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**Pallet Management System:  
A Study of the Implementation of UID/RFID Technology for  
Tracking Shipping Materials within the Department of  
Defense Distribution Network**

**20 June 2008**

**by**

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Diana Petross, Lecturer

Graduate School of Business & Public Policy

**Naval Postgraduate School**

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# Abstract

The purpose of this MBA project is to identify the typical pallet utilization for the Defense Distribution Depot San Joaquin (DDJC) shipments to the Defense Distribution Depot San Diego (DDDC). That information will be used as the basis for suggesting a standardized reutilization management system for wood and non-wood pallets. This project will analyze the inclusion of Radio Frequency Identification and Unique Item Identification in conjunction with bar code technology for the improvement of asset visibility within the Department of Defense's supply network.

**Keywords:** Pallet, Pallet Management, Pallet Pooling, Radio Frequency Identification, RFID, Unique Item Identification, UID, Asset Visibility, Bar Code, Distribution Network



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Jeffrey S. Harris and Jeffrey S. Worrell

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Jeffrey S. Worrell



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Disclaimer: The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or the Federal Government.



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# Table of Contents

<b>I.</b>	<b>Introduction .....</b>	<b>1</b>
A.	Background .....	1
B.	Purpose .....	1
C.	Scope .....	2
D.	Methodology.....	2
<b>II.</b>	<b>Pallets .....</b>	<b>5</b>
A.	Overview .....	5
B.	Pallet Standards and Regulations .....	10
C.	Pallet Management.....	13
<b>III.</b>	<b>Automatic Identification Technology .....</b>	<b>17</b>
A.	Bar code .....	17
B.	RFID.....	23
C.	UID .....	28
<b>IV.</b>	<b>Navy’s Non-wood Pallet Investigation.....</b>	<b>35</b>
A.	Background .....	35
B.	Research and Analysis of Investigation.....	37
C.	Chapter Summary .....	40
<b>V.</b>	<b>Pallet Management Model .....</b>	<b>43</b>
A.	Overview .....	43
B.	Open-loop to Closed-loop.....	43
C.	Establishing the Pool size.....	45
D.	Selection of Pallet Type.....	46
E.	Tracking Technology .....	47



<b>VI. Summary, Conclusions, and Recommendations .....</b>	<b>53</b>
A. Summary .....	53
B. Conclusions.....	53
C. Recommendations.....	54
<b>List of References.....</b>	<b>55</b>
<b>Appendix A. Bar Code Comparison Chart .....</b>	<b>59</b>
<b>Appendix B. Common RFID Frequencies .....</b>	<b>65</b>
<b>Appendix C. Examples of Recurring Cost and Potential Savings Utilizing a Pallet Pool without RFID from DDJC to DDDC.....</b>	<b>67</b>
<b>Appendix D. Examples of Recurring Cost and Potential Savings Utilizing a Pallet Pool with RFID from DDJC to DDDC .....</b>	<b>77</b>



## List of Acronyms and Abbreviations

AI:	Application Identifier
AIT:	Automatic Identification Technology
ASTM:	American Standards for Testing and Materials
BCA:	Business Case Analysis
CLJ:	C. Lloyd Johnson
COCOMs:	Combatant Commanders
CRRC:	Container Reuse and Refurbishment Center
DDDC:	Defense Distribution Depot San Diego
DDJC:	Defense Distribution Depot San Joaquin
DFARS:	Defense Federal Acquisition Regulations
DI:	Data Identifier
DoD:	Department of Defense
EPC:	Electronic Product Code
FOD:	Foreign Object Debris
GAO:	General Accounting Office
IFF:	Identify Friend or Foe
IPPC:	International Plant Protection Convention
ISO:	International Organization for Standardization
ISPM:	International Standards of Phytosanitary Measures
ITV:	In-Transit Visibility
IUID:	Item Unique Identification
MHIA:	Material Handling Industry of America
MIL-STD:	Military Standard
MRI:	Machine-readable Information
NAB:	Naval Amphibious Base
NASA:	National Aeronautics and Space Administration
NAVICP-M:	Naval Inventory Control Point—Mechanicsburg
NWP:	Non-wood Pallet
NWPCA:	National Wood Pallet & Container Association
OCR:	Optical Character Reader
RF:	Radio Frequency
RFID:	Radio Frequency Identification



ROI:	Return on Investment
RW:	Read-Write
SSCC:	Serial Shipping Container Code
SPV:	Subsistence Prime Vendor
TAV:	Total Asset Visibility
UID:	Unique Item Identification
Ull:	Unique Item Identifier
WAWF:	Wide-area Work Flow



# I. Introduction

## A. Background

The most underappreciated and unrecognized asset in the military logistics network is the pallet. Despite carrying billions of dollars worth of equipment, materials, and supplies around the world, the pallet gets no respect. Most often seen as just a consumable item, the pallet's true worth and vital link in the supply chain is simply overshadowed by the load carried upon its stringers.

In order to maximize a pallet's yield, organizations must leverage the pallet's value through reuse (Foster, 1999, May). Currently, the Department of Defense (DoD) does not have an official policy or regulation that governs the reuse of pallets. Most military organizations reuse pallets to supplement shipping and storage needs, but the majority of pallets utilized by DoD organizations are considered one-way conveyances, and they are either recycled or disposed of as solid waste. Therefore, the DoD is continually purchasing new pallets to meet its needs instead of tapping into a reusable asset.

Several large retail and shipping companies have instituted pallet management systems or have contracted with a pallet management company in order to reap the benefits of pallet reuse. Pallet inventory and quality is the most challenging aspect of managing shipping platforms (Naval Inventory Control Point, 2006). Therefore, through their management efforts, these companies have mitigated these challenges by reducing the variability within their pallet pools and have realized savings from not having to continually purchase pallets to fulfill their shipping needs.

## B. Purpose

The purpose of this MBA project is to identify the typical pallet utilization for the Defense Distribution Depot San Joaquin (DDJC) shipments to the Defense Distribution Depot San Diego (DDDC). That information will be used as the basis for



suggesting a standardized reutilization management system for wood and non-wood pallets.

### C. Scope

Typically, pallets are not viewed as an asset, and the lack of a joint pallet management system within the DoD exacerbates this perception. This project addresses the establishment of a pallet management system, leveraging RFID/UID and Bar Code technologies to aid in the tracking and management of pallets and in the improvement of total asset visibility.

### D. Methodology

The methodology applied in this research project consists of the following steps:

- Conduct a literature review of books, magazine articles, electronic media, and library resources related to the topic.
- Conduct a thorough review of Bar Code technology.
- Conduct a thorough review of RFID technology.
- Conduct a thorough review of UID technology.
- Conduct a review of the current RFID/UID and Bar Code mandates and regulations.
- Conduct a site visit to the Defense Distribution Depot San Joaquin (DDJC).
- Conduct a site visit to the Defense Distribution Depot San Diego (DDDC).
- Conduct a site visit to the Pepsi/Quaker Oats Distribution Center, Tracy, CA.
- Conduct a review and analysis of typical DoD utilization of pallets within the DoD supply chain.
- Conduct a review and analysis of commercial pallet management practices.
- Simulate a pallet management system, utilizing RFID/UID and Bar Code technologies that will translate to the DoD distribution system.





- Conduct a Business Case Analysis (BCA) and Return on Investment (ROI) analysis of the proposed pallet management system.
- Prepare a summary and make recommendations.



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## II. Pallets

### A. Overview

The pallet is a portable, horizontal, rigid platform used as a base for storing, stacking, handling, and transporting goods as a unit load (National Wooden Pallet and Container Association, 2007a). The pallet is literally and figuratively the interface between the packaged product and the unit load handling equipment; therefore, it is a critical component of the supply chain (White, 2005). Within the DoD, however, the pallet is not viewed with such relevance. Looked upon as merely a one-way conveyance and consumable, the pallet is often discarded or recycled without full utilization of its potential.

#### 1. History

The pallet is one of the most important innovations in material handling of the 20<sup>th</sup> Century. It revolutionized the way shipping and warehousing operations stacked, loaded, and containerized products. Industry and the military have greatly benefited from its development.

Though they appeared more than 105 years ago, pallets and palletization did not gain widespread popularity and prominence until the outbreak of World War II (LeBlanc, 2002). Pallets allowed more material to be moved with fewer personnel, freeing more employees for military service. Pallets were used in all theaters of the war, but their utilization was most prominent in the Pacific. With bases and battlefronts spread across more than 6,000 miles of ocean, the pallet allowed these forces to be re-supplied with materials and equipment quickly and in greater abundance. It has been reported that the military moved between 55 and 60 million pallets from 1941-1945 (IFCO Systems North America, 2008).

The demand for pallets and the palletization process grew dramatically after World War II. Today, experts estimate that over 2 million pallets are in use daily throughout the United States—making the pallet industry the largest consumer of



domestic, renewable, hardwood lumber in America (2008). Table 1 lists other facts concerning pallets and the pallet industry in 2004.

**Table 1. Pallet Industry Numbers for 2004**  
(IFCO Systems North America, 2008)

Annual Sales	\$6 Billion
Companies	Over 3,000
Daily Global Pallet Usage	1.9 Billion
Wood Pallets Produced in 2004	814 Million
New Wood Pallets in 2004	500 Million
Pallets Recycled in 2004	300 Million
Plastic Pallets in Use	8.3 Million
Corrugated Pallets in Use	5.5 Million
Metal Pallets in Use	1.1 Million

## 2. Types of Pallets

Most pallets are designed to meet the specific requirements of the customer. Pallets come in different sizes and configurations, but they mainly fall into two very broad categories: stringer pallets and block pallets.

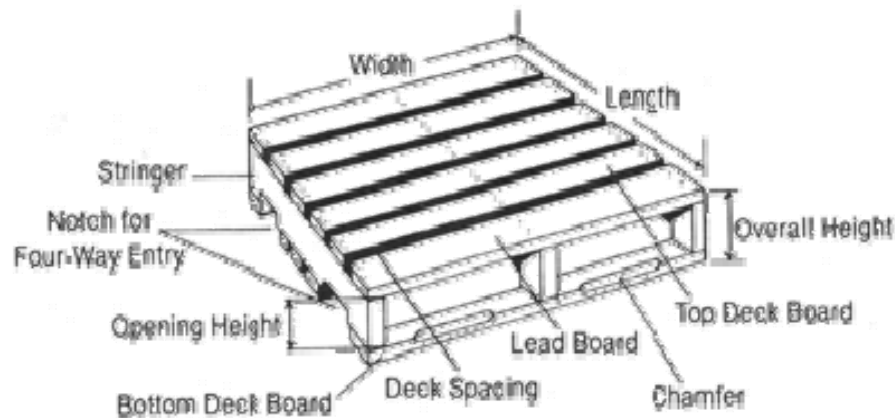
**Table 2. Typical United States Pallet Sizes and Consumer Industry**  
(IFCO Systems North America, 2008)

Pallet Size (in)	1996 Production (%)	Industry Used
48 x 40	30.0	Food
42 x 42	5.7	Chemical
48 x 42	4.7	Chemical
40 x 48	4.0	Government
48 x 48	3.7	Chemical
44 x 44	3.5	Steel
40 x 40	3.1	Dairy
36 x 36	3.0	Beverage
48 x 36	1.7	Paper



**a. Stringer Pallet**

The stringer pallet is the most commonly used pallet in the United States, with the most common size being 48 x 40 (Larson Pallet & Crating, 2006). A stringer is a continuous, longitudinal, solid or notched<sup>1</sup> beam component of the pallet used to support deck components, often identified by location as the outside or center stringer (National Wooden Pallet and Container Association, 2007a). The top deck boards are then affixed to the stringers to create the pallet structure. See Figure 1.



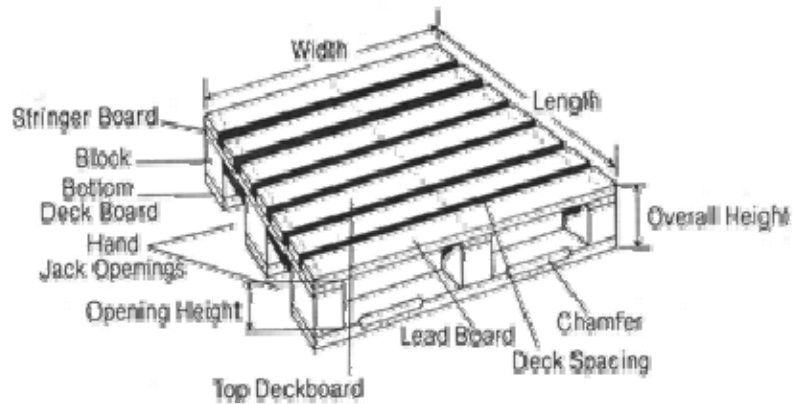
**Figure 1. Stringer Pallet Construction**  
(Larson Pallet & Crating, 2006)

**b. Block Pallet**

Block pallets are typically stronger than stringer pallets and are true four-way pallets. They utilize four to twelve blocks to support the top deckboards (Larson Pallet & Crating, 2006). Block pallets utilize both parallel and perpendicular stringers to better facilitate efficient handling. See Figure 2.

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<sup>1</sup> Notched stringers facilitate a four-way entry.



**Figure 2. Block Pallet Construction**  
(Larson Pallet & Crating, 2006)

**c. Pallet Types and Specifications**

In addition to the pallet construction, one may also consider the various pallet types currently available. Figure 3 provides an overview of the various pallet material types and their associated characteristics including the respective unit costs, disadvantages and advantages.



PALLET MATERIAL	NUMBER OF TRIPS	REPAIRABLE	RECYCLED CONTENT	BASE WEIGHT (LBS.)	DYNAMIC LOAD CAPACITY (LBS.)	UNIT COST	DISPOSAL OPTIONS	DISADVANTAGES	ADVANTAGES
<b>WOOD</b>	2-15 before repair	Yes	No	55-112	2,500	\$3.50-\$10	Recycle Compost Fuel Source Remanufacture Mulch	Product damage and lowered employee safety because of splinters, loose boards and nails	Wood is the standard pallet material; third party management can reduce costs and increase reuse
<b>PRESSED WOOD FIBER</b>	2-4	No	Yes	30-42	1,000-2,500 (uniform load)	\$5-\$7	Recycle Compost Fuel Source	Not very resistant to water or contamination, loads need to be uniform across pallet face	Slightly lighter than wood; round corners make ideal for stretch wrapping; nestable which means less storage space
<b>CORRUGATED FIBERBOARD</b>	1	No	Yes	7-12	1,700-4,000 (uniform load)	\$5-\$7	Recycle Compost Fuel Source	Not resistant to water or contamination, easily damaged, loads must be uniform across pallet	Easily recycled with OCC waste; some are nestable; light weight, no nails, no splinters – safer for employees
<b>PLASTIC</b>	250	No	Yes	35-75	1,500-4,000	\$20-\$80	Recycle	Usually used in closed-loop system, fair to high unit costs, poor reparability, potential fire hazard	Easy to clean; some are nestable; no splinters or nails – safer for employees; low cost per trip
<b>METAL</b>	15 year life	Yes	Yes	32-100	5,000	\$40-\$350	Recycle	Usually used as a captive pallet or in a closed loop system, very high unit costs	Meet FDA and USDA standards; strongest and longest life pallet; no fire hazard
<b>SLIPSHEET (PLASTIC, CORRUGATED, FIBER)</b>	1	No	Yes	2	Corrugated – 500 Solid fiber – 2,000 Plastic – 2,500	\$0.60-\$2.50	Recycle	High start-up costs; push/pull attachments are required on shipping and receiving ends	Lightweight, no nails or splinters – increased employee safety; less storage space; no need for tracking – cheap enough for one time use
<b>COMPOSITE</b>	100-150	Yes	Yes	55-75	5,000	\$22-\$70	Company buy back for recycling	Usually used in closed-loop system, fair to high unit cost, still fairly new in market so little performance data is known	Typically stronger than wood or plastic; sanitary, washable; some are fire retardant and self-extinguishing; water resistant

**Figure 3. Pallet Types and Specifications**  
(Naval Inventory Control Point, 2006)



## B. Pallet Standards and Regulations

No single pallet dimension satisfies all the needs of the world's economies. In some instances, organizations employ different-sized pallets within their operation. Even with all the different sizes, there remain five fundamental qualities on which every pallet must be judged by users to determine its suitability for a given application. These fundamental qualities are as follows:

- Strength—the load-carrying capacity throughout shipping and storage environments.
- Stiffness—the resistance of the pallet to deformation under load.
- Durability—the ability to withstand the rigors of the shipping and handling environments.
- Functionality—the compatibility of the pallet with the packaging and material-handling equipment.
- Price—the design criterion often given more consideration than the other factors. (Clarke, 2004)

Though no consensus has been reached on the best size for pallet construction, several organizations have published standards that govern the performance of pallets. Also, as environmental concerns increase through continued globalization, regulations have been established that govern international transport pallets.

### 1. International Standards and Regulations

To prevent the spread of pests and to provide for the safe transport of goods internationally, governments and governing bodies have developed and published regulations and standards for the employment of pallets.

#### a. Phytosanitation Standard

The International Plant Protection Convention (IPPC) is an international treaty to secure action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control (International Phytosanitary Portal, 2008). Treatment and marking of wood pallets must conform



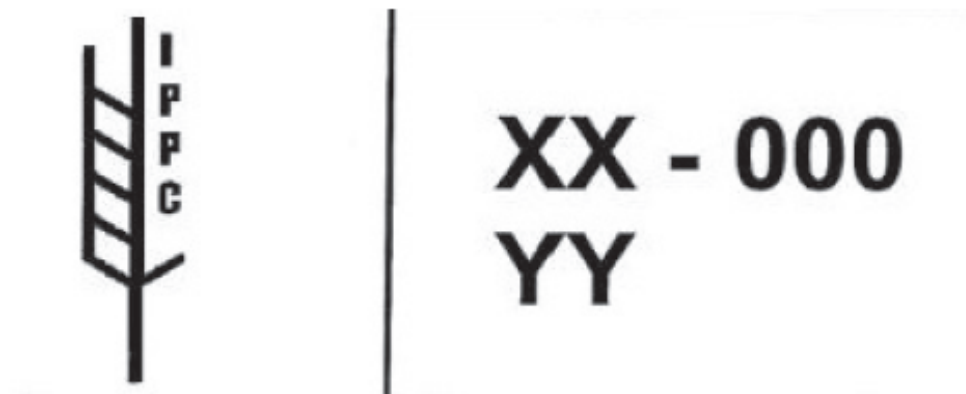


to the *International Standards of Phytosanitary Measures Publication No. 15 (ISPM 15)* guidelines for regulating wood packaging material in international trade (National Wooden Pallet and Container Association, 2007b).

Wood pallets can be *ISPM 15* compliant by adhering to either of the following:

- Heat treatment—the wood must be heated to achieve a temperature of 56o C for at least 30 minutes. Pallets treated via this method bear the initials HT by the IPPC logo.
- Chemical Fumigation—the wood must be fumigated with methyl bromide. Pallets treated via this method bear the initials MB by the IPPC logo.

Pallets must also utilize the standard IPPC markings as illustrated in Figure 4.



XX represents the International Standards Organization country.

000 represents the unique number assigned by the national plant protection organization to the treatment facility.

YY represents either HT for heat treatment or MB for methyl bromide fumigation.

**Figure 4. Example of the IPPC Marking**  
(USDA, 2005)

## b. International Organization for Standardization

The International Organization for Standardization (ISO) is a network of the national standards institutes of 157 countries, consisting of one member per country, with a central secretariat in Geneva, Switzerland, that coordinates the system; the ISO is the world's largest developer and publisher of International Standards (International Organization for Standardization, 2008). The ISO recognizes six pallet dimensions internationally. As highlighted in Table 3, the dimensions vary.

**Table 3. ISO Pallet Dimensions**  
(Clarke, 2004)

<b>Dimensions (mm)</b>	<b>Dimensions (inches)</b>	<b>Regions</b>
1200 x 1000	47.24 x 39.37	Europe, Asia
1200 x 800	47.24 x 31.50	Europe
1219 x 1016	48.00 x 40.00	North America
1140 x 1140	44.88 x 44.88	Australia
1100 x 1100	43.30 x 43.30	Asia
1067 x 1067	42.00 x 42.00	North America, Europe, Asia

## 2. National Standards

Pallets have historically been customized according to the customer's specifications. This trend has relied on the inherent flexibility of pallets to meet numerous requirements for a variety of industries and organizations. Several organizations have attempted to establish pallet standards and regulations, especially in the grocery industry, but they have failed to achieve widespread compliance and acceptance.

Organizations such as the National Wooden Pallet & Container Association (NWPCA),<sup>2</sup> Material Handling Industry of America (MHIA),<sup>3</sup> and the American

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<sup>2</sup> The NWPCA is dedicated to the success of its members by helping create cost-effective, environmentally responsible solutions to meet their customers' changing unit load-handling needs.

<sup>3</sup> The MHIA is the leading non-profit trade association representing the US material handling and logistics industry.



Standards for Testing and Materials (ASTM)<sup>4</sup> have established standards for wood quality and testing of pallets, but no one standard applies to the construction and size of pallets. Each of these organizations emphasize that the pallet producer should listen to its customers and produce pallets according to their requirements and specifications.

### **3. DoD Standards**

The DoD adopts commercial and industry standards for pallets employed within its transportation and supply systems. The DoD does, however, maintain *MIL-STD-1660, Design Criteria for Ammunition Unit Loads*, which details the military's requirements for the safe transportation and storage of ammunition. The standard highlights the size and specifications for pallets used for this hazardous operation.

## **C. Pallet Management**

Historically, pallets have been managed by one of three methods:

- Transfer of ownership
- Pallet exchange
- Pallet pooling

As pallets are viewed as assets, their management becomes essential to fully reap their benefits and to receive a measurable return on investment. This is most evident when organizations utilize more expensive non-wood pallets that hold the promise of longer lifecycles and performance.

### **1. Transfer of Ownership**

Traditionally, pallets were purchased and shipped without a seller expecting its customer to return them. The price of the pallet was associated with the material

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<sup>4</sup> ASTM is the most widely recognized and widely used national standards-setting organization in the United States for engineering-related materials and testing.



being shipped. Once delivery was made, the ownership was transferred to the receiving organization. Should the pallet provide a further use, the organization would utilize it within its facility; should it provide no further use, it would then be disposed of—most often as solid waste.

This method increased cost to the shipper because pallets needed to be purchased continuously to fulfill shipments. The receiver also incurred cost, since the addition of a pallet to its solid waste would increase the organization's waste management cost. In addition, the shipper would naturally incorporate the cost of the pallet in the price of the shipped material.

## **2. Pallet Exchange**

As defined by MHIA, a pallet exchange program is a program agreed upon by several shippers and receivers, with each party assuming responsibility for the total inventory of pallets; in such a program, these parties exchange pallets on a one-for-one basis, with each transaction recorded and documented (Material Handling Industry of America, 2008). As shipments are delivered, empty pallets are “exchanged” for the pallets under load. The receiver is expected to return the same style and number of pallets as it receives in the shipment.

The process is difficult to administer and often creates an adversarial environment between parties. The process lends itself to the prospect of one party exchanging low-quality pallets in order to reduce its own disposal cost, which ultimately increases the cost of future shipments. As a result, many carriers have resorted to charging pallet exchange fees or declining business to those that require pallet exchange.

## **3. Pallet Pooling**

Pallet pooling has increasingly become popular over the last two decades. Typical pallet pools include, but are not limited to, the following:



- Private Pool
- Third-party Owned Pool
- Third-party Managed Pool

**a. Private Pool**

The manufacturer owns the pallets and manages all aspects of the pallet pool. It creates the specifications for its pallets' use and arranges for pallet delivery and return (Naval Inventory Control Point, 2006). Should pallets become damaged or lost, the manufacturer must bear the cost of repair or replacement. This type of pool is best suited for closed-loop systems.

**b. Third-party-owned Pool**

Pallets are owned by a third-party that manages all aspects of the pallet pool (Naval Inventory Control Point, 2006). This party rents the pallets to a company for a period time, during which the responsibility of the pallet is transferred to the renting company. Once the rental period has expired, the pallets are returned to the third-party owner. Should a pallet become lost or damaged beyond use, the renting company is charged for the replacement of that pallet. This type of pool is suited for almost all applications, both locally and globally. Examples of third-party-owned pool companies are:

- CHEP—the world's largest third-party-owned company; utilizes wooden pallets for the majority of its pallet pools.
- iGPS—uses plastic pallets with imbedded RFID technology; allows for increased visibility of not only its pallets, but also for the renting company's merchandise.

**c. Third-party-managed Pool**

The pallets are owned by the user, but all aspects of the pallet pool are managed by a third party. The third party is responsible for the retrieval and recovery of the pallets, tracking of the inventory, and maintaining the pallet's condition. This type of pool is highly customized to meet a specific company's objectives (Naval Inventory Control Point, 2006).



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### III. Automatic Identification Technology

Automatic Identification Technology (AIT) is not a system or a single product but a family of commercial technologies that provides a range of capabilities (Harnitchek, 2007). AIT allows for hands-off data capture and processing. This results in improvements in asset and in-transit visibility, timeliness and accuracy of shipping, receiving, and transportation visibility within the DoD's transportation and supply systems. AIT includes, but is not limited to:

- Bar Code
- Radio Frequency Identification (RFID)
- Unique Item Identification (UID)<sup>5</sup>

#### A. Bar code

A bar code is a code designed to be scanned into computer memory that consists of a group of printed and variously patterned bars and spaces (and sometimes numerals) that contains information (as identification) about the object it labels ("Bar Code," 2008). Its invention was a culmination of over 30 years of research. The first bar code patent was awarded to a couple of Drexel University graduate students, Bernard Silver and Norman Woodland. Their system—based on ink patterns that glowed when exposed to ultraviolet light—provided the spark for a technology that would revolutionize the way information was gathered for product identification. The grocery industry was transformed by the introduction of the bar code, but not until the DoD adopted the bar code for marking all products sold to the United States military in 1981 did it achieve widespread adoption within industrial applications.

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<sup>5</sup> For the purposes of this project, UID is synonymous with Item Unique Identification (IUID).



## 1. Bar Code System

A bar code is “an array of rectangular bars and spaces in a predetermined pattern representing coded elements of data that can be automatically read and interpreted by automatic bar code reading devices” (DoD, 2007b). Dark bars within a bar code absorb light, and light spaces reflect light. This light absorption and reflection results in the primary algorithm, which is the fundamental method for assigning the binary values within a bar code. The waves are then converted to a frequency and assigned a value of 0 or 1. As a scanner passes over a bar code, the light waves are reflected and read by the scanner. Once a series of 0’s and 1’s are created from a bar code, a secondary algorithm is used to translate it to meaningful data (Bardi, Coyle & Novack, 2006, pp. 367-372).

A bar code symbology defines the technical details of a particular type of bar code: the width of the bars, character set, method of encoding, checksum<sup>6</sup> specifications, etc. (MakeBarcode.com, 2008). Appendix A contains a comparison chart that highlights the general capabilities of a particular bar code symbology. The symbology utilized is determined by the application and/or industry in which the bar code will be used. For example, the Department of Defense requires the use of both linear (Code 39) and two-dimensional (PDF417) bar codes for shipping labels and documentation. See Appendix A for illustrations and capabilities of Code 39 and PDF417 bar codes.

Globally accepted applications, such as the Serial Shipping Container Code (SSCC) have allowed bar codes to advance at the same rate as other electronic communication technologies. The SSCC-18 bar code acts as a “license plate” for unit loads carried on pallets, trucks, or shipping containers. When used in this capacity, the SSCC-18 allows for the quick and efficient movement of products from

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<sup>6</sup> A checksum is the sum of data calculated before and after transmission or storage to ensure the data is error and tamper free.





one organization to another. Figure 5 provides an example of the SSCC-18 bar code and its construct.



**Figure 5. SSCC-18**  
(GS1-128.INFO, 2006)

## 2. Bar Code Advantages and Limitations

Although bar codes have become a mainstay within our society and have had a revolutionary effect on industry—from retailing, shipping, and manufacturing to government agencies—their use has both advantages and limitations.

### a. Advantages

Bar code advantages include, but are not limited to, the following:

- **Speed**—A bar code of 12 characters can be scanned in approximately the time it takes a keyboard operator to make two keystrokes.
- **Cost Effectiveness**—Bar code systems have a demonstrated payback period of 6 to 18 months, and they provide the highest level of reliability in a wide variety of data collection applications. Bar code systems create value not only by saving time, but also by preventing costly errors.
- **Accuracy**—For every 1,000 characters typed by a keyboard operator, there are an average of 10 keying errors. For an Optical Character Reader (OCR), there is one error in every 10,000 reads. With wands, bar code systems approach one error in every 3,000,000 characters,



and with laser technology, they approach one error in 70 million entries. (Barcoding Incorporated, 2008)

**b. Limitations**

Bar code limitations include, but are not limited to, the following:

- Life span—Although a bar code has an unlimited shelf life, its life span is compromised by handling and environmental effects that can cause fading or degradation of its readability.
- Reading distance—Bar codes require an unabated line-of-sight in order to be read. This limitation requires astute attention when handlers process items and requires the bar codes to be free of dirt and/or moisture.
- Security—Since a bar code is most often printed onto a label, it is susceptible to counterfeiting. Bar codes can be photocopied, scanned, or faxed—providing the means for potential misuse or theft of material.

**3. DoD Bar Code Policy**

The DoD maintains the requirement for human-readable, linear bar codes and 2-D Military Shipping labels. The linear bar code is expected to remain the dominant auto ID technology within mainstream supply and transportation applications for the foreseeable future. In order to continue with its long history of bar code utilization and to incorporate the ongoing UID/RFID initiatives, the DoD has updated *MIL-STD-129* and *MIL-STD-130*.

**a. MIL-STD-129P w/Change 4**

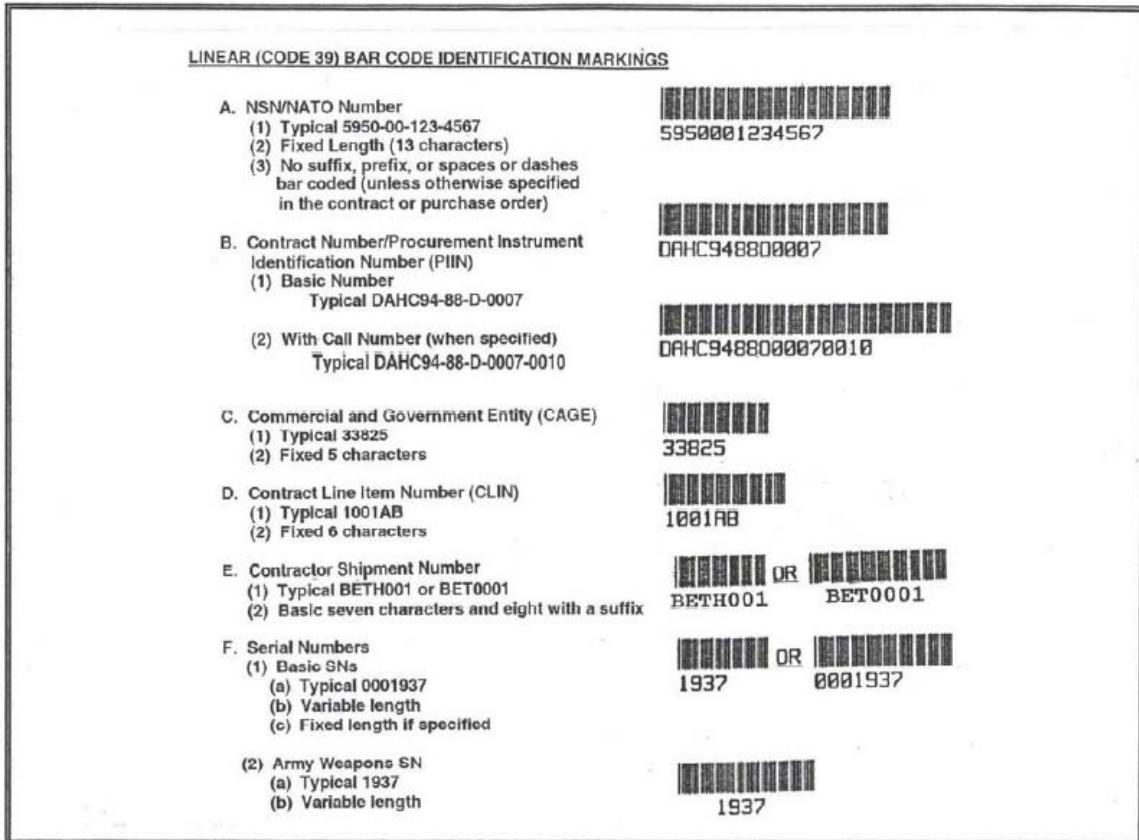
The purpose of *MIL-STD-129P* is to provide the minimum requirements for uniform military marking for shipment and storage. According to the standard, a marking is the application of numbers, letters, labels, tags, symbols, or colors that provides identification and expedites handling during shipment and storage (Department of Defense, 2007b). For bar codes, the standard stipulates the type, symbology, format for data, location, and number of bar codes needed for storage and shipment of materials and supplies. Figure 6 is an example of a military shipping label with the required bar codes, and Figure 7 illustrates the required fields for a linear (Code 39) bar code.



TCN <b>SW81238350D001XXX</b>			
			
From <b>SW8123</b> In-the-clear Address 3 Lines Max, 35 Characters Per Line XXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		TAC / Type Service / Postage <b>SZZZ</b> <b>Frt LTL</b>	
Piece <b>1</b> Of <b>1</b>	Weight (lb.) <b>7760</b>	Date Shipped <b>1090</b>	RDD <b>999</b>
	Cube (ft.) <b>385</b>	Project <b>9BU</b>	Priority <b>1</b>
Ship To / POE <b>DOV</b>	In-the-clear Address 5 Lines Max, 35 Characters Per Line Abcdefg Hijklmno Pqrstuv Wxyz Abcdefg Hijklmno Pqrstuv Wxyz XXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		
POD <b>RMS</b>	MSL, Supply, & TCMD Data 		
FMS Case <b>CKM</b>			
<b>W55XGJ</b>		Ultimate Consignee / Mark For Consignee Ultimate / Mark For Consignee Address 3 Lines Max, 35 Characters Per Line Abcdefg Hijklmno Pqrstuv Wxyz Abcdefg Hijklmno Pqrstuv Wxyz XXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
			

Figure 6. Military Shipping Label with Code 39 and PDF417 Bar Codes (Department of Defense, 2007b)



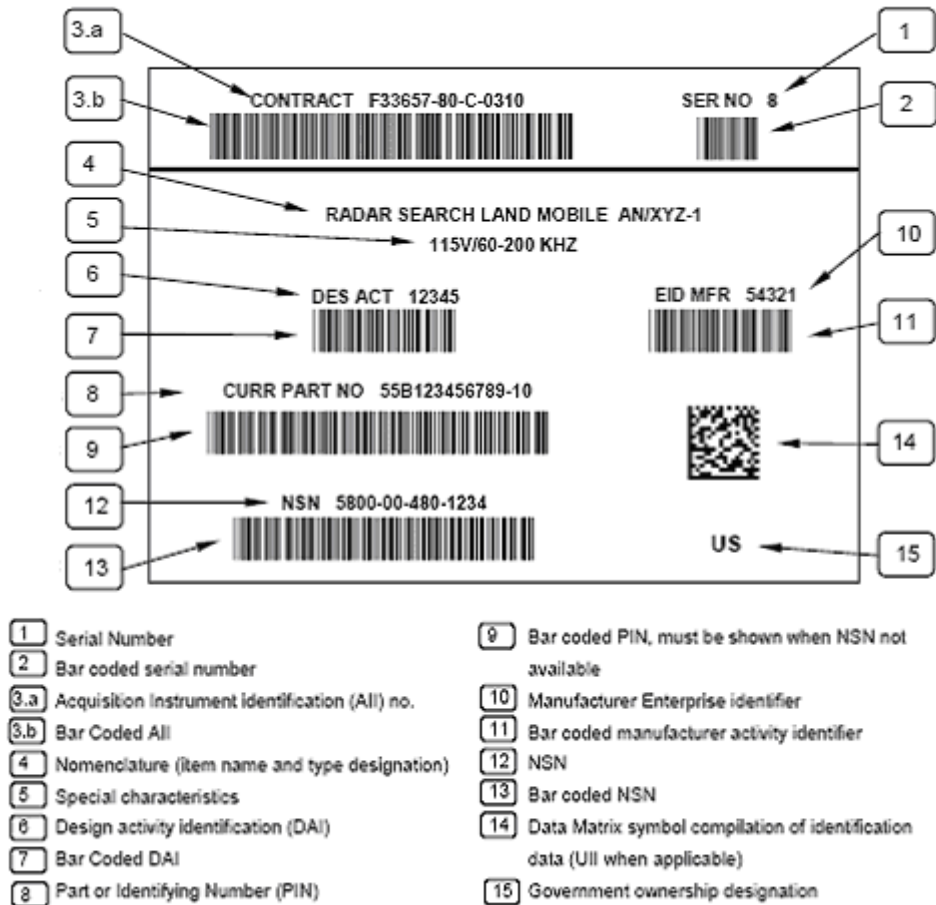


**Figure 7. Linear (Code 39) Bar Code Fields**  
 (Department of Defense, 2007b)

**b. MIL-STD-130N**

*MIL-STD-130N* provides the specific item-marking requirements and methods for identification of military property produced, stocked, stored, and issued by, of, or for the DoD (Department of Defense, 2007c). It further addresses criteria and data content for both free text and machine-readable information (MRI) applications of item-identification marking (Department of Defense, 2007c). The standard specifically outlines how bar codes are to be generated and to what quality they are to conform. Figure 8 is an example of an identification plate that shows the information needed to comply with the standard.





**Figure 8. Military Identification Plate**  
(After Department of Defense, 2007c)

B. RFID

Since the discovery of radar in the 1930s, radio frequency identification (RFID) has played a significant role in the military. Beginning as an early form of Identify Friend or Foe (IFF) system during World War II, RFID has evolved to become an international application that holds great promise for not only the logistics community but also for industry as a whole.

After the logistical nightmare that occurred during Desert Shield/Desert Storm—in which billions of dollars were spent on cargo that was never delivered and



that ultimately returned to the United States—the DoD began investigating technologies that would facilitate total asset visibility throughout its vast supply chain. According to the *2006 Quadrennial Defense Review Report*, active and passive RFID technologies will play a key role in achieving the Department's vision for implementing knowledge-enabled logistics support to the warfighter through automated asset visibility and management (Estevez, 2007).

## 1. RFID System

A typical RFID system consists of three elements:

- RFID Tags,
- Readers, and
- Middleware.

### a. RFID Tags

An RFID tag in its basic form is an electronic device that consists of a chip and an antenna. The chip contains a radio receiver, a radio modulator for sending a response back to the reader, control logic, some amount of memory, and a power system. According to the DoD, there are three basic categories of RFID tags:

- **Passive RFID tag**—Reflects energy from the reader/interrogator or receives and temporarily stores a small amount of energy from the reader/interrogator signal in order to generate the tag response. Passive RFID requires strong radio frequency (RF) signals from the reader/interrogator, and the RF signal strength returned from the tag is constrained to very low levels by the limited energy. Passive RFID tags are best when the tag and interrogator will be close to one another.
- **Active RFID tag**—Allows extremely low-level RF signals to be received by the tag (since the reader/interrogator does not power the tag), and the tag (powered by its internal source) can generate high-level signals back to the reader/interrogator. Active RFID tags are continuously powered, whether in the reader/interrogator field or not, and are normally used when a longer tag-read distance is desired.
- **Semi-passive RFID tag**—Uses a process to generate a tag response similar to that of passive tags. Semi-passive tags differ from passive in that semi-passive tags possess an internal power source (battery) for the tag's circuitry that allows the tag to complete other functions—such



as monitoring of environmental conditions (temperature, shock)—and which may extend the tag signal range. (DoD, 2003)

**b. Reader**

An RFID reader is a device used to communicate with RFID tags. An RFID reader is often referred to as an “interrogator” because it interrogates the tag. There are different types of readers; some of them can be quite complex, depending on the type of tags being supported. Readers can be small, handheld devices or large, fixed readers placed at the receiving and shipping warehouse doors.

The reader consists of three important elements:

- An antenna—Communicates with tags. The antenna broadcasts the reader transmitter’s RF signal into its surroundings and receives tag responses on the reader’s behalf.
- A transceiver—Sends the reader’s signal to the surrounding environment and receives tag responses back via the reader’s antenna. The transceiver houses the reader’s transmitter (used to transmit AC power and the clock cycle) and the receiver (used to receive analog signals from tags).
- A microprocessor—Implements the reader protocol to communicate with compatible tags. The microprocessor decodes and checks for errors in the analog signal from the receiver. It can also possibly contain custom logic for low-level filtering and processing of read-tag data (Lahiri, 2006).

**c. Middleware**

Perhaps the most complex and important component of the host and software system, middleware connects the data coming into the reader to the client’s host software systems. The middleware provides a coherent and stable interface between RFID hardware operations and the flow of data elements—such as electronic product code (EPC) numbers—into inventory, sales, purchasing, marketing, and similar database systems distributed throughout an enterprise (Sweeney, 2005). It can be seen as the central nervous system of the RFID system from the software perspective, in that it provides core functionality of the system, including the following:





- Data sharing, both inside and outside of an enterprise.
- Efficient management of massive data produced by an RFID system.
- Generic components that can be used as building blocks for implementing business-specific filtering and aggregation logic.
- An open standards base so that it is compatible with a wide range of other software systems.
- Loose coupling between the edge interface and the enterprise back-end interface. (Lahiri, 2006)

## 2. RFID Technology Advantages and Limitations

Although RFID has achieved international acceptance, just as the bar code technology listed above, it has both advantages and limitations.

### a. Advantages

RFID advantages include, but are not limited to, the following:

- Contactless—An RFID tag can be read without any physical contact between the tag and readers.
- Writable data—The data of a read-write (RW) RFID tag can be rewritten repeatedly.
- Absent line-of-sight—An RFID reader generally does not require line-of-sight to read an RFID tag.
- Variety of read ranges—An RFID tag can have a read range as small as a few inches to as large as more than 100 feet.
- Wide data-capacity range—An RFID tag can store anywhere from a few bytes of data to virtually any amount of data.
- Support for multiple tag reads—It is possible to use an RFID reader to automatically read several RFID tags in its read zone within a short period of time.
- Rugged—RFID tags can sustain fairly rough operational environmental conditions.
- Able to perform “smart tasks”—Besides being a carrier and transmitter of data, an RFID tag can be designed to perform other duties. (Lahiri, 2006)

### b. Limitations

RFID limitations include, but are not limited to, the following:





- Poor performance with RF-opaque and RF-absorbent objects—Currently, RFID does not work well with these materials and, in some cases, fails completely.
- Can be impacted by environmental factors—Surrounding conditions can greatly impact RFID solutions.
- Limitation on actual tag reads—A practical limit applies as to how many tags can be read within a particular time.
- Can be impacted by hardware interference—An RFID solution can be negatively impacted if the hardware is not set-up properly.
- Limited penetration power of the RF energy—Although RFID does not need line-of-sight, there is a limit as to how deep the RF energy can reach, even through RF-lucent objects.
- Immature technology—Although it is good news that the RFID technology is undergoing rapid changes, those changes can spell inconvenience for the unwary. (Lahiri, 2006)

### 3. DoD RFID Policy

The Deputy Under Secretary of Defense for Acquisition, Technology and Logistics published a Policy Memorandum dated July 30, 2004, directing DoD components to immediately resource and implement the use of high-data-capacity Active RFID in the DoD operational environment; the memo stated that the DoD would be an early adopter of Passive RFID technology (US Marine Corps, 2006). The policy focuses on In-transit Visibility (ITV) support of the Combatant Commanders (COCOMs) as the primary application of active RFID and focuses passive RFID on DoD's supply management applications (US Navy, 2005).

The policy has three parts:

- Calls for immediate implementation of the active RFID data-rich tag to meet COCOM ITV requirements for layer-4 containers (20- or 40-foot SeaVans) and palletized 463L pallets moving OCONUS.
- Calls for the DoD to be an adopter of innovative RFID technology.
- Introduces the Supplier Implementation Plan that describes the parameters and the schedule for DoD suppliers to attach passive RFID tags to material to be delivered. It also explains how this will be phased-in by procurement method, class/commodity, location and packaging layer.



C. UID

The General Accounting Office (GAO) reported in 1998 that the DoD’s logistical system could not perform the most basic of functions—knowing the number of assets, knowing the location of assets, and knowing the value of assets—to manage the estimated \$635 billion invested in military weapon systems (GAO, 1998). The GAO also reported that the DoD’s inventory exceeded its war reserve and current operating requirements but lacked key spare parts—as a result of inadequate accountability on material shipments and ineffective monitoring of defective spare parts (UID & eBusiness Forum, 2008). These deficiencies have aided in the DoD’s inability to achieve a clean audit as mandated by the 1990 *Chief Financial Officer’s Act* and have contributed greatly to its lack of asset visibility and logistics support. As a result, the DoD initiated a business transformation process that includes Unique Item Identification (UID), which will enable the DoD to value property, to achieve a clean audit, and to provide the tools for total asset visibility across the services (DoD DPAP, 2006). Figure 9 illustrates how the implementation of UIDs in the business enterprise architecture serves to improve accountability and lifecycle management.



Figure 9. UID Role—Business Enterprise Architecture (Reboulet & Wagner, 2004)



DoD unique item identification is a system of marking items delivered to the DoD with unique item identifiers that have machine-readable data elements to distinguish each item from all other like and unlike items (DoD DPAP, 2006). UID will enable multiple industries and governments to identify assets using one common unique number that stays on the asset throughout its lifecycle (DoD, 2005). As a result, the DoD will be capable of tracking assets throughout their lifecycles and of garnering valuable data to be used for maintenance and procurement of future weapons systems.

**1. UID Technology**

**a. Unique Item Identifier (UII)**

A Unique Item Identifier (UII) is a set of data elements marked on an item that is globally unique and unambiguous (DoD DPAP, 2006). With the UII, the DoD can associate valuable business intelligence with an item throughout its lifecycle and can accurately capture and maintain data for valuation and tracking of items (DoD, 2006). Table 4 provides an overview of those elements which are and which are not characteristics of a UII.

**Table 4. What DoD UII Is and Is Not**  
(Westmma, 2006)

A UII Is:	A UII Is Not:
<ul style="list-style-type: none"> <li>✓ A globally unique unambiguous item identifier</li> <li>✓ Permanent through life</li> <li>✓ Created by concatenating a string of specific data elements</li> <li>✓ Stored within a 2-D matrix</li> <li>✓ A means of creating and utilizing life cycle data</li> </ul>	<ul style="list-style-type: none"> <li>✓ A physical method of communicating data, such as radio frequency identification (RFID) tags, contact memory buttons, linear bar codes, or 2-D data matrices</li> <li>✓ A replacement for the national stock number</li> <li>✓ Intelligent stand-alone data that contain information about an item</li> </ul>

An enterprise has two choices for creating the UII. See Table 5. Whether it uses Construct #1 or Construct #2 depends on whether the enterprise serializes items within itself or within part number. Construct #2 allows for rolling part numbers



and still guarantees that the UII is permanent over the life of the item (Reboulet & Wagner, 2004).

**Table 5. Unique Item Identifier (UII) Construct Business Rule**  
(DoD, 2007c)

	UII Construct #1	UII Construct #2	
Based on current enterprise configurations	If items are serialized within the Enterprise	If items are serialized within Part, Lot or Batch Number	
UII is derived by concatenating the data elements IN ORDER:	Issuing Agency Code* Enterprise ID Serial Number	Issuing Agency Code* Enterprise ID	
		Original Part # Serial Number	Lot or Batch # Serial Number
Data Identified on Assets Not Part of the UII (Separate Identifier)	Current Part Number**	Current Part Number**	
<p>* The Issuing Agency Code (IAC) represents the registration authority that issued the enterprise identifier (e.g., Dun and Bradstreet, GS1). The IAC can be derived from the data qualifier for the enterprise identifier and does not need to be marked on the item.</p> <p>** In instances where the original part number changes with new configurations (also known as part number roll), the current part number may be included on the item as a separate data element for traceability purposes.</p>			

A commercial identifier can be considered a DoD UID equivalent if it meets the following criteria:

- Contains an enterprise identifier,
- Uniquely identifies an individual item within an enterprise identifier, product or part number, and
- Has an existing Data Identifier (DI) or Application Identifier (AI) listed in ANSI MH10.8.2, Data Identifier and Application Identifier Standard. (DoD DPAP, 2006)

**b. 2-D Matrix**

The bar coding industry, in partnership with the National Aeronautics and Space Administration (NASA), developed the two-dimensional data matrix as a successor to the traditional linear bar code in the 1990s (DoD, 2005). This new 2-D data matrix, shown in figure 10, allowed for an improved data storage of up to 100



times that of the linear bar code and provided industry with markings that could be read even when damaged (DoD DPAP, 2006). Additionally, the 2-D data matrix can be read omni-directionally and can be scaled down so that it can be affixed to small items.

The DoD brokered an agreement with EAN/UCC, the Air Transport Association, and the International Standards Organization to develop an interoperable, machine-readable, part-marking system that would be accepted internationally (DoD, 2005). This allowed for a common language that could be used between the DoD and its suppliers and industry partners.

In order to accurately store and retrieve the UII from its markings, the DoD utilized the 2-D data matrix. Its flexibility of size, data storage capacity, and the fact that it is compatible with nearly all part-marking techniques made the 2-D data matrix the DoD's choice for its UID initiative.



**Figure 10. 2-D Data Matrix**  
(DoD DPAP, 2006)

**c. UID Registry**

The UID Registry is the central repository for UID information and serves as an acquisition gateway to identify:

- What the item is,
- How and when it was acquired,
- The initial value of the item,
- Current custody (government or contractor), and
- How it is marked. (DoD AT&L, 2006)



- |  |   |
|--|---|
| <p style="text-align: center;"><u>Pedigree</u></p> <ul style="list-style-type: none"> <li>• Acquisition Contract Information</li> <li>• Original Part Number</li> <li>• Shipment and Delivery Information</li> </ul> | <p style="text-align: center;"><u>Accountability</u></p> <ul style="list-style-type: none"> <li>• Contractor Custody Information</li> <li>• Acceptance Data</li> <li>• Custodial Contract Data</li> </ul> |
| <p style="text-align: center;"><u>Valuation</u></p> <ul style="list-style-type: none"> <li>• Initial Acquisition Value</li> <li>• Changes in Valuation</li> </ul>  | <p style="text-align: center;"><u>Configuration</u></p> <ul style="list-style-type: none"> <li>• Embedded Items</li> <li>• Item Markings</li> <li>• Part Number Changes</li> </ul>                        |

**Figure 11. Data Included in the UID Registry**  
(DoD AT&L, 2006)

The UID registry will not, however, track an item’s location or be the basis for configuration management. Figure 11 shows the data elements included in the UID registry.

Contractors submit the data contained in the registry via the Wide Area Work Flow (WAWF). The WAWF is an electronic DoD-wide application that enables contractors to transmit shipping notices electronically and the DoD to perform both receipt and acceptance electronically (DoD, 2007a). It is designed to eliminate paper from the receipt, acceptance and invoicing process of the DoD contracting lifecycle (DoD DPAP, 2006).

## 2. UID Advantages

When coupled with supply and logistics AIT systems, UID affords the DoD tremendous capability to track and manage equipment. UID advantages include, but are not limited to, the following:

- Captures the value of items purchased by DoD,
- Controls items during use throughout their lifecycles,
- Combats counterfeiting, and
- Enhances the quality of information available for configuration management, systems engineering, logistics support, and operational planning. (DoD AT&L, 2006)





### 3. DoD UID Policy

The Deputy Under Secretary of Defense for Acquisition, Technology and Logistics published a Policy Memorandum dated July 29, 2003, establishing the DoD requirement for UID on all solicitations issued on or after January 1, 2004. The policy established four criteria for the placement of a UID:

- If the acquisition cost is \$5,000 or more,
- If it is either a serially managed, mission-essential or controlled-inventory piece of equipment, repairable item or consumable item or material on which permanent identification is required,
- If it is a component of a delivered item; if the program manager has determined that unique identification is required, or
- If a UID or a DoD-recognized UID equivalent is available. (DoD AT&L, 2003)

The policy further required modification of the *Defense Federal Acquisition Regulation Supplement (DFARS)* and the use of the Wide Area Workflow (WAWF) for UID data submission (DoD AT&L, 2003).

The policy has been updated through policy memorandums published in 2004 and 2005. These updates provide guidance for the expansion of the requirement to all significant items currently in the DoD inventory and for the inclusion of government property in possession of contractors.



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## IV. Navy's Non-wood Pallet Investigation<sup>7</sup>

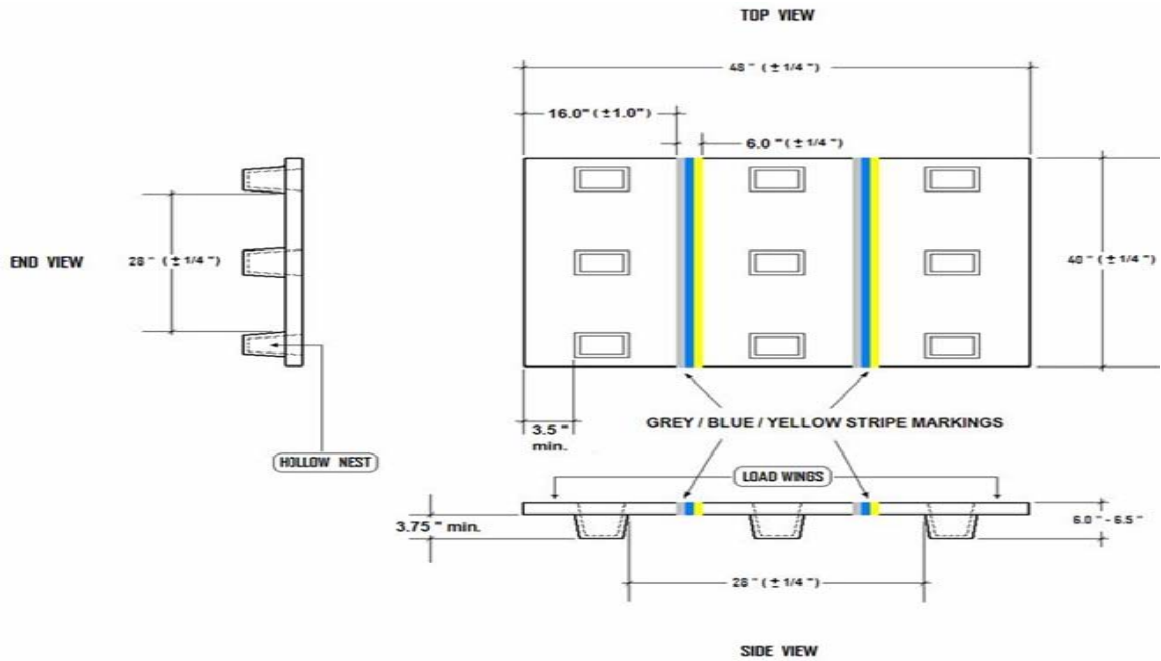
### A. Background

In response to the International Plant Protection Convention (IPPC) mandate that all pallet wood be certified as pest free, the Naval Inventory Control Point, Mechanicsburg (NAVICP-M) initiated a three-phase pilot program in the Norfolk, Virginia, area to determine the viability of using non-wood pallets within the Navy's supply system. The Norfolk Naval Station and the Naval Amphibious Base (NAB) Little Creek, Virginia, were selected as the test sights. Through extensive research of industry and literature, it was determined that a commercial pallet was not available that would meet the requirements to meet or exceed the Navy's current hardwood wing pallet (Naval Inventory Control Point, 2006). The NAVICP-M brought together industry and academic professionals to design and test their non-wood pallet concept. After meeting at Virginia Tech's Center for Unit Load Design, the design and specifications for the Navy/GSA non-wood pallet was finalized. See Figures 12 and 13.

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<sup>7</sup> This chapter is largely drawn from the works of NAVICP Asset Protection & Pollution Prevention Department, Code M077, Virginia Tech Center for Unit Load Design, DoD Joint Working Group on Pallet Standardization, Military Sealift Command, Code N4, Logistics, SYSCO Food Services of Hampton Roads, Inc., Suffolk, VA, General Services Administration (GSA), and Science Applications International Corporation (SAIC). Their investigation provided the inspiration and founding principles for our comparison of wood and non-wood pallets.





**Figure 12. Navy/GAS Non-wood Pallet Dimensions and Markings**  
(Naval Inventory Control Point, 2006)



**Figure 13. 10 Navy/GSA Non-wood Pallets**  
(Naval Inventory Control Point, 2006)



In addition to complying with international regulations, the NAVICP-M expected its design to provide additional benefits, such as:

- Longer lifecycle, hence a more economical option
- Lighter weight, easier to handle, stack, nest, and store
- Not prone to nematodes, beetles, termites, and mold
- Easier to sanitize
- Easily managed in a closed-loop system
- Less prone to hazards from Foreign Object Debris (FOD)
- Recyclable. (Naval Inventory Control Point, 2006)

## B. Research and Analysis of Investigation

### 1. Phase I

Phase I of the investigation began on July 27, 2006, and was completed on August 31, 2006. SYSCO Food Service was selected as the vendor and closed-loop system to evaluate the non-wood pallet. The non-wood pallets (NWP) were delivered to SYSCO Food Service the night before a scheduled delivery. Once the delivery was complete and the food was onboard the ship, the ship's crew would stack the pallets on the pier for pick-up by SYSCO Food Service the next day.

The pallets performed well. Items were loaded onto the pallets with ease; no problems occurred during the transportation of the pallets to the piers; no extra work was incurred during off-load and on-load processes; material handling equipment easily handled movement of the pallets; and removal from the ship was completed more swiftly due to the nesting/unit load capability (Naval Inventory Control Point, 2006). Many of the ship's crew commented that the non-wood pallets made for a faster and easier on-load of materials and supplies. They stated that there was less clean-up necessary, since the non-wood pallets did not splinter or break like wood pallets often do during lifting operations. Also, the evolution was quicker, because the non-wood pallet design allowed the loads to be hoisted onto the ships without the need for a slave pallet. See Figure 14.





**Figure 14. Navy/GSA Non-wood Pallet with Load Being Hoisted aboard Ship**  
(Naval Inventory Control Point, 2006)

The experiment also illuminated a few points for consideration. Several design changes were suggested by the riggers and ship's crew. First, the installation of a notch to the pallet's wing would serve to secure the sling in place while the pallet was being lifted. Second, the addition of non-skid to the feet of the pallet would help prevent the pallet from sliding on the deck of the ship and pier. Also, it was noted that the closed-loop system worked for the management of the pallets, but a more robust management system would need to be implemented.

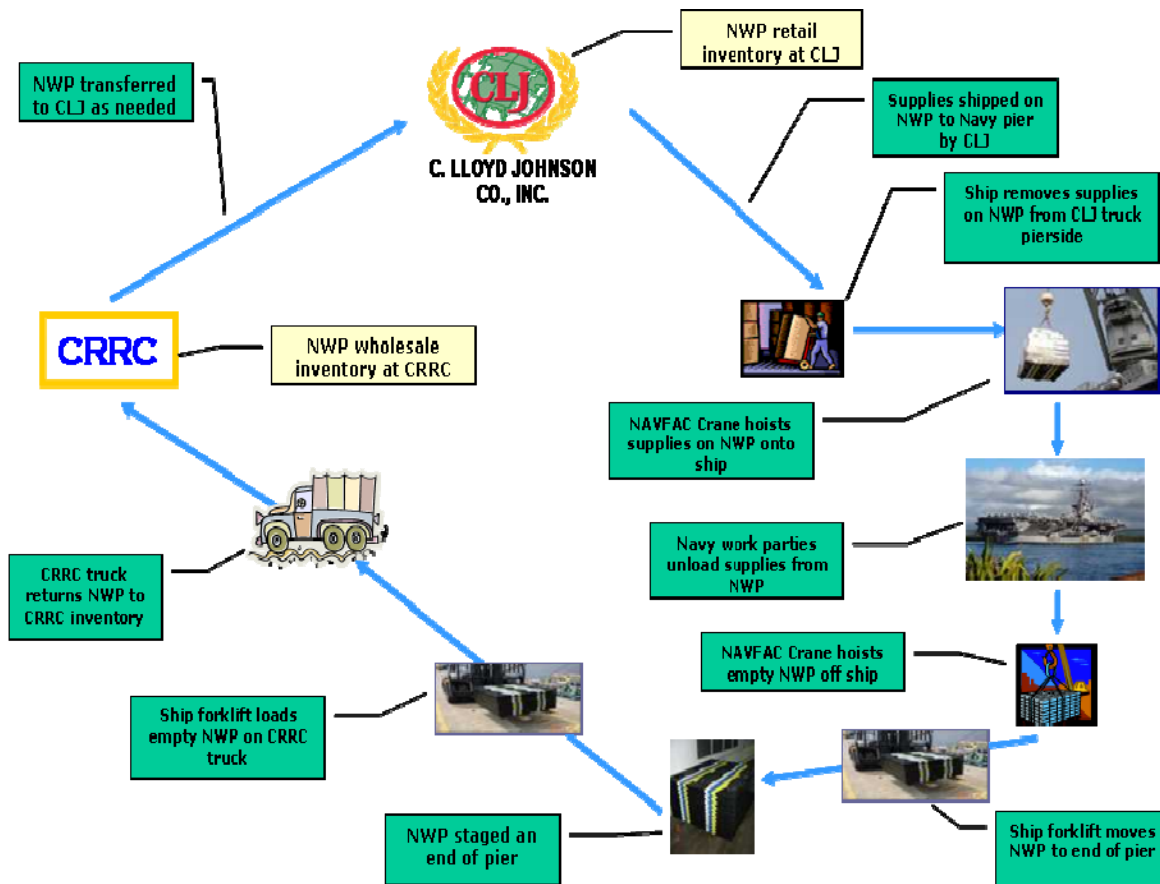
## **2. Phase II**

Phase II of the pilot program began September 24, 2007, and was completed on March 31, 2008. Phase II expectations and goals were similar in nature to those of Phase I but were expanded to include the following:

- The inclusion of more pallets,
- The inclusion of RFID tags on the pallets, and
- The inclusion of a pallet management system. (Mukherjee, 2007)

The test vendor was changed from SYSCO Food Service to C. Lloyd Johnson, the Subsistence Prime Vendor (SPV) for the ships in the Norfolk/Little Creek, Virginia, area. It was selected because it, too, operates in a closed-looped manner, and it delivers daily to the piers, but also because its number of shipments was not as large as to preclude the use of the NWP. The Phase II closed-loop system is depicted in Figure 15.





**Figure 15. PHASE II Closed-loop System**  
(Mukherjee, 2007)

**a. More Pallets**

The number of pallets was increased from the experimental 10 to 109 pallets—with the expectation of an additional 400 pallets, for a total of 500 pallets. It was believed that this pool of pallets would be sufficient to allow the vendor to fully utilize the pallets for shipments to the piers.

**b. RFID Tags**

RFID tags were a fixed so that the following data could be collected:

- Unique pallet identification
- Type of entry (manual vs. RFID)
- Date and time stamp



- Location (CRRC, CLJ, Ship, Pier)
- Action (inventory, issue, delivery, pick up, exception, etc.). (Mukherjee, 2007)

From data gathered from the RFID tags, the following metrics would be tracked:

- Pallet inventories, locations, issues, and deliveries,
- Trip data (completed trips, trips per pallet, time per trip, and time between touch points),
- RFID scan accuracy overall and by touch point,
- Pallets lost, damaged or pulled from service, and
- Pallets at risk within a closed-loop system (based on missing the next logical scan within a pre-determined time frame). (Mukherjee, 2007)

### c. **Pallet Management System**

The inclusion of a pallet management system was seen as imperative from the results of Phase I. Such a system was seen as the vehicle for capturing and recording the ROI for the purchase of the non-wood pallet (NWP). The system would allow the NWP to be viewed as an asset instead of just a consumable. The system sought to control the issue and receipt of pallets within the pilot loop and to track the location of the NWP during the trial.

## C. Chapter Summary

This chapter introduced the concept of utilizing a NWP, an RFID-enabled pallet management system, and a pallet pool within the Navy's supply system. The Navy's investigation illustrated the suitability and durability of the NWP, further providing evidence of the enhanced performance of a plastic or composite pallet over the standard wood pallet utilized by the DoD. Not only did the NWP provide the vendor with a reliability of 98%, but also provided the vendor with cost savings through reuse. Additionally, the NWP saved the receiving vessels time by greatly reducing the clean up required following delivery.



This chapter also highlighted the ability of RFID to effectively track and trace pallets within the Navy's supply system. The CRRC maintained 100% accountability through the use of RFID. It allowed for the location and possession of each pallet to be monitored and discrepancies to be reconciled with minimal effort.

Also demonstrated was the viability of a pallet pool within the DoD's supply system. The vendor's delivery needs were satisfied by utilizing a pool of only 107 NWP's—thus providing the vendor the cost avoidance of purchasing new pallets for each of the 636 deliveries accomplished during the test period and further illustrating the potential benefits of employing a pallet pool of plastic or composite pallets within the DoD's logistics network.



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## V. Pallet Management Model

### A. Overview

The Defense Logistics Agency (DLA) has reportedly spent over \$12 million on one type of pallet from May 2006 to March 2008 (T. Kunkel,<sup>8</sup> personal communication, March 3, 2008). Historically, pallets are purchased continually for shipment from DLA distribution depots to other DLA and DoD facilities. When shipments are complete, the pallets are utilized within the receiving command or, more normally, are discarded, recycled, or turned over to contractors for use in their organizations. Therefore, the DLA's current method of pallet management—transfer of ownership—is costly and wastes potential benefits from a vital component of the logistics network.

In order to reap the full benefits of pallets, the DoD must invest in a method of management that capitalizes on the re-use properties of pallets. One such method is pallet pooling. Pallet pooling affords an organization the opportunity to benefit from multiple uses before replacement. Coupled with technology such as bar codes and UID/RFID, the management of the pallet pool is not only streamlined, but it also has the potential for increased asset and in-transit visibility of supplies and materials.

### B. Open-loop to Closed-loop

An open-loop system is one in which shipments are originated at a distribution depot to a customer with little or no routine return shipments. A closed-loop system is one in which shipments originate at a distribution depot and contain return shipments from customers. The majority of shipments made by DLA and DoD entities are conducted along an open-loop system. One such shipping route is from DDJC in Tracy, California, to DDDC in San Diego, California. This route was

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<sup>8</sup> Trey Kunkel is employed at NAVICP-M Code 0772, Asset Protection and Pollution Prevention Department and is that office's lead for the Navy's NWP investigation.



selected for our study due to the proximity of the two facilities and for the current low level of pallet loads shipped weekly. Table 6 provides the shipping characteristics of the DDJC to DDDC route.

**Table 6. DDJC to DDDC Information**

Number of Miles (approximate)	443
Average Number of Pallets/Week	105 <sup>9</sup>

When asked why the route remained an open-loop and pallets were not returned to DDJC for reuse, personnel from both organizations stated that the cost of the return transportation prohibited a closed-loop system. Table 7 illustrates the transportation cost range associated with returning the pallets from DDDC to DDJC.

**Table 7. Transportation Cost from DDDC to DDJC**

Transportation Cost Range	\$800 to \$1000 <sup>10</sup>
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Table 8 shows the typical pallet quantities for CHEP<sup>11</sup> pallet orders per trailer size as found in the *CHEP Operating Guidelines*.

**Table 8. Typical CHEP Shipment Quantities**

Trailer Size	Pallet quantity
48 ft	588
53 ft	630

In order to facilitate a closed-loop system between DDJC and DDDC, return shipments are needed every six weeks to maximize the return load quantity as per the numbers above. This would provide for the minimum number of return shipments, thus minimizing the shipping cost. Table 9 illustrates the transportation options and associated costs to create a closed-loop system between DDJC and DDDC.

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<sup>9</sup> Information provided by DDJC personnel (3 trucks/week x 35 pallets/truck=105 pallets/week).

<sup>10</sup> Information provided by DDJC and DDDC personnel.

<sup>11</sup> CHEP is one of the world's largest pallet and container leasing companies.



**Table 9. Cycles and Transportation Cost Calculations**

Weekly Demand (D)	Trailer Size	
105 pallets	48 ft	51 ft
Pallet/Truckload (PT)	588	630
Lead Time/Truckload (LT) ( $\frac{PT}{D}$ )	5.6	6
# of Cycles/Year (CY) ( $\frac{52}{LT}$ )	9.3	8.7
Transportation Cost (TC)/Year ( $TC \times CY$ )		
\$800/Shipment	\$7,360	\$9,200
\$1,000/Shipment	\$6,960	\$8,700

C. Establishing the Pool size

The pallet pool size is determined by a number of variables. Not only must the average pallet demand at the originator be accounted for, but the cycle length and unexpected delays in the return shipment must also be considered. The *CHEP Operating Guidelines* recommend two shipments' worth of pallets be maintained as safety stock to handle unforeseen occurrences, such as shipping delays or large demand fluctuations. To obtain this level of safety stock and maintain a service level of 99% for pallet availability at DDJC, a standard deviation of 12.27 (11.69% of the weekly demand) must be included in the pallet pool calculations as shown in Table 10.

**Table 10. Pallet Pool Size Calculations**

Service Level	z-value	
99%	2.33	
Weekly Demand (D)	Standard Deviation (D x 0.1169)	
105	12.27	
Lead Time (LT)	5.6	6
Demand Over the Lead Time (DxLT)	588	630
Safety Stock ( $z\sigma\sqrt{LT}$ )	68	70
Pallet Pool Size ( $D \times LT + z\sigma\sqrt{LT}$ )	656	700



For this study, it is assumed that the return shipment from DDDC will be completed in one day. Otherwise, the delivery time must be included in the lead time calculations.

#### D. Selection of Pallet Type

Pallet quality is essential for the operation of a pallet pool. The higher the quality of pallets used, the greater the return on investment (ROI). There are a multitude of different materials used in the fabrication of pallets—soft wood to hard wood and cardboard to metal. Commercial pallet pool operators employ two main types of pallets: wood and plastic. Additionally, the Navy is continuing its efforts in testing a NWP within its supply channels. Therefore, this study concentrates on the difference between wood and plastic pallets.

##### 1. Material

According to Figure 3, a wood pallet has an expected functional lifespan of 2-15 trips before it needs to be repaired or discarded. A plastic pallet has an expected functional lifespan of 250 trips before it needs to be recycled or discarded. Additionally, a wooden pallet is much less expensive than a plastic pallet—with a range of \$3.50-\$13 compared to \$20-\$80 respectively.

**Table 11. Expected Number of Years of Utility**

Trips/Year	9.3	8.7
Wood @ 15 trips	1.6 yrs	1.7 yrs
Plastic @ 250 trips	26.9 yrs	28.7 yrs

Table 11 highlights the expected number of years of utility for a wooden and a plastic pallet. The table indicates that a plastic pallet has over 16 times the expected useful lifespan as a wooden pallet with the best-case scenario of expected trips. Through this analysis, it is easy to conclude that the plastic pallet is superior and should be selected for the pallet pool. However, cost must be considered before finalizing any selection.



## 2. Cost

Pallet pooling is only cost effective if the savings realized are greater than the recurring cost of purchasing pallets. Appendix C presents snapshots of recurring cost and potential savings provided by a pallet pool for the shipment route from DDJC to DDDC. These matrices illustrate that benefits are obtainable even if the price of the pallets are equal and provide a comparison between wood and plastic pallets. Pallet type and quality are essential factors in the cost and savings determination. Higher savings are realized if a cheaper pallet is purchased for the pallet pool; however, a cheaper, lower-quality pallet may require replacement more frequently—causing greater recurring cost. Yet, a higher quality or different type of pallet that may offer better reliability may not generate significant benefits compared to current purchasing practices.

Though pallet price and quality are essential deterministic elements, the pool's management is also a critical factor. Pallet tracking is indispensable if an organization is to achieve savings from pallet pooling. Commercial shipping and retailers report an average of 2% shrinkage or pilferage while products are in transit or on store shelves (Pisello, 2006). Translated to pallet pooling, it means that 2% of pallets are lost and need replacing. This factor alone results in dimensioned pallet pooling savings and, in most cases, prevents the adoption of pallet pools. Therefore, a tracking system must be established and executed accurately among the parties of a pallet pool. The inclusion of technology has provided many shippers and retailers with improved tracking abilities and has reduced, in most cases, shrinkage by approximately 20%.

### E. Tracking Technology

Automatic identification technologies such as bar codes, UID, and RFID provide the manager with vital information concerning an item. These technologies provide information such as location, inventory status, condition, and a multitude of additional data regarding the asset. Seeing the potential of these technologies, many vendors and pallet-management companies have begun utilizing them within



their operations. The technologies allow for tracking of the pallet as well as provide increased visibility as to the location and condition of the load it is bearing.

## **1. RFID and Bar Codes**

CHEP and iGPS utilize RFID to track and trace their pallets. CHEP predominately provides its customers with wooden pallets. It places one RFID tag on the pallet's middle stringer to facilitate the tracking of the pallet. This allows CHEP to accurately bill customers for usage and to resolve custody or damage issues.

iGPS provides its customers with plastic pallets featuring read-writable RFID tags embedded in the corners. By marrying RFID and bar code technology, iGPS has developed a system in which a license plate number (LPN) bar code is linked to the read-writable RFID tags. The LPN contains information on the contents of the pallet load and, once written to the RFID tags, the pallet is transformed into a smart pallet—such that it then carries not only the load but also the information about the load. Since the RFID tags are read-writable, the tag information can be changed multiple times, which allows the pallets to be utilized by multiple customers. Appendix D presents snapshots of recurring cost and potential savings provided by a pallet pool utilizing RFID for the shipment route from DDJC to DDDC.

## **2. RFID and UID**

Separately, RFID and UID have the potential to increase an organization's asset visibility, improve inventory management, reduce supply-chain errors, and improve capital asset tracking. By implementing the technologies concurrently in an organization, managers can significantly increase savings and cost avoidance. A study conducted by graduate students from the Naval Postgraduate School concluded that there is “a definite benefit to investing in RFID/UID technology” and that RFID/UID provide the capability of delivering the Total Asset Visibility (TAV) sought by the DoD to provide its leaders with the ability to “know and understand our



true logistics readiness posture at all times and, in turn, drive improvements in operational readiness” (Obellos, Collieran & Lookabill, 2007).

### 3. Additional AIT Benefits

The inclusion of technology to track the pallet pool does not provide the cost savings alone to justify the expense of including the technology, as shown in Table 12.

**Table 12. Basic Cost/Saving Comparison Example**

Cost/Savings Comparison for \$8 wood pallet and \$30 plastic pallet for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 21,001.63	\$ 23,381.82
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,004.00	\$ 2,920.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 2,036.00	\$ 2,120.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 26,134.80	\$ 25,404.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 17,713.20	\$ 18,444.00
# Cycles to Breakeven		3.1	3.4	10.3	11.0
Cost/Savings Comparison for \$8 wood pallet and \$50 plastic pallet for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 35,002.72	\$ 37,382.90
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,340.00	\$ 3,200.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 1,700.00	\$ 1,840.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 29,058.00	\$ 27,840.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 14,790.00	\$ 16,008.00
# Cycles to Breakeven		3.1	3.4	20.6	20.3
Cost/Savings Comparison for \$8 wood pallet and \$70 plastic pallet for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 49,003.81	\$ 51,383.99
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,676.00	\$ 3,480.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 1,364.00	\$ 1,560.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 31,981.20	\$ 30,276.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 11,866.80	\$ 13,572.00
# Cycles to Breakeven		3.1	3.4	35.9	32.9

Commercial and government agencies have previously instituted RFID technology within their organizations. These organizations have realized significant cost-reduction benefits. RFID cost-reduction benefits include, but are not limited to, the following:





- Reduce receiving time by 50% to 65%,
- Reduce stocking time by 22% to 30%,
- Reduce cycle counting by 40% to 60%, and
- Reduce physical counting by 90% to 100%. (RFID Product News, 2005)

**Table 13. Cost/Savings Example with Labor Cost/Savings**

Cost/Savings Comparison for \$8 wood pallet and \$30 plastic pallet					
for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 21,001.63	\$ 23,381.82
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,004.00	\$ 2,920.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 2,036.00	\$ 2,120.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 26,134.80	\$ 25,404.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 17,713.20	\$ 18,444.00
Yearly Labor Cost	\$ 93,333.33	\$ 93,333.33	\$ 28,388.89	\$ 93,333.33	\$ 28,388.89
Yearly Labor Savings	\$ -	\$ -	\$ 64,944.44	\$ -	\$ 64,944.44
Combined Yearly Savings	\$ -	\$ 15,710.27	\$ 80,849.59	\$ 17,713.20	\$ 83,388.44
Cost/Savings Comparison for \$8 wood pallet and \$50 plastic pallet					
for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 35,002.72	\$ 37,382.90
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,340.00	\$ 3,200.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 1,700.00	\$ 1,840.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 29,058.00	\$ 27,840.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 14,790.00	\$ 16,008.00
Yearly Labor Cost	\$ 93,333.33	\$ 93,333.33	\$ 28,388.89	\$ 93,333.33	\$ 28,388.89
Yearly Labor Savings	\$ -	\$ -	\$ 64,944.44	\$ -	\$ 64,944.44
Combined Yearly Savings	\$ -	\$ 15,710.27	\$ 80,849.59	\$ 14,790.00	\$ 80,952.44
Cost/Savings Comparison for \$8 wood pallet and \$70 plastic pallet					
for pallet pool of 700 with 6 week cycle					
	Continuous Purchase	Wood W/O RFID	Wood W/RFID	Plastic W/O RFID	Plastic W/RFID
Total initial Investment	\$ 5,040.00	\$ 5,600.44	\$ 6,195.48	\$ 49,003.81	\$ 51,383.99
Recurring/Cycle	\$ 5,040.00	\$ 3,234.22	\$ 3,211.82	\$ 3,676.00	\$ 3,480.00
Savings/Cycle	\$ -	\$ 1,805.78	\$ 1,828.18	\$ 1,364.00	\$ 1,560.00
Recurring/Year	\$ 43,848.00	\$ 28,137.73	\$ 27,942.85	\$ 31,981.20	\$ 30,276.00
Savings/Year	\$ -	\$ 15,710.27	\$ 15,905.15	\$ 11,866.80	\$ 13,572.00
Yearly Labor Cost	\$ 93,333.33	\$ 93,333.33	\$ 28,388.89	\$ 93,333.33	\$ 28,388.89
Yearly Labor Savings	\$ -	\$ -	\$ 64,944.44	\$ -	\$ 64,944.44
Combined Yearly Savings	\$ -	\$ 15,710.27	\$ 80,849.59	\$ 11,866.80	\$ 78,516.44

Labor cost based on 5 personnel performing receiving duties at a wage of \$16.00 per hour, 8 hours/day, 5 days/week, and 50 weeks/years.

Table 13 indicates that with the labor savings included, RFID provides a greater benefit. Further, the information used from the RFID system will allow for the improved management of personnel and equipment at the distribution centers. This benefit is further capitalized if the vendor allows the shipping information to flow to the awaiting customers. It allows the customers to anticipate deliveries so the correct personnel and equipment are in place to efficiently receive the shipment.





The addition of UID increases the potential benefits. Since UID provides for the tracking of the pallets throughout its lifespan, discrepancies of ownership or possession are greatly reduced, if not eliminated. Also, UID provides an audit trail with which to investigate pallet material and structural failures. These can be traced to the pallet manufacturer, eliminating the cost of testing all pallets within a pool since the information is available to track and trace the pallets constructed to a single manufacturer or to a specific manufacturing lot or batch.



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## VI. Summary, Conclusions, and Recommendations

### A. Summary

This project consisted of a review of pallets, pallet management and AIT that provided readers a thorough background of the importance of the pallet and pallet management within the DoD. It covered construction, history, policy, and an on-going Department of the Navy initiative regarding pallet development. With that foundation, the researchers then analyzed an existing pallet management system at PepsiCo and identified how such a system could be used at DDJC.

The pallet pooling system utilizing RFID/UID and bar codes was developed using information from PepsiCo, CHEP, and iGPS. The system specifically addressed the transportation for the return loop and demonstrated the cost effectiveness of AIT for tracking shipments and improving overall asset visibility.

### B. Conclusions

In response to the International Plant Protection Convention (IPPC) mandate that all pallet wood be certified as pest free, NAVICP-M initiated a three-phase pilot program in the Norfolk, Virginia, area to determine the viability of using non-wood pallets within the Navy's supply system. Phases I and II proved the pallet's design meets the Navy's requirements, that pallet pooling was viable within the Navy's supply chain, and that a pallet management system aided by AIT could track and trace these pallets. We focused our study on the pooling and management functions. We analyzed the current pallet management system of the DoD and assessed the viability of establishing a pallet pool and management system at DDJC. We conclude that a pallet pool and management system will bring DDJC cost savings and will increase asset visibility with the aid of AIT implementation.



## **1. Cost Savings through the Employment of a Pallet Pooling**

Pallet pooling provides cost savings by eliminating an organization's need to continually purchase pallets. Transportation costs are mitigated by ensuring the returning number of pallets is sufficient to fill a trailer. Also, the total pallet pool should be established such that unforeseen delays and orders do not require the return loop to be expedited.

## **2. Implementation of AIT—Increased Asset Visibility**

By harnessing the benefits of RFID/UID and bar codes, increased asset visibility is achieved throughout the supply chain. Asset visibility enables supply managers to plan and support the warfighter. The AIT implementation will provide visibility into the transit time and location of supplies for the end-user, thereby providing the leaders within the DoD with the information and capability necessary to measure true operational readiness.

## **C. Recommendations**

### **1. Investigation into Third-party Pallet Management**

The authors believe that future study should be devoted to the cost effectiveness of employing a third-party pallet manager. Existing companies operate globally and have expertise in managing large and varied pallet demands. This would eliminate the burden of management by the DoD.

### **2. Employ the NWP Operationally**

The Navy should partner with DDDC San Diego to employ the NWP for shipments to San Diego home-ported ships. DDDC should then seek to expand its use of the NWP to include the other bases and facilities within its delivery area, such as Marine Corps Air Station Miramar and Naval Air Station Fallon. This would fully test the viability of the NWP within the Navy's supply chain and make operational the pallet pooling and management concept.



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## Appendix A. Bar Code Comparison Chart

Bar Code	Type	Character Set	Length	Checksum	Applications Comments
<b>Australia Postal Code</b> 	2-D	Numbers Only	4	Required	Includes error correction
<b>Aztec Code</b> 	2-D	Full ASCII; FNC1 and ESI control codes	Variable Min 12 Max 3832	Required	Includes error correction; minimum is 15x15 square, largest is 151x151
<a href="#">Codabar</a>  1234567	Linear	Numbers: 0-9; Symbols: - : . \$ / + Start/Stop Characters: A, B, C, D, E, *, N, or T	Variable	None	Older code; often used in libraries and blood banks. See also USD-4, NW-7, 2of7
<a href="#">Code 11</a>  123456789	Linear	Numbers Only	Variable	Required	Recommend 2nd check digit
<a href="#">Code 128</a>  Abc123	Linear	All ASCII characters and control codes	Variable	Required	Widely used; excellent for many applications
<a href="#">Code 39</a>  ABC123	Linear	Uppercase letters A-Z; Numbers 0-9; Space - . \$ / + %	Variable	Optional	In very wide use for many types of applications
<a href="#">Extended Code 39</a>  ab123	Linear	All ASCII characters and control codes	Variable	Optional	Uses pairs of characters to encode non-standard symbols; wasteful of space










Bar Code	Type	Character Set	Length	Checksum	Applications Comments
<a href="#">Code 93</a> 	Linear	Uppercase letters A-Z; Numbers 0-9; Space - . \$ / + %	Variable	Optional	A more compact cousin of Code 39, not as widely in use
<a href="#">Composite Code</a> 	2-D	All ASCII characters	Variable	Required	Code comprised of a PDF417 code stacked on top of a Code128; used in UCC/EAN standards
<a href="#">DataMatrix</a> 	2-D	All ASCII characters	Variable	Required	Includes error correction, up to 2335 ASCII characters
<a href="#">EAN-13</a> 	Linear	Numbers Only	13 + check digit +2 optional +5 optional	Required	Retail product marking world-wide
<a href="#">EAN-8</a> 	Linear	Numbers Only	7 + check digit	Required	Retail product marking world-wide; compressed code for products with limited label space
<a href="#">EAN Bookland</a> 	Linear	Numbers Only	13 + check digit +2 optional +5 optional	Required	Special use of the EAN-13 symbol to encode ISBN number on books
<a href="#">Industrial 2 of 5</a> 	Linear	Numbers Only	Variable	None	Older type of code






Bar Code	Type	Character Set	Length	Checksum	Applications Comments
<u>Interleaved 2 of 5</u>  0097809789	Linear	Numbers Only	Variable	Optional	Very compact encodes digits in pairs so total length must be even number of digits
<u>ITF-14</u> <u>(UPC Ship Container Code)</u>  0 50 02100 07865 6	Linear	Numbers Only	13 + check digit	Required	Special use of the Interleaved 2 of 5 code to mark shipping cartons containing UPC-encoded products (see also SCC-14)
<u>LOGMARS</u>  ABC123	Linear	Uppercase letters A-Z; Numbers 0-9; Space - . \$ / + %	Variable	Optional	Same as Code 39; this is the US government specification
<u>Maxicode</u> 	2-D	All ASCII characters	93	Required	Includes error correction, developed by the United Parcel Service for encoding destination information
<u>MSI</u> <u>MSI Plessey</u>  09780	Linear	Numbers Only	Variable	Required	Grocery store shelf tags
<u>OPC</u> <u>Optical Industry Assoc.</u>  0097809789	Linear	Numbers Only	9 + check digit	Required	Special use of Interleaved 2 of 5 for marking retail optical products
<u>PDF-417</u> 	2-D	All ASCII characters	Variable	Required	Includes error correction, up to about 1850 ASCII or 2725 numeric characters



Bar Code	Type	Character Set	Length	Checksum	Applications Comments
<a href="#">Plessey</a>  09780	Linear	Numbers Only	Variable	Required	Grocery store shelf tags
<a href="#">Postnet</a> 	2-D*	Numbers Only	5 + check digit +4 optional +6 optional	Required	USA postal code (ZIP code)
<a href="#">QR Code</a> 	2-D	All ASCII Characters	Variable	Required	Includes error correction, up to about 1520 ASCII or 2509 numeric characters
<b>SCC-14</b> <b>(UCC/EAN Ship Cont. Code)</b>  (01) 5 0068458 00045 9	Linear	Numbers Only	13 + checksum	Required	Special use of Code 128 to mark shipping cartons containing UPC-encoded products (see also ITF-14)
<a href="#">Standard 2 of 5</a>  1234	Linear	Numbers Only	Variable	None	Also called Industrial 2 of 5
<b>UCC/EAN-128</b>  (10) ABC123 (11) 040104	Linear	All ASCII characters and control codes	Variable	Required	Special use of Code 128 which defines data formats for commerce
<b>UCC/EAN Shipping Container Code (SCC-14)</b>  (01) 5 0068458 00045 9	Linear	Numbers Only	13 +check digit	Required	Special use of Code 128 to mark shipping cartons containing UPC-encoded products (see also ITF-14)



Bar Code	Type	Character Set	Length	Checksum	Applications Comments
<u>UPC Shipping Container Code (ITF-14)</u>  0 50 02100 07865 6	Linear	Numbers Only	13 + check digit	Required	Special use of the Interleaved 2 of 5 code to mark shipping cartons containing UPC-encoded products (see also SCC-14)
<u>UPC-A</u>  0 21000 75896 8	Linear	Numbers Only	11 + check digit +2 optional +5 optional	Required	Retail product marking in USA and Canada
<u>UPC-E</u>  0 210007 4	Linear	Numbers Only	7 + check digit	Required	Retail product in USA and Canada; compressed code for products with limited label space

**Figure 16. Bar Code Comparison Chart**  
(MakeBarcode.com, 2008a)



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## Appendix B. Common RFID Frequencies

The table below lists the common RFID frequencies used throughout the world and lists the characteristics of those frequencies.

**Table 14. Common RFID Frequencies**  
(Wyld, 2005)

<b>Frequency Band</b>	<b>Description</b>	<b>Range</b>
125-134 KHz	Low frequency	To 18 inches
13.553-13.567 MHz	High frequency	3-10 feet
400-1000 MHz	Ultra-high frequency (UHF)	10-30 feet
2.45 GHZ	Microwave	10+ feet



**Table 15. RFID Range Characteristics  
(Wyld, 2005)**

<b>Frequency Band</b>	<b>System Characteristics</b>	<b>Example Applications</b>
Low (LF) 100-500 KHZ (typically 125-134 KHz worldwide)	<ul style="list-style-type: none"> <li>• Short read range (to 18 inches)</li> <li>• Low reading speed</li> <li>• Relatively inexpensive</li> <li>• Can read through liquids</li> <li>• Works well near metal</li> </ul>	<ul style="list-style-type: none"> <li>• Access control</li> <li>• Animal identification</li> <li>• Beer keg tracking</li> <li>• Inventory control</li> <li>• Automobile key/anti-theft systems</li> </ul>
High (HF) (typically 13.56 MHz)	<ul style="list-style-type: none"> <li>• 13.56 MHz frequency accepted worldwide</li> <li>• Short to medium range (3-10 feet)</li> <li>• Medium reading speed</li> <li>• Can read through liquids/works well in moist environment</li> <li>• Does not work well near metal</li> <li>• Moderate expense</li> </ul>	<ul style="list-style-type: none"> <li>• Access control</li> <li>• Smart cards</li> <li>• Electronic article surveillance</li> <li>• Library book tracking</li> <li>• Pallet/container tracking</li> <li>• Airline baggage tracking</li> <li>• Apparel/laundry item tracking</li> </ul>
Ultra High (UHF) 400-1000 MHz (typically 850-950 MHz)	<ul style="list-style-type: none"> <li>• Long read range (10-30 feet)</li> <li>• High reading speed</li> <li>• Reduced likelihood of signal collision</li> <li>• Difficulty reading through liquids</li> <li>• Does not work well in moist environments</li> <li>• Experiences interference from metals</li> <li>• Relatively expensive</li> </ul>	<ul style="list-style-type: none"> <li>• Item management</li> <li>• Supply chain management</li> </ul>
Microwave 2.4-6.0 GHz (typically 2.45 or 5.8 GHz)	<ul style="list-style-type: none"> <li>• Medium read range (10 + feet)</li> <li>• Similar characteristics to UHF tags, but with faster read rates</li> </ul>	<ul style="list-style-type: none"> <li>• Railroad car monitoring</li> <li>• Toll collection systems</li> </ul>





## Appendix C. Examples of Recurring Cost and Potential Savings Utilizing a Pallet Pool without RFID from DDJC to DDDC

The following matrices provide examples for the recurring cost and potential savings for utilizing a pallet pool without RFID from DDJC to DDDC.



Pool Recurring Cost Matrix for 5.6 Cycle				
	Pallet Cost	Continuous Purchase (CP)	Wood Pallet Pool (WP)	Plastic Pallet Pool (PP)
Cycle	5.6	\$2,058.00	\$2,801.03	
Demand	588	\$2,352.00	\$2,844.04	
Pool Size	656	\$2,646.00	\$2,887.04	
Avg Wood Pallet Trips	9	\$2,940.00	\$2,930.04	
Avg Plastic Pallet Trips	250	\$3,234.00	\$2,973.05	
Transportation Cost	###	\$3,528.00	\$3,016.05	
Storage Cost	###	\$3,822.00	\$3,059.06	
Lost %	0	\$4,116.00	\$3,102.06	
		\$4,410.00	\$3,145.07	
		\$4,704.00	\$3,188.07	
		\$4,998.00	\$3,231.08	
		\$5,292.00	\$3,274.08	
		\$5,586.00	\$3,317.08	
		\$5,880.00	\$3,360.09	
		\$6,174.00	\$3,403.09	
		\$6,468.00	\$3,446.10	
		\$6,762.00	\$3,489.10	
		\$7,056.00	\$3,532.11	
		\$7,350.00	\$3,575.11	
		\$7,644.00	\$3,618.12	
	\$20.00			\$2,814.88
	\$25.00			\$2,893.60
	\$30.00			\$2,972.32
	\$35.00			\$3,051.04
	\$40.00			\$3,129.76
	\$45.00			\$3,208.48
	\$50.00			\$3,287.20
	\$55.00			\$3,365.92
	\$60.00			\$3,444.64
	\$65.00			\$3,523.36
	\$70.00			\$3,602.08
	\$75.00			\$3,680.80
	\$80.00			\$3,759.52

Pool Recurring Cost Matrix for 6 Cycle				
	Pallet Cost	Continuous Purchase	Wood Pallet Pool	Plastic Pallet Pool
Cycle	6	\$2,205.00	\$2,821.22	
Demand	630	\$2,520.00	\$2,867.11	
Pool Size	700	\$2,835.00	\$2,913.00	
Avg Wood Pallet Trips	9	\$3,150.00	\$2,958.89	
Avg Plastic Pallet Trips	250	\$3,465.00	\$3,004.78	
Transportation Cost	1000	\$3,780.00	\$3,050.67	
Storage Cost	1500	\$4,095.00	\$3,096.56	
Lost %	0.02	\$4,410.00	\$3,142.44	
		\$4,725.00	\$3,188.33	
		\$5,040.00	\$3,234.22	
		\$5,355.00	\$3,280.11	
		\$5,670.00	\$3,326.00	
		\$5,985.00	\$3,371.89	
		\$6,300.00	\$3,417.78	
		\$6,615.00	\$3,463.67	
		\$6,930.00	\$3,509.56	
		\$7,245.00	\$3,555.44	
		\$7,560.00	\$3,601.33	
		\$7,875.00	\$3,647.22	
		\$8,190.00	\$3,693.11	
	\$20.00			\$2,836.00
	\$25.00			\$2,920.00
	\$30.00			\$3,004.00
	\$35.00			\$3,088.00
	\$40.00			\$3,172.00
	\$45.00			\$3,256.00
	\$50.00			\$3,340.00
	\$55.00			\$3,424.00
	\$60.00			\$3,508.00
	\$65.00			\$3,592.00
	\$70.00			\$3,676.00
	\$75.00			\$3,760.00
	\$80.00			\$3,844.00

Figure 17. Recurring Cost per Cycle for Wood and Plastic Pallet Pool



Potential Savings for Plastic Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

	Cost of Plastic Pallet															
	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80			
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 5.00	\$ 125	\$ 46	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 5.50	\$ 419	\$ 340	\$ 262	\$ 183	\$ 104	\$ 26	-	-	-	-	-	-	-	-		
\$ 6.00	\$ 713	\$ 634	\$ 556	\$ 477	\$ 398	\$ 320	\$ 241	\$ 162	\$ 83	\$ 5	-	-	-	-		
\$ 6.50	\$ 1,007	\$ 928	\$ 850	\$ 771	\$ 692	\$ 614	\$ 535	\$ 456	\$ 377	\$ 299	\$ 220	\$ 141	\$ 62			
\$ 7.00	\$ 1,301	\$ 1,222	\$ 1,144	\$ 1,065	\$ 986	\$ 908	\$ 829	\$ 750	\$ 671	\$ 593	\$ 514	\$ 435	\$ 356			
\$ 7.50	\$ 1,595	\$ 1,516	\$ 1,438	\$ 1,359	\$ 1,280	\$ 1,202	\$ 1,123	\$ 1,044	\$ 965	\$ 887	\$ 808	\$ 729	\$ 650			
\$ 8.00	\$ 1,889	\$ 1,810	\$ 1,732	\$ 1,653	\$ 1,574	\$ 1,496	\$ 1,417	\$ 1,338	\$ 1,259	\$ 1,181	\$ 1,102	\$ 1,023	\$ 944			
\$ 8.50	\$ 2,183	\$ 2,104	\$ 2,026	\$ 1,947	\$ 1,868	\$ 1,790	\$ 1,711	\$ 1,632	\$ 1,553	\$ 1,475	\$ 1,396	\$ 1,317	\$ 1,238			
\$ 9.00	\$ 2,477	\$ 2,398	\$ 2,320	\$ 2,241	\$ 2,162	\$ 2,084	\$ 2,005	\$ 1,926	\$ 1,847	\$ 1,769	\$ 1,690	\$ 1,611	\$ 1,532			
\$ 9.50	\$ 2,771	\$ 2,692	\$ 2,614	\$ 2,535	\$ 2,456	\$ 2,378	\$ 2,299	\$ 2,220	\$ 2,141	\$ 2,063	\$ 1,984	\$ 1,905	\$ 1,826			
\$ 10.00	\$ 3,065	\$ 2,986	\$ 2,908	\$ 2,829	\$ 2,750	\$ 2,672	\$ 2,593	\$ 2,514	\$ 2,435	\$ 2,357	\$ 2,278	\$ 2,199	\$ 2,120			
\$ 10.50	\$ 3,359	\$ 3,280	\$ 3,202	\$ 3,123	\$ 3,044	\$ 2,966	\$ 2,887	\$ 2,808	\$ 2,729	\$ 2,651	\$ 2,572	\$ 2,493	\$ 2,414			
\$ 11.00	\$ 3,653	\$ 3,574	\$ 3,496	\$ 3,417	\$ 3,338	\$ 3,260	\$ 3,181	\$ 3,102	\$ 3,023	\$ 2,945	\$ 2,866	\$ 2,787	\$ 2,708			
\$ 11.50	\$ 3,947	\$ 3,868	\$ 3,790	\$ 3,711	\$ 3,632	\$ 3,554	\$ 3,475	\$ 3,396	\$ 3,317	\$ 3,239	\$ 3,160	\$ 3,081	\$ 3,002			
\$ 12.00	\$ 4,241	\$ 4,162	\$ 4,084	\$ 4,005	\$ 3,926	\$ 3,848	\$ 3,769	\$ 3,690	\$ 3,611	\$ 3,533	\$ 3,454	\$ 3,375	\$ 3,296			
\$ 12.50	\$ 4,535	\$ 4,456	\$ 4,378	\$ 4,299	\$ 4,220	\$ 4,142	\$ 4,063	\$ 3,984	\$ 3,905	\$ 3,827	\$ 3,748	\$ 3,669	\$ 3,590			
\$ 13.00	\$ 4,829	\$ 4,750	\$ 4,672	\$ 4,593	\$ 4,514	\$ 4,436	\$ 4,357	\$ 4,278	\$ 4,199	\$ 4,121	\$ 4,042	\$ 3,963	\$ 3,884			

Cost of Wood Pallet

Figure 18. Potential Savings per Cycle Matrix for Plastic Pallet Pool of 656 Pallets



Potential Savings for Wood Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 139	\$ 96	\$ 53	\$ 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 433	\$ 390	\$ 347	\$ 304	\$ 261	\$ 218	\$ 175	\$ 132	\$ 89	\$ 46	\$ 3	-	-	-	-	-	-	-	-	-
\$ 6.00	\$ 727	\$ 684	\$ 641	\$ 598	\$ 555	\$ 512	\$ 469	\$ 426	\$ 383	\$ 340	\$ 297	\$ 254	\$ 211	\$ 168	\$ 125	\$ 82	\$ 39	-	-	-
\$ 6.50	\$ 1,021	\$ 978	\$ 935	\$ 892	\$ 849	\$ 806	\$ 763	\$ 720	\$ 677	\$ 634	\$ 591	\$ 548	\$ 505	\$ 462	\$ 419	\$ 376	\$ 333	\$ 290	\$ 247	\$ 204
\$ 7.00	\$ 1,315	\$ 1,272	\$ 1,229	\$ 1,186	\$ 1,143	\$ 1,100	\$ 1,057	\$ 1,014	\$ 971	\$ 928	\$ 885	\$ 842	\$ 799	\$ 756	\$ 713	\$ 670	\$ 627	\$ 584	\$ 541	\$ 498
\$ 7.50	\$ 1,609	\$ 1,566	\$ 1,523	\$ 1,480	\$ 1,437	\$ 1,394	\$ 1,351	\$ 1,308	\$ 1,265	\$ 1,222	\$ 1,179	\$ 1,136	\$ 1,093	\$ 1,050	\$ 1,007	\$ 964	\$ 921	\$ 878	\$ 835	\$ 792
\$ 8.00	\$ 1,903	\$ 1,860	\$ 1,817	\$ 1,774	\$ 1,731	\$ 1,688	\$ 1,645	\$ 1,602	\$ 1,559	\$ 1,516	\$ 1,473	\$ 1,430	\$ 1,387	\$ 1,344	\$ 1,301	\$ 1,258	\$ 1,215	\$ 1,172	\$ 1,129	\$ 1,086
\$ 8.50	\$ 2,197	\$ 2,154	\$ 2,111	\$ 2,068	\$ 2,025	\$ 1,982	\$ 1,939	\$ 1,896	\$ 1,853	\$ 1,810	\$ 1,767	\$ 1,724	\$ 1,681	\$ 1,638	\$ 1,595	\$ 1,552	\$ 1,509	\$ 1,466	\$ 1,423	\$ 1,380
\$ 9.00	\$ 2,491	\$ 2,448	\$ 2,405	\$ 2,362	\$ 2,319	\$ 2,276	\$ 2,233	\$ 2,190	\$ 2,147	\$ 2,104	\$ 2,061	\$ 2,018	\$ 1,975	\$ 1,932	\$ 1,889	\$ 1,846	\$ 1,803	\$ 1,760	\$ 1,717	\$ 1,674
\$ 9.50	\$ 2,785	\$ 2,742	\$ 2,699	\$ 2,656	\$ 2,613	\$ 2,570	\$ 2,527	\$ 2,484	\$ 2,441	\$ 2,398	\$ 2,355	\$ 2,312	\$ 2,269	\$ 2,226	\$ 2,183	\$ 2,140	\$ 2,097	\$ 2,054	\$ 2,011	\$ 1,968
\$ 10.00	\$ 3,079	\$ 3,036	\$ 2,993	\$ 2,950	\$ 2,907	\$ 2,864	\$ 2,821	\$ 2,778	\$ 2,735	\$ 2,692	\$ 2,649	\$ 2,606	\$ 2,563	\$ 2,520	\$ 2,477	\$ 2,434	\$ 2,391	\$ 2,348	\$ 2,305	\$ 2,262
\$ 10.50	\$ 3,373	\$ 3,330	\$ 3,287	\$ 3,244	\$ 3,201	\$ 3,158	\$ 3,115	\$ 3,072	\$ 3,029	\$ 2,986	\$ 2,943	\$ 2,900	\$ 2,857	\$ 2,814	\$ 2,771	\$ 2,728	\$ 2,685	\$ 2,642	\$ 2,599	\$ 2,556
\$ 11.00	\$ 3,667	\$ 3,624	\$ 3,581	\$ 3,538	\$ 3,495	\$ 3,452	\$ 3,409	\$ 3,366	\$ 3,323	\$ 3,280	\$ 3,237	\$ 3,194	\$ 3,151	\$ 3,108	\$ 3,065	\$ 3,022	\$ 2,979	\$ 2,936	\$ 2,893	\$ 2,850
\$ 11.50	\$ 3,961	\$ 3,918	\$ 3,875	\$ 3,832	\$ 3,789	\$ 3,746	\$ 3,703	\$ 3,660	\$ 3,617	\$ 3,574	\$ 3,531	\$ 3,488	\$ 3,445	\$ 3,402	\$ 3,359	\$ 3,316	\$ 3,273	\$ 3,230	\$ 3,187	\$ 3,144
\$ 12.00	\$ 4,255	\$ 4,212	\$ 4,169	\$ 4,126	\$ 4,083	\$ 4,040	\$ 3,997	\$ 3,954	\$ 3,911	\$ 3,868	\$ 3,825	\$ 3,782	\$ 3,739	\$ 3,696	\$ 3,653	\$ 3,610	\$ 3,567	\$ 3,524	\$ 3,481	\$ 3,438
\$ 12.50	\$ 4,549	\$ 4,506	\$ 4,463	\$ 4,420	\$ 4,377	\$ 4,334	\$ 4,291	\$ 4,248	\$ 4,205	\$ 4,162	\$ 4,119	\$ 4,076	\$ 4,033	\$ 3,990	\$ 3,947	\$ 3,904	\$ 3,861	\$ 3,818	\$ 3,775	\$ 3,732
\$ 13.00	\$ 4,843	\$ 4,800	\$ 4,757	\$ 4,714	\$ 4,671	\$ 4,628	\$ 4,585	\$ 4,542	\$ 4,499	\$ 4,456	\$ 4,413	\$ 4,370	\$ 4,327	\$ 4,284	\$ 4,241	\$ 4,198	\$ 4,155	\$ 4,112	\$ 4,069	\$ 4,026

Figure 19. Potential Savings per Cycle Matrix for Wood Pallet Pool of 656 Pallets



Potential Annual Savings for Plastic Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

	Cost of Plastic Pallet															
	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80			
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 5.00	\$ 1,164	\$ 432	-	-	-	-	-	-	-	-	-	-	-	-		
\$ 5.50	\$ 3,898	\$ 3,166	\$ 2,434	\$ 1,702	\$ 969	\$ 237	-	-	-	-	-	-	-	-		
\$ 6.00	\$ 6,632	\$ 5,900	\$ 5,168	\$ 4,436	\$ 3,704	\$ 2,972	\$ 2,239	\$ 1,507	\$ 775	\$ 43	-	-	-	-		
\$ 6.50	\$ 9,366	\$ 8,634	\$ 7,902	\$ 7,170	\$ 6,438	\$ 5,706	\$ 4,974	\$ 4,242	\$ 3,509	\$ 2,777	\$ 2,045	\$ 1,313	\$ 581	-		
\$ 7.00	\$ 12,100	\$ 11,368	\$ 10,636	\$ 9,904	\$ 9,172	\$ 8,440	\$ 7,708	\$ 6,976	\$ 6,244	\$ 5,512	\$ 4,779	\$ 4,047	\$ 3,315	-		
\$ 7.50	\$ 14,835	\$ 14,103	\$ 13,370	\$ 12,638	\$ 11,906	\$ 11,174	\$ 10,442	\$ 9,710	\$ 8,978	\$ 8,246	\$ 7,514	\$ 6,782	\$ 6,049	-		
\$ 8.00	\$ 17,569	\$ 16,837	\$ 16,105	\$ 15,373	\$ 14,640	\$ 13,908	\$ 13,176	\$ 12,444	\$ 11,712	\$ 10,980	\$ 10,248	\$ 9,516	\$ 8,784	-		
\$ 8.50	\$ 20,303	\$ 19,571	\$ 18,839	\$ 18,107	\$ 17,375	\$ 16,643	\$ 15,910	\$ 15,178	\$ 14,446	\$ 13,714	\$ 12,982	\$ 12,250	\$ 11,518	-		
\$ 9.00	\$ 23,037	\$ 22,305	\$ 21,573	\$ 20,841	\$ 20,109	\$ 19,377	\$ 18,645	\$ 17,913	\$ 17,180	\$ 16,448	\$ 15,716	\$ 14,984	\$ 14,252	-		
\$ 9.50	\$ 25,771	\$ 25,039	\$ 24,307	\$ 23,575	\$ 22,843	\$ 22,111	\$ 21,379	\$ 20,647	\$ 19,915	\$ 19,183	\$ 18,450	\$ 17,718	\$ 16,986	-		
\$ 10.00	\$ 28,506	\$ 27,774	\$ 27,041	\$ 26,309	\$ 25,577	\$ 24,845	\$ 24,113	\$ 23,381	\$ 22,649	\$ 21,917	\$ 21,185	\$ 20,453	\$ 19,720	-		
\$ 10.50	\$ 31,240	\$ 30,508	\$ 29,776	\$ 29,044	\$ 28,311	\$ 27,579	\$ 26,847	\$ 26,115	\$ 25,383	\$ 24,651	\$ 23,919	\$ 23,187	\$ 22,455	-		
\$ 11.00	\$ 33,974	\$ 33,242	\$ 32,510	\$ 31,778	\$ 31,046	\$ 30,314	\$ 29,581	\$ 28,849	\$ 28,117	\$ 27,385	\$ 26,653	\$ 25,921	\$ 25,189	-		
\$ 11.50	\$ 36,708	\$ 35,976	\$ 35,244	\$ 34,512	\$ 33,780	\$ 33,048	\$ 32,316	\$ 31,584	\$ 30,851	\$ 30,119	\$ 29,387	\$ 28,655	\$ 27,923	-		
\$ 12.00	\$ 39,442	\$ 38,710	\$ 37,978	\$ 37,246	\$ 36,514	\$ 35,782	\$ 35,050	\$ 34,318	\$ 33,586	\$ 32,854	\$ 32,121	\$ 31,389	\$ 30,657	-		
\$ 12.50	\$ 42,177	\$ 41,445	\$ 40,712	\$ 39,980	\$ 39,248	\$ 38,516	\$ 37,784	\$ 37,052	\$ 36,320	\$ 35,588	\$ 34,856	\$ 34,124	\$ 33,391	-		
\$ 13.00	\$ 44,911	\$ 44,179	\$ 43,447	\$ 42,715	\$ 41,982	\$ 41,250	\$ 40,518	\$ 39,786	\$ 39,054	\$ 38,322	\$ 37,590	\$ 36,858	\$ 36,126	-		

Cost of Wood Pallet

Figure 20. Potential Annual Savings per Cycle Matrix for Plastic Pallet Pool of 656 Pallets



Potential Annual Savings for Wood Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00	
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	1,292	892	493	93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	4,027	3,627	3,227	2,827	2,427	2,027	1,627	1,227	827	427	27	-	-	-	-	-	-	-	-	-	-
\$ 6.00	6,761	6,361	5,961	5,561	5,161	4,761	4,361	3,961	3,561	3,161	2,761	2,361	1,962	1,562	1,162	762	362	-	-	-	-
\$ 6.50	9,495	9,095	8,695	8,295	7,895	7,495	7,095	6,695	6,295	5,896	5,496	5,096	4,696	4,296	3,896	3,496	3,096	2,696	2,296	1,896	-
\$ 7.00	12,229	11,829	11,429	11,029	10,629	10,230	9,830	9,430	9,030	8,630	8,230	7,830	7,430	7,030	6,630	6,230	5,830	5,430	5,030	4,630	-
\$ 7.50	14,963	14,563	14,164	13,764	13,364	12,964	12,564	12,164	11,764	11,364	10,964	10,564	10,164	9,764	9,364	8,964	8,564	8,164	7,764	7,365	-
\$ 8.00	17,698	17,298	16,898	16,498	16,098	15,698	15,298	14,898	14,498	14,098	13,698	13,298	12,898	12,498	12,098	11,698	11,299	10,899	10,499	10,099	-
\$ 8.50	20,432	20,032	19,632	19,232	18,832	18,432	18,032	17,632	17,232	16,832	16,432	16,032	15,633	15,233	14,833	14,433	14,033	13,633	13,233	12,833	-
\$ 9.00	23,166	22,766	22,366	21,966	21,566	21,166	20,766	20,366	19,966	19,567	19,167	18,767	18,367	17,967	17,567	17,167	16,767	16,367	15,967	15,567	-
\$ 9.50	25,900	25,500	25,100	24,700	24,300	23,901	23,501	23,101	22,701	22,301	21,901	21,501	21,101	20,701	20,301	19,901	19,501	19,101	18,701	18,301	-
\$ 10.00	28,634	28,234	27,835	27,435	27,035	26,635	26,235	25,835	25,435	25,035	24,635	24,235	23,835	23,435	23,035	22,635	22,235	21,835	21,435	21,036	-
\$ 10.50	31,369	30,969	30,569	30,169	29,769	29,369	28,969	28,569	28,169	27,769	27,369	26,969	26,569	26,169	25,769	25,369	24,970	24,570	24,170	23,770	-
\$ 11.00	34,103	33,703	33,303	32,903	32,503	32,103	31,703	31,303	30,903	30,503	30,103	29,703	29,304	28,904	28,504	28,104	27,704	27,304	26,904	26,504	-
\$ 11.50	36,837	36,437	36,037	35,637	35,237	34,837	34,437	34,037	33,637	33,238	32,838	32,438	32,038	31,638	31,238	30,838	30,438	30,038	29,638	29,238	-
\$ 12.00	39,571	39,171	38,771	38,371	37,971	37,572	37,172	36,772	36,372	35,972	35,572	35,172	34,772	34,372	33,972	33,572	33,172	32,772	32,372	31,972	-
\$ 12.50	42,305	41,905	41,506	41,106	40,706	40,306	39,906	39,506	39,106	38,706	38,306	37,906	37,506	37,106	36,706	36,306	35,906	35,506	35,106	34,707	-
\$ 13.00	45,040	44,640	44,240	43,840	43,440	43,040	42,640	42,240	41,840	41,440	41,040	40,640	40,240	39,840	39,440	39,040	38,641	38,241	37,841	37,441	-

Figure 21. Potential Annual Savings per Cycle Matrix for Wood Pallet Pool of 656 Pallets





Potential Savings for Plastic Pallet Pool with a 6 Week Cycle and Pool Size of 700

	Cost of Plastic Pallet													
	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80	
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 5.00	\$ 314	\$ 230	\$ 146	\$ 62	-	-	-	-	-	-	-	-	-	
\$ 5.50	\$ 629	\$ 545	\$ 461	\$ 377	\$ 293	\$ 209	\$ 125	\$ 41	-	-	-	-	-	
\$ 6.00	\$ 944	\$ 860	\$ 776	\$ 692	\$ 608	\$ 524	\$ 440	\$ 356	\$ 272	\$ 188	\$ 104	\$ 20	-	
\$ 6.50	\$ 1,259	\$ 1,175	\$ 1,091	\$ 1,007	\$ 923	\$ 839	\$ 755	\$ 671	\$ 587	\$ 503	\$ 419	\$ 335	\$ 251	
\$ 7.00	\$ 1,574	\$ 1,490	\$ 1,406	\$ 1,322	\$ 1,238	\$ 1,154	\$ 1,070	\$ 986	\$ 902	\$ 818	\$ 734	\$ 650	\$ 566	
\$ 7.50	\$ 1,889	\$ 1,805	\$ 1,721	\$ 1,637	\$ 1,553	\$ 1,469	\$ 1,385	\$ 1,301	\$ 1,217	\$ 1,133	\$ 1,049	\$ 965	\$ 881	
\$ 8.00	\$ 2,204	\$ 2,120	\$ 2,036	\$ 1,952	\$ 1,868	\$ 1,784	\$ 1,700	\$ 1,616	\$ 1,532	\$ 1,448	\$ 1,364	\$ 1,280	\$ 1,196	
\$ 8.50	\$ 2,519	\$ 2,435	\$ 2,351	\$ 2,267	\$ 2,183	\$ 2,099	\$ 2,015	\$ 1,931	\$ 1,847	\$ 1,763	\$ 1,679	\$ 1,595	\$ 1,511	
\$ 9.00	\$ 2,834	\$ 2,750	\$ 2,666	\$ 2,582	\$ 2,498	\$ 2,414	\$ 2,330	\$ 2,246	\$ 2,162	\$ 2,078	\$ 1,994	\$ 1,910	\$ 1,826	
\$ 9.50	\$ 3,149	\$ 3,065	\$ 2,981	\$ 2,897	\$ 2,813	\$ 2,729	\$ 2,645	\$ 2,561	\$ 2,477	\$ 2,393	\$ 2,309	\$ 2,225	\$ 2,141	
\$ 10.00	\$ 3,464	\$ 3,380	\$ 3,296	\$ 3,212	\$ 3,128	\$ 3,044	\$ 2,960	\$ 2,876	\$ 2,792	\$ 2,708	\$ 2,624	\$ 2,540	\$ 2,456	
\$ 10.50	\$ 3,779	\$ 3,695	\$ 3,611	\$ 3,527	\$ 3,443	\$ 3,359	\$ 3,275	\$ 3,191	\$ 3,107	\$ 3,023	\$ 2,939	\$ 2,855	\$ 2,771	
\$ 11.00	\$ 4,094	\$ 4,010	\$ 3,926	\$ 3,842	\$ 3,758	\$ 3,674	\$ 3,590	\$ 3,506	\$ 3,422	\$ 3,338	\$ 3,254	\$ 3,170	\$ 3,086	
\$ 11.50	\$ 4,409	\$ 4,325	\$ 4,241	\$ 4,157	\$ 4,073	\$ 3,989	\$ 3,905	\$ 3,821	\$ 3,737	\$ 3,653	\$ 3,569	\$ 3,485	\$ 3,401	
\$ 12.00	\$ 4,724	\$ 4,640	\$ 4,556	\$ 4,472	\$ 4,388	\$ 4,304	\$ 4,220	\$ 4,136	\$ 4,052	\$ 3,968	\$ 3,884	\$ 3,800	\$ 3,716	
\$ 12.50	\$ 5,039	\$ 4,955	\$ 4,871	\$ 4,787	\$ 4,703	\$ 4,619	\$ 4,535	\$ 4,451	\$ 4,367	\$ 4,283	\$ 4,199	\$ 4,115	\$ 4,031	
\$ 13.00	\$ 5,354	\$ 5,270	\$ 5,186	\$ 5,102	\$ 5,018	\$ 4,934	\$ 4,850	\$ 4,766	\$ 4,682	\$ 4,598	\$ 4,514	\$ 4,430	\$ 4,346	

Cost of Wood Pallet

Figure 22. Potential Savings per Cycle Matrix for Plastic Pallet Pool of 700 Pallets



Potential Savings for Wood Pallet Pool with a 6 Week Cycle and Pool Size of 700

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 329	\$ 283	\$ 237	\$ 191	\$ 145	\$ 99	\$ 53	\$ 8	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 644	\$ 598	\$ 552	\$ 506	\$ 460	\$ 414	\$ 368	\$ 323	\$ 277	\$ 231	\$ 185	\$ 139	\$ 93	\$ 47	\$ 1	-	-	-	-	-
\$ 6.00	\$ 959	\$ 913	\$ 867	\$ 821	\$ 775	\$ 729	\$ 683	\$ 638	\$ 592	\$ 546	\$ 500	\$ 454	\$ 408	\$ 362	\$ 316	\$ 270	\$ 225	\$ 179	\$ 133	\$ 87
\$ 6.50	\$ 1,274	\$ 1,228	\$ 1,182	\$ 1,136	\$ 1,090	\$ 1,044	\$ 998	\$ 953	\$ 907	\$ 861	\$ 815	\$ 769	\$ 723	\$ 677	\$ 631	\$ 585	\$ 540	\$ 494	\$ 448	\$ 402
\$ 7.00	\$ 1,589	\$ 1,543	\$ 1,497	\$ 1,451	\$ 1,405	\$ 1,359	\$ 1,313	\$ 1,268	\$ 1,222	\$ 1,176	\$ 1,130	\$ 1,084	\$ 1,038	\$ 992	\$ 946	\$ 900	\$ 855	\$ 809	\$ 763	\$ 717
\$ 7.50	\$ 1,904	\$ 1,858	\$ 1,812	\$ 1,766	\$ 1,720	\$ 1,674	\$ 1,628	\$ 1,583	\$ 1,537	\$ 1,491	\$ 1,445	\$ 1,399	\$ 1,353	\$ 1,307	\$ 1,261	\$ 1,215	\$ 1,170	\$ 1,124	\$ 1,078	\$ 1,032
\$ 8.00	\$ 2,219	\$ 2,173	\$ 2,127	\$ 2,081	\$ 2,035	\$ 1,989	\$ 1,943	\$ 1,898	\$ 1,852	\$ 1,806	\$ 1,760	\$ 1,714	\$ 1,668	\$ 1,622	\$ 1,576	\$ 1,530	\$ 1,485	\$ 1,439	\$ 1,393	\$ 1,347
\$ 8.50	\$ 2,534	\$ 2,488	\$ 2,442	\$ 2,396	\$ 2,350	\$ 2,304	\$ 2,258	\$ 2,213	\$ 2,167	\$ 2,121	\$ 2,075	\$ 2,029	\$ 1,983	\$ 1,937	\$ 1,891	\$ 1,845	\$ 1,800	\$ 1,754	\$ 1,708	\$ 1,662
\$ 9.00	\$ 2,849	\$ 2,803	\$ 2,757	\$ 2,711	\$ 2,665	\$ 2,619	\$ 2,573	\$ 2,528	\$ 2,482	\$ 2,436	\$ 2,390	\$ 2,344	\$ 2,298	\$ 2,252	\$ 2,206	\$ 2,160	\$ 2,115	\$ 2,069	\$ 2,023	\$ 1,977
\$ 9.50	\$ 3,164	\$ 3,118	\$ 3,072	\$ 3,026	\$ 2,980	\$ 2,934	\$ 2,888	\$ 2,843	\$ 2,797	\$ 2,751	\$ 2,705	\$ 2,659	\$ 2,613	\$ 2,567	\$ 2,521	\$ 2,475	\$ 2,430	\$ 2,384	\$ 2,338	\$ 2,292
\$ 10.00	\$ 3,479	\$ 3,433	\$ 3,387	\$ 3,341	\$ 3,295	\$ 3,249	\$ 3,203	\$ 3,158	\$ 3,112	\$ 3,066	\$ 3,020	\$ 2,974	\$ 2,928	\$ 2,882	\$ 2,836	\$ 2,790	\$ 2,745	\$ 2,699	\$ 2,653	\$ 2,607
\$ 10.50	\$ 3,794	\$ 3,748	\$ 3,702	\$ 3,656	\$ 3,610	\$ 3,564	\$ 3,518	\$ 3,473	\$ 3,427	\$ 3,381	\$ 3,335	\$ 3,289	\$ 3,243	\$ 3,197	\$ 3,151	\$ 3,105	\$ 3,060	\$ 3,014	\$ 2,968	\$ 2,922
\$ 11.00	\$ 4,109	\$ 4,063	\$ 4,017	\$ 3,971	\$ 3,925	\$ 3,879	\$ 3,833	\$ 3,788	\$ 3,742	\$ 3,696	\$ 3,650	\$ 3,604	\$ 3,558	\$ 3,512	\$ 3,466	\$ 3,420	\$ 3,375	\$ 3,329	\$ 3,283	\$ 3,237
\$ 11.50	\$ 4,424	\$ 4,378	\$ 4,332	\$ 4,286	\$ 4,240	\$ 4,194	\$ 4,148	\$ 4,103	\$ 4,057	\$ 4,011	\$ 3,965	\$ 3,919	\$ 3,873	\$ 3,827	\$ 3,781	\$ 3,735	\$ 3,690	\$ 3,644	\$ 3,598	\$ 3,552
\$ 12.00	\$ 4,739	\$ 4,693	\$ 4,647	\$ 4,601	\$ 4,555	\$ 4,509	\$ 4,463	\$ 4,418	\$ 4,372	\$ 4,326	\$ 4,280	\$ 4,234	\$ 4,188	\$ 4,142	\$ 4,096	\$ 4,050	\$ 4,005	\$ 3,959	\$ 3,913	\$ 3,867
\$ 12.50	\$ 5,054	\$ 5,008	\$ 4,962	\$ 4,916	\$ 4,870	\$ 4,824	\$ 4,778	\$ 4,733	\$ 4,687	\$ 4,641	\$ 4,595	\$ 4,549	\$ 4,503	\$ 4,457	\$ 4,411	\$ 4,365	\$ 4,320	\$ 4,274	\$ 4,228	\$ 4,182
\$ 13.00	\$ 5,369	\$ 5,323	\$ 5,277	\$ 5,231	\$ 5,185	\$ 5,139	\$ 5,093	\$ 5,048	\$ 5,002	\$ 4,956	\$ 4,910	\$ 4,864	\$ 4,818	\$ 4,772	\$ 4,726	\$ 4,680	\$ 4,635	\$ 4,589	\$ 4,543	\$ 4,497

Cost of Wood Pallet

Figure 23. Potential Savings per Cycle Matrix for Wood Pallet Pool of 700 Pallets





Potential Annual Savings for Plastic Pallet Pool with a 6 Week Cycle and Pool Size of 700

Cost of Plastic Pallet

	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 2,732	\$ 2,001	\$ 1,270	\$ 539	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 5,472	\$ 4,742	\$ 4,011	\$ 3,280	\$ 2,549	\$ 1,818	\$ 1,088	\$ 357	-	-	-	-	-
\$ 6.00	\$ 8,213	\$ 7,482	\$ 6,751	\$ 6,020	\$ 5,290	\$ 4,559	\$ 3,828	\$ 3,097	\$ 2,366	\$ 1,636	\$ 905	\$ 174	-
\$ 6.50	\$ 10,953	\$ 10,223	\$ 9,492	\$ 8,761	\$ 8,030	\$ 7,299	\$ 6,569	\$ 5,838	\$ 5,107	\$ 4,376	\$ 3,645	\$ 2,915	\$ 2,184
\$ 7.00	\$ 13,694	\$ 12,963	\$ 12,232	\$ 11,501	\$ 10,771	\$ 10,040	\$ 9,309	\$ 8,578	\$ 7,847	\$ 7,117	\$ 6,386	\$ 5,655	\$ 4,924
\$ 7.50	\$ 16,434	\$ 15,704	\$ 14,973	\$ 14,242	\$ 13,511	\$ 12,780	\$ 12,050	\$ 11,319	\$ 10,588	\$ 9,857	\$ 9,126	\$ 8,396	\$ 7,665
\$ 8.00	\$ 19,175	\$ 18,444	\$ 17,713	\$ 16,982	\$ 16,252	\$ 15,521	\$ 14,790	\$ 14,059	\$ 13,328	\$ 12,598	\$ 11,867	\$ 11,136	\$ 10,405
\$ 8.50	\$ 21,915	\$ 21,185	\$ 20,454	\$ 19,723	\$ 18,992	\$ 18,261	\$ 17,531	\$ 16,800	\$ 16,069	\$ 15,338	\$ 14,607	\$ 13,877	\$ 13,146
\$ 9.00	\$ 24,656	\$ 23,925	\$ 23,194	\$ 22,463	\$ 21,733	\$ 21,002	\$ 20,271	\$ 19,540	\$ 18,809	\$ 18,079	\$ 17,348	\$ 16,617	\$ 15,886
\$ 9.50	\$ 27,396	\$ 26,666	\$ 25,935	\$ 25,204	\$ 24,473	\$ 23,742	\$ 23,012	\$ 22,281	\$ 21,550	\$ 20,819	\$ 20,088	\$ 19,358	\$ 18,627
\$ 10.00	\$ 30,137	\$ 29,406	\$ 28,675	\$ 27,944	\$ 27,214	\$ 26,483	\$ 25,752	\$ 25,021	\$ 24,290	\$ 23,560	\$ 22,829	\$ 22,098	\$ 21,367
\$ 10.50	\$ 32,877	\$ 32,147	\$ 31,416	\$ 30,685	\$ 29,954	\$ 29,223	\$ 28,493	\$ 27,762	\$ 27,031	\$ 26,300	\$ 25,569	\$ 24,839	\$ 24,108
\$ 11.00	\$ 35,618	\$ 34,887	\$ 34,156	\$ 33,425	\$ 32,695	\$ 31,964	\$ 31,233	\$ 30,502	\$ 29,771	\$ 29,041	\$ 28,310	\$ 27,579	\$ 26,848
\$ 11.50	\$ 38,358	\$ 37,628	\$ 36,897	\$ 36,166	\$ 35,435	\$ 34,704	\$ 33,974	\$ 33,243	\$ 32,512	\$ 31,781	\$ 31,050	\$ 30,320	\$ 29,589
\$ 12.00	\$ 41,099	\$ 40,368	\$ 39,637	\$ 38,906	\$ 38,176	\$ 37,445	\$ 36,714	\$ 35,983	\$ 35,252	\$ 34,522	\$ 33,791	\$ 33,060	\$ 32,329
\$ 12.50	\$ 43,839	\$ 43,109	\$ 42,378	\$ 41,647	\$ 40,916	\$ 40,185	\$ 39,455	\$ 38,724	\$ 37,993	\$ 37,262	\$ 36,531	\$ 35,801	\$ 35,070
\$ 13.00	\$ 46,580	\$ 45,849	\$ 45,118	\$ 44,387	\$ 43,657	\$ 42,926	\$ 42,195	\$ 41,464	\$ 40,733	\$ 40,003	\$ 39,272	\$ 38,541	\$ 37,810

Cost of Wood Pallet

Figure 24. Potential Annual Savings per Cycle Matrix for Plastic Pallet Pool of 700 Pallets



Potential Annual Savings for Wood Pallet Pool with a 6 Week Cycle and Pool Size of 700

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 2,860	\$ 2,461	\$ 2,062	\$ 1,663	\$ 1,263	\$ 864	\$ 465	\$ 66	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 5,601	\$ 5,202	\$ 4,802	\$ 4,403	\$ 4,004	\$ 3,605	\$ 3,205	\$ 2,806	\$ 2,407	\$ 2,008	\$ 1,609	\$ 1,209	\$ (25,870)	\$ 411	\$ 12	-	-	-	-	-
\$ 6.00	\$ 8,341	\$ 7,942	\$ 7,543	\$ 7,144	\$ 6,744	\$ 6,345	\$ 5,946	\$ 5,547	\$ 5,148	\$ 4,748	\$ 4,349	\$ 3,950	\$ (25,555)	\$ 3,151	\$ 2,752	\$ 2,353	\$ 1,954	\$ 1,554	\$ 1,155	\$ 756
\$ 6.50	\$ 11,082	\$ 10,683	\$ 10,283	\$ 9,884	\$ 9,485	\$ 9,086	\$ 8,686	\$ 8,287	\$ 7,888	\$ 7,489	\$ 7,090	\$ 6,690	\$ (25,240)	\$ 5,892	\$ 5,493	\$ 5,093	\$ 4,694	\$ 4,295	\$ 3,896	\$ 3,496
\$ 7.00	\$ 13,822	\$ 13,423	\$ 13,024	\$ 12,625	\$ 12,225	\$ 11,826	\$ 11,427	\$ 11,028	\$ 10,629	\$ 10,229	\$ 9,830	\$ 9,431	\$ (24,925)	\$ 8,632	\$ 8,233	\$ 7,834	\$ 7,435	\$ 7,035	\$ 6,636	\$ 6,237
\$ 7.50	\$ 16,563	\$ 16,164	\$ 15,764	\$ 15,365	\$ 14,966	\$ 14,567	\$ 14,167	\$ 13,768	\$ 13,369	\$ 12,970	\$ 12,571	\$ 12,171	\$ (24,610)	\$ 11,373	\$ 10,974	\$ 10,574	\$ 10,175	\$ 9,776	\$ 9,377	\$ 8,977
\$ 8.00	\$ 19,303	\$ 18,904	\$ 18,505	\$ 18,106	\$ 17,706	\$ 17,307	\$ 16,908	\$ 16,509	\$ 16,110	\$ 15,710	\$ 15,311	\$ 14,912	\$ (24,295)	\$ 14,113	\$ 13,714	\$ 13,315	\$ 12,916	\$ 12,516	\$ 12,117	\$ 11,718
\$ 8.50	\$ 22,044	\$ 21,645	\$ 21,245	\$ 20,846	\$ 20,447	\$ 20,048	\$ 19,648	\$ 19,249	\$ 18,850	\$ 18,451	\$ 18,052	\$ 17,652	\$ (23,980)	\$ 16,854	\$ 16,455	\$ 16,055	\$ 15,656	\$ 15,257	\$ 14,858	\$ 14,458
\$ 9.00	\$ 24,784	\$ 24,385	\$ 23,986	\$ 23,587	\$ 23,187	\$ 22,788	\$ 22,389	\$ 21,990	\$ 21,591	\$ 21,191	\$ 20,792	\$ 20,393	\$ (23,665)	\$ 19,594	\$ 19,195	\$ 18,796	\$ 18,397	\$ 17,997	\$ 17,598	\$ 17,199
\$ 9.50	\$ 27,525	\$ 27,126	\$ 26,726	\$ 26,327	\$ 25,928	\$ 25,529	\$ 25,129	\$ 24,730	\$ 24,331	\$ 23,932	\$ 23,533	\$ 23,133	\$ (23,350)	\$ 22,335	\$ 21,936	\$ 21,536	\$ 21,137	\$ 20,738	\$ 20,339	\$ 19,939
\$ 10.00	\$ 30,265	\$ 29,866	\$ 29,467	\$ 29,068	\$ 28,668	\$ 28,269	\$ 27,870	\$ 27,471	\$ 27,072	\$ 26,672	\$ 26,273	\$ 25,874	\$ (23,035)	\$ 25,075	\$ 24,676	\$ 24,277	\$ 23,878	\$ 23,478	\$ 23,079	\$ 22,680
\$ 10.50	\$ 33,006	\$ 32,607	\$ 32,207	\$ 31,808	\$ 31,409	\$ 31,010	\$ 30,610	\$ 30,211	\$ 29,812	\$ 29,413	\$ 29,014	\$ 28,614	\$ (22,720)	\$ 27,816	\$ 27,417	\$ 27,017	\$ 26,618	\$ 26,219	\$ 25,820	\$ 25,420
\$ 11.00	\$ 35,746	\$ 35,347	\$ 34,948	\$ 34,549	\$ 34,149	\$ 33,750	\$ 33,351	\$ 32,952	\$ 32,553	\$ 32,153	\$ 31,754	\$ 31,355	\$ (22,405)	\$ 30,556	\$ 30,157	\$ 29,758	\$ 29,359	\$ 28,959	\$ 28,560	\$ 28,161
\$ 11.50	\$ 38,487	\$ 38,088	\$ 37,688	\$ 37,289	\$ 36,890	\$ 36,491	\$ 36,091	\$ 35,692	\$ 35,293	\$ 34,894	\$ 34,495	\$ 34,095	\$ (22,090)	\$ 33,297	\$ 32,898	\$ 32,498	\$ 32,099	\$ 31,700	\$ 31,301	\$ 30,901
\$ 12.00	\$ 41,227	\$ 40,828	\$ 40,429	\$ 40,030	\$ 39,630	\$ 39,231	\$ 38,832	\$ 38,433	\$ 38,034	\$ 37,634	\$ 37,235	\$ 36,836	\$ (21,775)	\$ 36,037	\$ 35,638	\$ 35,239	\$ 34,840	\$ 34,440	\$ 34,041	\$ 33,642
\$ 12.50	\$ 43,968	\$ 43,569	\$ 43,169	\$ 42,770	\$ 42,371	\$ 41,972	\$ 41,572	\$ 41,173	\$ 40,774	\$ 40,375	\$ 39,976	\$ 39,576	\$ (21,460)	\$ 38,778	\$ 38,379	\$ 37,979	\$ 37,580	\$ 37,181	\$ 36,782	\$ 36,382
\$ 13.00	\$ 46,708	\$ 46,309	\$ 45,910	\$ 45,511	\$ 45,111	\$ 44,712	\$ 44,313	\$ 43,914	\$ 43,515	\$ 43,115	\$ 42,716	\$ 42,317	\$ (21,145)	\$ 41,518	\$ 41,119	\$ 40,720	\$ 40,321	\$ 39,922	\$ 39,522	\$ 39,123

Figure 25. Potential Annual Savings per Cycle Matrix for Wood Pallet Pool of 700 Pallets



## Appendix D. Examples of Recurring Cost and Potential Savings Utilizing a Pallet Pool with RFID from DDJC to DDDC

The following matrices provide examples for the recurring cost and potential savings for utilizing a pallet pool with RFID from DDJC to DDDC.



Pool Recurring Cost Matrix for 5.6 Cycles				
	Pallet Cost	Continuous Purchase (CP)	Wood Pallet Pool (WP)	Plastic Pallet Pool (PP)
Cycle	\$3.50	\$2,058.00	\$2,862.72	
Demand	\$4.00	\$2,352.00	\$2,833.54	
Pool Size	\$4.50	\$2,646.00	\$2,875.23	
Avg Wood Pallet Trips	\$5.00	\$2,940.00	\$2,916.92	
Avg Plastic Pallet Trips	\$5.50	\$3,234.00	\$2,958.62	
Transportation Cost	\$6.00	\$3,528.00	\$3,000.31	
Storage Cost	\$6.50	\$3,822.00	\$3,042.00	
Lost %	\$7.00	\$4,116.00	\$3,083.69	
Replace RFID Tags Wood	\$7.50	\$4,410.00	\$3,125.39	
Replace RFID Tags Plastic	\$8.00	\$4,704.00	\$3,167.08	
Price of RW RFID tags	\$8.50	\$4,998.00	\$3,208.77	
	\$9.00	\$5,292.00	\$3,250.46	
	\$9.50	\$5,586.00	\$3,292.16	
	\$10.00	\$5,880.00	\$3,333.85	
	\$10.50	\$6,174.00	\$3,375.54	
	\$11.00	\$6,468.00	\$3,417.23	
	\$11.50	\$6,762.00	\$3,458.93	
	\$12.00	\$7,056.00	\$3,500.62	
	\$12.50	\$7,350.00	\$3,542.31	
	\$13.00	\$7,644.00	\$3,584.00	
	\$20.00			\$2,807.01
	\$25.00			\$2,828.00
	\$30.00			\$2,893.60
	\$35.00			\$2,959.20
	\$40.00			\$3,024.80
	\$45.00			\$3,090.40
	\$50.00			\$3,156.00
	\$55.00			\$3,221.60
	\$60.00			\$3,287.20
	\$65.00			\$3,352.80
	\$70.00			\$3,418.40
	\$75.00			\$3,484.00
	\$80.00			\$3,549.60

Pool Recurring Cost Matrix for 6 Cycles				
	Pallet Cost	Continuous Purchase	Wood Pallet Pool	Plastic Pallet Pool
Cycle	\$3.50	\$2,205.00	\$2,887.05	
Demand	\$4.00	\$2,520.00	\$2,855.91	
Pool Size	\$4.50	\$2,835.00	\$2,900.40	
Avg Wood Pallet Trips	\$5.00	\$3,150.00	\$2,944.89	
Avg Plastic Pallet Trips	\$5.50	\$3,465.00	\$2,989.38	
Transportation Cost	\$6.00	\$3,780.00	\$3,033.87	
Storage Cost	\$6.50	\$4,095.00	\$3,078.36	
Lost %	\$7.00	\$4,410.00	\$3,122.84	
Replace RFID Tags Wood	\$7.50	\$4,725.00	\$3,167.33	
Replace RFID Tags Plastic	\$8.00	\$5,040.00	\$3,211.82	
Price of RW RFID tags	\$8.50	\$5,355.00	\$3,256.31	
	\$9.00	\$5,670.00	\$3,300.80	
	\$9.50	\$5,985.00	\$3,345.29	
	\$10.00	\$6,300.00	\$3,389.78	
	\$10.50	\$6,615.00	\$3,434.27	
	\$11.00	\$6,930.00	\$3,478.76	
	\$11.50	\$7,245.00	\$3,523.24	
	\$12.00	\$7,560.00	\$3,567.73	
	\$12.50	\$7,875.00	\$3,612.22	
	\$13.00	\$8,190.00	\$3,656.71	
	\$20.00			\$2,827.60
	\$25.00			\$2,850.00
	\$30.00			\$2,920.00
	\$35.00			\$2,990.00
	\$40.00			\$3,060.00
	\$45.00			\$3,130.00
	\$50.00			\$3,200.00
	\$55.00			\$3,270.00
	\$60.00			\$3,340.00
	\$65.00			\$3,410.00
	\$70.00			\$3,480.00
	\$75.00			\$3,550.00
	\$80.00			\$3,620.00

Figure 26. Recurring Cost per Cycle for Wood and Plastic Pallet Pool with RFID



Potential Savings for Plastic Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

Cost of Plastic Pallet

	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 133	\$ 112	\$ 46	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 427	\$ 406	\$ 340	\$ 275	\$ 209	\$ 144	\$ 78	\$ 12	-	-	-	-	-
\$ 6.00	\$ 721	\$ 700	\$ 634	\$ 569	\$ 503	\$ 438	\$ 372	\$ 306	\$ 241	\$ 175	\$ 110	\$ 44	-
\$ 6.50	\$ 1,015	\$ 994	\$ 928	\$ 863	\$ 797	\$ 732	\$ 666	\$ 600	\$ 535	\$ 469	\$ 404	\$ 338	\$ 272
\$ 7.00	\$ 1,309	\$ 1,288	\$ 1,222	\$ 1,157	\$ 1,091	\$ 1,026	\$ 960	\$ 894	\$ 829	\$ 763	\$ 698	\$ 632	\$ 566
\$ 7.50	\$ 1,603	\$ 1,582	\$ 1,516	\$ 1,451	\$ 1,385	\$ 1,320	\$ 1,254	\$ 1,188	\$ 1,123	\$ 1,057	\$ 992	\$ 926	\$ 860
\$ 8.00	\$ 1,897	\$ 1,876	\$ 1,810	\$ 1,745	\$ 1,679	\$ 1,614	\$ 1,548	\$ 1,482	\$ 1,417	\$ 1,351	\$ 1,286	\$ 1,220	\$ 1,154
\$ 8.50	\$ 2,191	\$ 2,170	\$ 2,104	\$ 2,039	\$ 1,973	\$ 1,908	\$ 1,842	\$ 1,776	\$ 1,711	\$ 1,645	\$ 1,580	\$ 1,514	\$ 1,448
\$ 9.00	\$ 2,485	\$ 2,464	\$ 2,398	\$ 2,333	\$ 2,267	\$ 2,202	\$ 2,136	\$ 2,070	\$ 2,005	\$ 1,939	\$ 1,874	\$ 1,808	\$ 1,742
\$ 9.50	\$ 2,779	\$ 2,758	\$ 2,692	\$ 2,627	\$ 2,561	\$ 2,496	\$ 2,430	\$ 2,364	\$ 2,299	\$ 2,233	\$ 2,168	\$ 2,102	\$ 2,036
\$ 10.00	\$ 3,073	\$ 3,052	\$ 2,986	\$ 2,921	\$ 2,855	\$ 2,790	\$ 2,724	\$ 2,658	\$ 2,593	\$ 2,527	\$ 2,462	\$ 2,396	\$ 2,330
\$ 10.50	\$ 3,367	\$ 3,346	\$ 3,280	\$ 3,215	\$ 3,149	\$ 3,084	\$ 3,018	\$ 2,952	\$ 2,887	\$ 2,821	\$ 2,756	\$ 2,690	\$ 2,624
\$ 11.00	\$ 3,661	\$ 3,640	\$ 3,574	\$ 3,509	\$ 3,443	\$ 3,378	\$ 3,312	\$ 3,246	\$ 3,181	\$ 3,115	\$ 3,050	\$ 2,984	\$ 2,918
\$ 11.50	\$ 3,955	\$ 3,934	\$ 3,868	\$ 3,803	\$ 3,737	\$ 3,672	\$ 3,606	\$ 3,540	\$ 3,475	\$ 3,409	\$ 3,344	\$ 3,278	\$ 3,212
\$ 12.00	\$ 4,249	\$ 4,228	\$ 4,162	\$ 4,097	\$ 4,031	\$ 3,966	\$ 3,900	\$ 3,834	\$ 3,769	\$ 3,703	\$ 3,638	\$ 3,572	\$ 3,506
\$ 12.50	\$ 4,543	\$ 4,522	\$ 4,456	\$ 4,391	\$ 4,325	\$ 4,260	\$ 4,194	\$ 4,128	\$ 4,063	\$ 3,997	\$ 3,932	\$ 3,866	\$ 3,800
\$ 13.00	\$ 4,837	\$ 4,816	\$ 4,750	\$ 4,685	\$ 4,619	\$ 4,554	\$ 4,488	\$ 4,422	\$ 4,357	\$ 4,291	\$ 4,226	\$ 4,160	\$ 4,094

Cost of Wood Pallet

Figure 27. Potential Savings per Cycle Matrix for Plastic Pallet Pool



Potential Savings for Wood Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 77	\$ 106	\$ 65	\$ 23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 371	\$ 400	\$ 359	\$ 317	\$ 275	\$ 234	\$ 192	\$ 150	\$ 109	\$ 67	\$ 25	-	-	-	-	-	-	-	-	-
\$ 6.00	\$ 665	\$ 694	\$ 653	\$ 611	\$ 569	\$ 528	\$ 486	\$ 444	\$ 403	\$ 361	\$ 319	\$ 278	\$ 236	\$ 194	\$ 152	\$ 111	\$ 69	\$ 27	-	-
\$ 6.50	\$ 959	\$ 988	\$ 947	\$ 905	\$ 863	\$ 822	\$ 780	\$ 738	\$ 697	\$ 655	\$ 613	\$ 572	\$ 530	\$ 488	\$ 446	\$ 405	\$ 363	\$ 321	\$ 280	\$ 238
\$ 7.00	\$ 1,253	\$ 1,282	\$ 1,241	\$ 1,199	\$ 1,157	\$ 1,116	\$ 1,074	\$ 1,032	\$ 991	\$ 949	\$ 907	\$ 866	\$ 824	\$ 782	\$ 740	\$ 699	\$ 657	\$ 615	\$ 574	\$ 532
\$ 7.50	\$ 1,547	\$ 1,576	\$ 1,535	\$ 1,493	\$ 1,451	\$ 1,410	\$ 1,368	\$ 1,326	\$ 1,285	\$ 1,243	\$ 1,201	\$ 1,160	\$ 1,118	\$ 1,076	\$ 1,034	\$ 993	\$ 951	\$ 909	\$ 868	\$ 826
\$ 8.00	\$ 1,841	\$ 1,870	\$ 1,829	\$ 1,787	\$ 1,745	\$ 1,704	\$ 1,662	\$ 1,620	\$ 1,579	\$ 1,537	\$ 1,495	\$ 1,454	\$ 1,412	\$ 1,370	\$ 1,328	\$ 1,287	\$ 1,245	\$ 1,203	\$ 1,162	\$ 1,120
\$ 8.50	\$ 2,135	\$ 2,164	\$ 2,123	\$ 2,081	\$ 2,039	\$ 1,998	\$ 1,956	\$ 1,914	\$ 1,873	\$ 1,831	\$ 1,789	\$ 1,748	\$ 1,706	\$ 1,664	\$ 1,622	\$ 1,581	\$ 1,539	\$ 1,497	\$ 1,456	\$ 1,414
\$ 9.00	\$ 2,429	\$ 2,458	\$ 2,417	\$ 2,375	\$ 2,333	\$ 2,292	\$ 2,250	\$ 2,208	\$ 2,167	\$ 2,125	\$ 2,083	\$ 2,042	\$ 2,000	\$ 1,958	\$ 1,916	\$ 1,875	\$ 1,833	\$ 1,791	\$ 1,750	\$ 1,708
\$ 9.50	\$ 2,723	\$ 2,752	\$ 2,711	\$ 2,669	\$ 2,627	\$ 2,586	\$ 2,544	\$ 2,502	\$ 2,461	\$ 2,419	\$ 2,377	\$ 2,336	\$ 2,294	\$ 2,252	\$ 2,210	\$ 2,169	\$ 2,127	\$ 2,085	\$ 2,044	\$ 2,002
\$ 10.00	\$ 3,017	\$ 3,046	\$ 3,005	\$ 2,963	\$ 2,921	\$ 2,880	\$ 2,838	\$ 2,796	\$ 2,755	\$ 2,713	\$ 2,671	\$ 2,630	\$ 2,588	\$ 2,546	\$ 2,504	\$ 2,463	\$ 2,421	\$ 2,379	\$ 2,338	\$ 2,296
\$ 10.50	\$ 3,311	\$ 3,340	\$ 3,299	\$ 3,257	\$ 3,215	\$ 3,174	\$ 3,132	\$ 3,090	\$ 3,049	\$ 3,007	\$ 2,965	\$ 2,924	\$ 2,882	\$ 2,840	\$ 2,798	\$ 2,757	\$ 2,715	\$ 2,673	\$ 2,632	\$ 2,590
\$ 11.00	\$ 3,605	\$ 3,634	\$ 3,593	\$ 3,551	\$ 3,509	\$ 3,468	\$ 3,426	\$ 3,384	\$ 3,343	\$ 3,301	\$ 3,259	\$ 3,218	\$ 3,176	\$ 3,134	\$ 3,092	\$ 3,051	\$ 3,009	\$ 2,967	\$ 2,926	\$ 2,884
\$ 11.50	\$ 3,899	\$ 3,928	\$ 3,887	\$ 3,845	\$ 3,803	\$ 3,762	\$ 3,720	\$ 3,678	\$ 3,637	\$ 3,595	\$ 3,553	\$ 3,512	\$ 3,470	\$ 3,428	\$ 3,386	\$ 3,345	\$ 3,303	\$ 3,261	\$ 3,220	\$ 3,178
\$ 12.00	\$ 4,193	\$ 4,222	\$ 4,181	\$ 4,139	\$ 4,097	\$ 4,056	\$ 4,014	\$ 3,972	\$ 3,931	\$ 3,889	\$ 3,847	\$ 3,806	\$ 3,764	\$ 3,722	\$ 3,680	\$ 3,639	\$ 3,597	\$ 3,555	\$ 3,514	\$ 3,472
\$ 12.50	\$ 4,487	\$ 4,516	\$ 4,475	\$ 4,433	\$ 4,391	\$ 4,350	\$ 4,308	\$ 4,266	\$ 4,225	\$ 4,183	\$ 4,141	\$ 4,100	\$ 4,058	\$ 4,016	\$ 3,974	\$ 3,933	\$ 3,891	\$ 3,849	\$ 3,808	\$ 3,766
\$ 13.00	\$ 4,781	\$ 4,810	\$ 4,769	\$ 4,727	\$ 4,685	\$ 4,644	\$ 4,602	\$ 4,560	\$ 4,519	\$ 4,477	\$ 4,435	\$ 4,394	\$ 4,352	\$ 4,310	\$ 4,268	\$ 4,227	\$ 4,185	\$ 4,143	\$ 4,102	\$ 4,060

Figure 28. Potential Savings per Cycle Matrix for Wood Pallet Pool of 656 Pallets with RFID





Potential Annual Savings for Plastic Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

	Cost of Plastic Pallet												
	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 1,237	\$ 1,042	\$ 432	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 3,971	\$ 3,776	\$ 3,166	\$ 2,556	\$ 1,946	\$ 1,335	\$ 725	\$ 115	-	-	-	-	-
\$ 6.00	\$ 6,705	\$ 6,510	\$ 5,900	\$ 5,290	\$ 4,680	\$ 4,070	\$ 3,460	\$ 2,850	\$ 2,239	\$ 1,629	\$ 1,019	\$ 409	-
\$ 6.50	\$ 9,439	\$ 9,244	\$ 8,634	\$ 8,024	\$ 7,414	\$ 6,804	\$ 6,194	\$ 5,584	\$ 4,974	\$ 4,364	\$ 3,753	\$ 3,143	\$ 2,533
\$ 7.00	\$ 12,174	\$ 11,978	\$ 11,368	\$ 10,758	\$ 10,148	\$ 9,538	\$ 8,928	\$ 8,318	\$ 7,708	\$ 7,098	\$ 6,488	\$ 5,878	\$ 5,268
\$ 7.50	\$ 14,908	\$ 14,713	\$ 14,103	\$ 13,492	\$ 12,882	\$ 12,272	\$ 11,662	\$ 11,052	\$ 10,442	\$ 9,832	\$ 9,222	\$ 8,612	\$ 8,002
\$ 8.00	\$ 17,642	\$ 17,447	\$ 16,837	\$ 16,227	\$ 15,617	\$ 15,006	\$ 14,396	\$ 13,786	\$ 13,176	\$ 12,566	\$ 11,956	\$ 11,346	\$ 10,736
\$ 8.50	\$ 20,376	\$ 20,181	\$ 19,571	\$ 18,961	\$ 18,351	\$ 17,741	\$ 17,131	\$ 16,521	\$ 15,910	\$ 15,300	\$ 14,690	\$ 14,080	\$ 13,470
\$ 9.00	\$ 23,110	\$ 22,915	\$ 22,305	\$ 21,695	\$ 21,085	\$ 20,475	\$ 19,865	\$ 19,255	\$ 18,645	\$ 18,035	\$ 17,424	\$ 16,814	\$ 16,204
\$ 9.50	\$ 25,845	\$ 25,649	\$ 25,039	\$ 24,429	\$ 23,819	\$ 23,209	\$ 22,599	\$ 21,989	\$ 21,379	\$ 20,769	\$ 20,159	\$ 19,549	\$ 18,939
\$ 10.00	\$ 28,579	\$ 28,384	\$ 27,774	\$ 27,163	\$ 26,553	\$ 25,943	\$ 25,333	\$ 24,723	\$ 24,113	\$ 23,503	\$ 22,893	\$ 22,283	\$ 21,673
\$ 10.50	\$ 31,313	\$ 31,118	\$ 30,508	\$ 29,898	\$ 29,288	\$ 28,677	\$ 28,067	\$ 27,457	\$ 26,847	\$ 26,237	\$ 25,627	\$ 25,017	\$ 24,407
\$ 11.00	\$ 34,047	\$ 33,852	\$ 33,242	\$ 32,632	\$ 32,022	\$ 31,412	\$ 30,802	\$ 30,192	\$ 29,581	\$ 28,971	\$ 28,361	\$ 27,751	\$ 27,141
\$ 11.50	\$ 36,781	\$ 36,586	\$ 35,976	\$ 35,366	\$ 34,756	\$ 34,146	\$ 33,536	\$ 32,926	\$ 32,316	\$ 31,706	\$ 31,095	\$ 30,485	\$ 29,875
\$ 12.00	\$ 39,516	\$ 39,320	\$ 38,710	\$ 38,100	\$ 37,490	\$ 36,880	\$ 36,270	\$ 35,660	\$ 35,050	\$ 34,440	\$ 33,830	\$ 33,220	\$ 32,610
\$ 12.50	\$ 42,250	\$ 42,055	\$ 41,445	\$ 40,834	\$ 40,224	\$ 39,614	\$ 39,004	\$ 38,394	\$ 37,784	\$ 37,174	\$ 36,564	\$ 35,954	\$ 35,344
\$ 13.00	\$ 44,984	\$ 44,789	\$ 44,179	\$ 43,569	\$ 42,959	\$ 42,348	\$ 41,738	\$ 41,128	\$ 40,518	\$ 39,908	\$ 39,298	\$ 38,688	\$ 38,078

Cost of Wood Pallet

Figure 29. Potential Annual Savings per Cycle Matrix for



Potential Annual Savings for Wood Pallet Pool with a 5.6 Week Cycle and Pool Size of 656

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 719	\$ 990	\$ 602	\$ 215	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 3,453	\$ 3,724	\$ 3,337	\$ 2,949	\$ 2,561	\$ 2,173	\$ 1,786	\$ 1,398	\$ 1,010	\$ 622	\$ 235	-	-	-	-	-	-	-	-	-
\$ 6.00	\$ 6,187	\$ 6,458	\$ 6,071	\$ 5,683	\$ 5,295	\$ 4,908	\$ 4,520	\$ 4,132	\$ 3,744	\$ 3,357	\$ 2,969	\$ 2,581	\$ 2,193	\$ 1,806	\$ 1,418	\$ 1,030	\$ 642	\$ 255	-	-
\$ 6.50	\$ 8,921	\$ 9,193	\$ 8,805	\$ 8,417	\$ 8,029	\$ 7,642	\$ 7,254	\$ 6,866	\$ 6,479	\$ 6,091	\$ 5,703	\$ 5,315	\$ 4,928	\$ 4,540	\$ 4,152	\$ 3,764	\$ 3,377	\$ 2,989	\$ 2,601	\$ 2,213
\$ 7.00	\$ 11,655	\$ 11,927	\$ 11,539	\$ 11,151	\$ 10,764	\$ 10,376	\$ 9,988	\$ 9,600	\$ 9,213	\$ 8,825	\$ 8,437	\$ 8,049	\$ 7,662	\$ 7,274	\$ 6,886	\$ 6,499	\$ 6,111	\$ 5,723	\$ 5,335	\$ 4,948
\$ 7.50	\$ 14,390	\$ 14,661	\$ 14,273	\$ 13,886	\$ 13,498	\$ 13,110	\$ 12,722	\$ 12,335	\$ 11,947	\$ 11,559	\$ 11,171	\$ 10,784	\$ 10,396	\$ 10,008	\$ 9,620	\$ 9,233	\$ 8,845	\$ 8,457	\$ 8,070	\$ 7,682
\$ 8.00	\$ 17,124	\$ 17,395	\$ 17,008	\$ 16,620	\$ 16,232	\$ 15,844	\$ 15,457	\$ 15,069	\$ 14,681	\$ 14,293	\$ 13,906	\$ 13,518	\$ 13,130	\$ 12,742	\$ 12,355	\$ 11,967	\$ 11,579	\$ 11,191	\$ 10,804	\$ 10,416
\$ 8.50	\$ 19,858	\$ 20,129	\$ 19,742	\$ 19,354	\$ 18,966	\$ 18,579	\$ 18,191	\$ 17,803	\$ 17,415	\$ 17,028	\$ 16,640	\$ 16,252	\$ 15,864	\$ 15,477	\$ 15,089	\$ 14,701	\$ 14,313	\$ 13,926	\$ 13,538	\$ 13,150
\$ 9.00	\$ 22,592	\$ 22,864	\$ 22,476	\$ 22,088	\$ 21,700	\$ 21,313	\$ 20,925	\$ 20,537	\$ 20,150	\$ 19,762	\$ 19,374	\$ 18,986	\$ 18,599	\$ 18,211	\$ 17,823	\$ 17,435	\$ 17,048	\$ 16,660	\$ 16,272	\$ 15,884
\$ 9.50	\$ 25,326	\$ 25,598	\$ 25,210	\$ 24,822	\$ 24,435	\$ 24,047	\$ 23,659	\$ 23,271	\$ 22,884	\$ 22,496	\$ 22,108	\$ 21,720	\$ 21,333	\$ 20,945	\$ 20,557	\$ 20,170	\$ 19,782	\$ 19,394	\$ 19,006	\$ 18,619
\$ 10.00	\$ 28,061	\$ 28,332	\$ 27,944	\$ 27,557	\$ 27,169	\$ 26,781	\$ 26,393	\$ 26,006	\$ 25,618	\$ 25,230	\$ 24,842	\$ 24,455	\$ 24,067	\$ 23,679	\$ 23,291	\$ 22,904	\$ 22,516	\$ 22,128	\$ 21,741	\$ 21,353
\$ 10.50	\$ 30,795	\$ 31,066	\$ 30,679	\$ 30,291	\$ 29,903	\$ 29,515	\$ 29,128	\$ 28,740	\$ 28,352	\$ 27,964	\$ 27,577	\$ 27,189	\$ 26,801	\$ 26,413	\$ 26,026	\$ 25,638	\$ 25,250	\$ 24,862	\$ 24,475	\$ 24,087
\$ 11.00	\$ 33,529	\$ 33,800	\$ 33,413	\$ 33,025	\$ 32,637	\$ 32,250	\$ 31,862	\$ 31,474	\$ 31,086	\$ 30,699	\$ 30,311	\$ 29,923	\$ 29,535	\$ 29,148	\$ 28,760	\$ 28,372	\$ 27,984	\$ 27,597	\$ 27,209	\$ 26,821
\$ 11.50	\$ 36,263	\$ 36,535	\$ 36,147	\$ 35,759	\$ 35,371	\$ 34,984	\$ 34,596	\$ 34,208	\$ 33,821	\$ 33,433	\$ 33,045	\$ 32,657	\$ 32,270	\$ 31,882	\$ 31,494	\$ 31,106	\$ 30,719	\$ 30,331	\$ 29,943	\$ 29,555
\$ 12.00	\$ 38,997	\$ 39,269	\$ 38,881	\$ 38,493	\$ 38,106	\$ 37,718	\$ 37,330	\$ 36,942	\$ 36,555	\$ 36,167	\$ 35,779	\$ 35,391	\$ 35,004	\$ 34,616	\$ 34,228	\$ 33,841	\$ 33,453	\$ 33,065	\$ 32,677	\$ 32,290
\$ 12.50	\$ 41,732	\$ 42,003	\$ 41,615	\$ 41,228	\$ 40,840	\$ 40,452	\$ 40,064	\$ 39,677	\$ 39,289	\$ 38,901	\$ 38,513	\$ 38,126	\$ 37,738	\$ 37,350	\$ 36,962	\$ 36,575	\$ 36,187	\$ 35,799	\$ 35,412	\$ 35,024
\$ 13.00	\$ 44,466	\$ 44,737	\$ 44,350	\$ 43,962	\$ 43,574	\$ 43,186	\$ 42,799	\$ 42,411	\$ 42,023	\$ 41,635	\$ 41,248	\$ 40,860	\$ 40,472	\$ 40,084	\$ 39,697	\$ 39,309	\$ 38,921	\$ 38,533	\$ 38,146	\$ 37,758

Figure 30. Potential Annual Savings per Cycle Matrix for Wood Pallet Pool of 656 Pallets with RFID





**Potential Savings for Plastic Pallet Pool with a 6 Week Cycle and Pool Size of 700**  
**Cost of Plastic Pallet**

	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	7	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 322	\$ 300	\$ 230	\$ 160	\$ 90	\$ 20	-	-	-	-	-	-	-
\$ 5.50	\$ 637	\$ 615	\$ 545	\$ 475	\$ 405	\$ 335	\$ 265	\$ 195	\$ 125	\$ 55	-	-	-
\$ 6.00	\$ 952	\$ 930	\$ 860	\$ 790	\$ 720	\$ 650	\$ 580	\$ 510	\$ 440	\$ 370	\$ 300	\$ 230	\$ 160
\$ 6.50	\$ 1,267	\$ 1,245	\$ 1,175	\$ 1,105	\$ 1,035	\$ 965	\$ 895	\$ 825	\$ 755	\$ 685	\$ 615	\$ 545	\$ 475
\$ 7.00	\$ 1,582	\$ 1,560	\$ 1,490	\$ 1,420	\$ 1,350	\$ 1,280	\$ 1,210	\$ 1,140	\$ 1,070	\$ 1,000	\$ 930	\$ 860	\$ 790
\$ 7.50	\$ 1,897	\$ 1,875	\$ 1,805	\$ 1,735	\$ 1,665	\$ 1,595	\$ 1,525	\$ 1,455	\$ 1,385	\$ 1,315	\$ 1,245	\$ 1,175	\$ 1,105
\$ 8.00	\$ 2,212	\$ 2,190	\$ 2,120	\$ 2,050	\$ 1,980	\$ 1,910	\$ 1,840	\$ 1,770	\$ 1,700	\$ 1,630	\$ 1,560	\$ 1,490	\$ 1,420
\$ 8.50	\$ 2,527	\$ 2,505	\$ 2,435	\$ 2,365	\$ 2,295	\$ 2,225	\$ 2,155	\$ 2,085	\$ 2,015	\$ 1,945	\$ 1,875	\$ 1,805	\$ 1,735
\$ 9.00	\$ 2,842	\$ 2,820	\$ 2,750	\$ 2,680	\$ 2,610	\$ 2,540	\$ 2,470	\$ 2,400	\$ 2,330	\$ 2,260	\$ 2,190	\$ 2,120	\$ 2,050
\$ 9.50	\$ 3,157	\$ 3,135	\$ 3,065	\$ 2,995	\$ 2,925	\$ 2,855	\$ 2,785	\$ 2,715	\$ 2,645	\$ 2,575	\$ 2,505	\$ 2,435	\$ 2,365
\$ 10.00	\$ 3,472	\$ 3,450	\$ 3,380	\$ 3,310	\$ 3,240	\$ 3,170	\$ 3,100	\$ 3,030	\$ 2,960	\$ 2,890	\$ 2,820	\$ 2,750	\$ 2,680
\$ 10.50	\$ 3,787	\$ 3,765	\$ 3,695	\$ 3,625	\$ 3,555	\$ 3,485	\$ 3,415	\$ 3,345	\$ 3,275	\$ 3,205	\$ 3,135	\$ 3,065	\$ 2,995
\$ 11.00	\$ 4,102	\$ 4,080	\$ 4,010	\$ 3,940	\$ 3,870	\$ 3,800	\$ 3,730	\$ 3,660	\$ 3,590	\$ 3,520	\$ 3,450	\$ 3,380	\$ 3,310
\$ 11.50	\$ 4,417	\$ 4,395	\$ 4,325	\$ 4,255	\$ 4,185	\$ 4,115	\$ 4,045	\$ 3,975	\$ 3,905	\$ 3,835	\$ 3,765	\$ 3,695	\$ 3,625
\$ 12.00	\$ 4,732	\$ 4,710	\$ 4,640	\$ 4,570	\$ 4,500	\$ 4,430	\$ 4,360	\$ 4,290	\$ 4,220	\$ 4,150	\$ 4,080	\$ 4,010	\$ 3,940
\$ 12.50	\$ 5,047	\$ 5,025	\$ 4,955	\$ 4,885	\$ 4,815	\$ 4,745	\$ 4,675	\$ 4,605	\$ 4,535	\$ 4,465	\$ 4,395	\$ 4,325	\$ 4,255
\$ 13.00	\$ 5,362	\$ 5,340	\$ 5,270	\$ 5,200	\$ 5,130	\$ 5,060	\$ 4,990	\$ 4,920	\$ 4,850	\$ 4,780	\$ 4,710	\$ 4,640	\$ 4,570

Cost of Wood Pallet

**Figure 31. Potential Savings per Cycle Matrix for Plastic Pallet Pool of 700 Pallets with RFID**



Potential Savings for Wood Pallet Pool with a 6 Week Cycle and Pool Size of 700

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 263	\$ 294	\$ 250	\$ 205	\$ 161	\$ 116	\$ 72	\$ 27	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 578	\$ 609	\$ 565	\$ 520	\$ 476	\$ 431	\$ 387	\$ 342	\$ 298	\$ 253	\$ 209	\$ 164	\$ 120	\$ 75	\$ 31	-	-	-	-	-
\$ 6.00	\$ 893	\$ 924	\$ 880	\$ 835	\$ 791	\$ 746	\$ 702	\$ 657	\$ 613	\$ 568	\$ 524	\$ 479	\$ 435	\$ 390	\$ 346	\$ 301	\$ 257	\$ 212	\$ 168	\$ 123
\$ 6.50	\$ 1,208	\$ 1,239	\$ 1,195	\$ 1,150	\$ 1,106	\$ 1,061	\$ 1,017	\$ 972	\$ 928	\$ 883	\$ 839	\$ 794	\$ 750	\$ 705	\$ 661	\$ 616	\$ 572	\$ 527	\$ 483	\$ 438
\$ 7.00	\$ 1,523	\$ 1,554	\$ 1,510	\$ 1,465	\$ 1,421	\$ 1,376	\$ 1,332	\$ 1,287	\$ 1,243	\$ 1,198	\$ 1,154	\$ 1,109	\$ 1,065	\$ 1,020	\$ 976	\$ 931	\$ 887	\$ 842	\$ 798	\$ 753
\$ 7.50	\$ 1,838	\$ 1,869	\$ 1,825	\$ 1,780	\$ 1,736	\$ 1,691	\$ 1,647	\$ 1,602	\$ 1,558	\$ 1,513	\$ 1,469	\$ 1,424	\$ 1,380	\$ 1,335	\$ 1,291	\$ 1,246	\$ 1,202	\$ 1,157	\$ 1,113	\$ 1,068
\$ 8.00	\$ 2,153	\$ 2,184	\$ 2,140	\$ 2,095	\$ 2,051	\$ 2,006	\$ 1,962	\$ 1,917	\$ 1,873	\$ 1,828	\$ 1,784	\$ 1,739	\$ 1,695	\$ 1,650	\$ 1,606	\$ 1,561	\$ 1,517	\$ 1,472	\$ 1,428	\$ 1,383
\$ 8.50	\$ 2,468	\$ 2,499	\$ 2,455	\$ 2,410	\$ 2,366	\$ 2,321	\$ 2,277	\$ 2,232	\$ 2,188	\$ 2,143	\$ 2,099	\$ 2,054	\$ 2,010	\$ 1,965	\$ 1,921	\$ 1,876	\$ 1,832	\$ 1,787	\$ 1,743	\$ 1,698
\$ 9.00	\$ 2,783	\$ 2,814	\$ 2,770	\$ 2,725	\$ 2,681	\$ 2,636	\$ 2,592	\$ 2,547	\$ 2,503	\$ 2,458	\$ 2,414	\$ 2,369	\$ 2,325	\$ 2,280	\$ 2,236	\$ 2,191	\$ 2,147	\$ 2,102	\$ 2,058	\$ 2,013
\$ 9.50	\$ 3,098	\$ 3,129	\$ 3,085	\$ 3,040	\$ 2,996	\$ 2,951	\$ 2,907	\$ 2,862	\$ 2,818	\$ 2,773	\$ 2,729	\$ 2,684	\$ 2,640	\$ 2,595	\$ 2,551	\$ 2,506	\$ 2,462	\$ 2,417	\$ 2,373	\$ 2,328
\$ 10.00	\$ 3,413	\$ 3,444	\$ 3,400	\$ 3,355	\$ 3,311	\$ 3,266	\$ 3,222	\$ 3,177	\$ 3,133	\$ 3,088	\$ 3,044	\$ 2,999	\$ 2,955	\$ 2,910	\$ 2,866	\$ 2,821	\$ 2,777	\$ 2,732	\$ 2,688	\$ 2,643
\$ 10.50	\$ 3,728	\$ 3,759	\$ 3,715	\$ 3,670	\$ 3,626	\$ 3,581	\$ 3,537	\$ 3,492	\$ 3,448	\$ 3,403	\$ 3,359	\$ 3,314	\$ 3,270	\$ 3,225	\$ 3,181	\$ 3,136	\$ 3,092	\$ 3,047	\$ 3,003	\$ 2,958
\$ 11.00	\$ 4,043	\$ 4,074	\$ 4,030	\$ 3,985	\$ 3,941	\$ 3,896	\$ 3,852	\$ 3,807	\$ 3,763	\$ 3,718	\$ 3,674	\$ 3,629	\$ 3,585	\$ 3,540	\$ 3,496	\$ 3,451	\$ 3,407	\$ 3,362	\$ 3,318	\$ 3,273
\$ 11.50	\$ 4,358	\$ 4,389	\$ 4,345	\$ 4,300	\$ 4,256	\$ 4,211	\$ 4,167	\$ 4,122	\$ 4,078	\$ 4,033	\$ 3,989	\$ 3,944	\$ 3,900	\$ 3,855	\$ 3,811	\$ 3,766	\$ 3,722	\$ 3,677	\$ 3,633	\$ 3,588
\$ 12.00	\$ 4,673	\$ 4,704	\$ 4,660	\$ 4,615	\$ 4,571	\$ 4,526	\$ 4,482	\$ 4,437	\$ 4,393	\$ 4,348	\$ 4,304	\$ 4,259	\$ 4,215	\$ 4,170	\$ 4,126	\$ 4,081	\$ 4,037	\$ 3,992	\$ 3,948	\$ 3,903
\$ 12.50	\$ 4,988	\$ 5,019	\$ 4,975	\$ 4,930	\$ 4,886	\$ 4,841	\$ 4,797	\$ 4,752	\$ 4,708	\$ 4,663	\$ 4,619	\$ 4,574	\$ 4,530	\$ 4,485	\$ 4,441	\$ 4,396	\$ 4,352	\$ 4,307	\$ 4,263	\$ 4,218
\$ 13.00	\$ 5,303	\$ 5,334	\$ 5,290	\$ 5,245	\$ 5,201	\$ 5,156	\$ 5,112	\$ 5,067	\$ 5,023	\$ 4,978	\$ 4,934	\$ 4,889	\$ 4,845	\$ 4,800	\$ 4,756	\$ 4,711	\$ 4,667	\$ 4,622	\$ 4,578	\$ 4,533

Cost of Wood Pallet

Figure 32. Potential Savings per Cycle Matrix for Wood Pallet Pool of 700 Pallets with RFID



Potential Annual Savings for Plastic Pallet Pool with a 6 Week Cycle and Pool Size of 700

	Cost of Plastic Pallet														
	\$ 20	\$ 25	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55	\$ 60	\$ 65	\$ 70	\$ 75	\$ 80		
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 4.50	\$ 64	-	-	-	-	-	-	-	-	-	-	-	-	-	
\$ 5.00	\$ 2,805	\$ 2,610	\$ 2,001	\$ 1,392	\$ 783	\$ 174	-	-	-	-	-	-	-	-	
\$ 5.50	\$ 5,545	\$ 5,351	\$ 4,742	\$ 4,133	\$ 3,524	\$ 2,915	\$ 2,306	\$ 1,697	\$ 1,088	\$ 479	-	-	-	-	
\$ 6.00	\$ 8,286	\$ 8,091	\$ 7,482	\$ 6,873	\$ 6,264	\$ 5,655	\$ 5,046	\$ 4,437	\$ 3,828	\$ 3,219	\$ 2,610	\$ 2,001	\$ 1,392	\$ 1,392	
\$ 6.50	\$ 11,026	\$ 10,832	\$ 10,223	\$ 9,614	\$ 9,005	\$ 8,396	\$ 7,787	\$ 7,178	\$ 6,569	\$ 5,960	\$ 5,351	\$ 4,742	\$ 4,133	\$ 4,133	
\$ 7.00	\$ 13,767	\$ 13,572	\$ 12,963	\$ 12,354	\$ 11,745	\$ 11,136	\$ 10,527	\$ 9,918	\$ 9,309	\$ 8,700	\$ 8,091	\$ 7,482	\$ 6,873	\$ 6,873	
\$ 7.50	\$ 16,507	\$ 16,313	\$ 15,704	\$ 15,095	\$ 14,486	\$ 13,877	\$ 13,268	\$ 12,659	\$ 12,050	\$ 11,441	\$ 10,832	\$ 10,223	\$ 9,614	\$ 9,614	
\$ 8.00	\$ 19,248	\$ 19,053	\$ 18,444	\$ 17,835	\$ 17,226	\$ 16,617	\$ 16,008	\$ 15,399	\$ 14,790	\$ 14,181	\$ 13,572	\$ 12,963	\$ 12,354	\$ 12,354	
\$ 8.50	\$ 21,988	\$ 21,794	\$ 21,185	\$ 20,576	\$ 19,967	\$ 19,358	\$ 18,749	\$ 18,140	\$ 17,531	\$ 16,922	\$ 16,313	\$ 15,704	\$ 15,095	\$ 15,095	
\$ 9.00	\$ 24,729	\$ 24,534	\$ 23,925	\$ 23,316	\$ 22,707	\$ 22,098	\$ 21,489	\$ 20,880	\$ 20,271	\$ 19,662	\$ 19,053	\$ 18,444	\$ 17,835	\$ 17,835	
\$ 9.50	\$ 27,469	\$ 27,275	\$ 26,666	\$ 26,057	\$ 25,448	\$ 24,839	\$ 24,230	\$ 23,621	\$ 23,012	\$ 22,403	\$ 21,794	\$ 21,185	\$ 20,576	\$ 20,576	
\$ 10.00	\$ 30,210	\$ 30,015	\$ 29,406	\$ 28,797	\$ 28,188	\$ 27,579	\$ 26,970	\$ 26,361	\$ 25,752	\$ 25,143	\$ 24,534	\$ 23,925	\$ 23,316	\$ 23,316	
\$ 10.50	\$ 32,950	\$ 32,756	\$ 32,147	\$ 31,538	\$ 30,929	\$ 30,320	\$ 29,711	\$ 29,102	\$ 28,493	\$ 27,884	\$ 27,275	\$ 26,666	\$ 26,057	\$ 26,057	
\$ 11.00	\$ 35,691	\$ 35,496	\$ 34,887	\$ 34,278	\$ 33,669	\$ 33,060	\$ 32,451	\$ 31,842	\$ 31,233	\$ 30,624	\$ 30,015	\$ 29,406	\$ 28,797	\$ 28,797	
\$ 11.50	\$ 38,431	\$ 38,237	\$ 37,628	\$ 37,019	\$ 36,410	\$ 35,801	\$ 35,192	\$ 34,583	\$ 33,974	\$ 33,365	\$ 32,756	\$ 32,147	\$ 31,538	\$ 31,538	
\$ 12.00	\$ 41,172	\$ 40,977	\$ 40,368	\$ 39,759	\$ 39,150	\$ 38,541	\$ 37,932	\$ 37,323	\$ 36,714	\$ 36,105	\$ 35,496	\$ 34,887	\$ 34,278	\$ 34,278	
\$ 12.50	\$ 43,912	\$ 43,718	\$ 43,109	\$ 42,500	\$ 41,891	\$ 41,282	\$ 40,673	\$ 40,064	\$ 39,455	\$ 38,846	\$ 38,237	\$ 37,628	\$ 37,019	\$ 37,019	
\$ 13.00	\$ 46,653	\$ 46,458	\$ 45,849	\$ 45,240	\$ 44,631	\$ 44,022	\$ 43,413	\$ 42,804	\$ 42,195	\$ 41,586	\$ 40,977	\$ 40,368	\$ 39,759	\$ 39,759	

Cost of Wood Pallet

Figure 33. Potential Annual Savings per Cycle Matrix for Plastic Pallet Pool of 700 Pallets with RFID



Potential Annual Savings for Wood Pallet Pool with a 6 Week Cycle and Pool Size of 700

Cost of Wood Pallet for Pallet Pool

	\$ 3.50	\$ 4.00	\$ 4.50	\$ 5.00	\$ 5.50	\$ 6.00	\$ 6.50	\$ 7.00	\$ 7.50	\$ 8.00	\$ 8.50	\$ 9.00	\$ 9.50	\$ 10.00	\$ 10.50	\$ 11.00	\$ 11.50	\$ 12.00	\$ 12.50	\$ 13.00
\$ 3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.00	\$ 2,288	\$ 2,559	\$ 2,172	\$ 1,784	\$ 1,397	\$ 1,010	\$ 623	\$ 236	-	-	-	-	-	-	-	-	-	-	-	-
\$ 5.50	\$ 5,028	\$ 5,299	\$ 4,912	\$ 4,525	\$ 4,138	\$ 3,751	\$ 3,364	\$ 2,977	\$ 2,590	\$ 2,203	\$ 209	\$ 1,429	\$ 1,041	\$ 654	\$ 267	-	-	-	-	-
\$ 6.00	\$ 7,769	\$ 8,040	\$ 7,653	\$ 7,265	\$ 6,878	\$ 6,491	\$ 6,104	\$ 5,717	\$ 5,330	\$ 4,943	\$ 524	\$ 4,169	\$ 3,782	\$ 3,395	\$ 3,008	\$ 2,621	\$ 2,234	\$ 1,847	\$ 1,460	\$ 1,073
\$ 6.50	\$ 10,509	\$ 10,780	\$ 10,393	\$ 10,006	\$ 9,619	\$ 9,232	\$ 8,845	\$ 8,458	\$ 8,071	\$ 7,684	\$ 839	\$ 6,910	\$ 6,522	\$ 6,135	\$ 5,748	\$ 5,361	\$ 4,974	\$ 4,587	\$ 4,200	\$ 3,813
\$ 7.00	\$ 13,250	\$ 13,521	\$ 13,134	\$ 12,746	\$ 12,359	\$ 11,972	\$ 11,585	\$ 11,198	\$ 10,811	\$ 10,424	\$ 1,154	\$ 9,650	\$ 9,263	\$ 8,876	\$ 8,489	\$ 8,102	\$ 7,715	\$ 7,328	\$ 6,941	\$ 6,554
\$ 7.50	\$ 15,990	\$ 16,261	\$ 15,874	\$ 15,487	\$ 15,100	\$ 14,713	\$ 14,326	\$ 13,939	\$ 13,552	\$ 13,165	\$ 1,489	\$ 12,391	\$ 12,003	\$ 11,616	\$ 11,229	\$ 10,842	\$ 10,455	\$ 10,068	\$ 9,681	\$ 9,294
\$ 8.00	\$ 18,731	\$ 19,002	\$ 18,615	\$ 18,227	\$ 17,840	\$ 17,453	\$ 17,066	\$ 16,679	\$ 16,292	\$ 15,905	\$ 1,784	\$ 15,131	\$ 14,744	\$ 14,357	\$ 13,970	\$ 13,583	\$ 13,196	\$ 12,809	\$ 12,422	\$ 12,035
\$ 8.50	\$ 21,471	\$ 21,742	\$ 21,355	\$ 20,968	\$ 20,581	\$ 20,194	\$ 19,807	\$ 19,420	\$ 19,033	\$ 18,646	\$ 2,089	\$ 17,872	\$ 17,484	\$ 17,097	\$ 16,710	\$ 16,323	\$ 15,936	\$ 15,549	\$ 15,162	\$ 14,775
\$ 9.00	\$ 24,212	\$ 24,483	\$ 24,096	\$ 23,708	\$ 23,321	\$ 22,934	\$ 22,547	\$ 22,160	\$ 21,773	\$ 21,386	\$ 2,414	\$ 20,612	\$ 20,225	\$ 19,838	\$ 19,451	\$ 19,064	\$ 18,677	\$ 18,290	\$ 17,903	\$ 17,516
\$ 9.50	\$ 26,952	\$ 27,223	\$ 26,836	\$ 26,449	\$ 26,062	\$ 25,675	\$ 25,288	\$ 24,901	\$ 24,514	\$ 24,127	\$ 2,729	\$ 23,353	\$ 22,965	\$ 22,578	\$ 22,191	\$ 21,804	\$ 21,417	\$ 21,030	\$ 20,643	\$ 20,256
\$ 10.00	\$ 29,693	\$ 29,964	\$ 29,577	\$ 29,189	\$ 28,802	\$ 28,415	\$ 28,028	\$ 27,641	\$ 27,254	\$ 26,867	\$ 3,044	\$ 26,093	\$ 25,706	\$ 25,319	\$ 24,932	\$ 24,545	\$ 24,158	\$ 23,771	\$ 23,384	\$ 22,997
\$ 10.50	\$ 32,433	\$ 32,704	\$ 32,317	\$ 31,930	\$ 31,543	\$ 31,156	\$ 30,769	\$ 30,382	\$ 29,995	\$ 29,608	\$ 3,359	\$ 28,834	\$ 28,446	\$ 28,059	\$ 27,672	\$ 27,285	\$ 26,898	\$ 26,511	\$ 26,124	\$ 25,737
\$ 11.00	\$ 35,174	\$ 35,445	\$ 35,058	\$ 34,670	\$ 34,283	\$ 33,896	\$ 33,509	\$ 33,122	\$ 32,735	\$ 32,348	\$ 3,674	\$ 31,574	\$ 31,187	\$ 30,800	\$ 30,413	\$ 30,026	\$ 29,639	\$ 29,252	\$ 28,865	\$ 28,478
\$ 11.50	\$ 37,914	\$ 38,185	\$ 37,798	\$ 37,411	\$ 37,024	\$ 36,637	\$ 36,250	\$ 35,863	\$ 35,476	\$ 35,089	\$ 3,989	\$ 34,315	\$ 33,927	\$ 33,540	\$ 33,153	\$ 32,766	\$ 32,379	\$ 31,992	\$ 31,605	\$ 31,218
\$ 12.00	\$ 40,655	\$ 40,926	\$ 40,539	\$ 40,151	\$ 39,764	\$ 39,377	\$ 38,990	\$ 38,603	\$ 38,216	\$ 37,829	\$ 4,304	\$ 37,055	\$ 36,668	\$ 36,281	\$ 35,894	\$ 35,507	\$ 35,120	\$ 34,733	\$ 34,346	\$ 33,959
\$ 12.50	\$ 43,395	\$ 43,666	\$ 43,279	\$ 42,892	\$ 42,505	\$ 42,118	\$ 41,731	\$ 41,344	\$ 40,957	\$ 40,570	\$ 4,619	\$ 39,796	\$ 39,408	\$ 39,021	\$ 38,634	\$ 38,247	\$ 37,860	\$ 37,473	\$ 37,086	\$ 36,699
\$ 13.00	\$ 46,136	\$ 46,407	\$ 46,020	\$ 45,632	\$ 45,245	\$ 44,858	\$ 44,471	\$ 44,084	\$ 43,697	\$ 43,310	\$ 4,934	\$ 42,536	\$ 42,149	\$ 41,762	\$ 41,375	\$ 40,988	\$ 40,601	\$ 40,214	\$ 39,827	\$ 39,440

Figure 34. Potential Annual Savings per Cycle Matrix for Wood Pallet Pool of 700 Pallets with RFID



# 2003 - 2008 Sponsored Research Topics

## **Acquisition Management**

- Software Requirements for OA
- Managing Services Supply Chain
- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Portfolio Optimization via KVA + RO
- MOSA Contracting Implications
- Strategy for Defense Acquisition Research
- Spiral Development
- BCA: Contractor vs. Organic Growth

## **Contract Management**

- USAF IT Commodity Council
- Contractors in 21st Century Combat Zone
- Joint Contingency Contracting
- Navy Contract Writing Guide
- Commodity Sourcing Strategies
- Past Performance in Source Selection
- USMC Contingency Contracting
- Transforming DoD Contract Closeout
- Model for Optimizing Contingency Contracting Planning and Execution

## **Financial Management**

- PPPs and Government Financing
- Energy Saving Contracts/DoD Mobile Assets
- Capital Budgeting for DoD
- Financing DoD Budget via PPPs
- ROI of Information Warfare Systems
- Acquisitions via leasing: MPS case
- Special Termination Liability in MDAPs



## Human Resources

- Learning Management Systems
- Tuition Assistance
- Retention
- Indefinite Reenlistment
- Individual Augmentation

## Logistics Management

- R-TOC Aegis Microwave Power Tubes
- Privatization-NOSL/NAWCI
- Army LOG MOD
- PBL (4)
- Contractors Supporting Military Operations
- RFID (4)
- Strategic Sourcing
- ASDS Product Support Analysis
- Analysis of LAV Depot Maintenance
- Diffusion/Variability on Vendor Performance Evaluation
- Optimizing CIWS Lifecycle Support (LCS)

## Program Management

- Building Collaborative Capacity
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to Aegis and SSDS
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Terminating Your Own Program
- Collaborative IT Tools Leveraging Competence

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