The Radio Frequency Identification enabled logistics process for supply chain event management from China to the United States via Hong Kong

by

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Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

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Abstract

This thesis reviews the current logistics processes and issues for container shipments in the supply chain. In particular, the problems associated with container shipments from China to the US, via the Hong Kong Port, includes low end-to-end visibility, security concerns, low product-handling productivity, and unmanageable unexpected events. Research was conducted using results from both interviews and surveys to collect information about the current process. This thesis also proposes the use of RFID-enabled logistics to improve the current processes and discusses the impact and value of the RFID-enabled processes. The research results show that through RFID technology, collaborators in the supply chain can improve product-handling productivity, supply chain visibility, and product security. Furthermore, the RFID application for supply chain management can increase the use of direct shipment and cross-docking, which result in considerable cost savings to both a manufacturer and a retailer.
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1 Introduction

Radio Frequency Identification (RFID) provides real time information for the location of products. Where the cost is not prohibited, this technology is of obvious use in supply chain management. For the thesis, I wish to demonstrate the utility of RFID by describing its for container tracking from China – via Hong Kong port – to U.S.

1.1 Background

1.1.1 RFID

Radio Frequency Identification (RFID) technology is frequently used for security and toll collection. Most people in supply chain management expect that RFID will enhance the supply chain management. Therefore, RFID technology is currently applied to various parts of supply chains.

For instance, to enhance inventory management, Wal-Mart has mandated that its top 100 consumer goods suppliers place RFID tags on all pallets and cases. This thesis focuses on the implementation RFID technology to Chinese factories and the Hong Kong port for the outbound logistics to the United States.

1.1.2 Hong Kong port RFID Demonstration Project

The Hong Kong Port RFID Demonstration Project is a collaboration between EPC global Hong Kong and the Article Numbering Association of Hong Kong to address the requirements for end to end supply chain visibility. The project seeks to identify points in the supply lane where RFID and sensor information enable business transformation.

The project is focusing on how to uniquely identify the “what, when, and where” of an RFID read event and to include other telemetry such as temperature and pressure, so that this information can be shared between collaborators in a supply lane.
1.2 Research Question

The primary research question is What are the main issues in current logistics processes in the route from China to the U.S. via the Hong Kong port and how can RFID solve the issues and improve current logistics processes?

In the route from China to the U.S. via the Hong Kong port, containers are supposed to be inspected for customs clearance at least three times: (1) Shenzhen customs, (2) Hong Kong customs and (3) U.S. customs. In a complicated logistics process like this, there is an opportunity for RFID to solve many issues.

Many companies have moved and continue to move their factories to China. The quantity of containers from China to the U.S. is continuously increasing. Hence, it is critical for companies in the supply chain to manage their containers efficiently. Another problem is that as the quantity of shipped containers increases, security inspections may be weakened. This weakened security could allow smuggling, terror and illegal customs clearance.

Therefore, to explore these theories, I will interview and survey consumer electronics and third party logistics companies doing business in China to find out what their real issues are in the supply chain from China to the U.S. via the Hong Kong port.

In addition to the primary research question, this thesis examines the impact and value of the use of RFID and sensors to improve supply chain event management. As RFID and sensors are used for supply chain event management, unexpected events in the supply chain can be detected in real time and response to these events can be more rapidly and automatically conducted.
2 Literature Review

This section surveys RFID technology by describing RFID systems and the components which made up these systems and the cases of using RFID to improve business processes.

In addition, this section surveys supply chain event management which can be enhanced by using RFID and sensors.

2.1 RFID related technology

This section gives an overview of radio frequency identification related technology such as RFID systems and the basic components of the systems.

2.1.1 Component

The basic components of the RFID system include RFID tags, readers, middleware, and Enterprise Applications.

The RFID tag consists of a chip and an antenna. The chip and antenna together are also called an RFID transponder. There are two types of RFID tags. One type is “active” and has a powered chip that emits its identity. The battery-supplied power of an active tag gives it a longer read range. The other type is “passive” and consists of a microchip with a coiled antenna. The microchip stores a serial number, such as an Electronic Product Code (EPC), that identifies a product and may also store additional information. At the moment, this is the most common method of identifying commercial objects using RFID. Passive tags can be applied at the item, case, and pallet level. Considering the privacy issues that arise from item-level tagging, retailers and Consumer product goods (CPG) manufacturers are now focused on testing RFID at the case
and pallet level. The RFID reader, which contains a chip, circuitry and an antenna, sends out an electromagnetic field. In using its antenna, a passive RFID tag draws power from the electromagnetic field and activates the microchip’s circuits. The chip then sends RF waves back to the reader, and the reader converts the signal into digital data. The data then are passed on to computers that can process and/or store them.

RFID middleware is a new type of software that sits between the RFID reader and conventional middleware according to a definition in “EPC Tag Data Standards Version 1.1 Rev.1.24”. Working together with conventional middleware, RFID middleware (or Savant middleware) facilitates communication between enterprise application systems and a variety of automatic identification devices, such as RFID readers and bar code scanners. A Savant is “middleware” software designed to process the streams of tag or sensor data (event data) coming from one or more reader devices. The Savant performs filtering, aggregation, and counting of tag data, reducing the volume of data prior to sending it to Enterprise Applications.

2.1.2 RFID Systems

Automated identification systems have been used industrially for almost twenty years. More recently the aim of the work of the Auto-ID center has been to develop standards and network infrastructure, for unique, item level identity and related product information, to be uniformly available to enhance production, distribution, storage and retail processes in the supply chain. The Center is also helping to bring the price of the automated identification process down so that it becomes feasible for everyday retail items. The initial systems being developed draw heavily on past and current developments in the area of RFID. RFID provides a simple means of obtaining unique, item level identity data, increasingly at a reasonably cost. These systems can be coupled to networked databases which enable additional data to be held about the item. A simple overview of a typical Auto-ID system is now provided. The intention here is not to provide a definitive description but a basic overview. Referring to left hand side of Figure 1 we note the following features:

1. An identity tag attached to a product with a chip capable of storing a unique identification number and communicating this number via an RFID communication system.
2. Networked RFID readers and data processing system capable of collecting signals from
multiple tags at high speed (100s per second) and of pre-processing this data in order to eliminate duplications and misreads.

3. One or more networked data bases storing information related to the product (basic product data, tracking history, processing instructions) whose entries are uniquely bound to the product identification number.

![Simple Schematic of an Auto-ID System and Control System](image.png)

*Source: Duncan McFarlane, Auto ID center white paper, 2003*

Figure 1. Auto ID system and control system

### 2.2 Supply Chain Event Management

In this section, the definition and concept of Supply Chain Event Management (SCEM) are reviewed, as well as the general benefit which SCEM provides.

Supply Chain Event Management evolved as an extension of process control. Organizations manage their processes with planning. But even the best laid plans can be interrupted by the unexpected. Consider a new product launch with an initial forecast that underestimated demand. In today's just-in-time manufacturing era, companies quickly discover not enough finished product exists to fill orders. Then, they find scant time available to procure more supplies and make more products within client delivery requirements. Add to the supply-chain complexity
other product launches in multiple markets for numerous customers, and process breakdown becomes a snowball expanding in size and gaining speed as it barrels downhill.

SCEM software enables companies to respond rapidly and sometimes automatically to unplanned events - without having to completely regenerate plans. SCEM applications accomplish this by notifying supply chain managers when specific "events" occur, e.g., when inventories are depleted or shipments delayed. Data that represent exceptions from the plan are red flags. Often, automated responses can resolve these issues promptly, but in all cases managers have the opportunity to analyze problems and determine solutions.

This visibility is SCEM's greatest benefit. Seeing a problem is 90 percent of fixing it. Individual events are leading indicators; i.e., opportunities to stop the snowball a few feet farther up the hill. In the past, companies dealt with emergencies after the figurative avalanche crushed the village. Supply chain managers waded through reams of reports after the fact and attempted to mitigate the damage of lagging production schedules missed shipments or spiraling costs. Only goodwill might keep a disgruntled customer in the fold.

In the long run, SCEM software not only improves efficiency, but increases customer satisfaction.

The key is the human element. SCEM software can automatically respond to events; e.g., trigger electronic purchase orders in response to low-stock alerts. This is done by integrating SCEM software with other business systems, such as purchasing applications. But without managers monitoring exceptions, analyzing impact and developing solutions to problems, SCEM software offers little benefit beyond convenience.

Furthermore, SCEM is more powerful when its underlying system collects business intelligence from multiple sources across the supply chain, inside as well as outside the organization. As noted before, visibility is SCEM's greatest benefit. Adding data sources and supply chain partners broadens visibility and therefore multiplies the benefit. Today's best business intelligence software uses the Internet to gather information and share it along the supply chain.

SCEM applications necessarily vary by industry, business environment and organizational requirements. But in all cases the greatest pitfall is reacting to SCEM's elevated tracking ability
rather than using it for analysis. Analytic applications counter this tendency by aggregating data from key business systems at a high level and presenting the ramifications of exceptions and the possibilities of solutions. The end result is a proactive, more efficient process.

### 2.3 Business processes by using RFID applications

RFID applications have been researched for implementation in manufacturing and transportation. In this section, I use the literature to review how RFID applications are able to be applied to manufacturing and transportation business processes.

#### 2.3.1 The manufacturing supply chain

The paper entitled “The Impact of Product Identity on Industrial Control Part 1: See More, Do More…” written by Duncan McFarlane discusses what benefit RFID systems make and how RFID systems improve manufacturing process in the manufacturing supply chain. The simplest benefits from the deployment of Auto-ID systems in the manufacturing supply chain is improved tracking and hence a product’s visibility and traceability. This is illustrated in Figure 2 for the case of a manufacturing control system. A manufacturing control system (Figure 2) consists of a hierarchy of nested control loops in which higher level decisions are broken down into a series of smaller, shorter term decisions. Requirements flow down the right hand side and sensing/reporting in increasingly aggregated forms flows up the left side. Figure 3 then shows the impact of product identity information on this control system hierarchy. Rather than have the order status determined solely from equipment derived information, the status of the products themselves is used to provide a more representative indication of order status. Note however, that the “decision” and “action” sections at the right hand side of Figure 3 are not changed.

It is the fact that collection of product identity data can be automated, and used to uniquely identify a specific item in real time, that is of most benefit when considering fundamental changes that automated identification might produce.
Figure 2. Impact of the introduction of process sensing

Figure 3. Impact of the introduction of process and product sensing
2.3.2 The transportation process

In the thesis—"The Value of RFID in Transportation: From Greater Operational Efficiency to Collaborative Transportation Management", Antoine Guitton states that the main changes and expected values of two processes. One is forecast & plan transportation process and execute transportation process. The figure 4 & 5 shows TO-BE RFID enabled process maps to improve the two transportation processes in supply chain.

![TO-BE RFID-enabled "Forecast & Plan Transportation" process mapping](image)

Source: Antoine Guitton, MLOG thesis, 2004

RFID-impacted processes include inventory management at Distribution Centers of both vendor and customer, and at customer’s store’s backrooms. Implementing RFID will enable a real time visibility on inventory at these locations. Moreover, and most importantly, RFID-generated data will be at customer’s and vendor’s disposal, so that everybody has the same level of information. Finally, a strong relationship must be developed between the customer and the vendor in order to fully take advantage of the common data and develop "joint forecast orders".

From a pure "product order" forecast point of view, a joint forecast should allow the vendor to
obtain a far better supply planning, with the ultimate goal for the whole channel to better match the demand. Improvements should lead to a reduction of product order forecast variability, which should reflect in shipment forecast variability.

From the carrier point of view, less variability in shipment forecast should enable a better capacity planning, for the long term forecast, and a better asset utilization planning for the short term shipments, with these two following direct consequences:

- A prevention of truck unavailability, avoiding shipper's dissatisfaction and possible penalties because of missing trucks.
- An avoidance of lost sales, preventing the shipper to turn to another carrier.

It should also be beneficial for the other players, as the shipper could avoid paying a premium for an expedited shipment, and the customer should avoid a stock-out.

![Diagram of TO-BE RFID-enabled "Execute Transportation" process mapping, for TL carriers](source)

Figure 5. TO-BE RFID-enabled "Execute Transportation" process mapping, for TL carriers

This is one of most impacted of the four processes. RFID can be used fully here, allowing labor reduction, data accuracy, speeding up and global visibility.
At receiving, as data can be collected automatically when a pallet passes through a portal, the need for scanning shipments’ bar codes is eliminated, potentially leading to a suppression of the scanning task. At the same time, the data captured can be compared to what is expected to be received (what has been sent by shipper through an Advanced Shipment Notice (ASN), avoiding manual verification, and reducing the possible mistakes. At shipping, documents such as ASN and Bill Of Lading (BOL) can be automatically generated when trailers are loaded. At the receiving end, data captured at unloading can be compared automatically with the RFID-generated ASN and BOL, and an automatic Proof of Delivery can be created. Finally, by systematically passing through a portal before being loaded, the shipment’s destination can be checked, avoiding misrouting of goods.

Early detection of loading and routing errors, as well as speeding up documentation, loading and unloading tasks should allow for a reduction of delayed deliveries. Delays in truck load (TL) transportation may be a few hours, or days if a shipment is misloaded. This may lead to a delivery in two days instead of one, or three instead of two. By reducing delays, the average lead time and the lead-time variability should decrease, allowing shippers and consignees to reduce their safety stocks.

The automatic verification and generation of documents at shipping and at receiving will reduce auditor and clerk cost, improve accuracy and therefore allow further savings in reconciliation for all players. Elimination of mis-shipments will result in less need for expedition. Tracking will offer better service to shippers and consignees, through shorter and more consistent transit times. Finally, automatic generation of documents as well as automatic detection of staging locations will also help to reduce loading, unloading, searching and waiting times for the driver, helping to comply with the new Hours Of Service regulations.
3 Methodology

3.1 Data and information gathering

The data used to quantify the impact of RFID has been gathered from a consumer electronics company. For confidentiality reasons, I do not cite the name of companies. Various information about logistics, China customs, and the Hong Kong port is collected by working with this consumer electronics company and a few third party logistics companies as well as by reading literature. In addition, through surveys and interviews of consumer electronics companies and third party logistics companies, I identify the priority areas where companies can make the most impact on their businesses through RFID technology.

3.2 Process analysis

I divide up the logistics processes into detailed parts and analyze each using the following method:

1. Mapping the AS-IS process
2. Main issues of the AS-IS process
3. Mapping of TO-BE RFID enabled process
4. The expected value of TO-BE RFID enabled process

3.3 Methods

In order to calculate holding costs saved by applications of RFID for increasing the use of direct shipment, the following equation is used:

\[
\text{Holding cost} = v \times r \times \frac{Q}{2}
\]
Where

\( v \): Variable (Purchase) Cost (dollars/unit)

\( r \): Carrying or Charge (dollars/dollars held/time)

\( Q \): Replenishment Order Quantity (units/order)

Holding cost: the cost of carrying one unit in inventory for a specified period of time, usually one year. (It includes the opportunity cost of the money invested, the expenses incurred in running a warehouse, handling and counting costs, the costs of special storage requirements, deterioration of stock, damage, theft, obsolescence, insurance, and taxes.)

I calculate the holding cost by using the actual data which a consumer electronics company provides.
4 Research: investigation and results

4.1 Survey: the anticipated area for application of RFID to supply chain management and logistics

4.1.1 The results of the survey: electronics companies

In order to improve the entire value chain among companies in the electronics industry through the use of RFID technology, collaborations among suppliers, manufacturers, and retailers are needed.

Hence, I surveyed companies in the electronics industry to learn in which area in the supply chain they would want to use RFID applications.

The purpose of this survey was to find out what the consensus among companies in the electronics industry had regarding areas in supply chain they could use RFID most efficiently.

The subject companies in this survey were three contract manufacturing/ original development Manufacturing companies, four global electronics manufacturers and three retailers.

Eight areas in which RFID could be applied were presented in the survey. Supply chain managers or directors of the ten companies then checked areas in which they could apply RFID technology.

The eight main areas were:

1. INVENTORY VISIBILITY: Ability to view and track discrete units of inventory in real time as they move across the value chain from components through items on the retail shelf.

2. PRODUCT HANDLING PRODUCTIVITY: Capability to improve productivity and reduce costs of product processing and handling at all nodes in the supply chain.
3. **DYNAMIC PRODUCT FLOW MANAGEMENT**: Capability to dynamically route product from the source of supply to the point of demand, based on flow paths optimized for cost, time or other priorities.

4. **RETURN/REPAIR/WARRANTY MANAGEMENT**: Ability to track and trace serialized product in the value chain and to use this information to improve containment of warranty costs, optimize processing of returned product and eliminate fraudulent claims.

5. **PRODUCT SECURITY**: Capability to monitor product flows across the supply chain from manufacturing through retail to identify sources of theft and shrinkage.

6. **FULFILLMENT & EXECUTION MANAGEMENT**: Ability to perform discrete monitoring of orders vs. commitments and to trigger alerts that will identify likely deviations from plan in time to take corrective actions.

7. **REAL TIME REPLENISHMENT**: Ability to view inventory deficits at key nodes in the supply chain in real time and trigger replenishments based on demand.

The survey results present two tables. One table indicates areas that the companies consider important for the application of RFID technology. The other table identifies areas where it would be easy to implement RFID technology.

**Note**: The number means how many companies consider that the area is able to make impact to improve business process by using RFID technology.

<table>
<thead>
<tr>
<th>The anticipated Areas</th>
<th>CM* ODM*</th>
<th>Manufacturers</th>
<th>Retailer</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory Visibility</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Product Handling Productivity</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Product Security</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Fulfillment &amp; Execution Management</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Dynamic Product Flow Management</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Real Time Replenishment</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Returns/Repair/Warranty management</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The results of the survey of electronics companies for evaluation of RFID possible area
As the table shows, most manufactures consider the areas of Inventory visibility, Product handling productivity and Product Security to be priority areas for application of RFID. Most retailers consider the areas of inventory visibility a priority area. In addition, they consider Dynamic Product Flow Management priority areas for application of RFID.

Table 2 indicates areas where would be easy for the companies to implement RFID technology.

<table>
<thead>
<tr>
<th>The easy areas to implement RFID</th>
<th>Rank</th>
<th>Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Handling Productivity</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Product Security</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Fulfillment and Exchange Management</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Dynamic Product Flow Management</td>
<td>4</td>
<td>38</td>
</tr>
<tr>
<td>Inventory Visibility</td>
<td>5</td>
<td>54</td>
</tr>
<tr>
<td>Real Time Replenishment</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Returns/Repair./Warranty</td>
<td>7</td>
<td>66</td>
</tr>
</tbody>
</table>

Table 2. The easy areas of RFID implementation

The companies gave points to each area. For instance, they gave 1 point to the easiest area and 7 points to the most complex area. Hence, the number in the point column is the sum of points which the companies gave. The lower point means the easier area for application of RFID.

As the easiest area for application of RFID, most companies chose product handling productivity. I made 'the ease of implementation - impact matrix' (Figure 6) to define which areas in value chain are priorities for application of RFID.
This figure 6 shows that product handling productivity and product security are in the priority area. The companies think that inventory visibility could make significant impact but it is not easy to implement using RFID technology. Therefore, they need to make a long-term plan to implement RFID in order to improve inventory visibility.
In addition, most companies gave their opinion that RFID could be considerably useful for the area of SCEM, which manages unexpected events in supply chain efficiently.

In conclusion, through this survey, I find that most companies in the electronics industry consider supply chain visibility, event management and Product Handling Productivity the most important and efficient areas where they can make the most impact on their business using RFID technology. Therefore, in this thesis, I mainly demonstrate TO-BE RFID enabled logistics processes focusing upon improving the three priority areas: supply chain visibility, event management and Product Handling Productivity.

4.1.2 The results of the survey: third party logistics companies (3PL)

I surveyed four global logistics companies, which do business in China, regarding RFID technology. The purpose of this survey is to define what problems and issues the companies have in the route from a Chinese factory – via Hong Kong port – to U.S customers and to find out how they expected RFID to solve their problems and issues.

In the survey, I make the following assumptions.

1. Figure 7 shows transportation route for the survey.

2. An RFID tag is attached to the container at the factory in China

3. The RFID tag can store the required information which collaborators need to manage supply chain

4. An RFID reader can be used at any place (for example, a factory exit, border in Hong Kong, entrance in Hong Kong port, and so on) and installed in any material handling equipment (for example, truck, crane, and so on)
5. The information on the RFID tag can be amended and revised at any place.

6. Information can be retrieved from RFID tags and sensors – temperature, light, humidity and tilt.

Below are answers the four global logistics companies provided.

[The current problems or issues in the route]
- low end to end visibility
- the unexpected event in supply chain
- difficult to track and trace precisely because the route is long and complicated
- high possibility of robbery and replacing with counterfeit goods in the route from China to Hong Kong port (Possible security issues)
- likely to take long time because there are three customer clearances. (China, Hong Kong and the U.S)
- Labor intensive product entry/exit
- Not able to know exactly what is in the container at a certain point in time
- Delay in gaining access to container and supply chain information

Figure 8 presents common issues which the companies consider in the route.

Figure 8. Common issues companies have in the China – Hong Kong – U.S route
[The anticipated RFID solutions to solve the above issues or problems]

- As RFID tag could be scanned at each border and port, they could track and trace their goods in real time.
- To increase the accuracy of inventory management at hubs.
- To remove the labor cost for cycle count of inventory at hubs.
- There will be efficiencies in reduction of Labor however there is a high cost of entry.
- Duplicate entries can be minimized and thus reduce any probability of transportation errors.
- Supply chain information can be accessed quicker thus leading to informed decision making.
- Improved supply chain security.
- Improved compliance with US customs requirements.

Figure 9 presents the common and expected RFID applicable areas which the logistics companies consider to be solutions of the above issues.

![Bar Chart]

Figure 9. Expected RFID applicable areas to solve the above issues.

[The anticipated impact by using RFID with various sensors (temperature, light, weight, humidity, and tilt sensors) ]

- prevent stealing goods in the container.
- analyze the cause of physical goods damage and prevent the physical damages from external crash.
For example, the cause could be traced by using crash severity sensors with RFID.
- prevent water damage of goods by using humidity sensor

As a result of the survey, I found that third party logistics companies want to use RFID in the supply chain to improve visibility, and manage the unexpected events, such as robbery and transportation delay. Hence, in next section, I define AS-IS supply chain process in the China – Hong Kong – U.S. route and present TO-BE RFID enabled process to improve supply chain visibility, product handling productivity and event management.
4.2 Analysis of AS-IS logistics process vs. TO-BE RFID enabled logistics process

As we see from the results of the surveys, there are issues such as low end to end visibility, security concerns, low product handling productivity and difficult to manage unexpected events in the supply chain from China - via Hong Kong port- to U.S. In this section, I present the current logistics processes and define their main issues. I then propose the RFID enabled TO-BE process to improve the current situation and describe their impact and value.

4.2.1 Outbound logistics process from China factory to U.S customer

Figure 10 shows the general working process to export goods from China factory to U.S. via Hong Kong port.
The carrier makes available regularly scheduled vessels to manufacturers who then make shipping plans using the vessel schedule. After manufacturing goods, the manufacturer requests the carrier to prepare vessels according to the schedule. The carrier checks available vessels and sends the ship information to the manufacturer. To facilitate customs clearance, the manufacturer should have products inspected by the Commodity Inspection Bureau. The manufacturer uses the system of the Commodity Inspection Bureau to get inspection certification.

After receiving the inspection certification, the manufacturer loads containers and dispatches the containers by truck to Hong Kong port. At the same time, the manufacture sends an invoice and packing list to the customs agent to get export permission from the customs clearance office.

After receiving export permission, the container is loaded on the ship and leaves for the U.S. The manufacturer then receives a bill of lading and sends billing and advanced shipping notification to customers in the U.S.

Unlike general import working process, in the case of the China – Hong Kong port – U.S. route, two customs clearances are needed: one is at the China customs office and the other at the Hong Kong customs office. In addition, the inspection for customs clearance also is needed twice. Hence, in the route, the flows of the red box and red arrow line (figure 10) occur two times.
because the container should pass through the China border and the Hong Kong border. For information, the black box and black line (figure 10) means the flow of data or document and the blue line (figure 10) means physical transportation flow.

In next sections, I discuss specific problems and suggestions on how to solve them using RFID by dividing the logistics processes into detailed parts.

### 4.2.2 Loading and dispatch process from a Chinese factory

I discuss here the loading and dispatch process from a Chinese factory.

Figure 11 (a) and Figure 11(b) show the current loading and dispatch work flow.

By using a barcode system, product boxes are scanned manually when they are loaded in the container. Normally, 140 units of the 29-inche-TV are able to be loaded in one container.

In this case, workers scan barcodes of all loaded boxes one by one (Figure 11 (a))

However, In the case of a camcorder or a DVD player which size is much smaller than a TV, it is hard to scan all barcodes of the loaded boxes one by one. About 8000 units of a camcorder or 2500 units of a DVD player usually are loaded in one container.

Therefore, workers can hardly scan barcodes when they load camcorders or DVD players in the container. (Figure 11(b))

In addition, the data from scanning barcode is sent to a PC at a Chinese factory. But, the data is not sent to customers or third party logistics companies.

A Chinese factory use the stored data to confirm the proof of loaded goods if products are missing or if there is a difference between the amount of product in an invoice and the amount of products arriving at the destination warehouse.

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![Flow chart](image.png)

**Figure 11-a.** The AS-IS loading and dispatch work flow of china factory (TV)
Main issues of AS-IS process

As I mentioned, when loading, workers do not scan the small size products such as camcorders or DVD players. This may cause the following problems:

- misloading: workers may load wrong goods in the right container or load right goods for wrong destination container.
- wrong quantity: possible to load a quantity of goods which is different from a quantity of goods in documents (invoice and packing list)

In addition, in order to scan barcodes on the TV boxes, workers put some TVs into a container and scan the barcodes and put other TVs into the container again because they can not scan the barcodes after they first stuff all the boxes of TVs in the container.

If a quantity of products or the name of products in container is different from the one in the documents, the Chinese customs office will not allow the factory to export the goods. In this case, the container goes back to the factory and is checked in detail manually. The documents such as invoice and packing list are also modified. Therefore, it considerably delays transportation time.

In order to see if RFID can solve these problems, I make an issue tree which shows root causes and expected effects of the problem.

Figure 12 represents the tree of issues which occur by not scanning barcodes of all products.
Increase costs  
Goods Return  
Reduce sales  
Decrease orders  
Reduce customer's reliability of supplier  
Low service quality  
Rework  
Failure of customs clearance  
Not send the loading data to customers  
Decrease order fill rate  
Missshipping  
Make the difference error between loaded goods and documents (invoice and packing list)  
Load the wrong product  
Load the wrong product quantity  
Not scan the barcodes of goods  
Too many goods in one container to be scanned (8000 units)  
Long scanning lead time  
Can not scan the goods surrounded by other goods on a pallet  

Figure 12. the tree of issues which occur by not scanning barcodes of all products

The three root causes that I identify have a negative influence such as increasing costs and reducing sales.

**TO-BE RFID-enabled loading and dispatch process of the factory in China**

Using the capabilities of RFID, I address the problems by handling the root causes.

Figure 13 shows the TO-BE RFID-enabled process to improve loading and dispatch process from a Chinese factory.
Attach RFID tags to boxes → Write the product UID and destination on the tags → Quality Inspection

Ficking and packing → Loading → Scan all RFID tags of boxes → Scan Container No. & Seal No. on RFID tag

Automatically confirm loaded goods with invoice and packing list → Dispatching container

Storing all the scanned data at main server → Sending the data to customers or 3PLs

Figure 13. The TO-BE RFID-enabled process to improve loading and dispatch process

RFID tags on boxes → Scan all the tags → Loading → Container Truck

Give an alert on the occasion that the loading data is different from invoice and packing list

Figure 14. System architecture for RFID enabled loading and dispatching process
In the manufacturing process, the RFID tag printed on the back of barcode tag is attached outside of each box. After quality inspection, when the palletized boxes pass by the antenna which is installed on the loading dock, all the tags on boxes are scanned automatically.

The RFID data scanned by the antenna is sent to local server in factory.

The local server has the information of the invoice and the packing list from the manufacturer’s main server.

The RFID data is compared with the data of the invoice and packing list. If there is a difference in quantity or product name between the data of loaded goods and the data of invoice and packing list, the monitor near the loading dock shows the alert to workers.

When workers get the alert on the monitor, the workers can check what the problem is and the source of the difference.

**The expected value**

1. **Read all data of boxes.**

   Although there are many boxes and some boxes are surrounded by others as the boxes are palletized, RFID tags can be scanned. It will enable manufacturers to provide better and various services to customers.

2. **Detect and prevent loading and routing errors.**

   As the scanned RFID data is compared with the data on the invoice and the packing list on server and differences between the two alert the workers. Hence, they can detect errors and correct them immediately.

   The detection and prevention are very important because the loading and route errors can cause considerable delays. Figure 15 shows the work flow of the alert system
Figure 15. Work flow of the alert system

3. Reduce labor costs and loading lead time.

As the RFID antenna scans automatically the tags, workers do not have to spend time scanning the barcodes one by one. Hence, RFID can generate value at the manufacturing site. Below I quantify the gain by reducing the barcode scanning labor.

[Assumption]

In order to calculate the savings, I make the following assumptions

- All barcodes on boxes of loaded goods are scanned by a barcode reader.
- A worker's annual salary : $ 30,000
- Scanning time : 2 seconds per box
- Shipping 1000 containers per product per year from China to U.S.
(Hard disc drive and optical disc drive: shipping 600 containers per year)
- Annual working hours: 2,000 hours (8 hours * 4 days/week * 50 weeks)
- Working cost per hour: $15 ($30,000 / 2,000 hours)

The table 3 indicates the annual estimated saving cost by product.
As shown table 3 and figure 16, the smaller the size of the product is, the more savings are generated. It means that as RFID is applied to small size goods, it can reduce the cost savings considerably. The sum of saving costs of all products is $339,369.
Furthermore, as the RFID antenna scans all palletized boxes at one time, it takes much less than 22,625 hours per year.

<table>
<thead>
<tr>
<th>Product</th>
<th>CBM (m$^3$)</th>
<th>Loading quantity per container</th>
<th>Scanning hours per container</th>
<th>Scanning hours per year</th>
<th>The estimated saving costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disc drive</td>
<td>0.002</td>
<td>33750</td>
<td>18.8</td>
<td>11,250</td>
<td>56,250</td>
</tr>
<tr>
<td>Optical Disc drive</td>
<td>0.005</td>
<td>13500</td>
<td>7.5</td>
<td>4,500</td>
<td>22,500</td>
</tr>
<tr>
<td>Camcorder</td>
<td>0.008</td>
<td>8438</td>
<td>4.7</td>
<td>4,688</td>
<td>23,438</td>
</tr>
<tr>
<td>DVD player</td>
<td>0.027</td>
<td>2500</td>
<td>1.4</td>
<td>1,389</td>
<td>6,944</td>
</tr>
<tr>
<td>17 inch monitor</td>
<td>0.12</td>
<td>563</td>
<td>0.3</td>
<td>313</td>
<td>1,565</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>0.118</td>
<td>572</td>
<td>0.3</td>
<td>318</td>
<td>1,589</td>
</tr>
<tr>
<td>25 inch TV</td>
<td>0.224</td>
<td>301</td>
<td>0.2</td>
<td>167</td>
<td>837</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>22,625</strong></td>
<td></td>
<td><strong>113,123</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. The annual estimated saving costs by product.

Figure 16. The comparison graph of the estimated saving costs by product.
In this section, I consider RFID benefit for the manufacturer. However, in order to calculate the ROI, the investment costs for application of RFID should be considered. But, since the cost of the RFID tags is going down and the investment costs are also decreasing, I calculate only the estimated cost savings to demonstrate the value from the application of RFID.

4.2.3 Trucking process from a Chinese factory to Hong Kong port

Containers dispatched from a Chinese factory pass through a Chinese customs clearance office and Hong Kong customs clearance office and arrive at the Hong Kong port.

Whenever the container passes through customs clearance offices, it should be inspected and sealed again. The reason to seal the container again is to confirm that the products in the container are identical to the products of documents for the customs clearance.

As a matter of course, all containers are not inspected at China and Hong Kong borders. About 5% of all containers normally are inspected.

[AS-IS process of sealing the container]

Figure 17 presents the AS-IS process of sealing the container from a Chinese factory via Chinese and Hong Kong borders to the Hong Kong port.

The container is sealed in a Chinese factory before dispatching. When the container arrives at the office of the customs clearance in Shenzhen, the factory seal is broken to inspect the container. After customs clearance, the container is sealed twice by the Chinese customs and the shipper. Once the container arrives at the Hong Kong customs clearance office, the China customs’ seal is broken and the container is sealed again by the Hong Kong customs, only in the case that the container is open to be inspected.

After leaving the Hong Kong customs clearance office, the container arrives at the Hong Kong port.

Once the container enters the container yard at Hong Kong port, the Hong Kong customs’ seal is taken off. Then there is only the shipper’s seal on the door of the container. The container, which is sealed by the shipper, is loaded onto the ship.
At present, the reason that the complicated sealing process is used is to prevent smuggling and robbery.

![Diagram of transportation process](image)

Figure 17. AS-IS process of transportation from a Chinese factory to the Hong Kong port

**Main issues of the AS-IS process**

The work-load increases due to the detail inspection at customs clearance offices. As the work-load increases, the labor cost also increases. In addition, the detail inspection, sealing and taking off the seal cause delays. The delay can be as much as a day. But, if the container does not arrive at the Hong Kong port on time and therefore misses the ship, it could add 2 or 3 more days. Furthermore, since the container seal is often taken off, it is quite probable that robbery of products from the container occurs.

As only 5% of all containers which come from a Chinese factory are inspected, it is very difficult for customs offices to detect smuggling and hazardous materials for terrorist such as arms and explosives and to prevent the illegal customs clearance.
[TO-BE RFID enabled transportation process from China factory to Hong Kong port]

As shown the figure 18, a reader installed in the container reads RFID tags attached to the products. The resulting data is then stored on the computer in the truck. Once the truck arrives at the customs office, the custom office can easily get the data from the PC in the truck and confirm that product name and quantity in the container match the documents without opening the container and unloading goods.

![Diagram of data flow among the China factory, the truck, the China customs office and the Hong Kong customs office.]

Figure 18. Data flow among the China factory, the truck, the China customs office and the Hong Kong customs office.

At the China factory, the seal number and container number should be written on the RFID tag attached on the container. This tag stores the updated seal number which the China and Hong Kong customs offices provide. After dispatching the truck, once the truck arrive at the china customs office, the RFID data in the PC of the truck is sent to the customs office’s server. The server compares the RFID data with the data of EDI documents for the customs clearance. If there is no difference, the customs office permits the export. As a proof of the permission, the China customs office writes new seal number on the tag of the container. The Hong Kong customs office does the same thing as the China customs.
The figure 19 shows the transportation process.

![Transportation Process Diagram]

Figure 19. RFID enabled-transportation process from a Chinese factory to the Hong Kong port

[The expected value]

1. Better inspection quality to prevent smuggling, transporting dangerous material and the illegal items.
   - The customs office can not open to inspect goods in containers because too many containers come in the offices to get the permission of the customs clearance. In the AS-IS process, the office inspects only 5% of the containers. But, if RFID is implemented, without opening the container, the office can check what is in containers. Therefore, RFID will provide better inspection quality to the office in order to detect smuggling and transporting dangerous and illegal material.

2. Reduce the customs clearance lead time
Normally, it takes about 9 to 11 hours from Chinese factories to the Hong Kong port through the customs offices. Figure 20 shows the approximate transportation time approximately.

If RFID is used for the customs clearance and inspection, it would take much less time. If RFID reduce the time for the all customs clearance by 2 hours, containers could be delivered to Hong Kong port before 1 PM. It means that the containers could be loaded on a ship on the afternoon and it could reduce one day of the shipping lead time or more because the ship does not depart everyday from Hong Kong port. If there are 3 shipments per week at Hong Kong port and if the container misses a ship due to delayed customs clearance, the containers would wait 2 additional days. It could delay the shipping lead time as well as deteriorate the service quality for customers. Therefore, as RFID is applied, not only the customs clearance lead time but also the ocean shipping lead time can be reduced considerably and further the better services such as the high rate of the on time delivery and the fast delivery can be provided to customers.

3. Minimize the possibility of robbery and missing
If RFID is implemented, the customs office could get the RFID data of products in a container. Hence, the door of the container doesn’t have to be opened for the inspection of the customs clearance. Since the door is not opened during a period of the transportation from a Chinese factory to U.S, the possibility that robbery or missing goods occur can be reduced remarkably.

4. Reduce the inspection labor.
As well as the inspection lead time, the labor for the inspection also would be reduced because the RFID reader could scan RFID tags of the goods in a container and the RFID data would be sent to the server of the customs office. Workers of the customs office do not have to open the
door of the container manually in order to inspect the goods in a container. Therefore, it will
decrease the labor costs as well as the customs clearance and inspection lead time.

4.2.4 Internal logistics process at Hong Kong port.

Below figure 21 shows the operation work flow of Hong Kong port briefly.

(1) In the pre planning step, key information such as container numbers, weight, size and type is
sent to HIT via Electronic Data Interchange and Information Exchange Service.
(2) Ship planners then plan vessel stowage for loading and discharge operations. Yard Planners
decide the most appropriate yard areas for grounding containers.
(3) At the gates, when external tractors enter HIT, gate checkpoints scan the driver's Tractor Identity Card (TID).
(4) HIT's 3P System acknowledges the vehicle's arrival.
(5) Tractor drivers go to the yard for container grounding.
(6) The tractor drivers complete the procedure at the exit gate for container inspection, data entry (seal number and container number). The TID is scanned again and a Terminal Receipt is printed.
(7) Gantry Cranes at the container yard are deployed for container grounding operations. External tractors go to the yard location and Crane operators perform the pickup/grounding operation.
(8) When complete, the crane operator sends a message to the 3P System.
(9) For vessel movements, internal tractors receive container locations through the Pager System and transfer containers to the quayside as required.
(10) Quay Cranes service ocean-going vessels. For loading, the internal tractor with an outbound container arrives under the Quay Crane and the container is picked up and loaded onto the vessel. Pier-side checkers and stevedores implement information exchange using hand-held terminals.
(11) The ocean vessel then leaves the Hong Kong port.

**Main issues of the AS-IS process**

The first issue is that there are many manual tasks. These manual tasks increase human error, labor costs and working time. Once the truck arrives at the gate of the Hong Kong port, TID should be scanned manually and the seal number on the door of a container should be confirmed manually by a worker. The worker also should type seal number and the information regarding the arrival of a truck. In addition, a worker at the exit gate of the Hong Kong port has many manual tasks. Once an external tractor leaves the Hong Kong port, the worker should inspect a container and the tractor manually and then should input the information of the leaving of the tractor manually. Furthermore, on quayside, Pier-side checkers and stevedores should check if containers are loaded onto a vessel or not manually. Since there are the many manual tasks in the process, it is likely to increase human errors such as mis-loading and inputting wrong data to the 3P system. The second issue is the low supply chain visibility at the Hong Kong port. It is difficult to check the visibility after leaving the container yard by loading a container onto a vessel. It might not have long distance between a container yard and a quayside, but the Hong
Kong port’s system can not know where the container is precisely because there is no checking point between them. Unless the container is loaded onto a vessel, it is difficult to track the exact location of the container and prevent someone from accessing the container for the purpose of smuggling or terror. Therefore, during the time from leaving the container yard to loading onto a vessel, smuggling, robbery or introduction of dangerous material could occur.

**RFID enabled internal logistics process of the Hong Kong port**

Figure 22 shows RFID enabled the internal logistics process and work flow of the Hong Kong port.

Figure 22. RFID enabled the internal logistics process and work flow of the Hong Kong port

1. The transportation company sends the pre-planning information.
2. By scanning RFID data of the truck at the entry and exit gate of the Chinese factory and Hong Kong customs offices, the tracking information could be made and sent to HIT via Electronic Data Interchange and Information Exchange Service. The pre-planning and tracking
information would be used for the internal logistics operation planning at the Hong Kong port.

3) Ship planners then plan vessel stowage for loading and discharge operations. Yard Planners decide the most appropriate yard areas for grounding containers.

4) At the gates, when external tractors enter HIT, the PC in the tractor sends the RFID data of container No., the customs offices’ seal numbers, product names, quantities and so on to the local PC at the gate office and the local pc then sends the vehicles’ arrival information to the HIT’s 3P system.

5) HIT’s 3P System acknowledges the vehicle’s arrival.

6) Tractor drivers go to the yard for container grounding.

7) The RFID tag of the tractor is scanned at the entry gate of the container yard. By using the data of the time when the tractor leaves the main gate of HIT and enters the entry of the container yard, the HIT office can manage the tractor efficiently. If it takes longer time than the standard transportation time from main gate of HIT to the container yard, the HIT’s system gives an alert. During the delayed transportation time, there would be smuggling or putting dangerous stuffs into the container for terror. Gantry Cranes at the container yard are deployed for container grounding operations. External tractors go to the yard location and Crane operators perform the pickup/grounding operation. The reader which is installed Gantry Cranes received the container No. from the RFID tag of the container and the information of the container yard location from the RFID tag which is attached on the ground or the pole indicating the location No. of the container yard. Through the scanning the RFID tags in the container and in ground or a pole, it would enable to manage the real time container movement and precise inventory at the container yard.

8) When complete, the crane operator sends a message to the 3P System.

9) Once the internal or external tractor leaves the container yard, the RFID tag of the truck is scanned at the exit gate of the container yard.

10) Once the external tractor arrives at the main exit gate of HIT, the RFID tag of the truck is also scanned. As mentioned in step (7), if it takes longer time than the standard transportation time from the container yard to the main exit gate of HIT, the HIT’s system gives an alert. Since the RFID data of the tractor is scanned, without manual inspection, the tractor could leave HIT. And the office at the exit gate would write terminal receipt onto the RFID tags of the tractor. Therefore, the tractor driver does not have to wait the printed receipt and keep the paper receipt.
(11) For vessel movements, internal tractors receive container locations through the Pager System and transfer containers to the quayside as required. As mentioned in step(7), if it takes longer time than the standard transportation time from the container yard to the quayside, the HIT’s system gives an alert. Quay Cranes service ocean-going vessels. For loading, the internal tractor with an outbound container arrives under the Quay Crane and the container is picked up and loaded onto the vessel. In stead of Pier-side checkers and stevedores, the RFID reader which is installed into the Quay Crane scans the RFID tags of the containers when picking containers up and the data is sent to the HIS’s system.

(12) The ocean vessel then leaves the Hong Kong port.

(13) After loading the vessel, by using the RFID data of the containers, ASN(Advanced Shipping Notification) can be made and sent to customers by using EDI and IES.

(14) The RFID data of loaded containers can be provided to the Hong Kong customs office and the U.S. customs for security.

The expected value
In this case, the most important value is improved visibility and security. Firstly, as the RFID technology is used at many areas of the Hong Kong port, the visibility to manage containers, trucking and many kinds of information can be considerably improved. In the AS-IS process, it is hard to control the supply chain of Hong Kong port precisely. Since the container yard and quayside is very broad, it is hard to find a container. The high visibility of containers at the yard could protect the product and prevent the goods holder from paying a demurrage charge by providing the accurate information to goods holders. Through the improved visibility, the more accurate tracking information could be provided to transportation companies and goods holders. Secondly, since the RFID data of the container can be scanned frequently at the Hong Kong port, the data can be verified by comparing it with the data of the invoice and packing list continuously. When the difference occurs, the HIT’s system can give the alert in real time to prevent missing goods or exploitation by terrorists. Hence, the RFID enable to manage the unexpected event in internal supply chain of the Hong Kong port.

In addition, using RFID technology for control of the entry/exit of tractors, the entrance and exit managing lead time can be reduced considerably. As the manual task for inspection and
confirming the loading container can be removed, human error such as misloading and not protecting smuggling also can be reduced significantly.
4.3 RFID-enabled logistics process for Supply Chain Event Management

In this section, I discuss how to use RFID technology in order to manage the events in the supply chain from China to the U.S. via the Hong Kong port more efficiently. I also describe the RFID enabled process map for improved supply chain event management and present a supply chain event management system architecture with RFID applications and various sensors. In addition, I deal with the expected impact and value of the application of RFID on supply chain event management.

4.3.1 The SCEM solution framework

Below are the some issues in current supply chain management
- Data inaccuracy
- Incapable of local real-time reactions
- Limited visibility and control
- Assumption-based planning
- Delay of the data input to enterprise systems
- Unsynchronized planning cycles

There are the two main reasons these issues occur. One is that there is a gap between supply chain planning and supply chain execution. The other is that the real time enterprises are not operated to manage supply chains. Hence, in order to solve these issues, many supply chain management software companies have developed supply chain event management systems to reduce the above mentioned gap and to operate real time-based supply chain management. Figure 23 shows a supply chain management software company’s SCEM solution framework.
5. Collaboration
Collaborate with business partners

1. Monitoring
Monitor for exceptions and deviations

2. Alert and Notification
Notify appropriate role(s)

3. Simulate and Optimize
Simulate resolution options

4. Control
Carry out resolution

6. Supply Chain Performance Measurement

Source: The i2 SCEM solution 2003

Figure 23. The SCEM solution framework

1. Monitoring
The events and exceptions across the value chain are monitored. The events that affect multiple departments are monitored, and the monitoring of events occurs as continuously as possible to ensure early detection. The monitoring part of the framework provides ongoing information about supply chain events, including the status of inventory, orders, shipments, production, and supply.

2. Alerts and Notification
This part helps to support real-time exceptions management through alert messaging, proactively warning a decision-maker if an action must be taken or if a trend is emerging.

3. Simulate and Optimize
Simulation and optimization part supports decision-making by assessing what will happen if specific events occur, or recommends that an action be taken in response to an event or trend analysis. This part also allows users to explore the impact of each event and analyze possibilities to ensure that events of different types are given appropriate attention. Event types will include one time events, recurring events, and trends.

4. Control
The control part of the framework lets a decision-maker change a previous decision or condition, such as diverting a shipment or expediting an order. In addition, the state management of the lifecycle of the event is provided to ensure that the resolution decided upon is indeed carried out.
5. Collaboration

The collaboration part overlays all parts to allow for multiple enterprises and users to work together to resolve an issue. Collaboration with partners is needed when events occur. The event details are passed to partners first for resolution and escalated internally for the resolution.

6. Supply Chain Performance Management

This part provides measurements, often Key Performance Indicators (KPIs) and metrics, for assessing how well the supply chain performs, past and present. Gathering event, exceptions, and resolution information across the value chain will ensure that solutions will enable the objective measurement of performance.

4.3.2 The RFID enabled logistics process map for SCEM

The unexpected event management

Figure 24 shows the work process of the system in the event of theft.

Figure 24. work process of the system in the event of theft
The scenario is that an unexpected event such as theft is detected at the U.S. port. Once containers arrive at the U.S. port, the RFID tag which has the information regarding the names and quantities of products in the container is sent to the server of the entry office at the U.S. port. In the case that the quantity data is different from the invoice data or the RFID data that the Hong Kong port sent, or that the light sensor in the container detects bright light in the container, the SCEM system considers it a theft and sends the information to the manufacturer and the customer. Through the monitoring of the theft, the SCEM system asks all supply chain partners such as the customs offices and the Hong Kong port to investigate the theft. Concurrently, the alert and notification part of the SCEM system sends the information of the unexpected event, provides the customer with options to fulfill their order and requests the customer’s opinion about the manufacturer’s options. After receiving feedback from the customer, through the simulation and optimization, the SCEM system makes decisions and solutions to fulfill the customer’s needs. For instance, if the customer still wants to receive the same amount as the missing goods on time, the SCEM system confirms that these goods are available as safety stocks in a distribution center near the warehouse of the customer or the same goods as cancelled orders of other customers. Furthermore, the system automatically sends the message that the customer’s order can be fulfilled on time to the customer. In addition, if the customer wants the goods but they do not have to be delivered on time, the system may ask the factory to manufacture as many goods as the customer wants. The results of the investigation are added to the measure part of the system, and this information is shared with all partners in the supply chain and used to prevent a similar theft from occurring. As various sensors are used with RFID technology, more unexpected events such as the physical damage from external crash, water damage of goods and delayed goods could be detected. The events could then be managed efficiently and coped with in real time.

The application of RFID for direct shipment
Direct shipment is a shipment from a factory directly to a retailer bypassing distribution centers or warehouses. Most electronic companies have sales subsidiaries or offices in the U.S. as well as factories in China. The sales subsidiary has warehouses or distribution centers to consolidate goods for the retailer’s order and to fulfill the order quickly. Normally, the goods from a factory in China go to the warehouse of the sales subsidiary. Once the sales subsidiary receives a
purchase order from a retailer, the goods are delivered from the warehouse of the sales subsidiary in U.S. In the case of direct shipment, however, once the sales subsidiary receives a purchase order from a retailer, the goods are shipped directly from a factory in China. By using direct shipment, the manufacturer can reduce logistics costs such as goods holding costs and operating warehouse costs considerably. Furthermore, the shipment lead time can be decreased because goods bypass the warehouse of the sales subsidiary. The shipment costs can also be reduced because of the shorter route. The important factor in increasing direct shipment is end-to-end visibility. Since it is very difficult for manufacturers to track containers in real time after they leave their factories, direct shipment is not used frequently. In order to increase the utilization of direct shipment, exact and real time supply chain visibility should be provided.

Figure 25 shows the RFID enabled direct shipment process.

The collaborators in a supply chain can get information to track containers in real time by using RFID technology. Although a container bypasses the warehouse of a sales subsidiary, a manufacturer can track the container in real time. A manufacturer can also monitor the delivery lead time and confirm the time of departure and arrival in real time.
This RFID technology would enable the companies to increase their utilization of direct shipment.

In Section 4.3.3, I calculate the cost savings that would occur through using direct shipment and analyze the sensitivity of the cost savings - result from increasing the ratio of using direct shipment.

The application of RFID for Cross docking

Cross-docking means receiving goods at one door and shipping out through the other door almost immediately without putting them in storage. In the cross docking system, goods arrive at warehouses from the manufacturer, are transferred to vehicles serving the retailers, and are delivered to the retailers as rapidly as possible. Goods spend very little time in storage at the warehouse – often less than 12 hours. Cross docking reduces handling and storage of inventory, and so the step of filling a warehouse with inventory before shipping it out is virtually eliminated. It serves a number of objectives. It helps reduce operating costs, increase throughput, reduces inventory levels, and helps to increase sales space.

Cross docking requires that distribution centers, retailers and manufacturers are linked with advanced information systems to ensure that all pickups and deliveries are made within the required time windows. If RFID technology is used for the cross docking system, real time information of scanning RFID data can be shared among the collaborators in the supply chain, which it would enable them to operate the cross docking system more precisely and to increase the utilization of cross docking. Therefore, real time information is a vital factor for using cross docking efficiently. Figure 26 presents the working flow of cross docking, using RFID technology.
Using scanned RFID data, 3PL can confirm actual time of arrival and departure of containers. Considering the transportation read time, 3PL requests a trucking company to send trucks before containers arrive at the cross docking warehouse. Within a few hours, the goods are unloaded from containers, consolidated according to destination, and loaded onto trucks waiting at the warehouse. Hence, as the cross docking system is used, goods do not have to be stored for long time at the warehouse. To sum up, RFID technology will enable companies to operate cross docking system efficiently and precisely. This technology also can reduce inventory costs and decrease lead times considerably.

Below figure 27 shows the SCEM system architecture with RFID infrastructure and sensors.
4.3.3 The expected value of the RFID enabled SCEM

Through RFID enabled supply chain event management, companies in the supply chain can attain real time visibility to operational deviations from execution plans and their expected performance. As they can monitor events actively, Companies can provide better customer service or maintain customer service levels at a lower costs by reducing expedites. Especially, as RFID technology is used for supply chain event management, by increasing the utilization of direct shipment and cross docking, companies can have tangible impact on costs and shortening delivery lead time.

The estimated cost savings by using direct shipment

Below I calculate the holding cost which is eliminated by using direct shipment. Holding cost is that the cost of carrying one unit in inventory for a specified period of time, usually one year. This includes the opportunity cost of the money invested, the expenses incurred in running a warehouse, handling and counting costs, the costs of special storage requirements, deterioration of stock, damage, theft, obsolescence, insurance, and taxes.
Assumption
Basically, I use the same assumption and data of 4.2.2., which were used to calculate the gain by reducing the barcode scanning labor.
- Below 7 electronic products are the subjects of calculation..
  Hard disc drive, Optical disc drive, Camcorder, DVD player, 17 inch monitor, Microwave oven and 25 inch TV (Appendix A)
- Shipping 1000 containers per product per year from China to U.S.
  (Hard disc drive and optical disc drive : shipping 600 containers per year )
- The delivery lead time from a Chinese factory to U.S Customs is 14 days (2 weeks)
- There is no seasonality and order quantity is always uniform. (Appendix B)
- 50 weeks per year

[Method]
For calculating holding cost, below equation is used

\[ \text{Holding cost} = v \times r \times \frac{Q}{2} \]

\( v \): Variable (Purchase) Cost (dollars/unit)
\( r \): Carrying or Charge (dollars/dollars held/time)
\( Q \): Replenishment Order Quantity (units/order)

I assume that \( r \) is 0.2 for the seven products and use the actual variable cost of the most popular products of an electronics company (Appendix C).
Since I assume there is no seasonality and order quantity is uniform for a year, in order to get \( Q \) value, the annual quantity of shipped products is divided by 25 (25 order times = 50 weeks per year \( \div \) 2 weeks of lead time) For instance, 8,437,500 units of a camcorder are shipped per year. In order to get \( Q \) value of the camcorder, 8,437,500 are divided by 25 and the \( Q \) is 337,500 units per order. Using the same method, I calculate the \( Q \) of seven products (Appendix B).
I created five different situations of direct shipment to analyze the sensitivity of increasing the use of direct shipment. 10% of the \( Q \), 20%, 30%, 40%, or 50% are shipped directly.
Below, the table presents the results of calculation by situation.

<table>
<thead>
<tr>
<th>Product</th>
<th>10% Holding Cost (vrQ/2)</th>
<th>20% Holding Cost (vrQ/2)</th>
<th>30% Holding Cost (vrQ/2)</th>
<th>40% Holding Cost (vrQ/2)</th>
<th>50% Holding Cost (vrQ/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disc drive</td>
<td>405,000</td>
<td>810,000</td>
<td>1,215,000</td>
<td>1,620,000</td>
<td>2,025,000</td>
</tr>
<tr>
<td>Optical Disc drive</td>
<td>113,400</td>
<td>226,800</td>
<td>340,200</td>
<td>453,600</td>
<td>567,000</td>
</tr>
<tr>
<td>Camcorder</td>
<td>1,687,500</td>
<td>3,375,000</td>
<td>5,062,500</td>
<td>6,750,000</td>
<td>8,437,500</td>
</tr>
<tr>
<td>DVD player</td>
<td>150,000</td>
<td>300,000</td>
<td>450,000</td>
<td>600,000</td>
<td>750,000</td>
</tr>
<tr>
<td>17 inch Monitor</td>
<td>78,820</td>
<td>157,640</td>
<td>236,460</td>
<td>315,280</td>
<td>394,100</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>18,305</td>
<td>36,610</td>
<td>54,915</td>
<td>73,220</td>
<td>91,525</td>
</tr>
<tr>
<td>25 inch TV</td>
<td>39,777</td>
<td>79,554</td>
<td>119,330</td>
<td>159,107</td>
<td>198,884</td>
</tr>
<tr>
<td>Total</td>
<td>2,492,802</td>
<td>4,985,604</td>
<td>7,478,406</td>
<td>9,971,207</td>
<td>12,464,009</td>
</tr>
</tbody>
</table>

Table 4. Result of calculation of saving holding cost

As 10% of Q is shipped directly, the saving holding cost is $2,025,000. If the portion of direct shipment increases to 50%, the saving holding cost would be $12,464,009.

If direct shipment is utilized more frequently and the more replenishment order quantity is shipped directly through the application of RFID, companies can reduce considerably costs and delivery lead time - a good reason to invest in RFID.
4.3.4 Cost benefit analysis

In this section, I analyze cost benefit, which can be had by using RFID, to a manufacturing company. In order to calculate cost benefit, I first calculate both investment costs for application of RFID and cost savings that can be reduced directly by using RFID and also calculate the difference between investment costs and the cost savings. I consider the difference cost benefit. Basically, I use the same assumption and data of 4.3.3., which were used to calculate the holding costs. In addition, this cost benefit is for a consumer electronics company that manufactures goods in China and ships these to retailers in the U.S.

Investment costs

Below table 5 shows investment costs for implementing RFID at a 7 Chinese factories of a company.

<table>
<thead>
<tr>
<th>items</th>
<th>$/unit</th>
<th>unit/year</th>
<th>Sum $</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>0.2</td>
<td>30,598,873</td>
<td>6,119,775</td>
<td>Total shipped units of 7 products per year</td>
</tr>
<tr>
<td>Reader</td>
<td>2000</td>
<td>14</td>
<td>28,000</td>
<td>1 reader per 1 loading dock / 2 loading docks per 1 factory</td>
</tr>
<tr>
<td>Controllers</td>
<td>3000</td>
<td>7</td>
<td>21,000</td>
<td>1 controller per 1 factory</td>
</tr>
<tr>
<td>Encoders/printers</td>
<td>3000</td>
<td>14</td>
<td>42,000</td>
<td>2 production lines per 1 factory</td>
</tr>
<tr>
<td>RFID Host server</td>
<td>40,000</td>
<td>7</td>
<td>280,000</td>
<td>1 host server per 1 factory</td>
</tr>
<tr>
<td>RFID Middleware</td>
<td>100,000</td>
<td>7</td>
<td>700,000</td>
<td>1 middleware per 1 factory</td>
</tr>
<tr>
<td>Controller Software</td>
<td>10,000</td>
<td>7</td>
<td>70,000</td>
<td>1 controller software per 1 factory</td>
</tr>
<tr>
<td>Systems integration</td>
<td>200,000</td>
<td>1</td>
<td>200,000</td>
<td>7 factories use the same ERP system</td>
</tr>
<tr>
<td>Maintenance and etc</td>
<td>50,000</td>
<td>7</td>
<td>350,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>7,810,775</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Investment cost

Total estimated investment cost is $7,810,775 for first year in implementing RIFD. As shown in Table 5, the cost of tag is the biggest part. Since the costs for tag and maintenance are variable costs, these two costs will be added from the second year.

Cost savings

I calculate costs which can be saved directly by using RFID. These cost savings include (1) labor costs to scan barcodes of all boxes at factories in China, (2) labor costs to scan barcodes of
goods that arrive at sales subsidiary’s warehouse in the U.S. and (3) holding costs which can be saved by using direct shipment.

Figure 29 shows the transportation flow regarding cost savings.

![Transportation Flow Diagram](image)

Figure 29. The transportation flow

In Appendix D, there is the detailed result of calculating (1)&(2) labor costs by situation.

Below, table 6 presents the result of calculating total cost savings.

<table>
<thead>
<tr>
<th>%</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping 10% of all goods directly</td>
<td>$3,329,912</td>
</tr>
<tr>
<td>Shipping 20% of all goods directly</td>
<td>$5,641,717</td>
</tr>
<tr>
<td>Shipping 30% of all goods directly</td>
<td>$8,066,645</td>
</tr>
<tr>
<td>Shipping 40% of all goods directly</td>
<td>$10,491,573</td>
</tr>
<tr>
<td>Shipping 50% of all goods directly</td>
<td>$12,916,501</td>
</tr>
</tbody>
</table>

Table 6. Result of calculation of cost savings

As 10% of Q is shipped directly, the total cost savings, which includes labor costs and holding costs, is $3,329,912. If the portion of direct shipment increases to 50%, the total cost savings would be $12,916,501.

**Cost benefit**

Table 7 presents the difference between saving costs and investment costs. In order to estimate the difference after first year of implementing RFID, these costs are accumulated.
<table>
<thead>
<tr>
<th></th>
<th>1 year</th>
<th>for 2 years</th>
<th></th>
<th>3 years</th>
<th>for 4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost savings</td>
<td>Investment</td>
<td>Difference</td>
<td>Cost savings</td>
<td>Investment</td>
</tr>
<tr>
<td>10%</td>
<td>3,329,912</td>
<td>7,810,775</td>
<td>-4,480,863</td>
<td>6,659,824</td>
<td>14,280,549</td>
</tr>
<tr>
<td>20%</td>
<td>5,641,717</td>
<td>7,810,775</td>
<td>-2,169,058</td>
<td>11,283,434</td>
<td>14,280,549</td>
</tr>
<tr>
<td>30%</td>
<td>8,066,645</td>
<td>7,810,775</td>
<td>255,870</td>
<td>16,133,290</td>
<td>14,280,549</td>
</tr>
<tr>
<td>40%</td>
<td>10,491,573</td>
<td>7,810,775</td>
<td>2,680,799</td>
<td>20,983,146</td>
<td>14,280,549</td>
</tr>
<tr>
<td>50%</td>
<td>12,916,501</td>
<td>7,810,775</td>
<td>5,105,727</td>
<td>25,833,003</td>
<td>14,280,549</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cost savings</th>
<th>Investment</th>
<th>Difference</th>
<th>Cost savings</th>
<th>Investment</th>
<th>Difference</th>
<th>Cost savings</th>
<th>Investment</th>
<th>Difference</th>
<th>Cost savings</th>
<th>Investment</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>9,989,736</td>
<td>20,750,324</td>
<td>-10,760,588</td>
<td>13,319,648</td>
<td>27,220,099</td>
<td>-13,900,451</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>16,925,151</td>
<td>20,750,324</td>
<td>-3,825,173</td>
<td>22,566,868</td>
<td>27,220,099</td>
<td>-4,653,230</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>24,199,935</td>
<td>20,750,324</td>
<td>3,449,611</td>
<td>32,266,580</td>
<td>27,220,099</td>
<td>5,046,482</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>31,474,720</td>
<td>20,750,324</td>
<td>10,724,396</td>
<td>41,966,293</td>
<td>27,220,099</td>
<td>14,746,194</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>38,749,504</td>
<td>20,750,324</td>
<td>17,999,180</td>
<td>51,666,005</td>
<td>27,220,099</td>
<td>24,445,907</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 7, in the cases of shipping 30%, 40% and 50% of all goods directly, RFID can make cost benefit. This result, however, doesn’t include other benefits but saved labor costs and holding costs. If other benefits such as better supply chain visibility and improved customer service are calculated, cost benefits would be increased.
5 Summary and Suggestions

In this section, I discuss some of the findings of this thesis and give some suggestions for future work on the subject.

5.1 Summary

Survey

Through the survey of electronics companies and third party logistics companies, I found that most of companies consider that supply chain visibility, event management and Product Handling Productivity are the most important and efficient areas where they can make the most impact on their businesses by applying RFID technology.

The application of RFID for improving the current logistics processes

Figure 29 shows the route from China to the U.S. via the Hong Kong port. In Section 4.2, by having divided up the logistics processes into detailed parts, I discuss specific issues and suggestions for solving them through RFID technology. Table 5 presents a synthesis of the main issues and the expected value of each part of the whole process.

![Route from China to the U.S. via Hong Kong port](Image)

Figure 29. Route from China to the U.S. via Hong Kong port
<table>
<thead>
<tr>
<th>Part</th>
<th>Main issues</th>
<th>Potential of RFID to solve the issues</th>
<th>Ease of implementing RFID</th>
<th>Expected value</th>
</tr>
</thead>
</table>
| 1    | - Not scan barcodes of all products  
- Possible to mis-load  
- Possible to mis-ship  
- Long loading lead time | High | Simple | - Scan all data  
- Prevent mis-loading and mis-shipment  
- Decrease loading lead time |
| 2    | - much work load  
- long working lead time  
- low inspection quality  
- Possible for robbery | Moderate | Complex | - Decrease workload  
- Decrease working lead time  
- High inspection quality  
- prevent robbery |
| 3    | - many manual tasks  
- low internal logistics visibility  
- low product security | High | Simple | - Decrease manual tasks  
- Improve internal logistics visibility  
- Improve product security |

**Note.**

[Potential of RFID to solve the issues]

High: impact much directly on solving issues.
Moderate: impact less directly on solving issues.

[Ease of implementing RFID]

Simple: need to implement RFID to one site (e.g. factory or port)
Complex: need to implement RFID to many sites and need collaboration

Table 5. synthesis of the main issues and the expected value

As shown Table 5, I suggest that RFID be implemented at a factory or the Hong Kong port because of the potential for improving the current process, and using RFID for one site is relatively easy. However, in order to maximize the potential of RFID, the RFID application should be applied to the whole supply chain, and the data from RFID should be shared with collaborators in the supply chain.
The application of supply chain event management (SCEM)
RFID technology with sensors can be used for supply chain event management. RFID enables companies to monitor unplanned events actively and to respond rapidly and automatically to the events. As various sensing data can be used with RFID, more detailed events such as robbery and spoiling of fresh products can be detected in real time. Furthermore, through the application of RFID, the precise and real time supply chain visibility can be provided. This visibility enables companies to increase the utilization of various value added logistics techniques such as direct shipment and cross docking.

As shown in Table 4 in section 4.3.3, in the case of shipping 10% of all export goods directly, the utilization of direct shipment, which can increase through the application of RFID, can create considerable cost savings as high as $2,897,802 per year. If 50% is shipped directly, costs as high as $14,489,009 per year can be saved.

5.2 Suggestions for future work
In this thesis, I surveyed consumer electronics companies and third party logistics companies and defined the main issues in the current supply chain from China to the U.S. via the Hong Kong port. I also suggested the TO-BE RFID enabled logistics processes to solve the issues and the application of RFID to improve supply chain event management.

However, it would be interesting to study how RFID technology is implemented to be able to operate the TO-BE RFID enabled logistics process. For example, it would be interesting to study certain questions: what kind of tags can be used, what kind of data format is shared among collaborators in supply chain and how sensors work with RFID.

In addition, from a financial point of view, it would also be interesting to calculate ROI of implementing RFID for various business processes. As the costs of RFID tag and reader are decreasing continuously, and the store of know-how about the application of RFID is accumulated through many companies' trial tests of RFID implementation, it is anticipated that investment in the application of RFID will decrease. Therefore, calculating Return On Investment (ROI) will be needed before applying RFID to real business processes.
References


Vairavan Ramanathan, “SAP Auto-ID Infrastructure”, SAP Corporate research, 2003


## Appendix

### Appendix A.

<table>
<thead>
<tr>
<th>Product</th>
<th>CBM</th>
<th>product quantity per container</th>
<th>container quantity per year</th>
<th>Shipping quantity per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disc drive</td>
<td>0.002</td>
<td>33750</td>
<td>600</td>
<td>20,250,000</td>
</tr>
<tr>
<td>Optical Disc drive</td>
<td>0.005</td>
<td>13500</td>
<td>600</td>
<td>8,100,000</td>
</tr>
<tr>
<td>Camcorder</td>
<td>0.008</td>
<td>8438</td>
<td>1,000</td>
<td>8,437,500</td>
</tr>
<tr>
<td>DVD player</td>
<td>0.027</td>
<td>2500</td>
<td>1,000</td>
<td>2,500,000</td>
</tr>
<tr>
<td>17 inch Monitor</td>
<td>0.12</td>
<td>563</td>
<td>1,000</td>
<td>563,000</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>0.118</td>
<td>572</td>
<td>1,000</td>
<td>572,034</td>
</tr>
<tr>
<td>25 inch TV</td>
<td>0.224</td>
<td>301</td>
<td>1,000</td>
<td>301,339</td>
</tr>
</tbody>
</table>

### Appendix B.

<table>
<thead>
<tr>
<th>Product</th>
<th>EOQ</th>
<th>Direct shipment Q (10%)</th>
<th>Direct shipment Q (20%)</th>
<th>Direct shipment Q (30%)</th>
<th>Direct shipment Q (40%)</th>
<th>Direct shipment Q (50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disc drive</td>
<td>810,000</td>
<td>81,000</td>
<td>162,000</td>
<td>243,000</td>
<td>324,000</td>
<td>405,000</td>
</tr>
<tr>
<td>Optical Disc drive</td>
<td>324,000</td>
<td>32,400</td>
<td>64,800</td>
<td>97,200</td>
<td>129,600</td>
<td>162,000</td>
</tr>
<tr>
<td>Camcorder</td>
<td>337,500</td>
<td>33,750</td>
<td>67,500</td>
<td>101,250</td>
<td>135,000</td>
<td>168,750</td>
</tr>
<tr>
<td>DVD player</td>
<td>100,000</td>
<td>10,000</td>
<td>20,000</td>
<td>30,000</td>
<td>40,000</td>
<td>50,000</td>
</tr>
<tr>
<td>17 inch Monitor</td>
<td>22,520</td>
<td>2,252</td>
<td>4,504</td>
<td>6,756</td>
<td>9,008</td>
<td>11,260</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>22,881</td>
<td>2,288</td>
<td>4,576</td>
<td>6,864</td>
<td>9,153</td>
<td>11,441</td>
</tr>
<tr>
<td>25 inch TV</td>
<td>12,054</td>
<td>1,205</td>
<td>2,411</td>
<td>3,616</td>
<td>4,821</td>
<td>6,027</td>
</tr>
</tbody>
</table>
Appendix C.

<table>
<thead>
<tr>
<th>Product</th>
<th>( v ) ($/unit)</th>
<th>( r ) ($/$/unit time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disc drive</td>
<td>100</td>
<td>0.2</td>
</tr>
<tr>
<td>Optical Disc drive</td>
<td>35</td>
<td>0.2</td>
</tr>
<tr>
<td>Camcorder</td>
<td>500</td>
<td>0.2</td>
</tr>
<tr>
<td>DVD player</td>
<td>150</td>
<td>0.2</td>
</tr>
<tr>
<td>17 inch Monitor</td>
<td>350</td>
<td>0.2</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>80</td>
<td>0.2</td>
</tr>
<tr>
<td>25 inch TV</td>
<td>330</td>
<td>0.2</td>
</tr>
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</table>

Appendix D

<table>
<thead>
<tr>
<th>Saved labor costs ($)</th>
<th>7 factories in China</th>
<th>Saved labor costs ($)</th>
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<tbody>
<tr>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales subsidiary's</td>
<td>Putting into</td>
<td>113,123</td>
</tr>
<tr>
<td>warehouse in the U.S.</td>
<td>warehouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery to retailers</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>723,987</td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales subsidiary's</td>
<td>Putting into</td>
<td>271,495</td>
</tr>
<tr>
<td>warehouse in the U.S.</td>
<td>warehouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery to retailers</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>542,990</td>
</tr>
<tr>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales subsidiary's</td>
<td>Putting into</td>
<td>237,558</td>
</tr>
<tr>
<td>warehouse in the U.S.</td>
<td>warehouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery to retailers</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>475,117</td>
</tr>
<tr>
<td>40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales subsidiary's</td>
<td>Putting into</td>
<td>203,621</td>
</tr>
<tr>
<td>warehouse in the U.S.</td>
<td>warehouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery to retailers</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>407,243</td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales subsidiary's</td>
<td>Putting into</td>
<td>169,684</td>
</tr>
<tr>
<td>warehouse in the U.S.</td>
<td>warehouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery to retailers</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>339,369</td>
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</tbody>
</table>
### Appendix E

<table>
<thead>
<tr>
<th>items</th>
<th>$/unit</th>
<th>unit/year</th>
<th>Sum $</th>
<th>Fixed or Variable cost</th>
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</thead>
<tbody>
<tr>
<td>Tag</td>
<td>0.2</td>
<td>30,598,873</td>
<td>6,119,775</td>
<td>V</td>
</tr>
<tr>
<td>Reader</td>
<td>2000</td>
<td>14</td>
<td>28,000</td>
<td>F</td>
</tr>
<tr>
<td>Handheld reader</td>
<td>3000</td>
<td>0</td>
<td>-</td>
<td>F</td>
</tr>
<tr>
<td>Controllers</td>
<td>3000</td>
<td>7</td>
<td>21,000</td>
<td>F</td>
</tr>
<tr>
<td>Encoders/printers</td>
<td>3000</td>
<td>14</td>
<td>42,000</td>
<td>F</td>
</tr>
<tr>
<td>RFID Host server</td>
<td>40,000</td>
<td>7</td>
<td>280,000</td>
<td>F</td>
</tr>
<tr>
<td>RFID Middleware</td>
<td>100,000</td>
<td>7</td>
<td>700,000</td>
<td>F</td>
</tr>
<tr>
<td>Controller Software</td>
<td>10,000</td>
<td>7</td>
<td>70,000</td>
<td>F</td>
</tr>
<tr>
<td>Systems integration</td>
<td>200,000</td>
<td>1</td>
<td>200,000</td>
<td>F</td>
</tr>
<tr>
<td>Maintenance and etc</td>
<td>50,000</td>
<td>7</td>
<td>350,000</td>
<td>V</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>7,810,775</strong></td>
<td></td>
</tr>
</tbody>
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### Appendix F

<table>
<thead>
<tr>
<th>Accumulated investment costs</th>
<th>1 year</th>
<th>2 year</th>
<th>3 year</th>
<th>4 year</th>
<th>5 year</th>
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</thead>
<tbody>
<tr>
<td>积価投資費用</td>
<td>7,810,775</td>
<td>14,280,549</td>
<td>20,750,324</td>
<td>27,220,099</td>
<td>33,689,873</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum of fixed cost</th>
<th>1,341,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of variable cost</td>
<td>6,469,775</td>
</tr>
</tbody>
</table>