Implementing Automatic Identification Technology to Improve the Construction of Naval and Commercial Ships

by

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Abstract

Automatic identification technology has been shown to provide significant improvements to business operations, especially in material control systems. Shipyards spend a great deal of time, money and labor to locate materials throughout the site. Automatic identification technology can provide shipyards with savings in capital and labor when locating, tracking and managing assets.

This thesis impartially explores the possibility of implementing automatic identification technology to benefit the ship construction industry. As part of this analysis, a material handling operation from an existing shipyard was examined. The existing process was simulated using a computer model. The future process and simulation model with identification technology was proposed and developed. The results were compared objectively to quantify potential gains from the use of automatic identification technology.

A representative return on investment analysis of introducing the new technology quantifies the benefit of streamlined material handling and fewer missing items. The technology must be implemented properly into the existing system in order to achieve the proposed benefit. The ability of the shipyard to effectively overcome the challenges of implementing automatic identification technology will determine the success of the system. This thesis presents a method to analyze the introduction of automatic identification technology in a shipyard and implement the technology to realize all of the promised benefits.

Thesis Advisor: Professor Henry S. Marcus
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Chapter 1 Introduction

Automatic identification technology has been shown to provide significant improvements to business operations. One branch of automatic identification technology is radio frequency identification (RFID) technology and it is maturing at a rapid rate. RFID has been proven to provide benefits in a wide variety of industrial applications. The goal of this thesis is to impartially explore the possibility of implementing this technology to benefit the ship construction industry. Shipyards spend a great deal of time, money and labor in locating materials throughout the site. RFID can provide shipyards with savings of their capital resources and labor when locating, tracking and managing assets.

A shipyard is an industrial operation that requires some developed form of material tracking and control requirements. A large shipyard's materials are typically spread out over many buildings and shops and in some cases off-site warehousing. There are typically thousands of pieces moving through the yard daily. This large volume of material requires extensive control and tracking procedures. Additionally, any number of personnel may have access to the parts. Yards may attempt to monitor part movements in conjunction with the person moving the part.

In ship construction or modification, materials can have rather high costs. In addition, the cost of losing the part may be many times greater if it is critical to the completing the next step in the construction. Often, a relatively inexpensive part will have a significant lead-time. Reordering a part with a six-month lead-time could delay the delivery of the ship. The resulting cost to the yard would then be many orders of magnitude greater than the actual cost of the part. Thus, shipyards need to be very careful with their material tracking processes. Exacerbating the problem, there are cases where items may sit in storage in the yard for long periods of time before being needed. This situation results not only in large storage volume requirements, but also increases the chance that material will be misplaced.

The importance of material tracking over this large area has often produced a bureaucratic style system. Complying with the material control procedure requires a large amount of labor, generates a lot of paperwork and results in only modest success. During a transfer or storage, material is inventoried either visually or using bar codes and requires labor time from both the receiver and the deliverer. Typically, shipyards have created their own material control database to control and track the movement of parts throughout the yard. Often the level of sophistication of this database is dependent on the tracking system in place on the ground. When a part slips through the cracks of this system, many man-hours may be spent locating the part and filling out paperwork regarding the missing part. Additionally, many more man-hours are necessary to maintain and enter data into the material control database.

RFID technology has the potential to enhance and eliminate many of the material control processes in a shipyard. Many of the most time consuming operations, such as inventory and searches, could be performed quickly and automatically using RFID. This would greatly lower the labor requirement to perform the material control tasks. The rate of lost items would become miniscule. Also, retrieving an item in storage will become a more fruitful search. Additionally, processing time for part transfers will be reduced, letting the personnel get back to their main work task quicker. All of these improvements will ultimately benefit the production rate at the shipyard.

As RFID continues to develop, the cost of the technology decreases. Depending on the choice of RFID system, the technology can be purchased at a very reasonable price without using a huge amount of shipyard capital. RFID offers a relatively low-cost option for many companies to improve their current level of material control. RFID improves the ways businesses gather and use information concerning material movement, location and distribution. If properly implemented, this increased use of data has the potential to reduce overall costs and improve operations. The shipyard is likely to see a return on its investment within a reasonable amount of time.

This thesis explores the use of automatic identification technology in the shipyard environment. No partiality was given to any specific technology vendor. As part of this analysis, a material handling operation from an existing shipyard was examined. The existing process was simulated using a computer model. The future process with RFID was proposed and developed. A simulation model of the RFID process was then created. The results were compared objectively to quantify potential gains or losses from the use of RFID.

The following methodology was used to determine the potential success of an RFID application in a shipyard. First, the current problems at the shipyard were identified. The difficulties facing the shipyard in its material locating procedures are discussed in Chapter 2. Next, a tool to replicate the current process and simulate the proposed new processes is selected. The theory and procedure to use the tool effectively is described in Chapter 3. Then, the processes surrounding the current material movements are modeled and validated. The description and development of the model along with significant assumptions are presented in Chapter 4. The potential solutions to the problem are then researched and explored. An explanation of radio frequency identification technology and a description of current RFID products are discussed in Chapter 5. In Chapter 6, the changes in the material control processes due to the introduction of RFID technology are described. In Chapter 7, the results of the simulation models are presented and analyzed. Additionally, the model results are used to perform a return on investment analysis on the new technology.

Finally, the solution technology must be implemented into the existing system. Some of the major hurdles and key factors involved in implementing a new technology system are discussed in Chapter 8. Conclusions, recommendations for further work and predictions for the future are presented in Chapter 9.

Chapter 2 Problem Identification

Material handling is an important issue at all industrial facilities and a shipyard is no exception. Portsmouth Naval Shipyard is a naval vessel repair yard, which provides periodic maintenance and upgrades for boats. Many of the materials at Portsmouth Naval Shipyard are critical. Portsmouth has been experiencing a high rate of lost items and has been devoting many hours of labor tracking down the items. While the monetary value of some pieces may not be substantial, parts can be very specialized and unique to the specific boat being repaired. These parts could require a lead-time of up to six months to be replaced. Also, items occasionally cannot be found and must be repurchased. The total resulting cost from all of these losses can be very high. The boats have a limited amount of service time between refueling. Any time lost while in the shipyard is lost time and reflects poorly on the shipyard.

Recently, the shipyard introduced bar coded tags into the material tracking process. Implementation of this enhancement has brought some accountability to the material movement process, but it has not solved many of the problems. To better predict the impact of an automatic identification technology it is imperative to fully understand the current material control practices at the shipyard.

The typical work cycle for the yard consists of three phases: 1) the rip out or unship phase, where parts are taken off the boat, 2) the repair phase where parts either on or off the boat are repaired or replaced, and 3) the reinstall phase where repaired or stored items are installed back on the boat. The material control process deals with not only the physical movement of parts but also the tagging requirements, database management and personnel responsibility aspects of material handling.

QA2 Tags

When a boat comes into the yard, engineering and planning personnel board the boat. They determine all of the pieces that must come off the boat to be repaired or replaced. Also parts will be taken off the boat if they are creating an obstruction. For example, a valve may be in the way of a pump in another piping system. This part will be taken off the boat and placed in storage.

The engineering and planning group relays the information from its survey to the work packaging group. The work packaging group creates the QA2 tags. QA2 tags are documents that must be on every part that comes off the boat. Each QA2 tag has the following information:

- Item yard internal serial number, which has the boat number, the shop number and the sequential part number
- Item's actual serial number which must be entered manually, by the craftsman removing the part from the boat

- Item description
- Job order number for all phases of the construction and the key operation number
- Information regarding the rip out work, the shop number, remarks about the part and the subsequent destination of the part, the signature and badge number of the craftsman performing the work and the date
- Information regarding the transfer of the material, the shop number, remarks about the part and the subsequent destination of the part and the date
- Information regarding the repair or storage phase of the work, the signature and badge number of the craftsman performing the work and the date; this indicates that all of the work has been completed satisfactorily
- Information regarding the installation work, the shop number, remarks about the part and the subsequent destination of the part, the signature and badge number of the craftsman performing the installation and the date

The work packager estimates how many pieces a unit will be separated into before coming off the boat. The estimates are based on experience or the input of an engineer or a shop foreman. The software used to generate the tags and maintain the material control database is called SEWS. The program is difficult to navigate through and not very user-friendly. Often the work packagers use conservative estimates, since it is easier to create another tag as needed than it is to delete an extraneous tag from the system. The QA2 tag is then delivered to the shop supervisor to be distributed to the craftsmen on the boat. Accompanying the QA2 tag is the task group instruction document that instructs the craftsman on the part removal and gives drawing references or the actual drawing to aid in the work.

Rip Out Phase

Once the laborer, usually from the mechanic shop, rips out the part, he or she completes the appropriate section of the QA2 tag. Then, the tag is attached to the part with either metal wire or a plastic tie. The part is then delivered to its specified destination. The part will be headed to one of the various shops or into the storage warehouse. Often, the laborer will leave the part on the boat or just off the boat before it gets delivered. The laborer can rip out more parts and deliver a few parts during the same trip. This action is understandable and likely more efficient. The mechanic's job is to rip out parts. The more time he spends walking around the yard, the less he will get ripped out. Unfortunately, there are very few places on the boat or off the boat that are not in somebody else's way. Parts that are left around to be delivered are frequently moved out of the way. This causes a delay in locating the parts and can result in missing parts.

Once the part has been ripped out, the craftsman enters his/her badge number and signs the QA2 tag. The craftsman is then responsible for the part until it is processed and accepted at the next location. At the repair shop or the SEWS warehouse, the same check-in process occurs. The receiving clerk must enter several pieces of information into the shipyard's material control database program, SEWS. When a part enters the new location, it must be considered sold to that location in the SEWS database. The clerk must enter his badge number, the deliverer's badge number, the shop location and the part's serial number. With the most recent boat arrival, all of these items now have bar codes on them. Unfortunately, the implementation of even the simple bar code technology has been slow. It has not yet achieved full acceptance with the workers. Most of this information is still entered into the program manually. The clerk then must sign the appropriate portion of the QA2 tag. This signifies the part status as received and transfers responsibility of the part to the receiver. Additionally in the SEWS warehouse, the clerk must enter another section of the program to properly store the item. The part serial number must be entered and the appropriate bin for the item must be found and entered into the program. This process is supposed to be replicated during any transfer of a part.

After a part is checked into the SEWS warehouse, it is placed in a numbered bin. However, all parts must be cleaned before they may be refitted on the boat. The cleaning facility is located adjacent to the storage facility. The personnel performing the cleaning simply take parts from the bins and bring them into the cleaning area. Once cleaned, an orange tag is fixed to the part, allowing it to go back on the boat. No record is made in the SEWS database when a part is taken from the storage warehouse for cleaning. If a part is not in its specified bin, the SEWS clerk must look to see if it was taken for cleaning. Also parts that remain in the shops and never go into the warehouse presumably do get cleaned. However, they do not necessarily receive the orange tag.

Repair Phase

The rip-out phase generally takes a couple of months to finish. Once complete, parts are then repaired during the next work phase. During this time, there is still quite a bit of material movement. The repair shops have a limited amount of space to repair and store material. Some parts could first go into storage, and then be transferred to one of the shops to be repaired when space in the shop is available. Also, once a part has been repaired, it could go into the SEWS warehouse to free up space in the shop. Parts may also move between shops if the repair work on the item crosses two disciplines. For example, an electronically controlled pump may have problems both with the solenoid and the impeller. Keeping the part intact, it could be repaired at the electronic shop first and the mechanical shop later. When work on a part is completed, the craftsman must sign, date, enter his/her badge number and any remarks about the part on the QA2 tag.

Reinstall phase

Once most of the repairable parts are ready and the replacement parts have arrived, the reinstall phase can begin. Parts being installed on the boat are coming from the SEWS warehouse or from any one of the repair shops. The craftsman must go to the shop or warehouse and "buy" the part. The part number and badge numbers of the seller and buyer must be scanned or entered in manually into the SEWS database. The craftsman again takes ownership of the item and installs it on the boat. Once the installation is complete, the final blocks of the QA2 tag are filled out. The installing worker's badge, signature, date and any remarks are to be written on the tag. The QA2 tag is then taken off the part and filed with the task group instruction document as complete. Entering the part as reinstalled in the SEWS database is the final step in the material control of that part.

Problem Discussion

The processes in place at Portsmouth do address the issues of identifying the parts, personnel taking responsibility for the parts and the work being performed on the parts. However, there are several places in the system where full compliance of the processes is lost or proven to be ineffective. First, the most obvious potential error is the possibility of the tag falling off the part. The QA2 tag is a paper tag attached to a part with a metal wire or a plastic tie. A shipyard is a construction site. There are thousands of ways to snag a piece of paper dangling off a part on something. Additionally, there is the weather to contend with in New England. Portsmouth did address this problem by placing the tag in a plastic bag. This does protect the tag from the weather, but it is still vulnerable to being ripped off the part.

There are problems with personnel leaving parts unattended. As mentioned earlier, people leave items just outside of the boat. Forklifts move the items out of the way and they become misplaced. Also, another situation arises upon the delivery of parts from the boat to the shops or the SEWS warehouse. If no one is there to check the parts in, the items may be just dropped off at the front. While the deliverer still has the responsibility for the part according to the SEWS database protocol, he has chosen not to follow this procedure. Understandably, he may not want to sit around and wait or carry the part back to the boat and try to deliver it again. Both of these options would not be productive. However, leaving the parts without seeing them checked in can lead to parts being misplaced, misrouted or permanently lost.

Since it exists in every yard and construction site, security is a problem. Items left to be checked in can easily be taken. Because they have not been checked in to the next location in the SEWS database, it becomes impossible to track the item. Personnel may not even be interested in stealing items. Personal conflicts may cause a person to hide an item simply to make life difficult for the personnel responsible for the item.

Further exacerbating the problem is the need to fill out the deficiency log. It is not a bad practice to record the problems when they occur. However, it adds further to the time spent due to a lost part. If the number of deficient items is decreased, then the time spent filling out deficiency logs will also be reduced.

Bar Code Technology

Portsmouth has just introduced bar code technology into their material control system. It is useful to understand the bar code technology being used at Portsmouth as well as the state of the art technology of bar codes. Bar codes, which consist of an array of narrow rectangular bars and spaces within a given symbology, permit scanners to capture data and submit it to a central computer system. This approach greatly improves accuracy and efficiency over manual data entry methods. The major drawback of this technology is that it requires a close line of sight to read. As a result, the operator is required to properly position the material in front of the reading device. Its strengths are that these devices are inexpensive, disposable, and are common in a wide array of businesses throughout the industrialized world. Some drawbacks to the technology are as follows: they are static codes, meaning they cannot be changed, they have very limited data storage capability, they have a very low tolerance to damage and they require a lot of human involvement to perform a successful read.

There are two principal types of bar code technology in use today. They are known as linear bar codes and two-dimensional (2-D) bar codes. The linear bar code is the version being used at Portsmouth. The linear bar code method is employed on most products in the commercial sector via the UPC symbol, and to a large extent by Department of Defense for general logistics material.

Two-dimensional bar codes offer substantial benefits over the traditional linear bar code. 2-D bar codes can hold substantially more data than the linear bar code (1850 characters versus 20 characters). Also the 2-D bar code is more tolerant to damage due to check sum parameters in the data field. Thus, the 2-D bar code permits more rapid scanning with improved accuracy. UPS developed such a symbol to increase the speed of their scanning lines to hundreds of feet per minute. This 2-D bar coding technology is also being used for ID card applications.

Employing bar codes at Portsmouth does have the potential to improve the material control system. While the linear bar code certainly does not represent a state of the art technology, it can help to reduce errors in entering information into the SEWS database. Additionally if the technology was properly implemented, processing times for the material transfers could be reduced. A description of modeling the current material control system is presented in Chapter 4.

Chapter 3 Simulation Modeling

Simulation modeling was chosen as the most effective tool to evaluate the performance of a new technology being introduced into a material handling process. The approach in this task emulates the scientific method as it follows the same thinking that has been employed by other process modeling philosophies such as IDEF and Kanban. The current process as it is without the technology is developed as the baseline case. The changes in processes that the new technology will induce are then modeled as the proposed future case. The differences in the performance of the overall system and any segment of the system due to the newly applied RFID technology can then be easily observed.

Algorithm Development

While singular processes can be defined, observed and analyzed manually, the interaction of one of these processes with one of the many others occurring simultaneously is very difficult to predict. Also, the discrete events that make up an entire operation may be enumerated, albeit a large number. However, the interactions between all of these events can be too many to count. Thus, the need for a software tool arose.

Many manufacturing companies have recently begun using simulation modeling software to analyze and optimize their production processes. These computer programs allow users to model complex processes on the computer and to then modify them and experiment in order to optimize overall performance. Simulation modeling tools are extremely effective because they have the capability to simulate complex systems that involve interactions between multiple processes.

ProModel

The particular tool used in this study is ProModel, a discrete event program written and distributed by the ProModel Corporation. The software has become one of the standard programs used by the manufacturing industry to analyze production processes. ProModel is a simulation tool to help improve the design and operation of manufacturing systems. This type of simulation modeling aids in eliminating bottlenecks, improving operating efficiency, reducing lead times, improving resource utilization and reducing inventories.

In ProModel a production system is viewed as an arrangement of processing locations such as machines or work stations through which entities such as parts are processed. A system may also include supporting resources such as operators and material handling equipment to aid in the processing and movement of entities.

Model Development

In building a model, the user is first required to define the overall layout of the system and is then required to describe the logic of operation for each individual event. The physical layout of the system is defined, including locations of events, paths of movement, description of material and identification of personnel and machinery operating the system. Variables are described, such as the rate at which material enters the system and the down times of particular resources.

In defining logic for each discrete event, the user must capture the actual operation of the real-life resources. Factors described in the logic include material used during the event, time required to process material, personnel required to complete the process, man-hours required, the output products of the process and the destination of the material once complete. Processing logic and other decision logic can be based on one of many built-in rules or on logic defined by the modeler. The logic is used to make decisions at each step. How the following decisions are made must all be carefully defined: the order in which items are processed, the use of particular workers, the distribution of products and the variability in processing. It is the interactions between the logic for each individual step that the program uses to determine the operation of the overall system.

Typically, the first step in creating a process model is to survey the actual operation of the current system on-site. All the factors that must be used to define the physical layout and logic description are observed and recorded. Obviously, in some cases, it can be difficult to obtain exact data on the system operation. In these cases, best estimates must be made, based on observation and experience. Data obtained in this stage is concerned with the operation of each individual element of the system.

Once the data has been obtained from the actual process, an initial model can be built. The physical layout and the logic can be programmed into the simulation, along with the estimates for the variables used in operation. The simulation is run and results calculated for the overall operation of the system. During the simulation, ProModel displays an animated representation of the system and gathers statistics on performance measures that are later automatically tabulated and plotted.

Verification

Once the initial results are produced and evaluated, they are then compared to the operation of the complete real-life system. Data is obtained from the actual system on overall performance and operation. The results of the model are analyzed in comparison to the real-life data to find deviations. After any irregularities are found, the logic, layout and variables in the model are analyzed to determine the source of the errors. This process can be time-consuming and may require numerous iterations before the performance of the simulation model corresponds to the real-life system. The process of fine-tuning the model is extremely important, however. In order to perform analysis of changes to the system and to optimize operation, the performance of the current processes must be accurately modeled.

In addition to checking the performance of the simulation to the actual system, a sensitivity analysis is also usually performed on the simulation model. In this analysis, input variables to the system are individually varied in small increments over a reasonable range and the model is rerun for each change. The outputs for each run are analyzed to determine the effect of the changes in the variables on the performance of the overall system. This type of analysis determines which variables have the greatest impact on performance and if there are certain ranges in which variables have extreme effects on results. This data helps in the running of the model and in the future optimization of processes.

Once a robust model is completed, experiments can begin on the simulation. Changes in layout, manning, variables and decision logic can be included in the model and the overall performance calculated. These results can then be compared to the baseline model to determine the effect on the operation of the system.

Simulation and Optimization

If an optimization of a particular process is to be performed, multiple runs must be completed with varying modifications to the model. During these runs, changes to the model must be made in an organized, incremental manner. Results must then be examined to determine the effect and degree of change to the model results. Additional changes, based on the results can then be made until an optimal solution is found.

Chapter 4 Current Process Simulation Model Development

Creating the baseline model is the next critical step in determining the value of an automatic identification technology in a shipyard. The model cannot be developed without making one or more site visits and interviewing the managers and actual users of the current system. These steps could not have been completed without the great help of several people at Portsmouth.

All of the critical areas in this process were observed. Speaking with the managers and personnel in work packaging lent a large amount of knowledge on the generation and life of material documentation. Also the advantages and disadvantages of the SEWS database were discussed. The clerk at the SEWS warehouse not only shared a lot of information about the practical workings of the material movement process, but also another perspective and functionality of the SEWS database. Additionally some valuable documentation was provided regarding the material control procedures. With all of this information gathered, the model could begin to be developed.

Locations

The locations of the areas involved in the process were the first parts of the model to be defined. The locations present in the model are:

- Boat

- SEWS Warehouse
- Cleaning Area adjacent to SEWS Warehouse
- Electrical Shop
- Mechanical Shop
- Pipe Shop
- Work Packaging Office

Each location must have a capacity value associated with it. For purposes of this model all of the locations were assumed to have capacities equal to four thousand entities. This figure is believed to be the best estimate for a work cycle at the shipyard. A future enhancement of the model would be to obtain the actual quantities. Unfortunately, that data were unavailable to be included in the model.

Entities

An entity is any item that moves through the model and has work or a process performed on it. The following entities were defined in the model:

- Part
- QA2 Tag
- Cleaned Tag
- Tagged Part
- Cleaned Tagged Part

Arrivals

The parts, QA2 tags and cleaned tags entity types are further defined as arrivals. Arrivals enter the system with a defined number and frequency at a certain location. For purposes of this model the number of parts was assumed to be four thousand. Thus, there are four thousand QA2 tags. The number of cleaned tags is also set at four thousand. However, only the portion of parts that enter the warehouse will need cleaned tags. So, some cleaned tags will go unused. All of the parts arrive in the model at the boat at the very start of the simulation. The QA2 tags are generated in work packaging at a rate of one every fifteen minutes. The cleaned tags are generated at the SEWS warehouse cleaning area.

Path Networks

Entities and resources move physically throughout the model along path networks. Additionally, path networks interface with the locations; connecting the various locations along a path. Path networks can be created to replicate exact distances between various locations on the site, even if the graphical display of the model is altered. In the case of the Portsmouth model, the distances between locations are not crucial. Although the layout may not be optimized, the distance and time spent in the actual material movement are not major concerns, nor would they be rectified by an RFID system. Three path networks were defined in the model:

- QA2 Tags Route
- Cleaning Route

- Parts Route

The QA2 tags route runs between the work packaging office and the boat. The boat is connected with the shops and the warehouse through the parts routes. The cleaning route links the SEWS warehouse and the cleaning area adjacent to the warehouse.

Resources

Resources move entities along the path networks in the model. At the Portsmouth site, all of the resources being considered are people in various positions. Portsmouth does have forklifts to move larger items. However as mentioned earlier, the movements themselves are not an issue in this application. The different tasks performed by personnel in the model are:

- Laborer
- SEWS Clerk
- Work Packager
- Finder

For each resource, a quantity, a home base and speeds, both when carrying an item and when empty, are defined as attributes of the resource. The resources were assumed to travel 150 feet per minute when empty and 100 feet per minute when carrying a part. This equates to speeds of 3.67 and 2.44 miles per hour, respectively. Four laborers were included, whereas the other resources have a quantity of one. The laborers and finder make their home base at the boat. The SEWS clerk is in the SEWS warehouse and work packager is at the work packaging office. The finder is actually another laborer. A separate resource was created to discern between the amount of time spent during normal operation of the laborers and the time spent finding misplaced items.

Processing

The processing portion is what makes the model tick. Every movement of every entity must be defined as a process. In addition to moving entities, the processing logic can be much more powerful in functions such as maintaining attributes, interrogating variables and manipulating entities and resources. In the Portsmouth case, most of the processes were movements and processing times, such as attaching QA2 tags, transferring ownership and entering data into the SEWS database. These times were specified using a standard normal distribution with a standard deviation equal to one-fourth of the mean time. The following processes were modeled as the Portsmouth current baseline case:

1. The QA2 tag arrives (created by the work packager) at a rate of every 15 minutes.
2. The QA2 tag is delivered to the boat by the work packager.
3. The work packager stays at the boat for 10 minutes to properly give and discuss all of the instructions.

4. The laborers are ripping out the parts on the boat. While the laborer is ripping out the part, he spends 15 minutes reading, filling out and attaching the QA2 tag and task group instruction.
5. The parts that have been tagged successfully are now known as tagged parts.
6. The tagged parts are delivered by one of the laborers to one of the following four locations: the SEWS warehouse, the electrical shop, the mechanical shop or the pipe shop. The model was permitted to choose the destination using a random function. This was chosen as the method to best simulate the actual occurrences in the shipyard. No one destination is biased; each has the same chance of receiving a part ripped out of the boat.
7. When the laborer reaches the destination with the tagged part, he spends 10 minutes checking the tagged part into the destination.
8. Additionally, this process occupies the clerk of the shop or the warehouse for the same amount of time. For this model, only the SEWS warehouse clerk is affected.
9. Tagged parts that have entered the SEWS warehouse must be cleaned. The tagged part stays at the SEWS warehouse for 10 hours. It is then moved by the SEWS clerk over to the cleaning section of the warehouse

10. The tagged part spends 5 hours at cleaning. A cleaned tag is attached to the part already tagged with a QA2 tag. This part is now known as a cleaned and tagged part.

11. The cleaned and tagged part is then moved back into the SEWS warehouse by the SEWS clerk. There is no time allotted for any checking-in or checking-out process involving a move between the warehouse and cleaning. This is because, no information is recorded into the SEWS database regarding the move.

12. Cleaned and tagged parts re-entering the SEWS warehouse stay there until being re-installed on the boat or they may be transported to one of the repair shops. It was assumed that 55% of these entities remain in storage at the warehouse, while the remaining 45% of the entities may be routed to one of the shops. Each shop has a 15% chance of receiving a cleaned and tagged part from the SEWS warehouse.

13. Cleaned and tagged parts that are tabbed to leave the warehouse to one of the shops must be checked out. This process requires the laborer and the SEWS clerk to spend 10 minutes together checking out the cleaned and tagged part.

14. The laborer delivers the cleaned and tagged part to the designated shop. Once again, the laborer must spend 10 minutes at the shop checking in the part.

15. The cleaned and tagged parts may either remain in the shop after the repair or they may be shipped back to the SEWS warehouse. These

are all of the possible movements for cleaned and tagged parts during the rip out and repair phases of the work cycle.

16. Those tagged parts that came off the boat and were delivered and checked into the shops by a laborer also have possible further movements. At each shop, there is an 80% chance the tagged part will remain at the shop for the duration of the work. 20% of these tagged parts will be moved into the SEWS warehouse for storage. These tagged parts must be first checked out by a laborer, which takes 10 minutes. Upon delivering the entity, the laborer and the SEWS clerk must check in the item for another 10 minutes.
17. These tagged parts entering the SEWS warehouse then go to cleaning and become cleaned and tagged parts. These entities then follow the processes for the other cleaned and tagged parts.
18. As mentioned in Chapter 2, there are many instances in this process where something can go wrong. It was assumed that 5% of the time items would be simply misrouted. The error would be realized upon or shortly after check in. Another 5% of the time it was assumed that a part would be lost. Its destination or location is unknown. To account for all of the possible errors, 10% of the parts will be shipped off the boat as parts without tags.
19. The parts are delivered off the boat by a laborer. The destination logic used for the untagged parts is the same that was used for the tagged parts.

20. The laborer attempts to check in the parts with the clerk. Half of the time the part is rejected due to the error.
21. The finder reports to the shop or the warehouse. The finder fills out the deficiency log. This was assumed to take 15 minutes.
22. The finder brings the part back to the boat.
23. Work packaging is then notified. A work packager delivers a tag for the part. The work packager and the finder each spend 15 minutes dealing with the part.
24. The finder tags the part. The tagged part is then routed like the normal tagged parts.
25. The other 50% of cases are dealt with slightly differently. The part has been entered into one of the shops or the warehouse. However, the part has not been registered with the SEWS database and it is therefore essentially lost. It was assumed that the finder spends 2 hours at each location attempting to track down the part.
26. Once the part has been found, the finder spends 30 minutes filling out the deficiency log.
27. The finder brings the part back to the ship like the other parts. The part is tagged and routed accordingly.
28. The lost parts can occur at any time during the rip out and repair phases.
29. Now that all of the parts have been tagged, and are off the boat, the reinstall phase can begin.

30. The laborers go from the boat to one of the shops or the warehouse to pick up an entity. The laborer must take ownership of the entity. At the warehouse, the SEWS clerk makes the entry in the SEWS database. This process takes 10 minutes.
31. Tagged parts and cleaned and tagged parts are delivered from the shops and warehouse to the boat by the laborers.
32. The laborer spends 10 minutes on each part filling out the final portion of the QA2 tag and filing the documentation.

Attributes and Variables

Entities can be manipulated to maintain user-defined attributes. This feature allows for more sophisticated processing logic to be employed. By assigning values to the QA2 tags and the parts, each QA2 tag is matched up with its corresponding part. Variables were used in several places throughout the model, such as determining which parts will get lost and controlling the graphical display counters during the simulation.

Simulation Parameters

The number of parts chosen for the simulation was four thousand, which represents a typical scenario at the shipyard. Additionally, the sampling is large enough to encounter all of the possible outcomes. A larger number of items will not shine any new light on the model. It would be repeating previously encountered situations.

The simulation run time was chosen as 3500 hours. The chosen simulation run time really just needs to allow enough time for all of the parts to come off the boat, be stored or repaired and returned to the boat. Assuming a forty-hour work week, the rip out phase was assumed to take just over six months to complete (1000 hours). The repair phase lasts approximately five months. The reinstall phase can last up to seven moths. The three phases add up to a total of 18 months, which is the typical work cycle for a boat coming into Portsmouth. These are not actually discrete phases either in practice at the shipyard or in the model. There is a degree of overlap during each of these phases. Parts ripped out of the boat can be repaired shortly after. Again, parts are being reinstalled on the boat while some are still being repaired. Please see Figure 1 for the physical layout of the current process model at Portsmouth. The results of the baseline model are analyzed in Chapter 7.

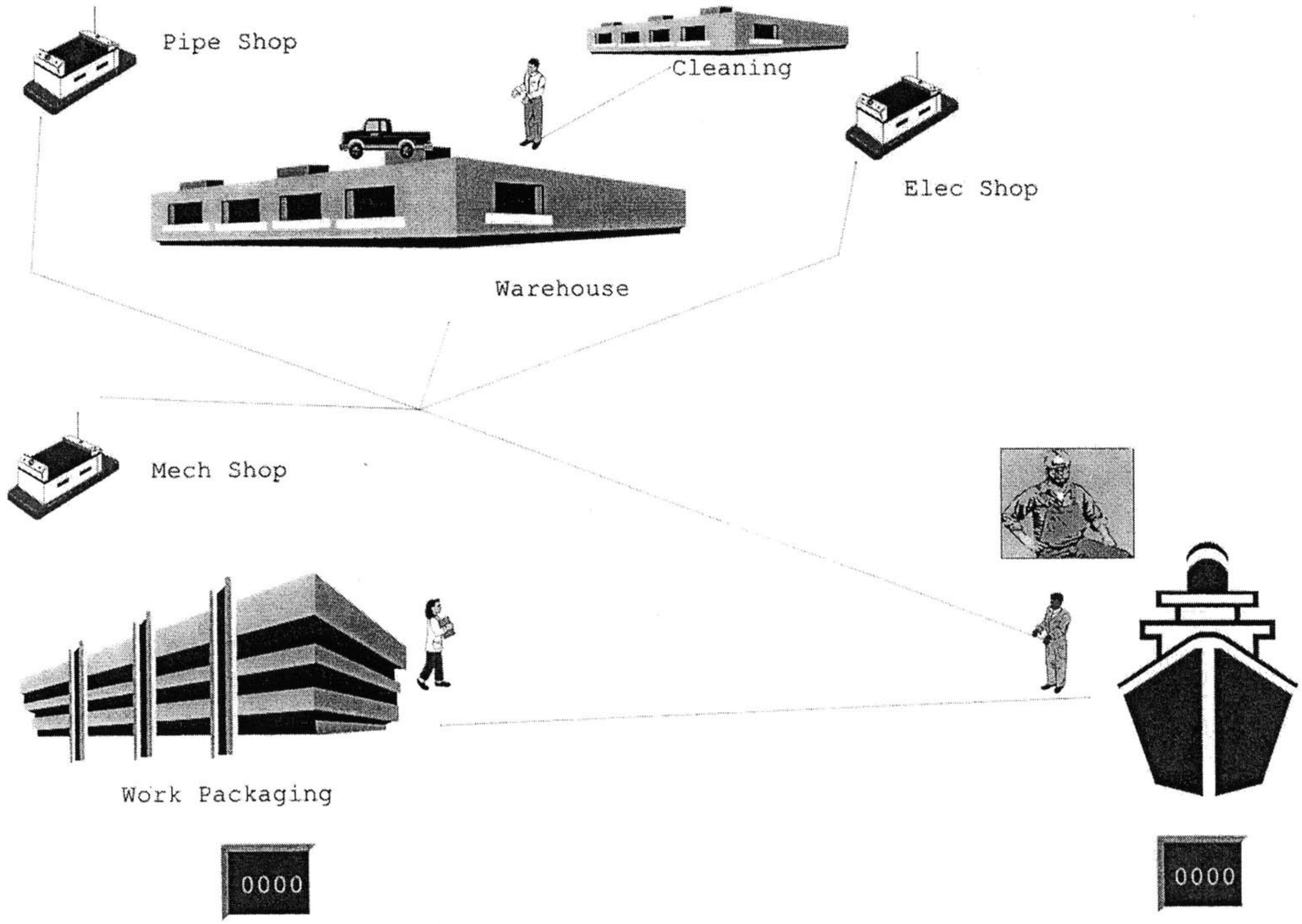


Figure 1. Layout of Current Model at Portsmouth

Chapter 5 Radio Frequency Technology

RFID is the technology of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit. This communication takes place without human intervention, direct contact, or line of sight between components. The RFID tag or integrated circuit, is usually a single, solid-state memory chip, but could also be designed where several electronic components together are used to form an integrated circuit design.

The circuit includes: one or more memory chips that are used for data storage, a substrate backing material or circuit board structure and an antenna of some type or design. This circuit may also contain a power source (battery) depending on the tag (transponder) design.

System Components

A typical RFID system consists of the following basic components:

Transponder - A transponder is an RFID tag. As stated earlier, it is an enclosed integrated circuit that stores data.

Interrogator - The interrogator or "reader" is a device that is used to primarily read and write data to RFID tags.

Radio Frequency - RFID uses a defined radio frequency and protocol to transmit and receive data from RFID tags. These RFID radio signals are subjected to the same physical phenomenon laws that affect normal electromagnetic radio transmissions, such as penetration difficulties through metal and liquids.

Tag Identifies Asset

The RFID tag works well in a hostile environment when it is attached to, or fitted into, items for identification. Depending on the type of tag and application, RFID can provide reading distances ranging from 5 centimeters to 100 meters.

The tag contains a unique number, which is provided at the manufacture or distribution level, and is never duplicated. This number acts as a trigger when captured by the reader and is used to identify the asset, record its details, and subsequently update the asset's record in the main database. Tags provide for billions of individual identification codes, which could include customer, categorization, routing, encrypting, and security codes. There are two major classifications of RFID tags: passive and active.

Passive Tags

Passive digitally encoded tags contain no internal power source, such as a battery, and thus are easier and less expensive to manufacture, than their active tag big brothers. These tags are purely passive or "reflective". They rely upon the electromagnetic energy radiated by an interrogator (reader) to power the RF integrated circuit, which makes up the tag itself. The tag reacts to a specific reader produced, inductively coupled, or radiated electromagnetic field, by delivering a data modulated radio frequency response. These types of tags are said to be "beam powered".

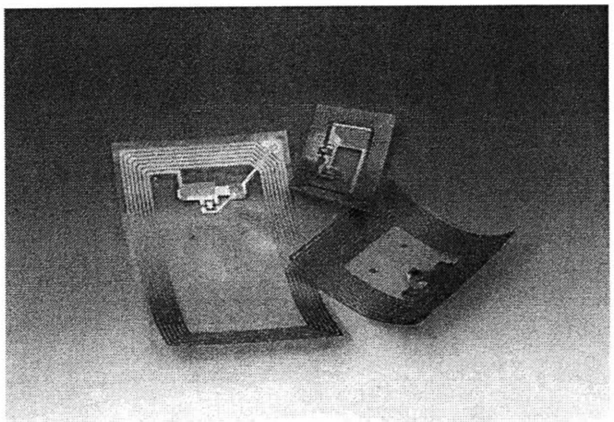


Figure 2. Assorted Passive Tags

Passive tag systems employ magnetic or radio encoded transceivers (tags) and specific antenna units (readers). This (theoretically) allows the system to be capable of communication for reading of hundreds of stacked tags, while providing full collision avoidance while moving at a high rate of speed.

- Read capacity: up to 250 tags/second (static)
- Operating range: up to 1 meter by 1 meter by 1 meter passive (3-D readability)
- Read error rate: <0.01%

Active Tags

Active tags contain both a radio frequency transceiver and battery to power the transceiver. Batteries may be replaceable, or sealed within the device, which are often referred to as a unitized active tag. The onboard radio in the active tag allows it to get substantially more range (up to 300 feet) than a passive tag, as the data modulated radio frequency response is amplified and broadcast to the reader.

Active tags are generally more expensive to manufacture than passive tags, and are limited by the battery life, which is typically between 3 and 5 years. As with any battery-powered product, battery life is dependent on level of use, or how frequently the tag broadcasts its signal.

Like all electrical devices, RFID tags and their reader/interrogator components are becoming smaller, more durable, longer-lived, and capable of being used over increasingly longer distances. Just as computer chips are becoming more imbedded and less intrusive, so is radio frequency *identification and tracking* technology.

Readers

Readers generally consist of an RF antenna, transceiver, and a microprocessor. The transceiver sends activation signals to and receives identification data from the tag. The antenna can be enclosed within the reader or located outside the reader as a separate piece. The reader can be a stationary or a hand-held component, housing a microprocessor that checks and decodes the data it receives. Once received, the reader transmits the data to a centrally located system server for record keeping and processing.

Tag Frequencies

RFID systems operate in several radio bandwidths, divided into low, intermediate and high frequency ranges.

A system operating in the low-frequency range, between 30 kilohertz (kHz) and 500 kHz, generates strong and broad signal spread. In this range, the device requires a shorter distance to communicate with a reader, typically at a distance of no more than 10 feet.

Most low-frequency systems are passive, so the tag is "off" until activated by the reader. Such devices can easily be activated and interrogated by hand-held readers. Since these systems allow for accurate transmission through most non-metallic materials, they are ideal for tracking, monitoring, or controlling process status, such as the work flow of products or containers in manufacturing, production or assembly lines.

The medium-frequency range is not as popular for RF tagging systems. This range is widely used by citizen band radios, automatic door openers, and remote control toys. Thus RF tagging applications operating in this range often experience interference. Despite this, many tagging applications, including inventory control or asset tracking systems, rely on medium range radio frequency, due to its versatility and strength.

High frequency systems operate in the ultrahigh frequency band from, ranging 500 megahertz to 2.5 gigahertz. These systems are mostly applied in the automobile and trucking industries. These tags can often communicate with readers at distances greater than 250 feet, while moving at high speeds.

RFID System Manufacturers

There are numerous manufacturers of RFID tags, readers, and supporting software. In his 1999 master's thesis at MIT entitled "Applied Information Technology For Ship Design, Production and Lifecycle Support: A Total Systems Approach", Gary Dunlap examines a number of RFID vendors, and compares their products and potential applications.

As stated previously, RFID systems operate in low, intermediate and high frequency ranges. There are also many different type of RFID tags on the market, ranging from simple "disposable" single-use paper tags to sophisticated "intelligent" tags, each offering their own level of benefit. The operating frequency and the tag type is determined by the specific application.

At the lower end of spectrum, there are quite a few companies in the RFID industry who manufacture a variety of "unintelligent" transponder products, or passive tags. These systems and tags are functionally similar to bar codes but offer the additional benefit of non-line of sight readability and hands-free data transmission and collection.

Currently, with the lack of any uniform standard, many potential users of passive tags still considered them to be too expensive to compete in a market dominated by the bar code and magnetic-stripe technologies.

According to their website the Uniform Code Council (UCC) has stated as their mission "to take a global leadership role in establishing and promoting multi-industry standards for product identification and related electronic communications." Their goal is to enhance efficient supply chain management, thus contributing added value to the customer.

Several RFID companies are specializing in the development of real time locating systems (RTLS) technology. RTLS provides managers constant, real-time on-demand information about the supply chain. The following discussion includes information on what, where, how much, and the current status of inventory and resources.

I.D. Systems, Inc. (IDS)

IDS, headquartered in Hackensack NJ, produces wireless monitoring and tracking systems for a wide range of customers, including shipping and delivery companies, car rental companies, railcar and transportation companies, and companies with forklift fleets. IDS has designed, developed, and manufactured a patented wireless programmable communications and monitoring system for vehicles, materials, equipment and personnel since the company's founding in 1993.

While the industry trend has been toward less functional, cheaper tags, IDS has taken a different approach. To meet the demands of the emerging industry, IDS has chosen to focus on making the tag do more, instead of making the tag cost less. The system can offer more to a customer than the previous systems. As a result, the expense of the tag can be more easily justified. In addition, IDS feels that their "intelligent" approach to tag design has actually lowered the overall system cost.

The primary components of the IDS system are the intelligent tags or miniature computers (asset communicators), which are affixed to the items being tracked or monitored. Each asset communicator possesses its own unique identification code. Once affixed to its assigned asset, the asset communicator provides for the two-way transfer of information using radio transmissions to and from strategically located monitoring devices (gateways). Typically, numerous gateways are networked together throughout a facility, to provide real-time visibility of the location and status of assets measured from a central location.

IDS products are being used in a wide range of applications, from shipping and deliveries, to fleet management of rental cars, forklifts, railcars, and transportation vehicles, and also personnel monitoring.

PinPoint Corporation

PinPoint Corporation, located in Billerica, MA, is a leading developer for mobile resource management solutions. Their systems are developed for industries requiring a high degree of live information on resources and critical assets. These include industrial, manufacturing, and healthcare environments, which use PinPoint solutions to locate, monitor, and manage resources, inventory, and personnel.

Resource Manager Software

The backbone of PinPoint's system is their resource manager software. The individual components of the RTLS system, the tags, antennas, and cell controllers, are all tied together in the resource manager. The software can provide the end-user only the information that he has requested, through a "publish / subscribe" architecture and a series of proprietary NT services, greatly reducing network traffic. The PinPoint resource manager can deliver data to any personal computer, handheld device or WAP device.

PinPoint offers third-party developers a completely open software platform, which allows for the creation of custom applications for specific markets and industries. On November 29, 2000, PinPoint announced a strategic agreement with RF Code. The goal of the agreement is to provide customers with the ability to gather real-time location information of assets throughout a facility.

RF Code, Inc.

RF Code, Inc. is a leading developer of Radio Frequency Identification (RFID) technologies. Established in 1996, they provide advanced RFID and tracking solutions to the express delivery industry. RF Code's mission statement is to become a leading provider of high volume asset tracking and identification systems.

The Spider system is a 303.8 MHz RFID portable asset tracking solution, which features small, long-range tags and readers. Tags can be read up to 400 feet while localizing position to within an accuracy of 20 feet through an attenuation process.

Spider Tags (Active Beacon)

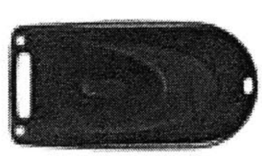


Figure 3. Spider Tag

The Spider tag is a unique RFID tag that provides long-range or short-range identification. These small tags, which measure 1.2" x 2.4", can be identified at distances up to

300 feet from the reader with optional antennas. They were originally designed for the infant security market, and provide high volume identification. The Spider system is suitable for pallet and rolling stock management, hospital asset tracking, personnel locating, and security and warehouse management.

The Spider's unique collision avoidance system provides read capability for up to 500 tags at a standard 7.5 second beacon interval, and up to 1,000 tags at a 15.4 second interval.

Spider Reader

The Spider reader is the component of this RFID system that provides configurable long-range or short-range identification of RF Code Spider tags, at a range of up to 300 feet. Through a process of modifying attenuation, the readers are able to localize a tag's position to within 20 feet of the reader, as well as inform the host computer whenever something changes. For example, when a tag enters or leaves the range of the reader, an alert will sound notifying the system of a change in tag location.

Figure 4. Spider Reader
(Source: RFCode)

Some benefits of the Spider readers include:

- A small footprint – the reader can be mounted just about anywhere,

- Compatibility with multiple communication options including wireless – giving the system the flexibility to operate in virtually any environment,
- Ability to acquire, identify, and track up to 1,000 spider tags – the reader utilizes a state-of-the-art anti-collision communications protocol,
- Rechargeable batteries – for mobile operation of the reader, and for uninterrupted stationary operation even during a power outage.

PinPoint has integrated RF Code's Spider products with its Mobile Resource Manager software platform. The Spider readers connect to the PinPoint resource manager via a wired or wireless local area network (LAN). The Spider tag's small footprint and three to five year battery life, permit them to be mounted just about anywhere. The readers also support a mobile mode through a rechargeable battery, enabling mobile, wireless asset management applications.

As the research for this report was being carried out, PinPoint Corporation met the fate of numerous dot.com companies, with millions of dollars of venture capital yet never turning a profit. Pinpoint Corporation filed for Chapter 7 bankruptcy protection on March 29, 2001, after defaulting on a loan to a secured creditor. However, the technology developed by PinPoint has not been lost. Several principal former members of PinPoint have established a new company continuing the product development and strategy of PinPoint.

WhereNet

WhereNet systems have been developed specifically to manage inventory, track containers, locate property, monitor job orders, ensure quality processes, connect wireless call systems, and provide personal safety. WhereNet has extensively developed its real-time locating system (RTLS). The RTLS is configured as a local positioning system, similar to the GPS system, but on a massively smaller scale. The RTLS works in tandem with wireless local area networks and bar code data capture products to provide information from a single, integrated tracking system.

WhereNet enables real-time management of assets in locations requiring local area coverage by utilizing a combination of hardware and software. The hardware of the system consists of a communications infrastructure of read/write RF tags, fixed-position antennas, location processors andhand- held tag-communicator terminals. WhereNet has developed software to support and manage tracking assets and integrates the hardware into the system. By customizing their software packages, several industrial applications have arisen from the RTLS system.

WhereNet has developed different types of sophisticated tags, depending on the application. One of their tags has a battery life up to 7 years and can be read by readers 750 feet away under the proper conditions. This read / write tag is a high-frequency tag operatingat a frequency range between 2.4 and 2.483 GHz. A communicator card, which plugs into any standard personal computer, is used to configure tags. Tag information and settings can be written onto the tag using the communicator card at a distance of 5 feet. WhereNet's fixed-position antennas operate on power supplied by the location processor. The antenna is connected to the location processor via a coaxial cable and can be located up to 2000 feet away from the processor. The fixed-position antenna is seen in Figure 5.

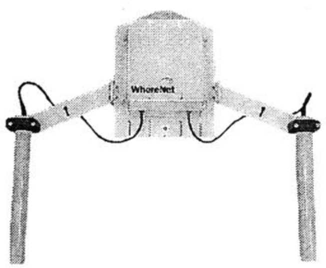


Figure 5. Fixed-Position Antenna (Source:

The location processor can handle several thousand tags on the system and up to eight antennas. The accuracy of the location computedby the location processor is typically 10 feet.

WhereNet has developed portal technology to be used in conjunction with their RTLS. The device known as WherePort is a magnetic exciter that acts like a gate-type portal, while lacking the physical encumbrance of a gate. The device has a range up to 20 feet in diameter. WherePort reconfigures the RF tag to blink with a unique ping. The software package is set up to identify the part as being within the range of the device. The device's dimensions measure less than one foot and can be seen in Figure 6.

Figure 6. WherePort (Source: WhereNet)

WhereNet has been aggressive in developing products for high-end, asset-rich customers and has succeeded in producing very sophisticated local positioning system applications for several industries. Bringing in such a system to a plant takes significant financial commitment. With the right match of volume, asset value and potential savings, the WhereNet real-time locating system is an extremely effective and powerful resource.

The Market for RFID

The global market for conventional RFID is presently a several billion-dollar industry, and growing at a rate of 20 to 30 % annually. These RFID tags typically cost anywhere from a few dollars to almost one hundred dollars each. However, there are many new innovations with RFID tags, which are promising to greatly lower the cost possibly down to a dollar or less. At the same time, the battery life of the tags have grown exponentially from a few months a short time ago to several years currently. See Figure 7 for an example of current expected battery life. It is generally agreed that these lower priced tags and longer life tags will create even bigger markets, than those specialized markets for conventional RFID systems. This can primarily be attributed to the fact that these tags can now be considered single use or disposable.

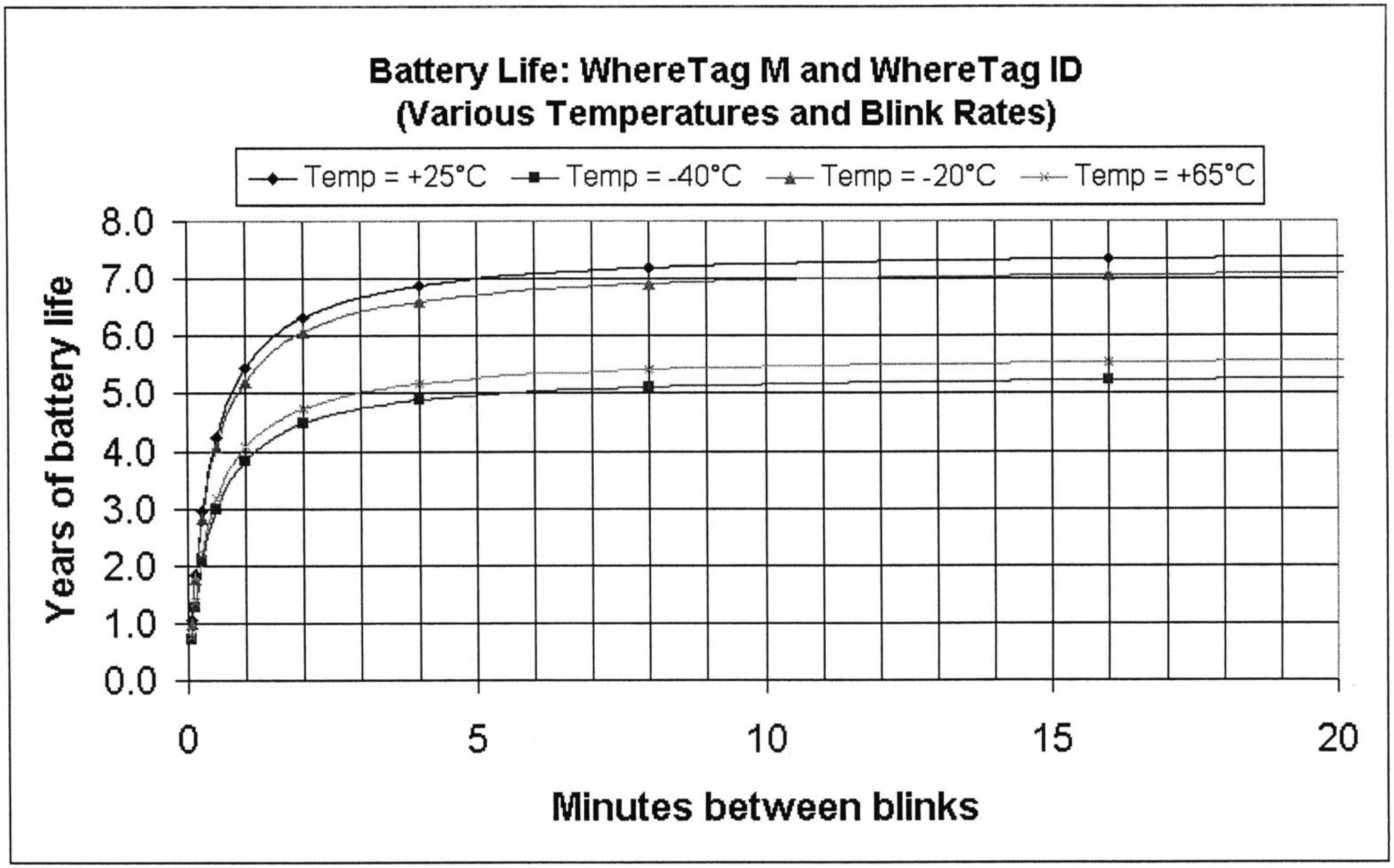


Figure 6. Battery Life of WhereNet Tags

(Source: WhereNet)

Chapter 6 Radio Frequency Process Modeling

Radio frequency identification technology was identified as a possible solution to the material control procedures at Portsmouth. In order to analyze and quantify the potential success of the technology, the future processes must be developed into a simulation model. Comparing the results of this model with the current process model allows for objective analysis of the proposed system.

System Description

Based on the needs at Portsmouth, a mixture of simple, low-end RFID technology and some advanced, newer RFID applications is preferred. The needs were discovered from years of desiring improved performance. The three major areas to improve upon are 1) lowering the rate of lost parts, 2) locating parts in a timely fashion in the SEWS warehouse and 3) significantly reducing the lengthy processing times at the warehouse and the shops.

The initial system to be considered at the shipyard would consist of: 1) portals at the entrance of all of the shops, the warehouse, cleaning and the boat and 2) full location tracking of the SEWS warehouse.

Tags

The RF tags are compatible with both segments of the system and small enough to be attached directly onto the majority of parts. For small parts, such as bolts, the tag could be affixed to the designated carrying device. Currently, zip-loc type plastic bags are used. The bag containing parts with an RF tag attached should be sturdier for prolonged use. A thicker, more durable plastic could be used in conjunction with a zipper enclosure for less frequent accidental openings.

Active tags are required for a locating system. Portsmouth does have an option as to the level of sophistication of the tag. The tags can be read-only tags or read/write tags. With the read/write tags, the number of tags to be purchased would be equal to the total number of parts for any given boat. The tags could then be re-used on following boats. With the read-only tags, the shipyard could re-use the tags on a subsequent boat, but only with extreme diligence and a committed effort to maintain the tag/parts database to avoid confusion with the preceding boat. The other option would be for the shipyard to consider the tags disposable and purchase new tags for each boat.

The tags are relatively easy to configure. The configuration can be completed with either portable hand-held devices or a PC card that mounts to any standard personal computer. This task is very similar to the generation of bar codes by the work packager. Thus, the work packager is already familiar with all of the procedures in generating a marker for a part; he/she will just have to become proficient at a new application.

Portals

The portals, stationed at the shops, the boat and cleaning, have the potential to greatly expedite check-in/check-out times. Portals can be similar to those found in department stores to prevent shoplifting. The laborer would have to physically walk through the portal for the tag to be read. New technology combines the functionality of a portal without the need for an actual portal. This advancement could prove effective in eliminating attempts to circumvent the system.

The effectiveness of the portals can only be fully developed through full integration of the software. When an item passes through the portal, the part serial number and the location of the portal should be recorded into the database automatically. The part description and the appropriate destination of the part were previously entered into the database by the work packager and are associated with the part number. This will instantly indicate whether the part is in the correct location and result in averting misrouted items.

Locating System

Complete coverage in the SEWS warehouse is desired to reduce the time it takes to search for parts. Full coverage would require antennas and a location processor. This could locate the real-time information of tagged parts within the warehouse. The antennas could be connected to the location processor either by a coaxial cable or through a wireless infrastructure. The SEWS warehouse is made up of rows of high metal shelves. The shelves interfere with the propagation of radio waves. This problem is simply overcome through the deployment of more antennas.

When a part is requested by a laborer from SEWS, the clerk can locate the part at the computer terminal. Another option is to pick up the items using a portable reader. The clerk with the reader can go to the precise location and pick up the part. In a congested environment, such as the SEWS warehouse, the bin number should still be entered into the database. However, the locating system will always indicate whether the part is in the correct location, the actual location of the part and if the part is actually in the building.

Software and Database Management

This technology would then have to be integrated with the database in place at Portsmouth. This could be the more difficult task. The SEWS database software is quite archaic. Several data fields must be entered at the check-in computer terminals in the shops and SEWS. The interface with the user is very poor and navigation through the program is difficult. Updating the software to look and feel like a windows program will offer many benefits. These points are discussed in greater detail in Chapter 8.

The introduction of bar codes has not had much of an effect on the overall system performance. They simply lessen the number of manual data entry fields, but all of fields still need to be completed. However the program must be set up to receive each specific field, while others still need to be typed in manually.

Full integration of software to maintain, track and update the tags as well as the parts database will result in greatly reduced part processing times. With the proper alarms set up in the software, parts will no longer be allowed to enter the wrong location.

The revamped material control database will contain all of the relevant information about the part. The RF tag will only store a serial number that will serve as a pointer to its corresponding part. Thus, interception of the radio waves will yield a part only number, not any information about the actual part. This is beneficial for security and protection concerns.

Processing

Overall many of the processes remain unchanged, because the function of the material control system remains unchanged. When the bar codes were introduced, very little of the processes changed as well. Unfortunately, very few of the practices performed by the people in the system were changed. As a result, bar codes have had a small impact on the performance of the material control system.

Some of the current processing time required using the barcode system could be reduced somewhat through the use of updated software. However, the combination of RFID technology and an integrated software package will result in much greater reductions in processing times. The reduction allows for great ease and intelligence in the data collection processes.

With the RFID system and its integrated software package in place, the following processes were changed relative to the bar code model (or warrant an explanation):

1. The time necessary for the work packager to configure the RF tag was assumed to be 15 minutes. While this is the same amount of time as the bar code process, more information has been entered into a more robust database.
2. The work packager stays at the boat for 10 minutes to properly distribute the RF tags and discuss all of the instructions.
3. While the laborer is ripping out the part, he spends 15 minutes reading the task group instruction, attaching the RF tag, double-checking the destination at the boat kiosk and checking the part off the boat.
4. When the laborer reaches the destination with the tagged part, he now spends 3 minutes checking the tagged part into the destination. Additionally, this process occupies the clerk of the shop or the warehouse for the same amount of time, just 3 minutes. The information on the part will be entered into the SEWS database when

the laborer walks through the portal. The clerk then swipes his ID badge bar code and that of the deliverer, which the computer automatically prompts as a new part enters the portal. Once those three acts are completed (walking through the portal and swiping two ID badges), the part has transferred ownership.

5. The clerk then enters a bin number in the next field in the database and places the tagged part in the corresponding bin.
6. When a tagged part enters cleaning, it passes through the portal at the cleaning entrance. Using a predefined setting, the portal technology enters into the database that the tagged part is in the cleaning area.
7. There is no longer a need to attach a cleaned tag to the part. The cleaner has to maintain careful control over the in / out box in order to avoid confusing parts. The identification of the work done by the cleaner may still have to be completed on paper, or it could be entered directly into the database. Additionally, the cleaner would have to use the database to determine which parts in the warehouse are still waiting to be cleaned. (If these two tasks prove to be too much for cleaning to handle, the cleaned tags will have to stick around.)
8. As the cleaned and tagged part re-enters the warehouse from cleaning, no time is spent for a checking-in or checking-out process. While this is the same as the current model, in this case the cleaned and tagged part is actually checked-in. This process occurs instantaneously as the cleaned and tagged part passes through the

portal exiting cleaning. Additionally, the tagged part would not be able to exit the warehouse portal until it has been through the cleaning area. An alarm within the database would notify the clerk.

9. Cleaned and tagged parts that are tabbed to leave the warehouse to one of the shops must be checked out. This process requires the laborer and the SEWS clerk to spend just 3 minutes together checking out the cleaned and tagged part, repeating the exact process from the check-in.
10. Once the laborer delivers the cleaned and tagged part to the designated shop, he spends 3 minutes at the shop checking in the part.
11. As in the current process, those tagged parts that came off the boat and were delivered and checked into the shops by a laborer may end up being moved into the SEWS warehouse for storage. These tagged parts must be first checked out by a laborer, which takes 3 minutes. Upon delivering the entity, the laborer and the SEWS clerk must check in the item for another 3 minutes.
12. Essentially every chance of a part being misrouted has been eliminated with the RFID system. If a part showed up at the wrong portal, the system would automatically notify the clerk. However, because the system in place is not a complete locating system of the entire yard, there still remains a possibility of a part being lost. This can only happen if a part leaves the one of the areas and never gets

checked-in to its next destination. The most likely event is if a laborer leaves a part out in the yard unattended and someone else moves it. The other possibility for failure is the RF tag falling off the part. To account for all of the possible errors, 2% of the parts will be shipped off the boat as parts without tags and considered lost.

13. Since these parts are lost, it was assumed that the finder spends 2 hours at each location attempting to track down the part.
14. Once the part has been found, the finder follows the same procedure as in the current process model.
15. After the rip out and repair phases have taken place, the reinstall phase begins. When the laborers go from the boat to one of the shops or the warehouse to pick up an entity, he must take ownership of the entity. This checkout process takes 3 minutes.
16. The laborer spends 10 minutes on each part removing the tag and filing the task group instruction.

Assumptions

As stated earlier, a few key assumptions were made to develop the RFID model. The rate of lost and misplaced parts would be significantly reduced from 10% down to 2%. The software package supplied by the RFID vendor would be fully integrated into a revamped, user-friendly material control database. The integration of RFID and software would speed up the check-in / checkout processes from 10 minutes to 3 minutes.

From a top-level point of view, the functionality and major processes within the system remain unchanged. However, the advantages of the RFID technology are brought out by actually performing the tasks. Thus, the system could be installed without interrupting or drastically altering the large majority of yard activities. Most of the changes will have to occur in the practices by all levels of persons involved in the material control system. The challenges of implementing such a system are discussed in greater detail in Chapter 8.

Simulation

See Figure 7 for the physical layout of the current process model at Portsmouth. The parameters for the simulation runs of this model were kept constant against the baseline model. This control allows for a fair and objective analysis of the two systems, which is discussed in Chapter 7.

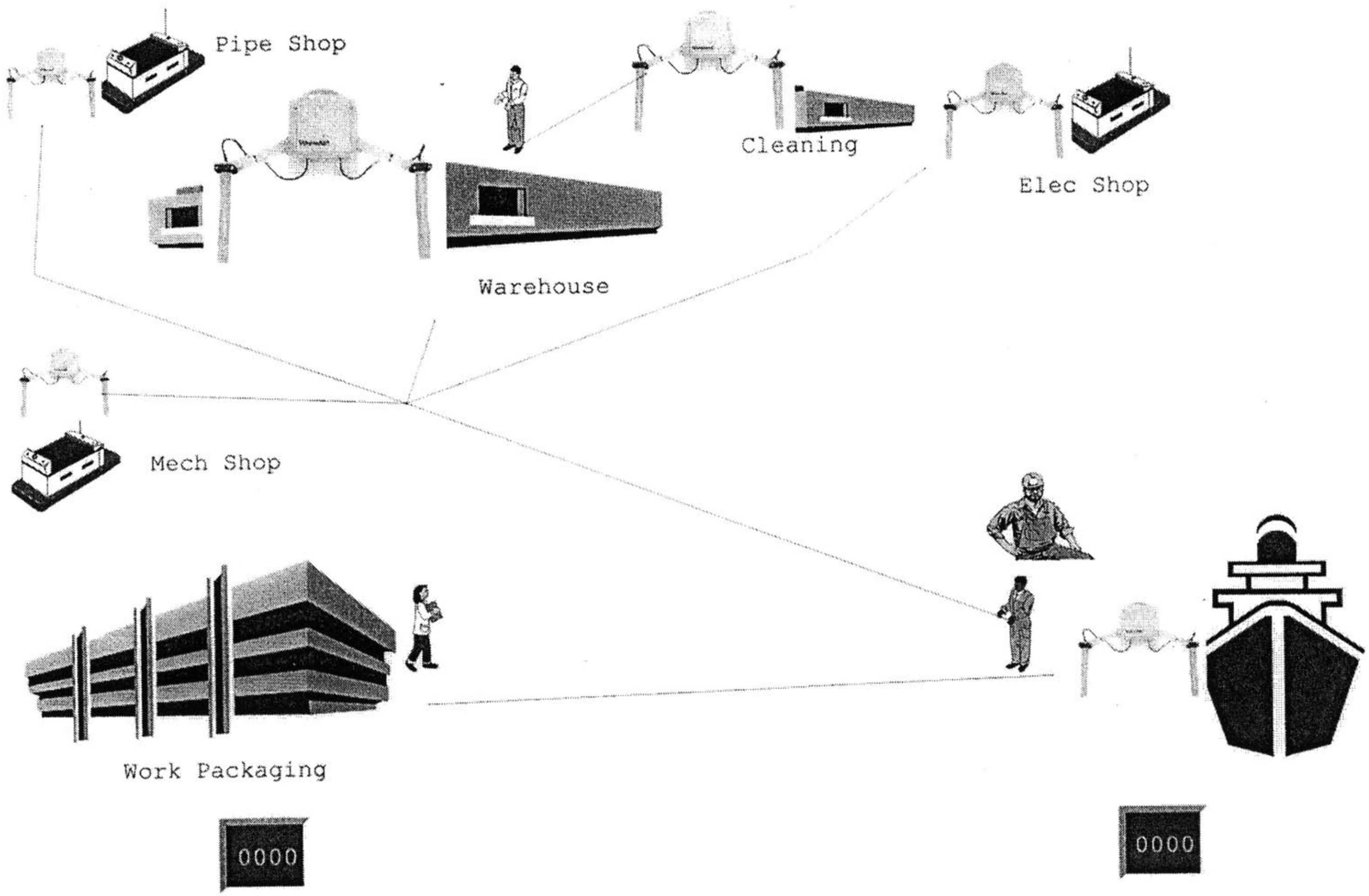


Figure 7. Layout of the RF Model Proposed at Portsmouth

Chapter 7 Analysis

The purpose of this thesis is to perform a representative objective analysis of the implementation of RFID in a shipyard. Obviously, the most important factor in a business decision such as this is usually financially based. What is the potential return on the investment?

Methodology

The method employed for this return on investment analysis is easy to follow. The investment is the cost of the RFID technology, both the initial cost and the annual costs to maintain the system. The returns from this investment are realized in two forms: 1) fewer man-hours spent in the material control process, both normally and during some failure and 2) less capital spent replacing lost or missing assets.

The cost of the RFID system was estimated through extensive research and communication with several RFID vendors. Based on the requirements for the RFID system at Portsmouth, prices were obtained for all of the components. As a conservative estimate, the amount of hardware (not including the software or the tags) required for the system was doubled. The total initial investment for the RFID system used solely for purposes in this analysis was $240,000.

Additionally, there are annual costs associated with the system. These costs include software upgrades and technical support. Also, it was assumed that 1% of the tags would be replaced per year. Thus, the annual maintenance cost of the system was set at $10,000.

The return on investment calculation is performed over a six-year period. Six years was chosen because it represents four consecutive work cycles of boats entering and leaving the shipyard. The cost of capital for the shipyard was assumed to be 10%.

The current process model was developed as a baseline. Running the simulation of the bar code model yields detailed output regarding the activities of all the people, places and things involved in the system. The time spent by all of the personnel in the model is recorded by the computer program ProModel. This establishes the baseline or do-nothing case.

Likewise the model with RFID technology is simulated. The hours worked by the laborer, SEWS clerk, finder and work packager are recorded and compared against the baseline case. The differences in time are multiplied by the wage rate including overhead to determine the labor savings in dollars. Since the work cycle lasts eighteen months, the figures are then converted to an annual amount.

The other, albeit smaller portion of the savings from RFID comes from the expected lower incidence of lost parts. Portsmouth currently must pay to replace parts too frequently. When this occurs, it costs the shipyard in money spent on the part, personnel time to order the part and in delaying work. Any combination of several small parts or just a few expensive ones can easily add up to several thousand dollars. It was assumed that Portsmouth spends $20,000 annually on all of the costs associated with lost parts. A very conservative estimate of the ability of RFID was taken as preventing one-half of these occurrences. This results in a savings of $10,000 annually.

In the bar code model, two key elements are 1) the time spent checking parts in and out of the facilities and 2) the rate of lost parts. The estimate for the part checking time of ten minutes was based on observations of the process. The rate of lost parts was estimated to be 10% from a manager involved in the material control system. In the RFID model, it was assumed that the check-in / check-out time could be reduced to 3 minutes and only 2% of the parts would be lost. The analysis of this model, calculated using a $25 wage with overhead rate and without annual increase, is considered the best estimate scenario.

Each of the major assumptions was subjected to a sensitivity analysis in order to develop more cogent conclusions. The processing time for checking parts was simulated at 5 minutes and 1 minute, in addition to the estimated 3 minutes. Parts were lost at rates of 4% and 6% in the RFID model. Results with overhead wage rates of $15 and $35 were calculated, as well as allowing for annual raises of 2.5% and 5%.

Radio Frequency Identification Best Estimate

The results of the calculations from the best estimate model are presented in Figure 8. The rate of return for RFID technology is 16%, which is above the hurdle rate of a large majority of businesses. The hurdle rate is the rate of return a company needs to expect in order for it to risk initial capital. In this case, the hurdle would be at least 10% plus the rate of the risk associated with the project. A 16% rate of return is certainly makes RFID an enticing investment.

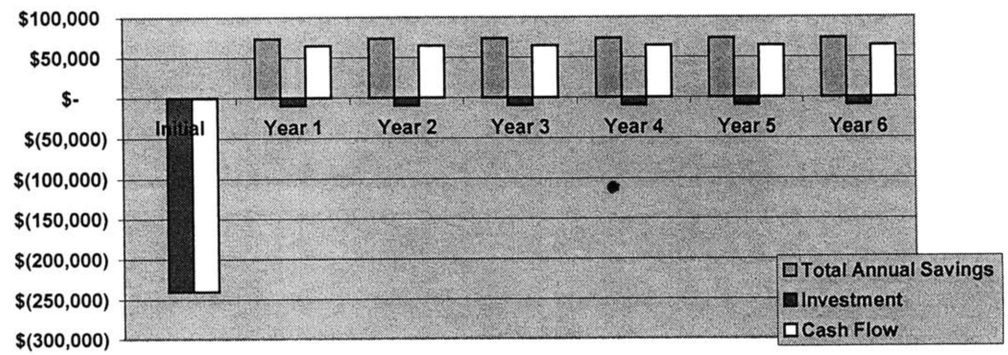
Check-In Time Sensitivity Analysis

When properly implemented RFID is expected to decrease the time of these processes from ten minutes down to three minutes. A calculation based on five minutes was performed to represent a worse case. This case could portray a stage early in the implementation of the technology before the personnel are accustomed to the new practices. If the staff is not properly trained or the system is not properly implemented, five minutes could be the normal time achieved with RFID at Portsmouth. The results of this analysis are presented in Figure 9.

When the technology is fully implemented and the processes have been streamlined, one minute check-in times are achievable. Rate of return analysis of one minute processing times is shown in Figure 10.

Return on Investment — ROI Model of RF Best Estimate

Payback Period for Investment	45 months
Internal Rate of Return	16%
Net Present Value	$ 41,181
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 322,374

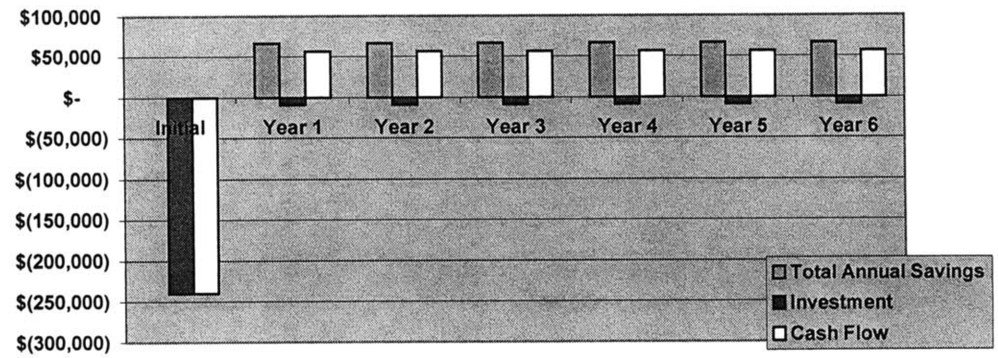


Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 64,019	$ 64,019	$ 64,019	$ 64,019	$ 64,019	$ 64,019	$ 320,097
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 74,019	$ 74,019	$ 74,019	$ 74,019	$ 74,019	$ 74,019	$ 370,097
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 64,561	$ 64,561	$ 64,561	$ 64,561	$ 64,561	$ 64,561	$ 73,349
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 58,692	$ 53,356	$ 48,506	$ 44,096	$ 40,088	$ 36,443	$ 41,181

Figure 8. Return on Investment of RF Best Estimate

Return on Investment	ROI Model of RF 5 Minute Check-in

Payback Period for Investment	**52 months**
Internal Rate of Return	**11%**
Net Present Value	**$ 7,465**
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 288,657

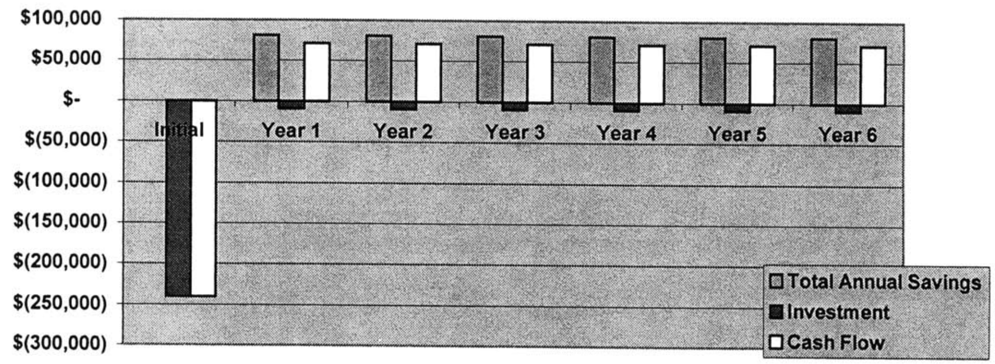


Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 56,278	$ 56,278	$ 56,278	$ 56,278	$ 56,278	$ 56,278	$ 281,389
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 66,278	$ 66,278	$ 66,278	$ 66,278	$ 66,278	$ 66,278	$ 331,389
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 56,820	$ 56,820	$ 56,820	$ 56,820	$ 56,820	$ 56,820	$ 34,641
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 51,654	$ 46,958	$ 42,690	$ 38,809	$ 35,281	$ 32,073	$ 7,465

Figure 9. Return on Investment with RF 5 Minute Check-in

	Return on Investment	ROI Model of RF 1 Minute Check-in

Payback Period for Investment	41 months
Internal Rate of Return	20%
Net Present Value	$ 72,924
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 354,116



Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 71,308	$ 71,308	$ 71,308	$ 71,308	$ 71,308	$ 71,308	$ 356,538
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 81,308	$ 81,308	$ 81,308	$ 81,308	$ 81,308	$ 81,308	$ 406,538
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 71,850	$ 71,850	$ 71,850	$ 71,850	$ 71,850	$ 71,850	$ 109,790
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 65,318	$ 59,380	$ 53,982	$ 49,074	$ 44,613	$ 40,557	$ 72,924

Figure 10. Return on Investment with RF 1 Minute Check-in

Figure 10. Return on Investment with RF 1 Minute Check-in

The rates of return from the five and one minute calculations are compared with the best estimate value. The results are shown below:

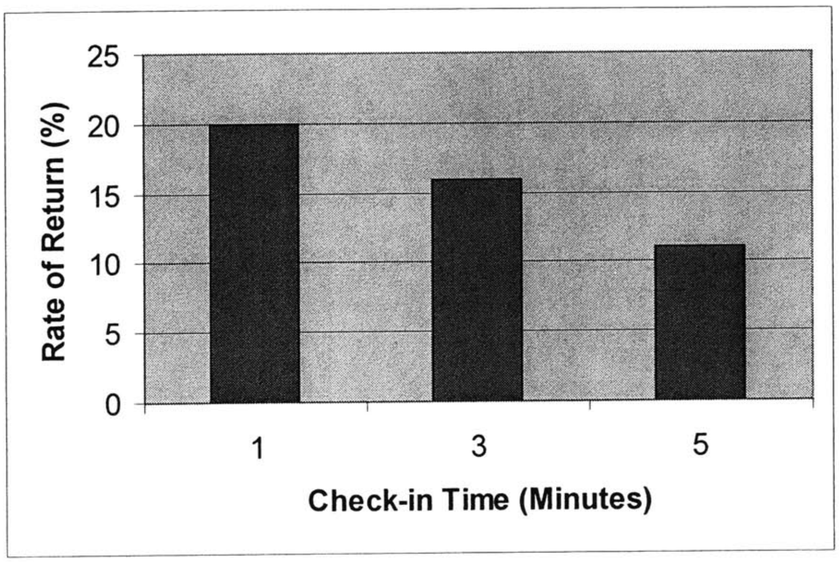


Figure 11. Check-in Time Sensitivity Analysis

Predictably, there is some decay as check-in time increases. However even achieving just processing times of five minutes, RFID still offers a high rate of return. By improving processing times through implementation practices, RFID can offer returns on investment over 20%.

Lost Part Rate Sensitivity Analysis

It is anticipated that RFID will lower the lost parts rate from 10% down to 2%. This is the rate when a part is misrouted, spends some amount of time in the wrong place or is actually permanently lost. A worker is sent out to locate the part, costing time and money. A 2% rate represents a significant improvement over the current 10%. Thus, it makes sense to analyze two steps along the way. Lost parts rates of 4 and 6% were analyzed and are presented in Figures 13 and 14, respectively. The results were plotted against the best estimate and are shown below:

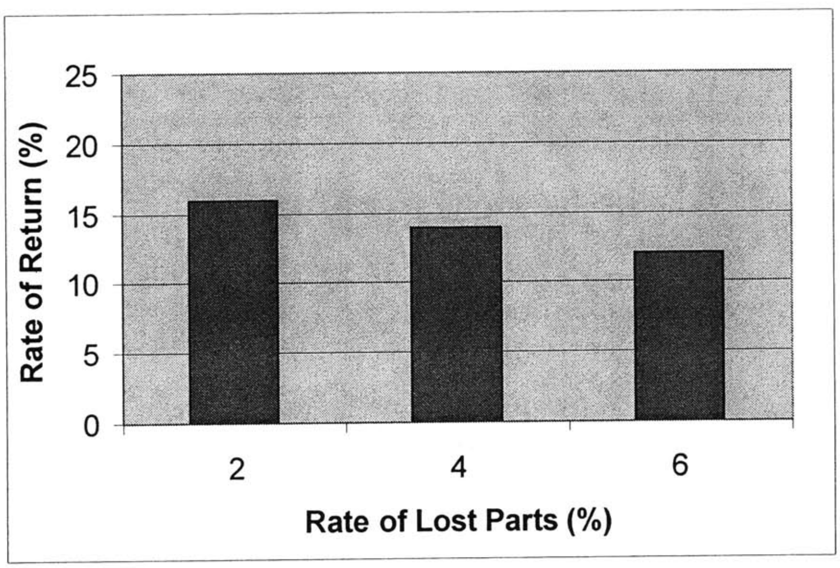
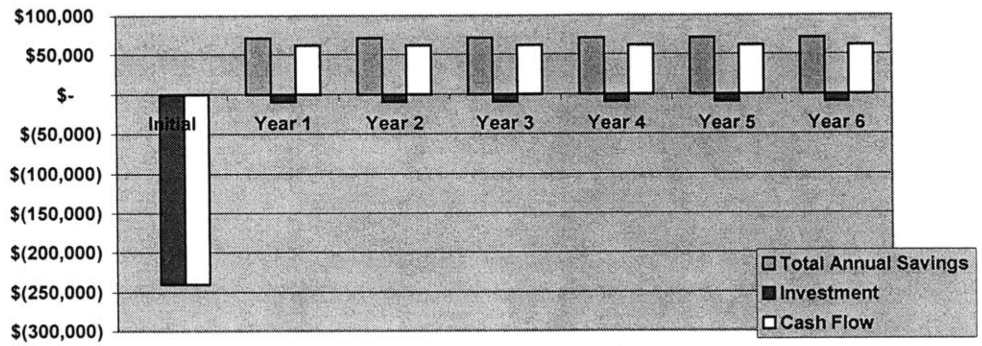


Figure 12. Lost Part Rate Sensitivity Analysis

The rate of return remains high even if the reduction in lost parts is not as great as desired. With proper implementation of the technology, misdirected parts should be avoided at a much greater rate. The RTLS in the warehouse should eliminate the possibility of any part getting lost within the coverage area of the system.

	Return on Investment	ROI Model of RF 4% Lost Part Rate

Payback Period for Investment	47 months
Internal Rate of Return	14%
Net Present Value	$ 30,597
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 311,789

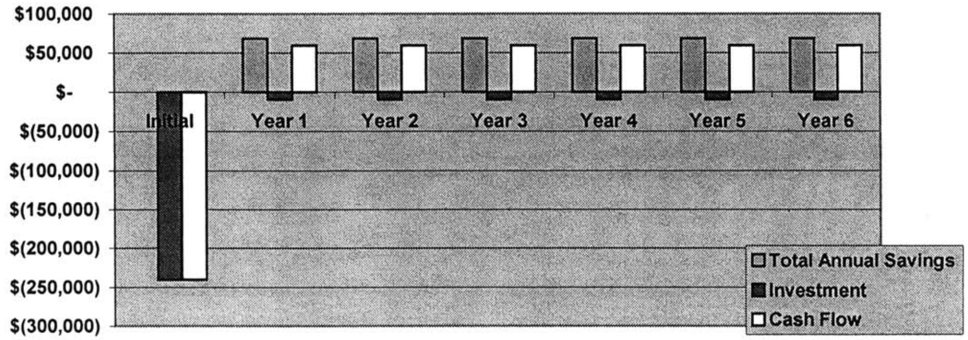


Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 61,589	$ 61,589	$ 61,589	$ 61,589	$ 61,589	$ 61,589	$ 307,945
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 71,589	$ 71,589	$ 71,589	$ 71,589	$ 71,589	$ 71,589	$ 357,945
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 62,131	$ 62,131	$ 62,131	$ 62,131	$ 62,131	$ 62,131	$ 61,197
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 56,483	$ 51,348	$ 46,680	$ 42,436	$ 38,578	$ 35,071	$ 30,597

Figure 13. Return on Investment with RF 4% Lost Part Rate

	Return on Investment	ROI Model of RF 6% Lost Part Rate

Payback Period for Investment	**50 months**
Internal Rate of Return	**12%**
Net Present Value	**$ 17,835**
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 299,027



Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 58,659	$ 58,659	$ 58,659	$ 58,659	$ 58,659	$ 58,659	$ 293,294
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 68,659	$ 68,659	$ 68,659	$ 68,659	$ 68,659	$ 68,659	$ 343,294
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 59,201	$ 59,201	$ 59,201	$ 59,201	$ 59,201	$ 59,201	$ 46,546
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 53,819	$ 48,926	$ 44,478	$ 40,435	$ 36,759	$ 33,417	$ 17,835

Figure 14. Return on Investment with RF 6% Lost Part Rate

Wage Rate Sensitivity Analysis

The wage rate including overhead was assumed to be $25 for the best estimate case. This assumption was based on information available from similar industry sites. However, because the actual current wage rate is unknown, wage rates of $15 and $35 were analyzed as well. The calculations for the $15 rate are shown in Figure 16 and the results for the $35 rate are presented in Figure 17. The effect of wage rates on the internal rate of return is shown below:

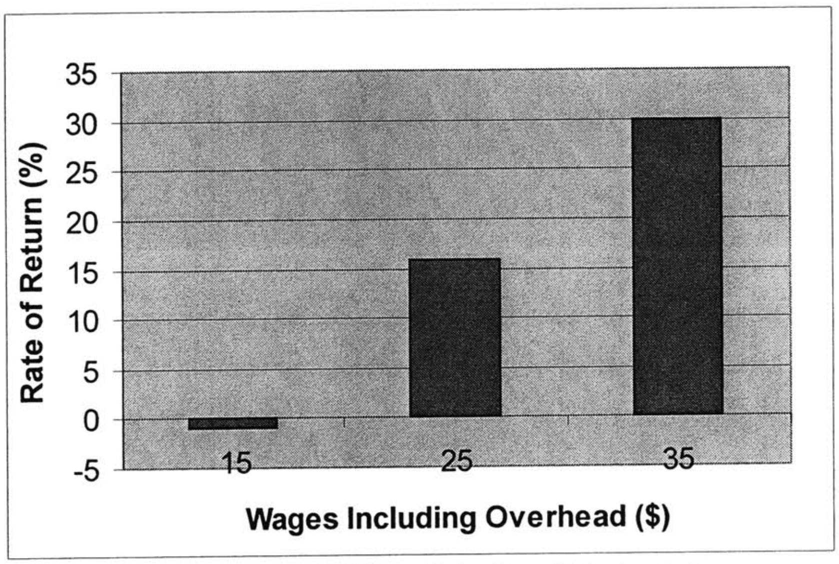
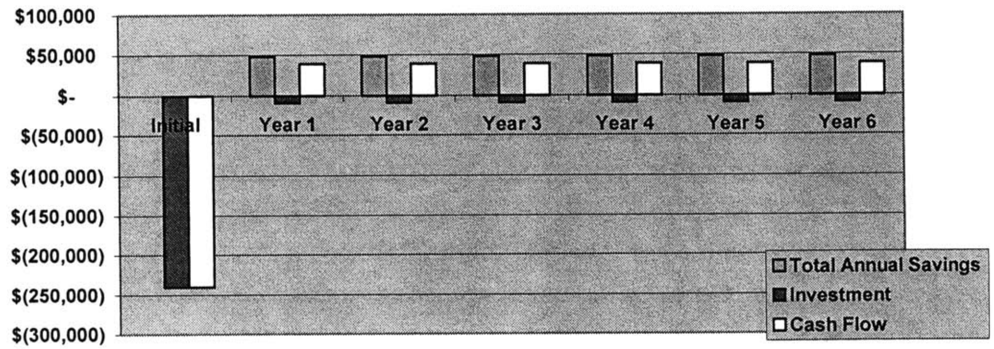


Figure 15. Wage Rate Sensitivity Analysis

There is quite a large variation in rate of return due to changing wage rates, which shows how large a part labor plays in the material control system. Although the $15 rate is below the hurdle rate, installing the system could still be considered in anticipation of future wage increases. The exponential increase in return as wages increase indicates that labor-intensive material control systems in high wage areas would benefit greatly from RFID technology.

Return on Investment	ROI Model of RF Wage Rate of $15

Payback Period for Investment	72 months
Internal Rate of Return	-1%
Net Present Value	$ (70,347)
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 210,845

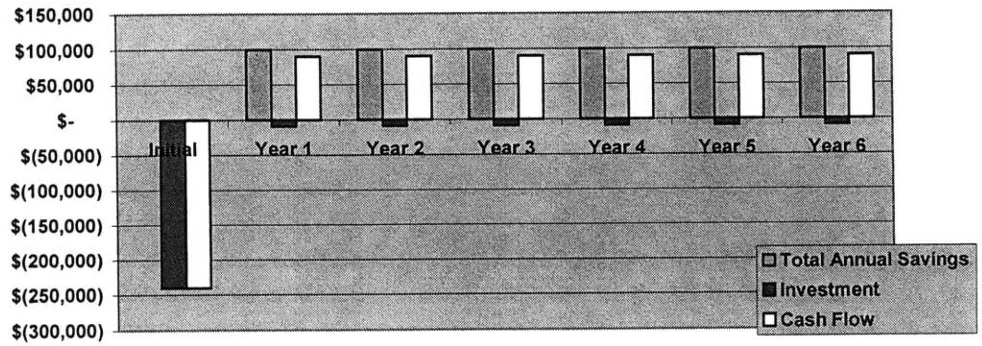


Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 38,412	$ 38,412	$ 38,412	$ 38,412	$ 38,412	$ 38,412	$ 192,058
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 48,412	$ 48,412	$ 48,412	$ 48,412	$ 48,412	$ 48,412	$ 242,058
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 38,954	$ 38,954	$ 38,954	$ 38,954	$ 38,954	$ 38,954	$ (54,690)
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 35,412	$ 32,193	$ 29,266	$ 26,606	$ 24,187	$ 21,988	$ (70,347)

Figure 16. Return on Investment with RF $15 Wage Rate

	Return on Investment	ROI Model of RF Wage Rate of $35

Payback Period for Investment	32 months
Internal Rate of Return	30%
Net Present Value	$ 152,710
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 433,902



Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 89,627	$ 89,627	$ 89,627	$ 89,627	$ 89,627	$ 89,627	$ 448,135
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 99,627	$ 99,627	$ 99,627	$ 99,627	$ 99,627	$ 99,627	$ 498,135
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 90,169	$ 90,169	$ 90,169	$ 90,169	$ 90,169	$ 90,169	$ 201,387
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 81,972	$ 74,520	$ 67,745	$ 61,587	$ 55,988	$ 50,898	$ 152,710

Figure 17. Return on Investment with RF $35 Wage Rate

Annual Wage Rate Increase Sensitivity Analysis

The wages in the best estimate were kept constant at $25 throughout the six-year period of this analysis. Wage increases during the life of this analysis could affect the impact of the new system. Wage increases of 2.5% and 5.0%, compounded annually, were investigated in this sensitivity analysis. The results are presented for 2.5% in Figure 19 and for 5.0% in Figure 20. The effects of a yearly raise on the rate of return are shown below:

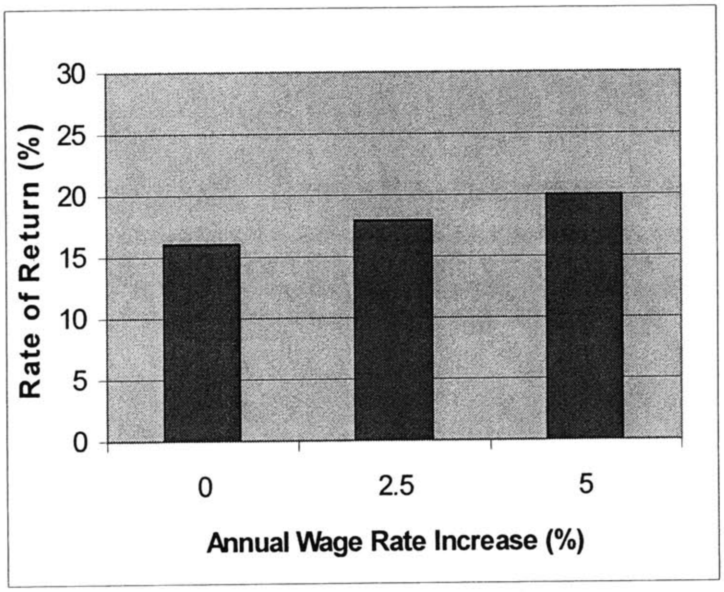
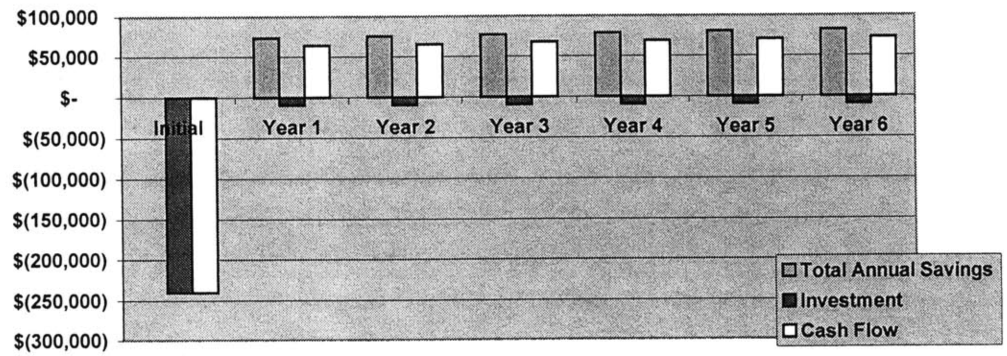


Figure 18. Annual Wage Rate Increase Sensitivity Analysis

There is a moderate effect on the internal rate of return from an annual wage increase. While this analysis does not appear to be groundbreaking, it serves to show an added factor to consider when analyzing a labor-saving technology.

Return on Investment — ROI Model of RF 2.5% Annual Raise

Payback Period for Investment	44 months
Internal Rate of Return	18%
Net Present Value	$ 57,177
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 338,369

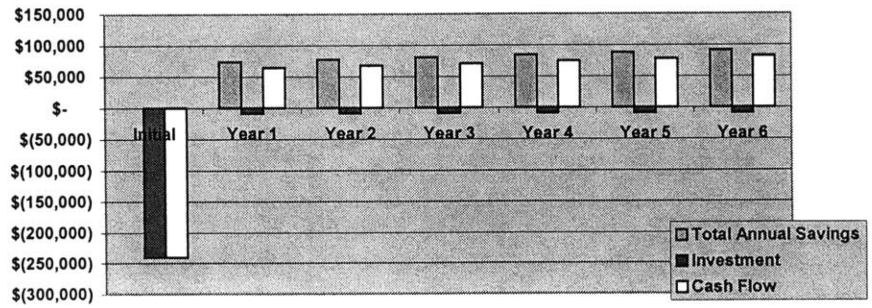


Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 64,019	$ 65,620	$ 67,260	$ 68,942	$ 70,665	$ 72,432	$ 344,919
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 74,019	$ 75,620	$ 77,260	$ 78,942	$ 80,665	$ 82,432	$ 394,919
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 64,561	$ 66,162	$ 67,802	$ 69,484	$ 71,207	$ 72,974	$ 98,171
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 58,692	$ 54,679	$ 50,941	$ 47,458	$ 44,214	$ 41,192	$ 57,177

Figure 19. Return on Investment with RF 2.5% Annual Wage Increase

	Return on Investment	ROI Model of RF 5.0% Annual Raise

Payback Period for Investment	43 months
Internal Rate of Return	20%
Net Present Value	$ 74,200
6 year Investment (present value)	$ (281,192)
6 year Return (present value)	$ 355,392



Detailed	Initial	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Savings								
Labor cost savings		$ 64,019	$ 67,220	$ 70,581	$ 74,110	$ 77,816	$ 81,707	$ 371,435
Asset savings		$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
Total Annual Savings		$ 74,019	$ 77,220	$ 80,581	$ 84,110	$ 87,816	$ 91,707	$ 421,435
Investment	$ (240,000)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (9,458)	$ (296,748)
Cash Flow	$ (240,000)	$ 64,561	$ 67,762	$ 71,123	$ 74,652	$ 78,358	$ 82,249	$ 124,687
Discount Rate	1.00	0.91	0.83	0.75	0.68	0.62	0.56	
Discounted Cash Flow	$ (240,000)	$ 58,692	$ 56,002	$ 53,436	$ 50,989	$ 48,654	$ 46,427	$ 74,200

Figure 20. Return on Investment with RF 5.0% Annual Wage Increase

Analysis Findings

Throughout all of the sensitivity analyses, only one condition failed to exceed the expected hurdle rate for implementing RFID technology. This was the $15 wage rate with overhead scenario. Otherwise, the majority of cases yielded rates of return over 20%. The rate of return values range from -1% up to 30%, with the best estimate case in the middle at 16% for this representative objective analysis.

Each sensitivity analysis was performed discretely. The varying factors were not analyzed simultaneously to develop a worst case scenario or even a best case scenario for that matter. Either scenario is possible; it all comes down to the implementation, which is discussed in Chapter 8.

Chapter 8 Implementing Radio Frequency Technology

The true value of a new technology can only be fully realized through effective implementation. The implementation must occur at all levels within an organization. Many of the challenges faced in the implementation of RFID are common to any other technological enhancement of a need. Obstacles must be overcome at the industry-wide level, the company executive level, through the tiers of management and the workers. Often, the introduction of a new technology brings with it many peripheral changes. Software must be implemented and practices must be changed to take advantage of the technology.

Industry

The ship construction and repair industries in the United States have historically been slow to adopt changes in their practices. The US Department of Defense has funded the major shipyards in the US with continued contracts. The perceived perpetual support from the DOD left little incentive for the shipyards to really make any major changes to improve their efficiency.

Over the last two decades, the shipyards have been put on notice that they could no longer count on the government for life support. Both parties involved have been slow to realize the ramifications of this threat. Some shipyards have been in a state of denial, while the government has not put enough teeth into its threat. Some shipyards have made strides in recent years, through the financial assistance of Office of Naval Research grants.

The driving force to universal industry acceptance in US shipyards would be a mandate or strong encouragement from the Department of Defense. If the Navy began tagging items on its ships for location tracking or inventory management, the shipyards would be wise to incorporate this enhancement into their practices.

Currently, there is no push from the Navy for this technology. This brings up another obstacle to introducing the technology into the shipyard. Shipyards are reluctant to spend money on a system that provides value to something that they do not own. If parts were being tagged throughout the yard with standard RF tags, they would improve the efficiency of the repair or construction project at the yard. Likewise the tags could also improve practices onboard the vessel. However, both the shipyard and the owner must recognize the value of the system in each party's area of concern.

Another concern with shipyards is spending any money without first testing the concept on a smaller scale. With an RFID system the investment can be interpreted as "all or nothing". Because readers are needed at every gate of every shop and storage facility (and wherever else the carrier wishes to read the tags), there is no point in going half way. The system efficiency will work best when everything that is going to be tagged, is actually tagged.

Either the US Department of Defense or the shipyards must take the initiative and convince the other of the benefits of an RFID system throughout both the construction and operation of a vessel.

Company

For each shipyard, there are several challenges to investing in a new technology. RFID technology is still on the upswing of the product maturity curve. This causes trepidation for company heads for three reasons: 1) they fear the product will become obsolete in a short period of time, 2) they know that the same product will be cheaper in the future and 3) a better technology may be introduced after an investment is made.

Alongside the issue of obsolescence of the product is the concern of universal compatibility. The stability of the RFID vendor is a major concern to potential buyers due to compatibility issues. The development of a universal standard for RFID systems faces the challenge of getting various computing environments to communicate with each other. Emerging technologies often attempt to address this issue; however, in practice not all systems have been successful. Many RFID vendors have recognized the need for standards and interoperability of systems. Strides have been made in this area and systems are operating successfully together. However, other RFID vendors understandably are trying to develop and sell their products and are reluctant to cooperate and coordinate with competitors who may not even be in business in a few months. As the technology matures, the standards and compatibility of the products will mature accordingly.

With a high rate of change in emerging technologies and the general financial state of US shipyards, the concern for costs is strong. As the product becomes accepted, it becomes more capable and cheaper. The most classic example of this phenomenon is witnessed in the cost of computing memory. The cost of RFID products has decreased noticeably recently.

In a dynamic environment, technology advancements will continue to take place. Companies do not need to be overly concerned with the ability of the products. The key factor will be to what extent any technology will meet the customers' needs.

With any technological advancement there are going to be glitches and barriers to overcome. While a shipyard may be reluctant to make an investment, as the cost of the product decreases and the ability improves, they must recognize the cost of lost savings by not introducing RFID technology in their practices.

Managers

While the shipyards have several qualms regarding the viability of the technology confronting them, the managers overseeing the implementation of the technology have a different set of obstacles to overcome. Material control improvement needs to become primarily a management responsibility. Management has to understand that its role is to see the overall system, develop a vision of an improved, more accurate flow for the future, and lead its implementation. This responsibility cannot be delegated. Managers can ask the front lines to work on eliminating waste in the process, but only management has the perspective to see the total improvement as the benefits of RFID implementation are felt across departmental and functional boundaries.

Implementing a new technology will require a firm conviction that the technology can be adapted to work in the shipyard, coupled with a willingness to try, fail and learn. Many errors simply go with the territory when implementing change in long-established material control practices. Such iteration is a normal part of any lean implementation effort. Success will be achieved by those who have the determination to personally work through the obstacles.

Several factors within the shipyard will ensure success by the managers. The material control department needs to fully support the implementation of RFID technology. Additionally, the person in charge of material control must report to senior management.

Another way for the managers to successfully gain the support and understanding from the workers is for the managers to dedicate time and to really learn the system for themselves. They should learn it to the point that they can actually teach it. Then they need to actually teach it in their daily interactions with their staff.

The manager's job is not just to lead the people operating the process in material control, but also to take responsibility for the cost, quality and accuracy of the system in the present while leading implementation of the future process.

In the beginning, most managers and their staff will benefit from some outside technical assistance in introducing and refining the RFID technology, instituting a quick changeover of equipment. However, the experts in RFID function must be the coaches rather than the actual implementers, with the clear objective of transferring all of their experience to the manager and others as quickly as possible.

The only way to actually learn the methods introduced with RFID is to apply the techniques hands-on. The tragedy is that so many managers want to retain a consultant expert to solve their immediate problem for them without need for their active involvement. Of course they discover that they are never able to solve their own problems themselves and often fall into a spiral of consultant dependency.

The managers will be more capable of gaining results from the staff if they have the full support and involvement of senior management. Managers must be able to overcome setbacks and take responsibility for the material control system during the transition. More than a broad knowledge of the workings of the RFID system is required. Managers need to take the time with the RFID experts to completely learn the system to successfully pass the knowledge onto the staff. With these commitments, the managers will be able to achieve a successful implementation of RFID technology.

Workers

The staff performing the actual practices with the new technology must be convinced of the usefulness of the system. Additionally they must recognize the benefits it provides them on a day-to-day basis. With RFID implemented, the staff will spend less time tracking down mistakes, filling out paperwork and being frustrated with an archaic system.

That being said, there is a natural tendency for people to resist change. "This is the way I've always done it," is a common refrain heard in shipyards. Many individuals will take this stance because a new system means a change from their present, more comfortable environment. In addition, with a new system workers will take some time to become accustomed to it. A good human-machine interface is essential for a successful implementation.

Software Change

As stated previously, integration of the software to support RFID and the database is an integral ingredient in the success of the technology. The user will feel more comfortable with a program that looks familiar to other programs previously used by the user. The majority of younger people have extensive knowledge and experience with computers, regardless of educational background. Additionally, a reverse effect also benefits the shipyard. If other programs used by the employees are windows based, then they may become more proficient at those as well. For example, a shortcut learned in one program may be used in another. This makes the user more productive but can also feel more rewarding by lessening the tedium.

Implementing RFID into the shipyard can be accomplished successfully, if the right formula is used. There will be some bumps in the road along the way. One example of RFID technology implementation involves tags for luggage carts at an airport. At first the workers ripped the tags off fearing a "big brother" like system. However, during a crisis when a cart needed to be located immediately, the RFID system proved its usefulness to the workers. Now the system is accepted.

At whatever level, from CEO to plant floor supervisor, the managers must be pushing the implementation of the technology. It should be part and parcel of each day's activities. If the money is spent on the system, every effort must be made to realize the returns RFID can bring.

Chapter 9 Conclusions

The implementation of automatic identification technology in the shipyard environment to improve naval and commercial ship construction was explored. Shipyards incur large amounts of cost and delays from their material control systems. A method was developed to analyze and implement the impact the RFID technology in the shipyard.

Portsmouth Naval Shipyard was used as an example of possible RFID implementation. The shipyard has just introduced bar code technology as a possible fix to the high rates of lost and misdirected parts they are experiencing. Additionally, those involved in material handling both primarily (work packagers and clerks) and secondarily (laborers ripping out, repairing and reinstalling parts) spend a great deal of time processing the material movements.

The potential solutions to the problem are then researched and explored. Current RFID products were identified as possible supplements to the material control system. No attempt was made to determine an optimal technology vendor. In addition to the RFID hardware, significant upgrades in the software to support RFID and streamlined material handling would be needed.

Simulation modeling was identified as the tool to assist in the method to analyze the implementation of RFID technology. By developing simulation models of the present process with bar codes and the future process with RFID at Portsmouth, the improvement in performance from RFID could be observed.

From the results of the simulation modeling, a rate of return analysis was performed. While the analysis is representative of a notional installation, RFID was shown to provide a high rate of return over a six-year time period. All of the assumed variables in the analysis were subjected to a sensitivity analysis and, with the exception of one case, an acceptable rate of return could be realized.

Implementation of a new technology requires cooperation and synergy throughout all levels of an organization. The US government, as a primary customer of most US shipyards, could drive the use of RFID in a shipyard once it recognizes the value of RFID during the life of its ships. Managers, with the support of senior management, must be diligent and dedicated to effectively achieve change from the staff. A well-informed and goal-oriented staff is more likely to deal with the change positively and would be encouraged to use a computer system that produces for them.

Using the methodology employed in this thesis, shipyards can evaluate RFID technology to determine the potential benefits in their yard. Effective implementation of RFID technology offers not only a positive rate of return from their investment but also vast improvement of material control practices to become a more productive shipyard.

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Appendix A: Baseline Current Bar Code Process Model Results

General Report
Output from C:\ProMod4Student\models\asis14\ASIS15.MOD
Date: Aug/09/2001 Time: 05:56:55 PM

Scenario : Normal Run
Replication : 1 of 1
Simulation Time : 3500 hr

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4191	34422.78	686.98	1547	0	17.17
ship	3500	6000	8414	14240.79	570.58	4000	0	9.51
Elec Shop	3500	4000	2169	36288.57	374.80	896	0	9.37
Mech Shop	3500	4000	2080	37522.16	371.64	893	0	9.29
Pipe Shop	3500	4000	2153	36153.81	370.66	895	0	9.27
Work Packaging	3500	4000	4000	18.89	0.35	7	0	0.01
Cleaning	3500	6000	1599	319.49	2.43	25	0	0.04
WarehouseB	3500	4000	4000	140417.04	2674.61	3935	2401	66.87
ShipA	3500	1000	0	0.00	0	0	0	0.00
WarehouseC	3500	1000	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	2.81	97.19	0.00	0.00
ship	3500	71.46	28.54	0.00	0.00
Elec Shop	3500	16.51	83.49	0.00	0.00
Mech Shop	3500	18.24	81.76	0.00	0.00
Pipe Shop	3500	16.09	83.91	0.00	0.00
Work Packaging	3500	81.18	18.82	0.00	0.00
Cleaning	3500	57.23	42.77	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00
ShipA	3500	100.00	0.00	0.00	0.00
WarehouseC	3500	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	4861	16.71	0.27	0.42	0.00	39.32
Laborer.2	1	3500	2888	18.53	0.23	0.43	0.00	25.83
Laborer.3	1	3500	1387	20.99	0.22	0.43	0.00	14.01

Laborer.4	1	3500	558	27.43	0.26	0.43	0.00	7.36
Laborer	4	14000	9694	18.48	0.25	0.43	0.00	21.63
SEWS Clerk	1	3500	9082	5.02	0.05	0.13	0.00	21.96
Work Packager	1	3500	4414	12.21	0.18	0.26	0.00	26.07
Finder	1	3500	414	135.05	0.84	0.55	0.00	26.79

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	38.68	0.64	0.49	60.19	0.00
Laborer.2	3500	25.50	0.33	0.33	73.85	0.00
Laborer.3	3500	13.86	0.15	0.16	85.83	0.00
Laborer.4	3500	7.29	0.07	0.05	92.59	0.00
Laborer	14000	21.33	0.30	0.26	78.11	0.00
SEWS Clerk	3500	21.73	0.22	0.07	77.97	0.00
Work Packager	3500	25.68	0.38	0.15	73.79	0.00
Finder	3500	26.63	0.17	0.01	73.20	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	29.28	27.28	0.00	2.00	0.00
Cleaned Tag	1599	2401	40136.90	4.35	0.00	0.00	40132.54
Tagged Part	2401	0	120279.00	39.11	30030.31	90209.57	0.00
Cleaned Tagged Part	1599	0	131635.00	80.94	29891.34	101662.71	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	93.16	0.00	6.83	0.01
Cleaned Tag	0.01	0.00	0.00	99.99
Tagged Part	0.03	24.97	75.00	0.00
Cleaned Tagged Part	0.06	22.71	77.23	0.00

Appendix B: Radio Frequency Best Estimate Model Results

General Report
Output from C:\ProMod4Student\models\rf1\rfbl.MOD
Date: Aug/09/2001 Time: 07:00:47 PM

Scenario : Normal Run
Replication : 1 of 1
Simulation Time : 3500 hr

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4150	35078.72	693.22	1556	0	17.33
ship	3500	6000	8072	14843.02	570.53	4000	0	9.51
Elec Shop	3500	4000	2053	38667.36	378.02	920	0	9.45
Mech Shop	3500	4000	2025	38176.97	368.13	898	0	9.20
Pipe Shop	3500	4000	2024	37276.52	359.27	863	0	8.98
Work Packaging	3500	4000	4000	4.26	0.08	4	0	0.00
Cleaning	3500	6000	1612	299.03	2.29	15	0	0.04
WarehouseB	3500	6000	4000	139846.29	2663.74	3944	2388	44.40
Loc2	3500	1	0	0.00	0	0	0	0.00
Loc3	3500	1	0	0.00	0	0	0	0.00
Loc4	3500	1	0	0.00	0	0	0	0.00
Loc5	3500	1	0	0.00	0	0	0	0.00
Loc6	3500	1	0	0.00	0	0	0	0.00
Loc7	3500	1	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	1.95	98.05	0.00	0.00
ship	3500	71.48	28.52	0.00	0.00
Elec Shop	3500	17.63	82.37	0.00	0.00
Mech Shop	3500	16.66	83.34	0.00	0.00
Pipe Shop	3500	15.87	84.13	0.00	0.00
Work Packaging	3500	93.48	6.52	0.00	0.00
Cleaning	3500	56.75	43.25	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Loc2	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc3	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc4	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc5	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc6	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc7	3500	0.00	0.00	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	7871	4.77	0.22	0.43	0.00	18.76
Laborer.2	1	3500	1312	4.78	0.30	0.42	0.00	3.18
Laborer.3	1	3500	147	4.85	0.40	0.42	0.00	0.37
Laborer.4	1	3500	20	6.22	0.37	0.40	0.00	0.06
Laborer	4	14000	9350	4.78	0.24	0.43	0.00	5.59
SEWS Clerk	1	3500	9010	1.32	0.04	0.13	0.00	5.88
Work Packager	1	3500	4072	10.68	0.05	0.26	0.00	20.83
Finder	1	3500	72	55.58	0.32	0.55	0.00	1.92

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	17.90	0.86	0.97	80.27	0.00
Laborer.2	3500	2.99	0.19	0.12	96.69	0.00
Laborer.3	3500	0.34	0.03	0.01	99.62	0.00
Laborer.4	3500	0.06	0.00	0.00	99.94	0.00
Laborer	14000	5.32	0.27	0.27	94.13	0.00
SEWS Clerk	3500	5.67	0.21	0.10	94.03	0.00
Work Packager	3500	20.72	0.12	0.40	78.77	0.00
Finder	3500	1.91	0.01	0.02	98.07	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	14.60	12.60	0.00	2.00	0.00
Cleaned Tag	1612	2388	40077.55	0.38	0.00	0.00	40077.16
Tagged Part	2388	0	119619.97	5.27	29717.23	89897.46	0.00
Cleaned Tagged Part	1612	0	131751.53	10.57	30266.34	101474.61	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	86.29	0.00	13.69	0.01
Cleaned Tag	0.00	0.00	0.00	100.00
Tagged Part	0.00	24.84	75.15	0.00
Cleaned Tagged Part	0.01	22.97	77.02	0.00

Appendix C: Radio Frequency Five Minute Check-in Model Results

```
--------------------------------------------------------------------------------
General Report
Output from C:\ProMod4Student\models\rf1\rf CKIN5.MOD
Date: Aug/09/2001   Time: 06:51:45 PM
--------------------------------------------------------------------------------
Scenario        : Normal Run
Replication     : 1 of 1
Simulation Time : 3500 hr
--------------------------------------------------------------------------------
```

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4161	35099.44	695.47	1558	0	17.39
ship	3500	6000	8072	14771.34	567.78	4000	0	9.46
Elec Shop	3500	4000	2039	37651.44	365.57	877	0	9.14
Mech Shop	3500	4000	2007	38261.94	365.67	892	0	9.14
Pipe Shop	3500	4000	2103	37096.98	371.5	892	0	9.29
Work Packaging	3500	4000	4000	4.47	0.08	4	0	0.00
Cleaning	3500	6000	1628	300.67	2.33	19	0	0.04
WarehouseB	3500	6000	4000	139257.92	2652.53	3926	2372	44.21
Loc2	3500	1	0	0.00	0	0	0	0.00
Loc3	3500	1	0	0.00	0	0	0	0.00
Loc4	3500	1	0	0.00	0	0	0	0.00
Loc5	3500	1	0	0.00	0	0	0	0.00
Loc6	3500	1	0	0.00	0	0	0	0.00
Loc7	3500	1	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	1.37	98.63	0.00	0.00
ship	3500	71.62	28.38	0.00	0.00
Elec Shop	3500	17.43	82.57	0.00	0.00
Mech Shop	3500	18.62	81.38	0.00	0.00
Pipe Shop	3500	15.88	84.12	0.00	0.00
Work Packaging	3500	93.18	6.82	0.00	0.00
Cleaning	3500	56.75	43.25	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Loc2	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc3	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc4	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc5	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc6	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc7	3500	0.00	0.00	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	7248	6.91	0.23	0.43	0.00	24.67
Laborer.2	1	3500	1859	7.08	0.27	0.42	0.00	6.52
Laborer.3	1	3500	273	7.07	0.36	0.41	0.00	0.97
Laborer.4	1	3500	42	6.32	0.40	0.44	0.00	0.13
Laborer	4	14000	9422	6.95	0.24	0.43	0.00	8.07
SEWS Clerk	1	3500	9062	2.02	0.04	0.13	0.00	8.95
Work Packager	1	3500	4072	10.78	0.06	0.26	0.00	21.04
Finder	1	3500	72	59.20	0.33	0.55	0.00	2.04

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	23.87	0.80	0.90	74.43	0.00
Laborer.2	3500	6.27	0.25	0.20	93.28	0.00
Laborer.3	3500	0.92	0.05	0.02	99.01	0.00
Laborer.4	3500	0.13	0.01	0.00	99.86	0.00
Laborer	14000	7.80	0.28	0.28	91.65	0.00
SEWS Clerk	3500	8.74	0.21	0.09	90.95	0.00
Work Packager	3500	20.91	0.12	0.39	78.57	0.00
Finder	3500	2.03	0.01	0.02	97.94	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	14.92	12.92	0.00	2.00	0.00
Cleaned Tag	1628	2372	40286.01	0.48	0.00	0.00	40285.53
Tagged Part	2372	0	119518.15	6.93	29775.55	89735.65	0.00
Cleaned Tagged Part	1628	0	131379.29	15.05	29820.79	101543.44	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	86.59	0.00	13.40	0.01
Cleaned Tag	0.00	0.00	0.00	100.00
Tagged Part	0.01	24.91	75.08	0.00
Cleaned Tagged Part	0.01	22.70	77.29	0.00

Appendix D: Radio Frequency One Minute Check-in Model Results

```
--------------------------------------------------------------------------------
General Report
Output from C:\ProMod4Student\models\rf1\rf ckin1.MOD
Date: Aug/09/2001   Time: 07:26:12 PM
--------------------------------------------------------------------------------
Scenario        : Normal Run
Replication     : 1 of 1
Simulation Time : 3500 hr
--------------------------------------------------------------------------------
```

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4075	35027.52	679.70	1524	0	16.99
ship	3500	6000	8072	14810.17	569.27	4000	0	9.49
Elec Shop	3500	4000	2009	37796.18	361.58	891	0	9.04
Mech Shop	3500	4000	2020	38332.62	368.72	896	0	9.22
Pipe Shop	3500	4000	2132	37557.95	381.30	915	0	9.53
Work Packaging	3500	4000	4000	4.49	0.08	5	0	0.00
Cleaning	3500	6000	1594	300.64	2.28	20	0	0.04
WarehouseB	3500	6000	4000	140424.54	2674.75	3932	2406	44.58
Loc2	3500	1	0	0.00	0	0	0	0.00
Loc3	3500	1	0	0.00	0	0	0	0.00
Loc4	3500	1	0	0.00	0	0	0	0.00
Loc5	3500	1	0	0.00	0	0	0	0.00
Loc6	3500	1	0	0.00	0	0	0	0.00
Loc7	3500	1	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	0.81	99.19	0.00	0.00
ship	3500	71.54	28.46	0.00	0.00
Elec Shop	3500	17.96	82.04	0.00	0.00
Mech Shop	3500	18.21	81.79	0.00	0.00
Pipe Shop	3500	14.65	85.35	0.00	0.00
Work Packaging	3500	93.30	6.70	0.00	0.00
Cleaning	3500	57.16	42.84	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Loc2	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc3	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc4	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc5	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc6	3500	0.00	0.00	100.00	0.00	0.00	0.00

Loc7	3500	0.00	0.00	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	8487	2.66	0.23	0.43	0.00	11.72
Laborer.2	1	3500	825	2.20	0.33	0.42	0.00	1.00
Laborer.3	1	3500	53	2.21	0.37	0.44	0.00	0.07
Laborer.4	1	3500	2	1.49	0.36	0.00	0.00	0.00
Laborer	4	14000	9367	2.62	0.24	0.43	0.00	3.20
SEWS Clerk	1	3500	8875	0.61	0.04	0.13	0.00	2.78
Work Packager	1	3500	4072	10.70	0.05	0.26	0.00	20.86
Finder	1	3500	72	59.91	0.32	0.55	0.00	2.07

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	10.77	0.95	1.03	87.24	0.00
Laborer.2	3500	0.87	0.13	0.07	98.93	0.00
Laborer.3	3500	0.06	0.01	0.00	99.93	0.00
Laborer.4	3500	0.00	0.00	0.00	100.00	0.00
Laborer	14000	2.92	0.27	0.28	96.53	0.00
SEWS Clerk	3500	2.58	0.20	0.10	97.12	0.00
Work Packager	3500	20.75	0.11	0.40	78.74	0.00
Finder	3500	2.05	0.01	0.02	97.92	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	14.84	12.83	0.00	2.00	0.00
Cleaned Tag	1594	2406	39627.89	0.34	0.00	0.00	39627.54
Tagged Part	2406	0	119756.18	4.06	29967.73	89784.38	0.00
Cleaned Tagged Part	1594	0	130543.44	6.37	29727.73	100809.33	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	86.51	0.00	13.48	0.01
Cleaned Tag	0.00	0.00	0.00	100.00
Tagged Part	0.00	25.02	74.97	0.00
Cleaned Tagged Part	0.00	22.77	77.22	0.00

Appendix E: Radio Frequency 4% Lost Part Rate Model Results

General Report
Output from C:\ProMod4Student\models\rf1\rf LP4.MOD
Date: Aug/09/2001   Time: 07:36:59 PM

Scenario : Normal Run
Replication : 1 of 1
Simulation Time : 3500 hr

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4034	34940.63	671.19	1497	0	16.78
ship	3500	6000	8157	14649.61	569.03	4000	0	9.48
Elec Shop	3500	4000	2116	37523.70	378.09	906	0	9.45
Mech Shop	3500	4000	2047	38374.01	374.05	902	0	9.35
Pipe Shop	3500	4000	2093	37375.22	372.50	893	0	9.31
Work Packaging	3500	4000	4000	7.72	0.14	8	0	0.00
Cleaning	3500	6000	1569	297.54	2.22	18	0	0.04
WarehouseB	3500	6000	4000	141578.83	2696.74	3932	2431	44.95
Loc2	3500	1	0	0.00	0	0	0	0.00
Loc3	3500	1	0	0.00	0	0	0	0.00
Loc4	3500	1	0	0.00	0	0	0	0.00
Loc5	3500	1	0	0.00	0	0	0	0.00
Loc6	3500	1	0	0.00	0	0	0	0.00
Loc7	3500	1	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	1.12	98.88	0.00	0.00
ship	3500	71.50	28.50	0.00	0.00
Elec Shop	3500	15.75	84.25	0.00	0.00
Mech Shop	3500	16.62	83.38	0.00	0.00
Pipe Shop	3500	17.39	82.61	0.00	0.00
Work Packaging	3500	90.37	9.63	0.00	0.00
Cleaning	3500	57.58	42.42	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Loc2	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc3	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc4	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc5	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc6	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc7	3500	0.00	0.00	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	7882	4.77	0.22	0.43	0.00	18.78
Laborer.2	1	3500	1369	4.70	0.31	0.42	0.00	3.27
Laborer.3	1	3500	163	4.68	0.38	0.41	0.00	0.39
Laborer.4	1	3500	19	5.24	0.41	0.39	0.00	0.05
Laborer	4	14000	9433	4.76	0.24	0.43	0.00	5.62
SEWS Clerk	1	3500	8780	1.37	0.04	0.13	0.00	5.94
Work Packager	1	3500	4157	11.11	0.09	0.26	0.00	22.20
Finder	1	3500	157	61.86	0.40	0.55	0.00	4.66

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	17.93	0.85	0.98	80.24	0.00
Laborer.2	3500	3.07	0.20	0.13	96.59	0.00
Laborer.3	3500	0.36	0.03	0.01	99.60	0.00
Laborer.4	3500	0.05	0.00	0.00	99.95	0.00
Laborer	14000	5.35	0.27	0.28	94.09	0.00
SEWS Clerk	3500	5.74	0.20	0.09	93.96	0.00
Work Packager	3500	22.01	0.19	0.33	77.47	0.00
Finder	3500	4.62	0.03	0.04	95.31	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	18.11	16.11	0.00	2.00	0.00
Cleaned Tag	1569	2431	39881.16	0.38	0.00	0.00	39880.78
Tagged Part	2431	0	119899.30	5.49	29846.80	90047.01	0.00
Cleaned Tagged Part	1569	0	131065.31	10.74	29877.90	101176.66	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	88.95	0.00	11.04	0.01
Cleaned Tag	0.00	0.00	0.00	100.00
Tagged Part	0.00	24.89	75.10	0.00
Cleaned Tagged Part	0.01	22.80	77.20	0.00

Appendix F: Radio Frequency 6% Lost Part Rate Model Results

General Report
Output from C:\ProMod4Student\models\rf1\rf LP6.MOD
Date: Aug/09/2001 Time: 07:46:04 PM

Scenario : Normal Run
Replication : 1 of 1
Simulation Time : 3500 hr

LOCATIONS

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry	Average Contents	Maximum Contents	Current Contents	% Util
Warehouse	3500	4000	4078	34649.97	672.87	1514	0	16.82
ship	3500	6000	8251	14518.90	570.45	4000	0	9.51
Elec Shop	3500	4000	2175	37495.06	388.34	944	0	9.71
Mech Shop	3500	4000	2064	37295.39	366.56	883	0	9.16
Pipe Shop	3500	4000	2080	36944.63	365.92	872	0	9.15
Work Packaging	3500	4000	4000	12.30	0.23	6	0	0.01
Cleaning	3500	6000	1575	299.58	2.24	18	0	0.04
WarehouseB	3500	6000	4000	141223.52	2689.97	3938	2425	44.83
Loc2	3500	1	0	0.00	0	0	0	0.00
Loc3	3500	1	0	0.00	0	0	0	0.00
Loc4	3500	1	0	0.00	0	0	0	0.00
Loc5	3500	1	0	0.00	0	0	0	0.00
Loc6	3500	1	0	0.00	0	0	0	0.00
Loc7	3500	1	0	0.00	0	0	0	0.00

LOCATION STATES BY PERCENTAGE (Multiple Capacity)

Location Name	Scheduled Hours	% Empty	% Partially Occupied	% Full	% Down
Warehouse	3500	5.78	94.22	0.00	0.00
ship	3500	71.46	28.54	0.00	0.00
Elec Shop	3500	16.97	83.03	0.00	0.00
Mech Shop	3500	16.04	83.96	0.00	0.00
Pipe Shop	3500	17.29	82.71	0.00	0.00
Work Packaging	3500	86.63	13.37	0.00	0.00
Cleaning	3500	56.98	43.02	0.00	0.00
WarehouseB	3500	0.00	100.00	0.00	0.00

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Loc2	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc3	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc4	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc5	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc6	3500	0.00	0.00	100.00	0.00	0.00	0.00
Loc7	3500	0.00	0.00	100.00	0.00	0.00	0.00

RESOURCES

Resource Name	Units	Scheduled Hours	Number Of Times Used	Average Minutes Per Usage	Average Minutes Travel To Use	Average Minutes Travel To Park	% Blocked In Travel	% Util
Laborer.1	1	3500	7831	4.82	0.22	0.43	0.00	18.83
Laborer.2	1	3500	1495	4.78	0.28	0.43	0.00	3.61
Laborer.3	1	3500	176	4.34	0.37	0.42	0.00	0.40
Laborer.4	1	3500	17	4.09	0.42	0.51	0.00	0.04
Laborer	4	14000	9519	4.80	0.23	0.43	0.00	5.72
SEWS Clerk	1	3500	8853	1.40	0.04	0.13	0.00	6.14
Work Packager	1	3500	4251	11.51	0.12	0.26	0.00	23.57
Finder	1	3500	251	65.18	0.48	0.55	0.00	7.85

RESOURCE STATES BY PERCENTAGE

Resource Name	Scheduled Hours	% In Use	% Travel To Use	% Travel To Park	% Idle	% Down
Laborer.1	3500	17.98	0.85	0.97	80.20	0.00
Laborer.2	3500	3.40	0.20	0.16	96.23	0.00
Laborer.3	3500	0.36	0.03	0.01	99.59	0.00
Laborer.4	3500	0.03	0.00	0.00	99.96	0.00
Laborer	14000	5.45	0.27	0.29	94.00	0.00
SEWS Clerk	3500	5.94	0.20	0.09	93.76	0.00
Work Packager	3500	23.31	0.26	0.26	76.16	0.00
Finder	3500	7.79	0.06	0.05	92.10	0.00

FAILED ARRIVALS

Entity Name	Location Name	Total Failed
Part	ship	0
QA2 Tag	Work Packaging	0
Cleaned Tag	WarehouseB	0

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Part	0	0	-	-	-	-	-
QA2 Tag	4000	0	22.64	20.63	0.00	2.00	0.00
Cleaned Tag	1575	2425	39620.87	0.38	0.00	0.00	39620.49
Tagged Part	2425	0	120058.27	5.62	30221.65	89830.99	0.00
Cleaned Tagged Part	1575	0	130684.28	11.08	29489.80	101183.39	0.00

ENTITY STATES BY PERCENTAGE

Entity Name	% In Move Logic	% Wait For Res, etc.	% In Operation	% Blocked
Part	-	-	-	-
QA2 Tag	91.16	0.00	8.83	0.01
Cleaned Tag	0.00	0.00	0.00	100.00
Tagged Part	0.00	25.17	74.82	0.00
Cleaned Tagged Part	0.01	22.57	77.43	0.00