID Solutions Center would like to express our thanks to Procter & Gamble, Wright State University, and the Department of Quantitative Analysis and Operations Management College of Business, University of Cincinnati that made this report possible.

We would like to thank these organizations and acknowledge their significant efforts in providing support for this report.

1.2 Contract Information

Offering Department: U.S. Air Force Research Laboratory, Materials and Manufacturing Directorate ("AFRL/MLM")

Recipient: Wright Brothers Institute

Vehicle: Memorandum of Understanding / Partnership Intermediary Agreement ("MOU" / "PIA") FA8650-06-3-9000

Contract: Collaborative Purchase Order ("CPO") FA8650-06-3-9021

Title: RFID Rapid Adoption Collaboration Initiative ("RRACI")

The objective of the program is for the recipient to stimulate the rapid transition of radio frequency identification (RFID) technologies by developing an RFID solutions center. The RFID solutions center shall provide an effective way to collaborate with government end users, contractors, and defense industry suppliers. The solutions center shall provide education, training, and application of specific system design capabilities to transition RFID technologies to meet military needs. The RFID solutions center shall provide the capabilities and services that shall assist the government in streamlining both internal and external supply chain challenges to support the war fighter.

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2 EXECUTIVE SUMMARY

This report examines the potential benefits of implementing performance monitoring, discusses the anticipated costs, and details next steps to be taken to fully assess the impact of performance monitoring implementation.

RFID installations consist of a large number of interdependent and interconnected components that work together as a unit for proper functionality and operations of the system. These components include tags, readers, antennas, networks, computing systems, power supplies, and peripherals, accessories and other mechanical systems that are controlled by the RFID implementation.

The advantages to RFID technology are great; however current RFID hardware is still relatively delicate and few implementations are exactly the same. Even after an RFID system has been successfully installed, there is a possibility that it will face various performance-related issues. These issues can involve reader failure, tag failure, problems with the middleware, RF environment changes, network, power, or computing systems. With a myriad of different hardware options maintaining RFID system at an effective operational level can be challenging, especially when a problem occurs. For companies utilizing RFID, hardware failure can be disastrous; late orders, mismanaged inventory, or the grinding halt of an assembly line can prove costly to companies.

In order to track, predict trend and prevent performance problems, the system will need to be closely monitored. Monitoring read rates and other performance measurements can help determine when a problem is occurring and aid troubleshooting efforts. While most RFID reader manufacturers provide basic troubleshooting guides for their products, such guides are typically very specific to devices and models, or they are too low level for troubleshooting a complete installation.

The goal of this report is to investigate the impact of deploying preventative maintenance for the RFID systems currently in place across P&G's supply chain. P&G's J. Nakra prefers the term "performance monitoring." Also, to provide a generalized monitoring and troubleshooting guide that will allow individuals of different skills to determine problem areas and potentially fix current issues or prevent potential future problems.

We will focus on P&G's Gillette-Fort Devens distribution center as a template. The Fort Devens facility provides a good place to start looking into the benefits of performance monitoring (PM) as they have carried out a previous trial using RF Technology that showed an excellent return on investment (Collins 2006). As more and more of this technology is rolling out to end users, the opportunities for failures increase. For most users, PM is done locally because of the small number of sites considered. As the scale of the rollouts increase, this is not possible. In addition, there is more visibility needed throughout the whole supply chain from manufacturing through retail outlets (Nakra 2007). There will become the need to remotely determine when there is failure of a tag, reader or antenna placement.

When one considers the potential scale of P&G production even on "testable" products alone, there is a huge need to develop guidelines for performance monitoring.

One purpose of this report is to aid RFID integrators, system administrators, and end-users with a guide to answer the following two questions, and provide a generalized method for reaching a solution.

1. Has a hardware failure occurred?

2. What can cause a hardware failure?

The prime contractor for this activity was the Wright Brother's Institute, the program was sponsored by the Air Force Research Laboratory, and the program manager was the RFID Solutions Center.

3 Introduction

This chapter defines the passive RFID technology tested in the study. It also lists a benefits analysis of Preventive Maintenance for RFID infrastructures and the project team.

3.1 About Passive RFID

Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. Utilizing radio frequency waves, an RFID tag can be applied to or incorporated into a product for the purpose of location and identification. UHF Passive RFID can be read from several meters away and beyond the line of sight of the reader. Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a (RF) signal and can also be used for other specialized functions. The second is an antenna for receiving and transmitting the signal.

RFID technology is in increasing use in enterprise supply chain management, improving the efficiency of inventory tracking and management. The Department of Defense, along with major commercial companies such as Wal-Mart, is implementing systems to test the ability of this technology to improve asset visibility, product integrity and readiness throughout the supply chain.

The use of RFID in the DoD supply chain has the potential to provide real benefits in inventory management, asset visibility, and interoperability in an end-to-end integrated environment. RFID encapsulates the data accuracy advantages inherent in all types of automatic identification technology (AIT). Additionally, RFID is a totally non-intrusive methodology for data capture (requires no human intervention), is non- line of sight technology, and is a technology that possesses both read and write options within the same equipment item.

RFID addresses a key challenge that has been noted at every node within the DoD supply chain – lack of visibility of item data. As an integral aspect of the overarching suite of AIT capabilities, RFID will become a key technology enabler for the DoD logistics business transformation and will support long-term integration of the Unique Identification (UID) into the DoD end-to-end supply chain. RFID (both active and passive) is required by DoD to:

- Provide near-real time in-transit visibility for all classes of supplies and material
- Provide "in the box" content level detail for all classes of supplies and materiel
- Provide quality, non- intrusive identification and data collection that enables enhanced inventory management
- Provide enhanced item level visibility

Recent research has indicated that the potential for passive RFID applications is growing rapidly. As this growth occurs, more refined trouble shooting and maintenance procedure will be required.

3.2 Benefit Analysis

Our benefit assessment is based on interviews with P&G personnel and examination of the existing literature. The Table below summarizes the expected benefits from implementing performance monitoring for the current RFID systems.

The first column of the Table below lists the perceived benefit. The second column defines the supply chain management process affected by this benefit. These may include "Plan," "Source," "Make," "Deliver" and "Returns." Note that a single benefit may affect multiple supply chain processes. This column is based on the well-known Supply-Chain Operations Reference (SCOR) Model used to describe, measure, and evaluate supply

chain activities. Here we have adapted the typical SCOR methodology to apply to RFID implementations. The third column describes the metric most affected by the perceived benefit. The possible values in column three are "Speed," "Efficiency," "Reliability" and "Information Visibility." The fourth column provides comments that give more details on how RFID is expected to lead to the defined benefit. The final column lists the qualitative impact assessment relative to the other perceived benefits. This column corresponds to potential benefits to be achieved by P&G but also shared with other members of the supply chain. Ideally, these values would be replaced with actual dollar values, but this is not possible at the current time without extensive input from P&G personnel and further analysis.

Benefit	Supply Chain Process	Metric	Comment	Impact
Improved forecasting	Plan	Information Visibility	Better demand management	Low
Reduce down time	Make	Information Visibility	Ability to predict and prevent system downtime	High
Reduce response time	Make	Speed	Remote monitoring and recovery Automatic action initiation	Medium
Reduce labor for performance monitoring	Make	Efficiency	Reduced periodic inspection Reduced repair	High
Increased read rate	Make	Information Visibility	Improved RF benefits	High

Table 1: Expected Benefit Analysis from RFID Implementation

Impact on Supply Chain Risk

It should be pointed out that the table above considers those elements which are a direct result of performance monitoring. The real benefit of a successful PM program is the achievement of all of the benefits of RFID implementation within the supply chain. These include saving labor in moving goods throughout the supply chain, increasing the speed and accuracy of goods arriving to the right place at the right time, curtailing shrinkage, lowering inventory costs, increasing on-shelf availability and improving customer service levels. With 1.7 billion tags applied per year, the potential for failures can have a huge impact on P&G's bottom line. It is estimated that one particular promotional event (for the Braun CruZer shaver) could have resulted in lost revenue of "half a million dollars or more" (Roberti 2006) if displays were not active at the right time. RFID technology was used to ensure that displays were made available to consumers at the correct time. Multiplying this by the number of product rollouts and promotions, the risks are more than significant. A successful performance monitoring program can mitigate against this loss.

Implementing RFID within a facility can mitigate each of these business problems and result in a substantial return on investment. More importantly, the return on investment for RFID cascades for every additional problem addressed. The resulting return on investment grows even more rapidly as each new application is brought on-line.

Investment

The implementation of a RFID contains two cost components: a fixed cost consisting of the antennas and readers and a variable cost consisting of the "tags" that identify an asset or an individual.

RFID's substantial return on investment is due to its flexible nature. That is, once the fixed cost components are installed, they may be used for a variety of applications. Each new application addresses a business problem, which in turn increases the return on investment.

Potential Benefits Defined

- Reduce Down Time: Ability to predict and prevent system downtime
- Reduce Labor for Performance Monitoring: Reduced periodic inspection and repair
- Increased Read Rates: Improved RF benefits
- Reduced Response Time: Remote monitoring and recovery
- Improved Forecasting: Better demand management

3.3 Project Team

This project was conducted by a team of passive RFID and Academia professionals and supported by Procter & Gamble. The project team was comprised of Procter & Gamble, the Wright Brother's Institute, Alien Technology, University of Cincinnati, and Ohio University. The team members are described below.

Procter & Gamble

Three billion times a day, P&G brands touch the lives of people around the world. The company has one of the strongest portfolios of trusted, quality, leadership brands, including Pampers®, Tide®, Ariel®, Always®, Whisper®, Pantene®, Mach3®, Bounty®, Dawn®, Pringles®, Folgers®, Charmin®, Downy®, Lenor®, Iams®, Crest®, Oral-B®, Actonel®, Duracell®, Olay®, Head & Shoulders®, Wella, Gillette®, and Braun®. The P&G community consists of over 135,000 employees working in over 80 countries worldwide.

Wright Brothers Institute

The Wright Brothers Institute was the recipient of the grant and is the prime contractor for this contract.

Alien Technology Corporation

Alien Technology Corporation (ATC) was the sole subrecipient of the grant and provided overall program management as well as significant support through the RFID Solution Center (RSC) for training, integration facility support, and RFID solution engineering support. Alien Technology provides UHF Radio Frequency Identification (RFID) products and services to customers in retail, consumer goods, manufacturing, defense, transportation and logistics, pharmaceuticals and other industries. The RFID Solutions Center, a division of ATC, is the most advanced facility devoted entirely to the application of RFID technology. Open to enterprises, government agencies and their partners, the Center comprises 23,000 square feet of educational, R&D and real-world implementation resources designed to enable the global RFID community to tap the potential of RFID technology.

Department of Quantitative Analysis and Operations management College of Business, University of Cincinnati

University of Cincinnati developed the Business Case Study for this document

Wright State University

Wright State University performed the technical study for this document.

4 Methodology

This chapter describes the study and its phases.

4.1 Study Information

This study concentrate on two primary areas to be monitored: (i) monitoring of basic system status, and (ii) monitoring the overall system behavior. Monitoring the basic status is a method that helps troubleshoot and prevent problems with data collected by the RFID system. Monitoring the system behavior is a way to monitor the system by gathering reader statistics. There are several ways to achieve this, including monitoring the reader by either using the ping command or by using the Simple Network Management Protocol (SNMP). Another way to gather reader statistics is by measuring the system behavior by intrusive monitoring; which can be done by issuing commands to the reader to gather information about its internal operations, or by analyzing the information provided by the reader. While intrusive monitoring is possibly the most accurate method of obtaining information on a reader, a potential downside of this method is that the reader will potentially be unavailable during the monitoring process, affecting its normal operations. To avoid such problems, readers can be monitored using non-intrusive monitoring methods, which do not send commands directly to the readers, but coordinate with the middleware systems to extract reader performance metrics. Of course, designing such non-intrusive monitoring methods can be tricky because of the potentially proprietary nature of the middlewares being used.

There are several theoretical and statistical methods that could be useful in analyzing read rates; they can also show patterns in behaviors of the system and help graph the flow of tags. Average tag traffic volume is a measurement that helps you understand the flow pattern of the tags through the RFID system. Finding the ratio of read errors to total reads can help locate problems dealing with faulty tags, antennae, network connections, improper placement of antennas, improper tag types, signal interferences, or even low signal strength. The read error change rate can be used to determine the stability a system, and can also be used to identify some problems related to the reader's performance. Comparison between the actual tag traffic rate to the predicted tag rate can be helpful to detect anomalies in the performance characteristics of the readers. The expected failure rate over time can also be measured by using the failure rates of individual RFID components. This metric, typically known as the mean time between failures (MTBF), can help determine how reliable the system is. The data for these metrics can be acquired using intrusive or non-intrusive collection strategies. Many middleware programs and RFID software will automatically keep track of this data.

When installing an RFID system it is important to remember that the readers can only read items from a certain distance. Tag placement on items can be critical in achieving high read rates. Multiple readers may have to be set up and configured differently for different applications. When you are trying to diagnose reader failure, some things you need to check are the communication between the reader and the software application, the type and number of antennas being used, the type of tags, the firmware versions, errors in codes and power output, the positioning of the antennas and the position of the tags in the RF field, the power setting for each antenna, the antenna gain, and the length of the cables.

When trying to troubleshoot common antenna issues there are several possible solutions. If there is no signal reception, and the power and system connections are working, it is possible that either the RF cable has incorrect termination, or it may be improperly connected or it may have excessive transmission loss, or the antenna polarity of the receiving antenna is the reverse of the transmitting antenna. If a reader cannot communicate with the tag due to poor signal strength, you will need to check to make sure that all of the connections and cables are tightly attached. Irregular signal changes during the transmission and the reception can be the result of interferences from other equipment or possibly metal in the interrogation zone.

Since tags can be easily damaged, they can be interesting to troubleshoot. The problems can range from nonfunctioning tags to environmental conditions, such as temperature and humidity, and even interference. The integrated circuit of a tag can also be dislocated, if the silicon bonds in the semiconductor break due to stress or when an unexpected expansion within the silicon wafer takes place due to a sudden rise in temperature. Another possible problem is tag detuning, this can happen when several tags are being read in the same area, when metal and different dielectric mediums are near the tags, and a shift in resonance frequency from the operating frequency.

Many business operations have generated the demand for RFID technology to be connected to each other on isolated EPC networks in order to create a global RFID network. Middleware plays an important role in managing data and devices, while also providing strategic opportunities and functions. You must be able to make sure that your middleware can handle the scale of your operations, while also providing the correct security features. The network must also be able to handle the scale of what you need to use it for. Most RFID systems have at least one Reader Network Controller, which provides control and data-path interface to a reader network. The Simple Lightweight RFID Reader Protocol is a protocol that is used in an IP-based network to send and receive information on configuration, control parameters, status, and tag from readers. RFID readers can help manage network traffic; they can also act as a gateway between an IP network and the tags.

As companies today are spending more resources to research and implement RFID solutions, issues such as a preventative means to stop problems from ruining a project, increasing monetary costs, plus the over burdening the company with a lack of ROI are becoming more important. In addition, academic universities, like Wright State, could benefit from troubleshooting assistance for students learning RFID concepts in a lab environment. With this in mind, plus the RFID knowledge imparted in the aforementioned discussion, a troubleshooting guide was created that hopefully will be useful in solving many a persons' problem over time.

The primary purpose of this report is to aid RFID integrators, system administrators, and end-users with a guide to answer the following two questions, and provide a generalized method for reaching a solution.

I. Has a failure occurred?

The best way to see if a component has failed is to continuously monitor it and check if it is working properly. The two main ways to monitor are monitoring the basic status and monitoring system behavior. Monitoring the basic status uses a feedback system to notify the operator or system whether a read has been successful and how to respond to unsuccessful reads. Using read rates and read accuracy data to monitor system behavior can provide system behavior information.

II. What can cause a failure?

There are many possible issues that can cause failure of RFID hardware and software. By collecting and analyzing equipment and software service data over time, issues and trends can be found and future installation can benefit by modifications that eliminate the root causes to the failures. This information can then be used to build troubleshooting tools such as the one discussed in section six.

5 Results

As a guide to the type of issues that need to be resolved in order to monitor, troubleshoot, and prevent issues with the RFID implementation, the administrative personnel will need to systematically answer several questions that will either lead to solutions or other questions that need to be answered. A set of such questions is presented below. These questions provide a reasonable complete set of troubleshooting guidelines, and will provide the troubleshooter with a roadmap towards a solution to a current problem or the prevention of a potential problem with the system. For the purpose of clarity, we have divided the questions into 9 sections: (i) general questions addressing basic monitoring issues, (ii) environmental questions addressing issues with the interrogation zone, (iii) antenna related questions to address problems with antennas, (iv) network-related questions to address issues with the network, (v) tag-related questions to address problems with tags, (vi) metrics-based questions to address complex problems with interaction, (vii) middleware/code related questions to address software issues, (viii) cable-related questions to address problems with cables, and finally (ix) miscellaneous questions to address anything not covered in the other sections.

I. General Questions

1. What was the behavior of the reader before it failed?
2. Does the reader directly face another reader?
3. How focused or narrow is the read beam?
   a. A higher antenna gain plus link margin will occur if the beam is more focused and narrow.
4. Does the reader have any physical damage symptoms that may indicate that it isn't working correctly?
5. How old is the reader, antennas and cables?
   a. Return Material Authorization records
6. Has the reader been properly grounded to prevent damages that electrostatic discharge may cause?
7. Does restarting the reader restore its ability to operate?
8. Has your reader been intentionally or unintentionally bumped around or knocked out of place?
9. Is the reader configured properly?
10. Is the reader's power indicator light lit?
11. Were the reader and antennas installed properly?

II. Environment Questions

12. Are there any nearby devices that may have interfering frequencies that would cause the reader to not function properly?
13. What kinds of read unfriendly materials are around? (ex. Metal or water)

14. Is the Fresnel zone, or propagation path that the signal takes through the air blocked or obstructed?

III. Antenna Related Questions

15. Is the power level that feeds the antenna high enough to enable a proper read?
16. Are the proper antennas attached and are the tags you are trying to read aligned properly?

IV. Network Related Questions

17. Is the reader properly attached to the network?
    a. Use ping command or SNMP.
18. Are proper software and network processors installed to enable RFID readers to handle network traffic?

V. Tag Related Questions

19. Are you using the appropriate tag types with the prospective item you are tagging?
20. Are the tagged items within range of the reader?
21. Have the tags been properly placed on the item?
22. Is there an instance that the reader hasn't failed but that the tags have?
23. Does the tag you are attempting to read have enough dwell time in the interrogation zone?

VI. Metrics-based Questions

24. Has there been a steady increase or fluctuation in the read rate?
    a. This may indicate a fault in either the design of the system or in the hardware.
25. What kinds of results are being produced by formulas such as the actual versus predicted traffic rate?
    a. APTR values can be used to detect anomalies in the performance characteristics of readers.
26. Was the link margin or some of the RFID equipment losses/gains calculated correctly?
    a. These calculations improperly figured could lead to improperly tuned antennas and thus reader failures.

VII. Code/Middleware Questions

27. Is your program code that triggers the read as you really want it?
28. Is the RFID middleware properly monitoring RFID reader network traffic and filtering useful information?
29. Are the I/O devices and reader software functioning properly?
    a. If not, they may indicate that the reader is not functioning properly when it really is.
30. When was the reader firmware software last upgraded?
    a. In terms of ISO standards, the software/hardware may no longer be compatible.
    b. According to best practice, when purchasing readers, one must make sure that the item is forward compatible with what may be coming out and that the reader contains a digital signal processor chip which is upgradeable.
31. Is the RFID middleware appropriate for the system?

VIII. Cable/Accessory Questions

32. Have you changed the cable length, connector, adapters, or environmental conditions to where the RFID system signal is reduced?
    a. Bandwidth is reduced and transmission is delayed by lengthening a transmission line.
33. Is the reader equipment compatible with the rest of the RFID system components?
34. Is the connection medium between the reader and host operating/functioning properly?
35. Has the power supply failed?
36. Have you used a spectrum analyzer to test for path loss and verify the strength of the interrogation zone RF field?
37. Do you have the right power supply for the reader?

IX. Miscellaneous Questions.

38. Was a site survey performed prior to the installation of the RFID system to help identify and eliminate interference effects in an environment?

6 Conclusions

Based on the above questionnaire, and a rudimentary dependency characterization of the questions, a basic troubleshooting wizard is currently being prototyped to test the feasibility of the approach. The initial tests with this prototype show the viability of such a system. To be successful, a more intelligent system capable of weighting the questions to determine the "correct" sequence of questions needs to be developed, which is beyond the scope of this report. However, for the reader's curiosity, some screen shots of this wizard are shown below:

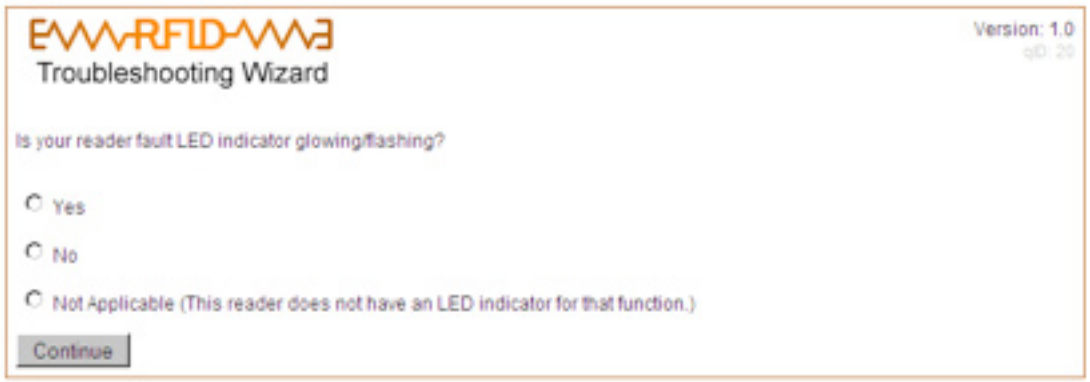

Fig. 1. Screenshots from the troubleshooting wizard prototype

6.1 Feasibility

The initial experiments with the prototype and troubleshooting of real hardware at the RFID lab at the Raj Soin College of Business show the feasibility of this methodology and potentials of an actual implementation.

6.2 Summary of Results

The nature of this study was limited, and utilized a limited number of tests and time spans that do not necessarily reflect all scenarios. This study was intended to examine the potential benefits of implementing performance monitoring and troubleshooting techniques to support the improved up time of RFID implementations. The study has identified potential benefit areas and cost concerns.

While full preventative maintenance impacts were not able to be accurately projected through the limited nature of the study, it has been shown that improvements to the efficiencies of current passive RFID technology is capable by monitoring the performance of implemented RFID systems and taking pre-emptive measures to ensure the optimal performance of all equipment.

6.3 Next Steps

Our preliminary analysis has identified potential benefit areas and cost concerns. Next steps include the development of a pilot project that would 1) quantify cost reductions and revenue enhancements made possible by RFID implementation; 2) evaluate RFID implementation strategy under alternative operating conditions. This pilot is expected to involve small scale practical tests to determine the parameters of an RFID implementation. The full RFID system implementation and testing alternative configurations would then be modeled using simulation. Simulation is the use of computers to "imitate, or simulate, the operations of various kinds of real-world facilities or processes" (Law and Kelton 2000). Simulation models allow for performance evaluation of complex operating systems under many different conditions in a timely and cost-effective manner.

7 APPENDICES

7.1 Appendix B: Reference Documentation

The following documentation was developed or referenced to complete this activity:

ID	Document Name
1	Loftware RFID Reader Solutions User's Guide. Version 2.x. Visited through Google on 4/12/2007. http://loftware.com/documents/rrm/rrm.pdf
2	RFID Switchboard Visited 4/15/2077 http://www.rfidsb.com/
3	Unit 10: Monitoring and Troubleshooting. *CompTIA RFID+ Certification*. Boston: Thomson Course Technology, 2006.
4	Wiesenfield, Ira and Robert Smith. "Antenna System Troubleshooting Simplified." Mobile Radio Technology. Visited 4/15/2007. http://mrtmag.com/mag/radio_antenna_system_troubleshooting/
5	Sirico, Louis. "Tag It Right!" RFID Wizards.com. Visited 4/15/2007. www.rfidwizards.com
6	Collins, Jonathon. "P&G Finds RFID 'Sweet Spot'". *RFID Journal*. May 3, 2006.
7	Gilmore, Dan. "Procter & Gamble on RFID/EPC." *Supply Chain Digest*. February 9, 2006.
8	Law, Averill M. and W. David Kelton. *Simulation Modeling and Analysis*, 3rd Edition, McGraw Hill, New York, NY. 2000.
9	Nakra, Jahinquir. Personal correspondence with authors. June 2007.
10	Roberti, Mark. "P&G Adopts EPC Advantaged Strategy." *RFID Journal*. January 24, 2006.

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