ANALYSIS, DESIGN, AND IMPLEMENTATION OF AN RFID-ENABLED INVENTORY MANAGEMENT SYSTEM

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Title: Analysis ,Design and Implement of RFID enabled Inventory Management System

Introduction

"Inventory" to many business owners is one of the more visible and tangible aspects of doing business. Raw materials, goods in process and finished goods all represent various forms of inventory. Each type represents money tied up until the inventory leaves the company as purchased products. Likewise, merchandise stocks in a retail store contribute to profits only when their sale puts money into the cash register.

In a literal sense, inventory refers to stocks of anything necessary to do business. These stocks represent a large portion of the business investment and must be well managed in order to maximize profits. In fact, many small businesses cannot absorb the types of losses arising from poor inventory management. Unless inventories are controlled, they are unreliable, inefficient and costly.

If you're standing in the middle of a big retailer such as Wal-Mart, and you look around, you're witnessing one of history's greatest logistical triumphs. Retailers such as Target, Lowe's and Best Buy stock tens of thousands of items from all over the world. Wal-Mart alone stocks items made in more than 70 countries (10). At any given time, the Arkansas-based retailer manages an average of $32 billion in inventory, reports Supply Chain Digest. (10)

With those kinds of numbers, having an effective, efficient inventory control system, or inventory management system, is imperative. Wal-Mart's system helps it maintain its signature "everyday low prices" by telling store managers which products are selling and which are taking up shelf and warehouse space.

Inventory management systems are the rule for such enterprises, but smaller businesses and vendors use them, too. The systems ensure customers always have enough of what they want and balance that goal against a retailer's financial need to maintain as little stock as possible. Mismanaged inventory means disappointed customers, too much cash tied up in warehouses and slower sales. Factors such as quicker production cycles, a proliferation of products, multi-national production contracts and the nature of the big-box store make them a necessity.

Modern inventory management systems must have the ability to track sales and available inventory, communicate with suppliers in near real-time and receive and incorporate other data, such as seasonal demand. They also must be flexible, allowing for a merchant's intuition. And, they must tell a storeowner when it's time to reorder and how much to purchase.

To achieve this, inventory management systems pull together several technologies into one cohesive approach. Automatic Identification and Data Capture (AIDC) techniques like barcode and Radio Frequency Identification (RFID) are used to automatically identifying objects, collecting data about them, and entering that data directly into computer systems (i.e. without human involvement).

Chapter 1

Role of inventory management in working capital

Inventories are a component of the firm's working capital and, as such, represent a current asset. Some characteristics are important in the broad context of working capital management

ROLE IN WORKING CAPITAL

Inventories are a component of the firm's working capital and, as such, represent a current asset. Some characteristics are important in the broad context of working capital management, including:

1. **Current Asset:** It is assumed that inventories will be converted to cash in the current accounting cycle, which is normally, one year. In some cases, this is not entirely true, for example, a vintner may require that the wine be aged in casks or bottles for many years. In spite of these and similar problems, we will view all inventories as being convertible into cash in a single year.

2. **Level of Liquidity:** Inventories are viewed as a source of near-all cash. For most products, this description is accurate. At the same time, most firms hold some slow-moving items that may not be sold for a long time. With economic slowdowns or changes in the market for goods, the prospects for sale of entire product lines may be diminished. In these cases, the liquidity aspects of inventories become highly important to the manager of working capital. At a minimum, the analyst must recognize that inventories are the least liquid of current assets. For firms with highly uncertain operating environments, the analyst must discount the liquidity value

PURPOSE OF INVENTORIES

The purpose of holding inventories is to allow the firm to separate the processes of purchasing, manufacturing, and marketing of its primary products. The goal is to achieve efficiencies in areas where costs are involved and to achieve sales at competitive prices in the marketplace. Within this broad statement of purpose, we can identify specific benefits that accrue from holding inventories.

1. **Avoiding Lost Sales:** Without goods on hand, which are ready to be sold, most firms would lose business. Some customers are willing to wait particularly when an item must be made to order or is not widely available from competitors. In most cases, however, a firm must be prepared to deliver goods on demand. Shelf stock refers to items that are stored by the firm and sold with little or no modification to customers. An automobile is an item of shelf stock. Even though customers may specify minor variations, the basic item leaves a factory and is sold as a standard item. The same situation exists for many items of heavy machinery, consumer products, and light industrial goods.

2. **Gaining Quantity Discounts:** In return for making bulk purchases, many suppliers will reduce the price of supplies and component parts. The willingness to place large orders may allow the firm to achieve discounts on regular prices. These discounts will reduce the cost of goods sold and increase the profits earned on a sale.

3. **Reducing Order Costs:** Each time a firm places an order, it incurs certain expenses. Forms have to be completed, approvals have to be obtained, and goods that arrive must be accepted, inspected, and counted. Later, an invoice must be processed and payment made. Each of these costs will vary with the number of orders placed. By placing fewer orders, the firm will pay less to process each order.

4. **Achieving Efficient Production Runs:** Each time a firm sets up workers and machines to produce an item, startup costs are incurred. These are then absorbed as production begins. The longer the run, the smaller the costs to begin producing the goods. As an example, suppose it costs $12,000 to move machinery and begin an assembly line to produce electronic printers. If 1,200 printers are produced in a single three-day run, the cost of absorbing the startup expenses is $10 per unit (12,000/1,200). If the run could be doubled to 2,400 units, the absorption cost would drop to $5 per unit (12,000/2,400). Frequent setups produce high startup costs; longer runs involve lower costs.

These benefits arise because inventories provide a "buffer" between purchasing, producing, and marketing goods. Raw materials and other inventory items can be purchased at appropriate times and in proper amounts to take advantage of economic conditions and price incentives. The manufacturing process can occur in sufficiently long production runs and with pre-planned schedules to achieve efficiency and economies. The sales force can respond to customer needs and demands based on existing finished products. To allow each area to function effectively, inventory separates the three functional areas and facilitates the interaction among them.

Reducing Risk of Production Shortages: Manufacturing firms frequently produce goods with hundreds or even thousands of components. If any of these are missing, the entire production operation can be halted, with consequent heavy expenses. To avoid starting a production run and then discovering the shortage of a vital raw material or other component, the firm can maintain larger than needed inventories.

TYPES OF INVENTORY

Four kinds of inventories may be identified:

1. **Raw materials Inventory:** This consists of basic materials that have not yet been committed to production in a manufacturing firm. Raw materials that are purchased from firms to be used in the firm's production operations range from iron ore waiting processing into steel to electronic components to be incorporated into stereo amplifiers. The purpose of maintaining raw material inventory is to uncouple the production function from the purchasing function so that delays in shipment of raw materials do not cause production delays.

2. **Stores and Spares:** This category includes those products, which are accessories to the main products produced for the purpose of sale. Examples of stores and spares items are bolts, nuts, clamps, screws etc. These spare parts are usually bought from outside or sometimes they are manufactured in the company also.

3. **Work-in-Process Inventory:** This category includes those materials that have been committed to the production process but have not been completed. The more complex and lengthy the production process, the larger will be the investment in work-in-process inventory. Its purpose is to uncouple the various operations in the production process so that machine failures and work stoppages in one operation will not affect the other operations.

4. **Finished Goods Inventory:** These are completed products awaiting sale. The purpose of finished goods inventory is to uncouple the productions and sales functions so that it no longer is necessary to produce the goods before a sale can occur.

Costs Associated with Inventories

The effective management of inventory involves a tradeoff between having too little and too much inventory. In achieving this trade off, the Finance Manager should realize that costs may be closely related.

The effective management of inventory involves a tradeoff between having too little and too much inventory. In achieving this trade off, the Finance Manager should realize that costs may be closely related. To examine inventory from the cost side, five categories of costs can be identified of which three are direct costs that are immediately connected to buying and holding goods and the last two are indirect costs which are losses of revenues that vary with differing inventory management decisions.

The five costs of holding inventories are:

1. Material Costs of Inventory:

These are the costs of purchasing the goods including transportation and handling costs.

2. Ordering Costs:

Any manufacturing organization has to purchase materials. In that event, the ordering costs refer to the costs associated with the preparation of purchase requisition by the user department, preparation of purchase order and follow-up measures taken by the purchase department, transportation of materials ordered for, inspection and handling at the warehouse for storing. At times even demurrage charges for not lifting the goods in time are included as part of ordering costs.

3. Carrying Costs:

These are the expenses of storing goods. Once the goods have been accepted, they become part of the firm's inventories. These costs include insurance, rent/depreciation of warehouse, salaries of storekeeper, his assistants and security personnel, financing cost of money locked-up in inventories, obsolescence, spoilage and taxes.

4. Cost of funds tied up with Inventory:

Whenever a firm commits its resources to inventory, it is using funds that otherwise might be available for other purposes. The firm has lost the use of funds for other profit making purposes. This is its opportunity cost. Whatever the source of funds inventory has a cost in terms of financial resources. Excess inventory represents an unnecessary cost.

Ordering Costs of inventory:

Any manufacturing organization has to purchase materials. In that event, the ordering costs refer to the costs associated with the preparation of purchase requisition by the user department, preparation of purchase order and follow-up measures taken by the purchase department, transportation of materials ordered for, inspection and handling at the warehouse for storing. At times even demurrage charges for not lifting the goods in time are included as part of ordering costs. Sometimes, some of the components and/or material required for production may have facilities for manufacture internally.

If it is found to be more economical to manufacture such items internally, then ordering costs refer to the costs associated with the preparation of requisition forms by the user department, set-up costs to be incurred by the manufacturing department and transport, inspection and handling at the warehouse of the user department. By and large, ordering costs remain more or less constant irrespective of the size of the order although transportation and inspection costs may vary to a certain extent depending upon order size. But this is not going to significantly affect the behavior of ordering costs. As ordering costs are considered invariant to the order size, the total ordering costs can be reduced by increasing the size of the orders.

Suppose, the cost per order is $100 and the company uses 1200 units of a material during the year. The size of the order and the total ordering costs to be incurred by the company are given below.

Size of order (units)	100	150	200
Number of orders in a year	1	2	8
Total ordering costs @ $ 100 / order	$1200	$800	$600

From the above example, it can be easily seen that a company can reduce its total ordering costs by increasing the order size which in turn will reduce the number of orders. However, reduction in ordering costs is usually followed by an increase in carrying costs to be discussed now.

Carrying Inventory Costs:

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Size of orders (units):	100	500	200
Average value of inventory:	$2000	$3000	$4000
Carrying cost @ 25 percent of above:	$500	$750	$1000

From the above calculations, it can be easily seen that as the order size increases, the carrying cost also is increasing in a directly proportionate manner.

Cost of Running out of Goods:

These are costs associated with the inability to provide materials to the production department and / or inability to provide finished goods to the marketing department as the requisite inventories are not available. In other words, the requisite items have run out of stock for want of timely replenishment. These costs have both quantitative and qualitative dimensions. These are, in the case of raw materials, the loss of production due to stoppage of work, the uneconomical prices associated with `cash' purchases and the set-up costs, which can be quantified in monetary terms with a reasonable degree of precision.

As a consequence of this, the production department may not be able to reach its target in providing finished goods for sale. Its cost has qualitative dimensions as discussed below:

When marketing personnel are unable to honor their commitment to the customers in making finished goods available for sale, the sale may be lost. This can be quantified to a certain extent.

However, the erosion of the good customer relations and the consequent damage done to the image and good will of the company fall into the qualitative dimension and elude quantification.

Even if the stock-out cost cannot be fully quantified, a reasonable measure based on the loss of sales for want of finished goods inventory can be used with the understanding that the amount so measured cannot capture the qualitative aspects.

Chapter 2: Inventory Management Techniques

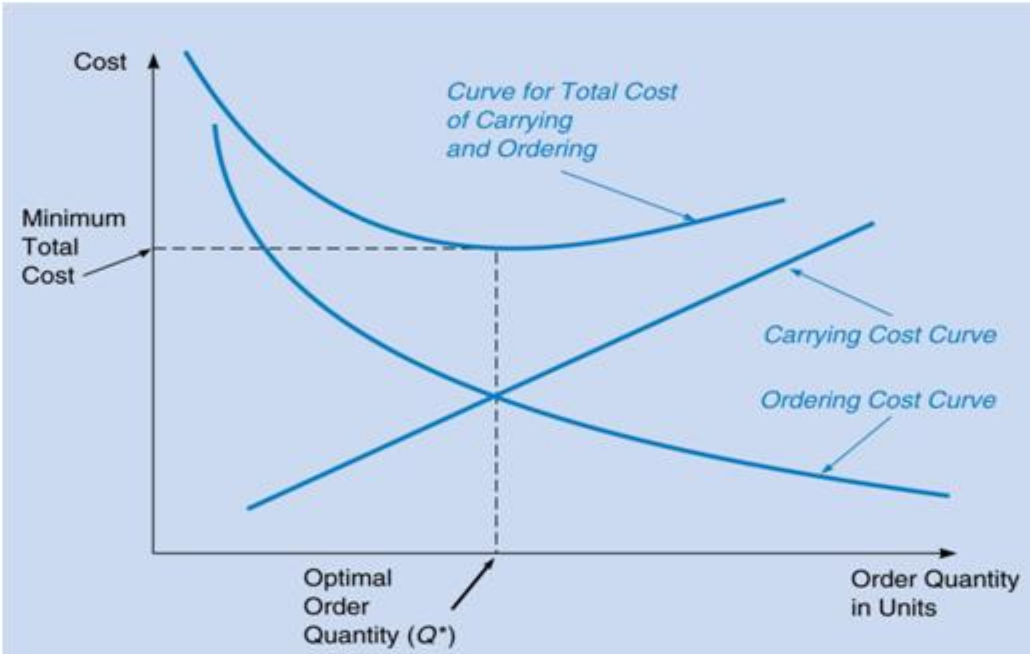
While the total ordering costs can be decreased by increasing the size of order, the carrying costs increase with the increase in order size indicating the need for a proper balancing of these two types of costs behaving in opposite directions with changes in order size.

Again, if a company wants to avert stock-out costs it may have to maintain larger inventories of materials and finished goods, which will result in higher carrying costs. Here also proper balancing of the costs becomes important.

Thus, the importance of effective inventory management is directly related to the size of the investment in inventory. To manage its inventories effectively, a firm should use a systems approach to inventory management. A systems approach considers in a single model all the factors that affect the inventory.

ECONOMIC ORDER QUANTITY

The economic order quantity (EOQ) refers to the optimal order size that will result in the lowest total of order and carrying costs for an item of inventory given its expected usage, carrying costs and ordering cost. By calculating an economic order quantity, the firm attempts to determine the order size that will minimize the total inventory costs.



Total inventory cost = Ordering cost + Carrying cost

Total ordering costs = Number of orders x Cost per order

= $ U / Q X F

Where

U = Annual usage

Q = Quantity ordered

F = Fixed cost per order

the total carrying costs = Average level of inventory x Price per unit x Carrying cost (percentage)

Total carrying costs

= $ Q / 2 x P x C

= $ QPC / 2

Where

Q = Quantity ordered

P = Purchase price per unit

C = Carrying cost as %

As the lead-time (i.e., time required for procurement of material) is assumed to be zero an order for replenishment is made when the inventory level reduces to zero. The level of inventory will be equal to the order quantity (Q units) to start with. It progressively declines (though in a discrete manner) to level O by the end of period 1. At that point an order for replenishment will be made for Q units. In view of zero lead-time, the inventory level jumps to Q and a similar procedure occurs in the subsequent periods. As a result of this the average level of inventory will remain at (Q/2) units, the simple average of the two end points Q and Zero.

From the above discussion the average level of inventory is known to be (Q/2) units. From the previous discussion, we know that as order quantity (Q) increases the total ordering costs will decrease while the total carrying costs will increase. The economic order quantity, denoted by Q*, is that value at which the total cost of both ordering and carrying will be minimized. It should be noted that total costs associated with inventory

$$T = \$\,UF / Q + \$QPC / 2$$

Where the first expression of the equation represents the total ordering costs and the second expression the total carrying costs.

The total cost curve reaches its minimum at the point of intersection between the ordering costs curve and the carrying costs line. The value of Q corresponding to it will be the economic order quantity Q*. We can calculate the EOQ formula.

Behavior of costs associated with inventory for changes in order quantity. For order quantity Q to become EOQ the total ordering costs at Q should be equal to the total carrying costs.

Carry cost = Ordering cost

(D/Q*) x Co = (Q*/2) x Ch

Rearranging to solve for Q*:

Q* = $\sqrt{(2DC_o / C_h)}$

In the above formula, when `U' is considered as the annual usage of material, the value of Q* indicates the size of the order to be placed for the material, which minimizes the total inventory-related costs. When `U' is considered as the annual demand Q* denotes the size of production run.

Suppose a firm expects a total demand for its product over the planning period to be 10,000 units, while the ordering cost per order is $100 and the carrying cost per unit is $2. Substituting these values, EOQ = 2 x10, 000 x100 = 1000 units. 2

Thus, if the firm orders in 1000-unit lot size, it will minimize its total inventory costs.

SAFETY STOCK

Once again in real life situations one rarely comes across lead times and usage rates that are known with certainty. When usage rate and/or lead time vary, then the reorder level should naturally be at a level high enough to cater to the production needs during the procurement period and also to provide some measure of safety for at least partially neutralizing the degree of uncertainty.

The question will naturally arise as to the magnitude of safety stock. There is no specific answer to this question.

However, it depends, inter alia, upon the degree of uncertainty surrounding the usage rate and lead-time. It is possible to a certain extent to quantify the values that usage rate and lead-time can take along with the corresponding chances of occurrence, known as probabilities. These probabilities can be ascertained based on previous experiences and/or the judgmental ability of astute executives. Based on the above values and estimates of stock-out costs and carrying costs of inventory it is possible to work out the total cost associated with different levels of safety stock.

Once we realize that the higher the quantity of safety stock, the lower will be the stock-out cost and the higher will be the incidence of carrying costs, the formula for estimating the reorder level will call for a trade-off between stock-out costs and carrying costs. The reorder level will then become one at which the total stock-out costs (to be more precise, the expected stock-out costs) and the carrying costs will be at its minimum.

REORDER POINT SUBSYSTEM

In the EOQ model discussed we have made the assumption that the lead-time for procuring material is zero. Consequently, the reorder point for replenishment of stock occurs when the level of inventory drops down to zero. In view of instantaneous replenishment of stock the level of inventory jumps to the original level from zero level. In real life situations one never encounters a zero lead-time. There is always a time lag from the date of placing an order for material and the date on which materials are received. As a result the reorder level is always at a level higher than zero, and if the firm places the order when the inventory reaches the reorder point, the new goods will arrive before the firm runs out of goods to sell. The decision on how much stock to hold is generally referred to as the order point problem, that is, how low should the inventory be depleted before it is reordered.

The two factors that determine the appropriate order point are the procurement or delivery time stock which is the Inventory needed during the lead time (i.e., the difference between the order date and the receipt of the inventory ordered) and the safety stock which is the minimum level of inventory that is held as a protection against shortages.

Therefore Reorder Point = Normal consumption during lead-time + Safety Stock.

Several factors determine how much delivery time stock and safety stock should be held. In summary, the efficiency of a replenishment system affects how much delivery time is needed. Since the delivery time stock is the expected inventory usage between ordering and receiving inventory, efficient replenishment of inventory would reduce the need for delivery time stock. And the determination of level of safety stock involves a basic trade-off between the risk of stock-out, resulting in possible customer dissatisfaction and lost sales, and the increased costs associated with carrying additional inventory.

Another method of calculating reorder level involves the calculation of usage rate per day, lead time which is the amount of time between placing an order and receiving the goods and the safety stock level expressed in terms of several days' sales.

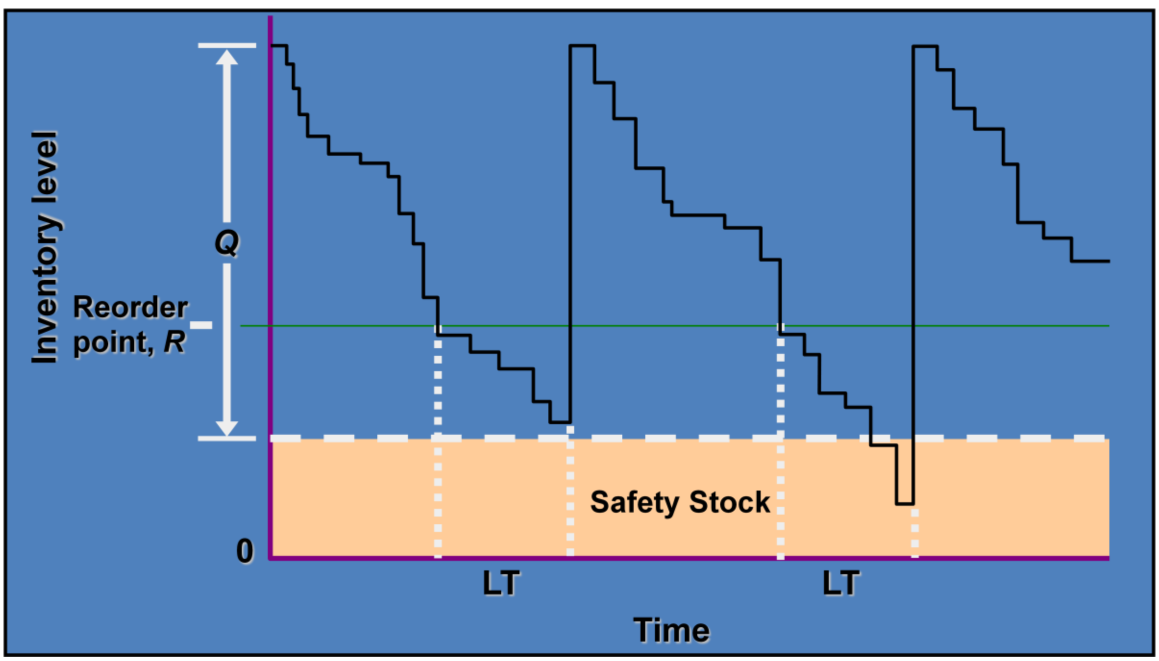
Reorder level = Average daily usage rate x lead-time in days.

From the above formula it can be easily deduced that an order for replenishment of materials be made when the level of inventory is just adequate to meet the needs of production during lead-time.

If the average daily usage rate of a material is 50 units and the lead-time is seven days, then

Reorder level =Average daily usage rate x Lead time in days = 50 units x 7 days = 350 units

When the inventory level reaches 350 units an order should be placed for material. By the time the inventory level reaches zero towards the end of the seventh day from placing the order materials will reach and there is no cause for concern.



Inventory Management History

In the earliest days of shop keeping, merchants wrote down purchases, or they looked at how many units were gone at the day's end and then did their best to forecast future needs. Experience and intuition were key skills, but it remained an inexact method, even when applied to operations that were quite small by today's standards.

After the Industrial Revolution, efficiency and mass production became the main goals of businesses, along with an improved customer experience at the point of sale. A team at Harvard University designed the first modern check-out system in the early 1930s. It used punch cards that corresponded with catalog items. A computer would read the punch cards and pass the information to the storeroom, which would then bring the item up front to the waiting customer. Because of the automated system, the machines could also generate billing records and manage inventory. The system proved to be too expensive to use, but a version of it is in use today in some stores, where merchants place cards with product information on the aisle for customers to select and bring to the checkout line. This usually applies to items that are expensive or large and to controlled items, such as medicines.

Merchants knew they needed a better system, and researchers created the forerunner of the modern bar-coding system in the late 1940s and early 1950s. It used ultraviolet light-sensitive ink and a reader to mark items for sale. Again, the system was too cumbersome and lacked the computing power needed to make it work. Technology had yet to catch up with their ideas.

The development of affordable laser technology in the 1960s revived the concept. Lasers allowed smaller, faster and cheaper readers or scanners. The modern bar code, or the Universal Product Code (UPC), was born and caught on just before the 1970s. As computing power became better, the power of UPC codes to help track and manage inventory improved exponentially.

During the mid to late 1990s, retailers began implementing modern inventory management systems, made possible in large part by advances in computer and software technology. The systems work in a circular process, from purchase tracking to inventory monitoring to re-ordering and back around again.

In recent years, another promising technology for tracking inventory has also has made its way into stores, warehouses and factories. Radio frequency identification, or RFID, uses a microchip to transmit product information -- such as type, manufacturer and serial number -- to a scanner or other data collection device. It's superior to bar codes in several ways. For instance, a scanner reads the information from an RFID from several yards away, making it ideal for tracking items stacked on high shelves in warehouses. It also can encode more data than a bar code and in some systems tell merchants if an item is out of place in the store, providing excellent anti-theft characteristics.

This thesis has focus on design and implementation of Inventory Management system using RFID technology at local retailer‘s warehouse – N-line Traffic Maintenance. Before we go ahead, we would have an overview of the RFID technology.

Chapter 3: Overview of RFID Technology

Radio Frequency Identification technology dates back to World War II. Attempting to reduce incidents of “friendly fire,” radio signals from one aircraft were beamed towards an approaching aircraft’s transponder; a corresponding signal from the second plane identified it as a friendly aircraft. Sixty some years later RFID has finally begun to gain widespread popularity, primarily because of recent reductions in size and cost, as well as more sophisticated functionality. This has led to the widespread applications making it prominent.

1. Introduction to RFID

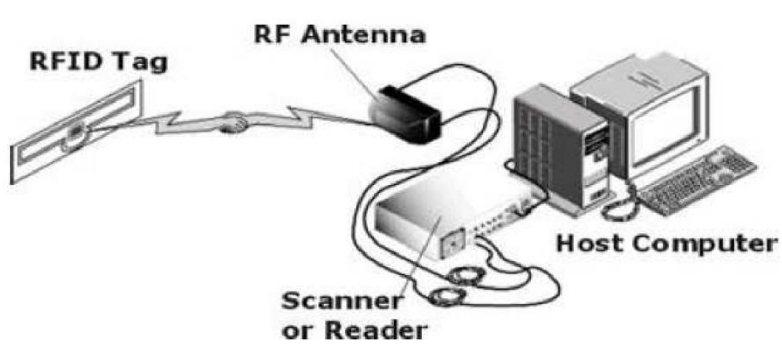
This is a flexible technology that is convenient, easy to use, and well-suited for automatic operation. It combines advantages not available with other identification technologies. It can be supplied as read-only or read/write, does not require contact or line-of-sight to operate, can function under a variety of environmental conditions, and provides a high level of data integrity. In addition, because the technology is difficult to counterfeit, RFID provides a high level of security.

RFID is similar in concept to bar coding. Bar code systems use a reader and coded labels that are attached to an item, whereas RFID uses a reader and special RFID devices that are attached to an item. Bar code uses optical signals to transfer information from the label to the reader; RFID uses RF signals to transfer information from the RFID device to the reader.

1.1 Components of RFID System

The principal components that constitute an RFID system are:

- RFID tag
- Interrogator / Scanner / Reader
- Middleware



1. *RFID Tag*

RFID tags consist of a microchip and a coupling element - an antenna. Most tags are only activated when they are within the interrogation zone of the interrogator; outside they "sleep". Tags can be both read-only (programmed during manufacture) or, at higher complexity and cost, read-write, or both. The tags contain memory. The size of the tag depends on the size of the antenna, which increases with range of tag and decreases with frequency.

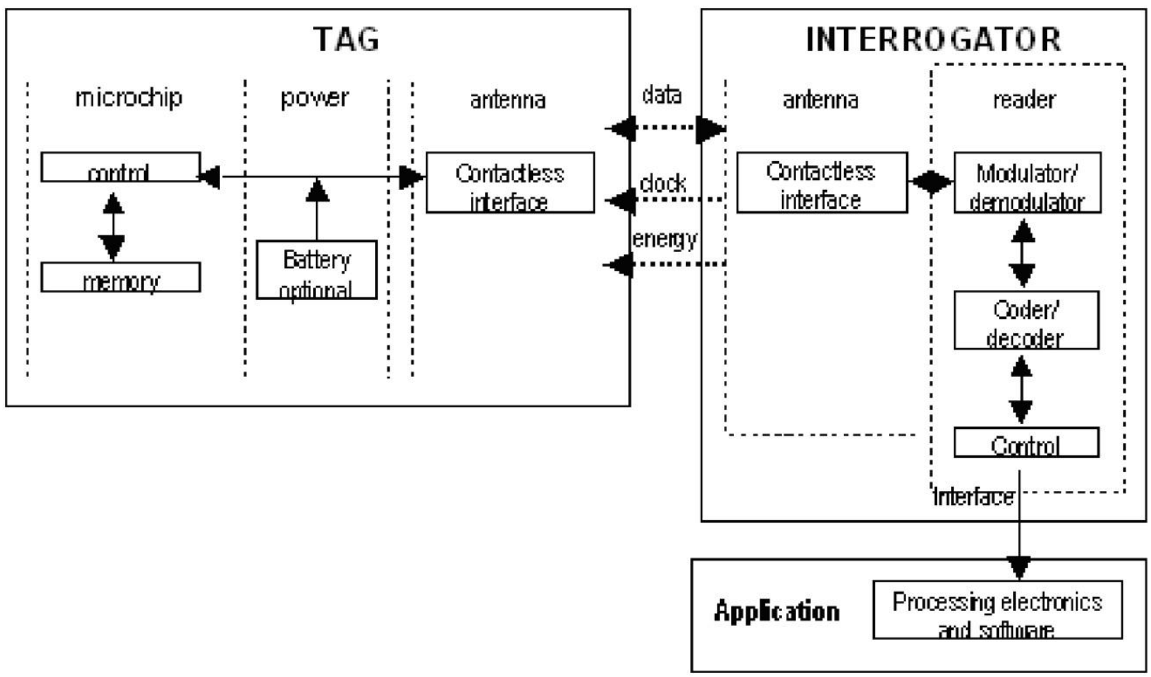
2. *Interrogator*

Depending on the application and technology used, some interrogators not only read, but also remotely write to, the tags. For the majority of low cost tags (tags without batteries), the power to activate the tag microchip is supplied by the reader through the tag antenna when the tag is in the interrogation zone of the reader, as is the timing pulse - these are known as passive tags.

3. *Middleware*

Middleware is the interface needed between the interrogator and the existing company databases and information management software.

System Overview



2. Description of devices and Operating frequencies

2.1 RFID tags

The Tags form the preliminary or the first stage of an RFID system. This in lot of applications initiates the working of the system. The tags are of various kinds and posses respective features which are adopted based on the applications. They are affixed over the item to be identified.

The basic constituents of an RFID tag are a microchip embedded with a unique code called as the Electronic product code (EPC) and an antenna. The presence of the EPC over the tags facilitates the identification process in the system. The EPC is unique for each tag being manufactured and is embedded onto the chip during manufacturing and cannot be tampered with after production.

In action, the tags communicate with the interrogators or RFID readers using the antenna and transmit the EPC which is used to identify the item. Based on their ability to communicate they are classified as Active, Passive and Semi-passive.

- Passive tags use the reader field as a source of energy for the chip and for communication from and to the reader. The available power from the reader field, not only reduces very rapidly with distance ,but is also controlled by strict regulations, resulting in a limited communication distance of 4 - 5m when using the UHF frequency band (860 MHz – 930 MHz).

- Semi-Passive (battery assisted backscatter) tags have built in batteries and therefore do not require energy from the reader field to power the chip. This allows them to function with much lower signal power levels, resulting in greater distances of up to 100 meters.

Distance is limited mainly due to the fact that tag does not have an integrated transmitter, and is still obliged to use the reader field to communicate back to the reader.

- Active tags are battery powered devices that have an active transmitter onboard. Unlike passive tags, active tags generate RF energy and apply it to the antenna. This autonomy from the reader means that they can communicate at distances of over several kilometers.

Passive tags are supposed to be the cheapest to produce, and must be within 4 feet of the reader. Like active tags, semi -passive tags also contain a battery, but the tag lies dormant until receiving a signal from the reader. This has the desirable effect of conserving battery power.

Both active and passive tags possess either read/write or read-only functionality. Read-only tags usually function like license plates by identifying the object and pointing to more specific information stored in a database. Read/write tags allow the information stored on the tag to be edited, locked or completely erased, which makes them re-usable. Read/write tags also store more information on the tag and may not require a database lookup or any contact with an external system

The three operating frequency bands of the RFID system are LF, HF and UHF. RFID tags can also be classified by frequency band used. The following table summarizes the characteristics and example applications of each band.

Frequency band	Frequency being used	Characteristics	Typical applications
LF - 100-500 kHz	125, 134 kHz	Short to medium read range Inexpensive low reading speed	Access control Animal identification Inventory control Car immobilizer
HF - 10-15 MHz	13.56 MHz	Short to medium read range potentially inexpensive medium reading speed	Access control Smart cards
UHF - 850-950 MHz 2.4-5.8 GHz	Dependent on country	Long read range High reading speed Line of sight required	Railroad car monitoring Toll collection systems

The tags are manufactured in various sizes and form to suite various applications. Some of the different formats are:

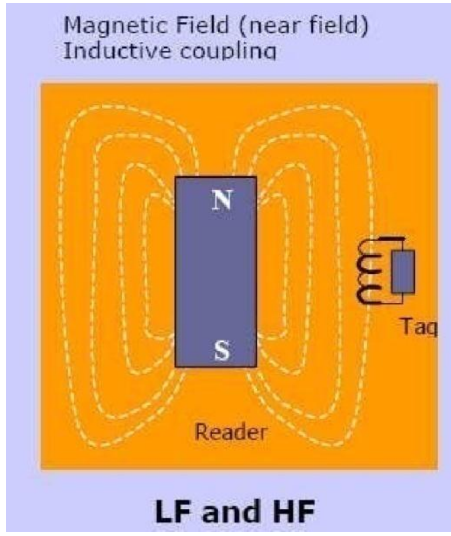
- Credit card size flexible labels with adhesive backs
- Tokens and coins
- Embedded tags – injection molded into plastic products such as cases
- Wrist band tags
- Hard tags with epoxy case

- Key fobs
- Tags designed especially for Palettes and cases
- Paper tags

2.4 Tag communication

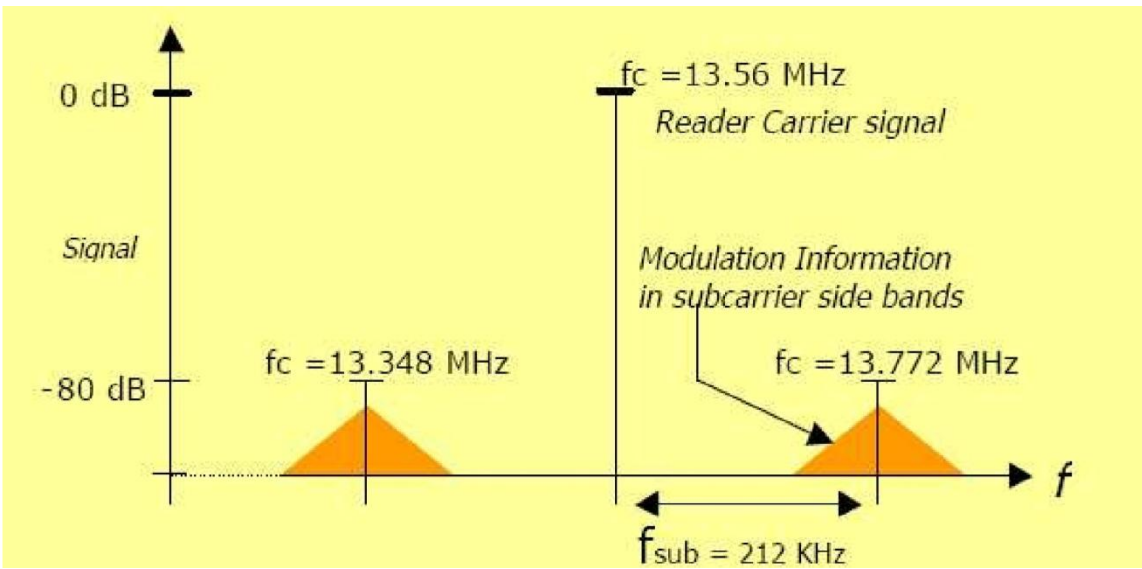
In order to receive energy and communicate with a reader, passive tags use one of the two following methods. These are near field which employs inductive coupling of the tag to the magnetic field circulating around the reader antenna (like a transformer), and far field which uses similar techniques to radar (backscatter reflection) by coupling with the electric field. The near field is generally used by RFID systems operating in the LF and HF frequency bands, and the far field for longer read range UHF and microwave RFID systems. The theoretical boundary between the two fields depends on the frequency used, and is in fact directly proportional to l/2p where l = wavelength. This gives for example around 3.5 meters for an HF system and 5 cm for UHF, both of which are further reduced when other factors are taken into account

2.4.1 Inductive coupling (Near fields)

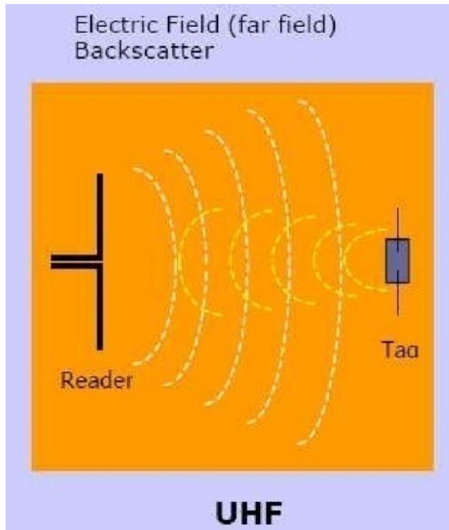


LF and HF tags use inductive coupling between two coils (reader antenna and tag antenna) in order to supply energy to the tag and send information. The coils themselves are actually tuned LC circuits, which when set to the right frequency (ex; 13.56 MHz) will maximize the energy transfer from reader to tag. The higher the frequency the less turns required (13.56 MHz typically uses 3 to 5 turns). Communication from reader to tag occurs by the reader modulating (changing) its field amplitude in accordance with the digital information to be transmitted (base band signal). The result is the well known technique called AM or Amplitude Modulation. The tags receiver circuit is able to detect the modulated field, and decode the original information from it.

However, while the reader has the power to transmit and modulate its field, a passive tag does not. The communication being achieved back from tag to reader is similar to a transformer, when the secondary coil (tag antenna) changes the load and the result is seen in the Primary (reader antenna).The tag chip accomplishes this same effect by changing its antenna impedance via an internal circuit, which is modulated at the same frequency as the reader signal. In fact it’s a little more complicated than this because, if the information is contained in the same frequency as the reader, then it will be swamped by it, and not easily detected due to the weak coupling between the reader and tag. To solve this problem, the real information is often instead modulated in the side-bands of a higher sub-carrier frequency which is more easily detected by the reader.



2.4.2 Backscatter reflection



Passive tags operating at the UHF and higher frequencies use similar modulation techniques (AM) as lower frequency tags, and also receive their power from the reader field. What is different however is the way that energy is transferred is, and the design of the antennas required capturing it? At this point, there is no further possibility of inductive coupling like in HF systems, because the magnetic field is no longer linked to the antenna. Transmission of this wave in the far field is the basis of all modern radio communication. In some systems such as transmission lines (coaxial cables), the propagation of these waves is restricted as much as possible via special shielding as they constitute a power loss. For antennas it’s the inverse, propagation is encouraged. When the propagating wave from the reader collides with a tag antenna in the form of a dipole, part of the energy is absorbed to power the tag and a small part is reflected back to the reader in a technique known as back-scatter. For the optimal energy transfer the length of the dipole must be equal to l/2, which gives a dimension of around 16 cm. The dipole is made up of two l/4 lengths.

Just as for lower frequency tags using near field inductive coupling, a passive UHF tag does not have the power to transmit independently. Communication from tag to reader is achieved by altering the antenna input impedance in time with the data stream to be transmitted. This results in the power reflected back to the reader being changed in time with the data i.e. it is modulated.

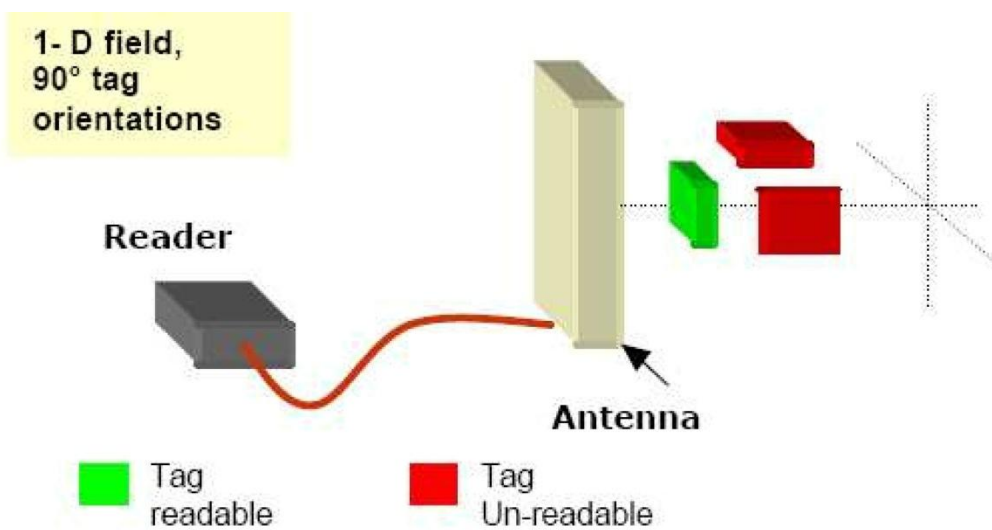
From an applications point of view, using the technique of far field back-scatter modulation introduces many problems that are not so prevalent in HF and lower frequency systems. One of the most important of these is due to the fact that the field emitted by the reader is not only reflected by the tag antenna, but also by any objects with dimensions in the order of the wavelength used. These reflected fields, if superimposed on the main reader field can lead to damping and even cancellation.

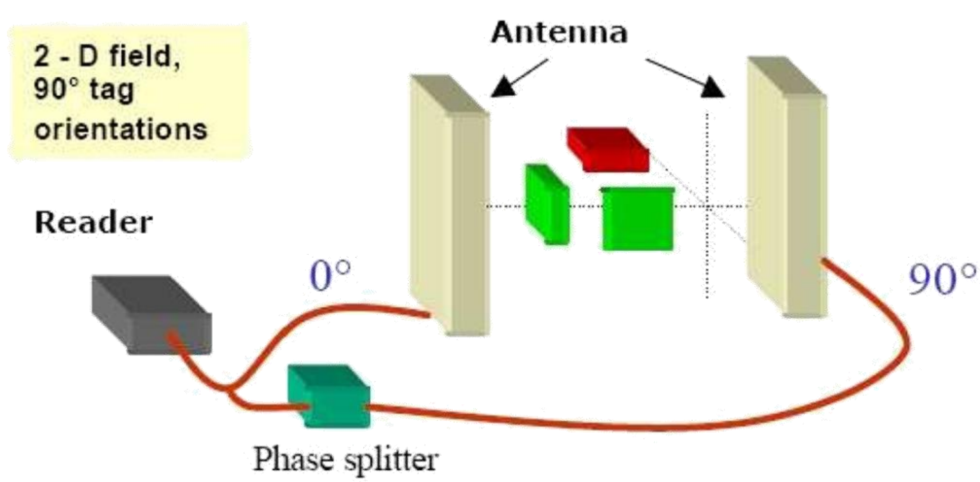
3. Antenna and Tag orientation

The Antennas form an integral part of the RFID system. The parameter of the antennas being employed decides the operational features of the system. The entire working of the system can be modeled basing the antenna parameters.

Antennas are found on the Tags and Interrogators in various forms and adhere to several factors such as frequency, polarization, medium of operation, antenna material, application, etc. They usually enhance the communication distance between the tags and the interrogators. Antennas on the tags are used for communication data stored on them, whereas the antennas on Interrogators are used for identifying the tags. Hence the orientation of the tags and the antennas at the read location matters to the application.

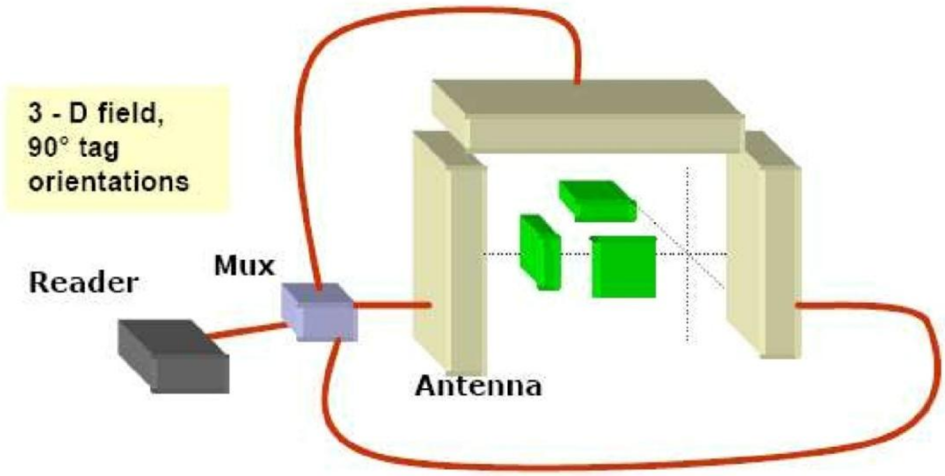
Here is described a case of tag orientation for HF tags and antennas at a read location for an Interrogator.





This case requires the tag to be parallel to the antenna as shown above for it to be identified and read by the Interrogator.

Here a Phase splitter is employed for two antenna structures being fed by a signal which is 90 degree out of phase with the original. This makes the tag readable in both directions.



This is the 3D case where tags are read in almost all the directions.

4. RFID Tag classes

The Auto-ID center at MIT is the body that ratifies standards for all RFID tags. The group called as EPC-Global defines the classes. Based on the ability of tags to read and write data. Currently, several classes of tags fall under the EPC global defined library. The difference between Class 0 and Class 1 is in the data structure and operation. Class 0 tags are read only. Class 1 tags are one-time writeable.

The EPC standards call for 5 classes of tags over time. The following table outlines the roadmap for the EPC tag class type:

Class type	*Features*	*Tag type*
Class 0	Read Only	Passive (64 bit only)
Class 1	Write Once, Read Many (WORM)	Passive (96 bit min.)
Class 2 *(Gen 2)*	Read Many (WORM) Passive (96 bit min.) Class 2 (Gen2)	Passive (96 bit min.)
Class 3	Read/Write with battery power to enhance range	Semi-Active
Class 4	Read/Write active transmitter	Active

CLASS 0 – READ ONLY. – Factory programmed

These are the simplest type of tags, where the data, which is usually a simple ID number, (EPC) is written only once into the tag during manufacture. The memory is then disabled from any further updates. Class 0 is also used to define a category of tags called EAS (electronic article surveillance) or anti-theft devices, which have no ID, and only announce their presence when passing through an antenna field.

CLASS 1 – WRITE ONCE READ ONLY (WORM) – Factory or User programmed

In this case the tag is manufactured with no data written into the memory. Data can then either be written by the tag manufacturer or by the user – one time. Following this no further writes are allowed and the tag can only be read. Tags of this type usually act as simple identifiers

CLASS 2 – READ WRITE

This is the most flexible type of tag, where users have access to read and write data into the tags memory. They are typically used as data loggers, and therefore contain more memory space than what is needed for just a simple ID number.

CLASS 3 – READ WRITE – with on board sensors

These tags contain on-board sensors for recording parameters like temperature, pressure, and motion, which can be recorded by writing into the tags memory. As sensor readings must be taken in the absence of a reader, the tags are either semi-passive or active.

CLASS 4 – READ WRITE – with integrated transmitters.

These are like miniature radio devices which can communicate with other tags and devices without the presence of a reader. This means that they are completely active with their own battery power source.

The chip manufacturer can only program the Class 0 tag; the Class 1 Version 1 tag can be programmed on the factory floor.

While functionally equivalent under the EPC global classification system, Class 0 and Class 1 use different hardware technologies to implement the Identity tag functionality. Class 0 tags are programmed when they are manufactured (referred to as “Read-Only” or “R/O”), assuring uniqueness of the tag ID. Class 1 tags can be programmed once, referred to as “Write Once Read Many” or “WORM”, by the user, providing operational flexibility.

Class 0 and Class 1 tags also use different protocols, or “air interfaces” to communicate. So, while both Identity tag implementations perform the required functions, they cannot communicate with each other. Tags of both classes can coexist in an environment, but require readers that “speak their language” to be identified.

4.1 EPC structure

As described above each tag contains a unique code facilitating the identification process known as EPC. The structure of this code been embedded is described below.

1. The EPC is a number made up of a header and three sets of data. The header identifies the EPC©s version number, allowing for different lengths or types of EPC later on.
2. The second part of the number identifies the EPC Manager, most likely the manufacturer of the product.
3. The third, called object class refers to the exact type of product, most often the Stock Keeping Unit (SKU).
4. The fourth is the serial number unique to the item, which can tell us, for example, exactly to which 330 ml can of Diet Coke we are referring. This makes it possible to quickly find products that might be nearing their expiration date.

Example of EPC 01.115A1D7.28A1E6.421CBA30A

01	Version of EPC (8 bit header)
115A1D7	Manufacturer Identifier 28 bits
28A1E6	Product Identifier 24 bits
421CB30A	Item serial number 36 bits

5. RFID standards

The international organization for standards has ratified standards for the RFID tags. The compliance depends on factors such as the operating frequency, type of tag and area of application.

ISO Standards for Proximity Cards:

ISO 14443 for *"proximity"* cards and ISO 15693 for *"vicinity"* cards both recommend 13.56 MHz as its carrier frequency. These standards feature a thinner card, higher memory space availability and allow numerous cards in the field to be read almost simultaneously using anti-collision, bit masking and time slot protocols.

- ISO 14443 proximity cards offer a maximum range of only a few inches. It is primarily utilized for financial transactions such as automatic fare collection, bankcard activity and high security applications. These applications prefer a very limited range for security.
- ISO 15693 vicinity cards, or Smart Tags, offer a maximum usable range of out to 28 inches from a single antenna or as much as 4 feet using multiple antenna elements and a high performance reader system.

ISO Standards for RFID Air interface.

The ISO 18000 series is a set of proposed RFID specifications for item management that could be ratified as standards during 2004. The series includes different specifications that cover all popular frequencies, including 135 KHz, 13.56 MHz, 860-930 MHz and 2.45 GHz.

- 18000 – 1 Part 1 – Generic Parameters for Air Interface Communication for Globally Accepted Frequencies

  - 18000 - Part 2: Parameters for Air Interface Communications below 135 KHz o ISO standard for Low Frequency

  - 18000 - Part 3: Parameters for Air Interface Communications at 13.56 MHz o ISO standard for High Frequency
- Read \ Write capability
  - 18000 - Part 4: Parameters for Air Interface Communications at 2.45 GHz
- ISO standard for Microwave Frequency o Read \ Write capability
- 18000 - Part 5: Parameters for Air Interface Communications at 5.8 GHz
- 18000 - Part 6: Parameters for Air Interface Communications at 860 – 930 MHz o ISO standard for UHF Frequency
- Read \ Write capability
- Targeted for same markets as EPC standards.
- 18000 – Part 7: Parameters for Air Interface Communications at 433.92 MHz
- Manifest tag for Department of Defense (DOD)

ISO Standards for Animal Identification

• ISO 11748 / 11785: Standard for Animal Identification

ISO Supply Chain Standards

These are used to identify different types of logistics containers and packaging, in addition to individual items.

- ISO 17358 - Application Requirements, including
- Hierarchical Data Mapping
- ISO 17363 - Freight Containers

- ISO 17364 - Returnable Transport Items
- ISO 17365 - Transport Units
- ISO 17366 - Product Packaging
- ISO 17367 - Product Tagging (DoD)
- ISO 10374.2 - RFID Freight Container Identification

Chapter 4: N-Line Pain Points

The N-line Inventory Management system implementation at N-Line Traffic is the primary goal of this thesis. We would first understand the business overview of the company.

Business Overview of N-Line traffic Maintenance

N-line Traffic is one of the largest traffic maintenance firms in Texas. It has around 250 employees together at 3 locations – Waco, Austin and Bryan. It also has a small manufacturing unit for making Traffic signs at Waco. N-Line sells as well as rents out traffic signs, cones and other related items to contractors who are working on maintenance of freeways and roads across Texas and nearby states. Sometimes, these items are directly leased to state agencies.

TX-DoT invites bids from the traffic maintenance companies when there is a need to block / divert the traffic on road due to repair work or any other reason. Generally the lowest bid wins. The bidding for N-Line is done by Chad England (co-owner). Occasionally it happens that the firm that wins the bid cannot execute the job; then these firms' requests others to do the jobs on their behalf. N-Line occasionally gets such requests.

Once the job's bid is won by N-line, then depending upon the size / type of job upper management plans for the job. The various activities that can be included in this planning are as under:

1. The job is carried out from the warehouse that is nearest to the job site to minimize cost.
2. Sometimes the items required for the job are not present in required quantities at the warehouse. In such a case the items are brought in from other warehouse else newly procured.
3. Occasionally N-Line gets a job which was not executed during last few years. In such cases the employees are trained for couple of days before the job.

4. For large jobs – generally with more than 50 items, the items are pre-loaded on the trucks. This ensures that the crew does not spend any time in the morning on job's day for loading.
5. For small jobs, crew loads items in the morning of the job.

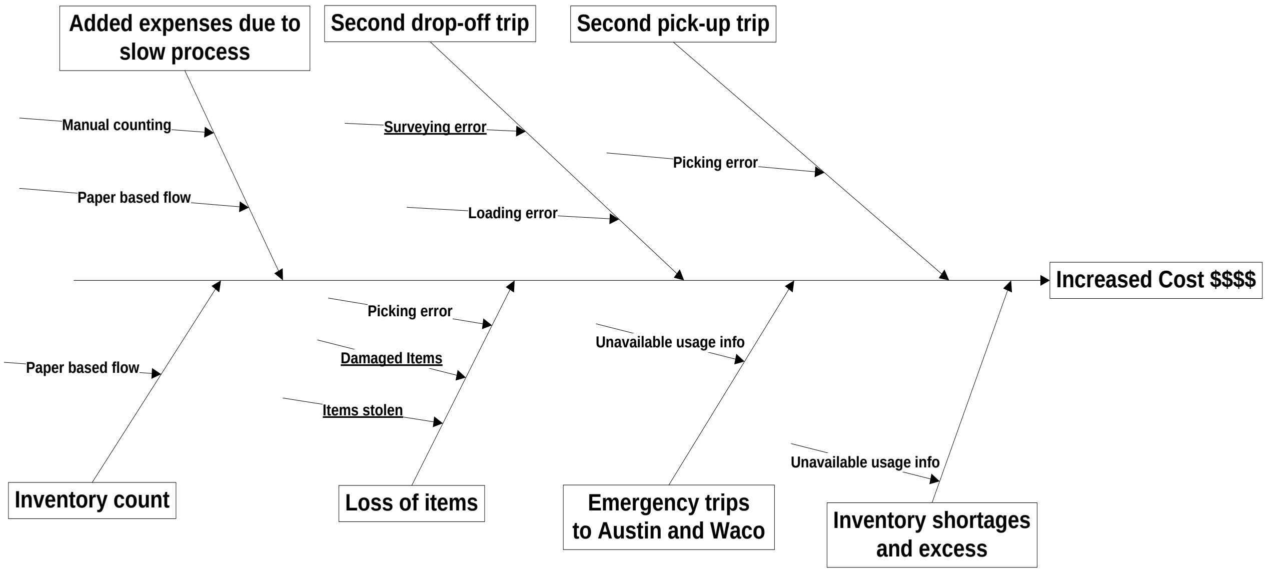
Other than the bids, N-Line also gets walk-in customers who either buy / lease the items. In such cases they have lease tickets which are essentially contracts between N-Line and the customer.

Pain area for N-Line

N-line currently uses a system similar to Excel spreadsheet to keep track of the inventory. The inventory is maintained by manually counting the items and then manual data entry into the system. This process has following drawbacks:

- ✓ Error prone at both stages (counting the items and data entry)
- ✓ Does not provide means to verify the inventory figures with the actual warehouse inventory
- ✓ Requires extensive manual intervention
- ✓ Considerable losses are incurred due to actions taken without having the knowledge of actual inventory status

The cause- effect (Ishikawa) diagram below helps to visualize the factors generating each one of the identified problems and the final effect (i.e., an increment in the total operational cost). It is important to clarify that some causes such as damaged or stolen items cannot be solved with the use of RFID technology.



Note: The underlined causes cannot be solved by RFID

Problems with Existing Inventory process at N-Line Traffic

1. Multiple drops off to job site:

We observed that on an average it takes around 1.5 trips to job site to drop the items. The 2nd trip is to drop items which the crew did not take in required quantity from warehouse or something they missed to account for during survey. Usually, it is a practice at N-line to carry about 10% more items than required to avoid shortages. The chances of missing in survey are rare as the site survey is generally done by experienced crew only. We can resolve the first issue of items forgot to pick up by having an electronic pick list. The system will not allow the crew to leave unless all the items on the pick list are scanned on the truck.

One more reason for multiple trips is that sometimes the crew forgets accessories like mounting iron brackets, cables etc. Although the cost of these items is very less (generally less than $10), crew has to make costly trips back and forth to warehouse to pick up them. We will not be tagging metal posts or cables, but we will include in the pickup sheet to verify whether crew has sufficient amount of these items on their truck. This will greatly reduce the chances that these items are left behind in warehouse.

2. Loss / Damage of assets :

   Considerable loss of N-Line’s assets is caused by the loss or damage of items. The main reasons are mishandling by employees or contractors, ageing of items and items being stolen or misplaced. We cannot prevent the items from being damaged / lost with the use of RFID technology, but we can isolate the culprit with it. Required action can be taken against the contractor or employees who are consistently causing damage to items.

3. Repeated trips to Waco / Austin warehouses :

   The Inventory system currently used by N-Line does not reflect accurate figures. It has observed many times that decisions were taken based upon these incorrect figures e.g. jobs were accepted when sufficient numbers of items are not present in warehouse actually. The management realized this mistake on verge of start of the job and hence had to expedite the delivery at a high cost to avoid the penalty on job contracts.

   With RFID implementation, management would receive real time updated information about the Inventory status. This would minimize the losses due to incorrect status of inventory.

4. Inventory Shortage in warehouses :

   This is similar to problem in previous point. Due to incorrect status of inventory in the current system, the management has challenges in maintaining the correct inventory level of all items in the warehouse. This leads to shortages at many times and management has to compromise with the jobs i.e. either reschedule them or fetch the items from other warehouses.

   We can reduce this issue to a great extent with use of RFID technology.

5. Excess Inventory :

   We found that N-line maintain much larger inventory than required primarily because they do not have correct inventory figures. For example: N-line‘s Bryan warehouse has around 2300 grabber cones while the peak annual usage is around 1100.

   We can release the large capital invested in the excess inventory by optimizing it with accurate inventory data using RFID technology.

6. Extensive manual intervention in Inventory process

   Currently the check in / checkout is managed by writing the details on paper which are later manually entered into the system by office clerk. This provides a lot of scope of manual errors like incorrect entry by worker/ clerk. We have observed many times that it is difficult to interpret the handwriting of the worker on piece of paper as they had scribbled while rushing to job.

   We will be automating the complete process with usage of RFID technology and would eliminate most of the manual errors subsequently.

7. Frequent count of Inventory

   We observed that management asks one of the crew to check the number of available items of required type for job every time they do planning for the job. This causes considerable waste of human resources. Moreover, often the crew cannot locate the items as they are not kept in appropriate locations. Hence management resorts to expediting the items from other warehouses.

Problem	Caused by	Consequences	Solved by RFID
1) Second drop-off trip to jobsite because material not sufficient	a) Human error in preparing survey/plan b) Human error in loading materials	• Increased operational costs: transportation cost, labor cost. • Wasted labor time in looking for items in the warehouse	a) No b) Yes
2) Second pick up trip to jobsite because material left at site	a) Human error in picking up items	• Increased operational costs: transportation cost, labor cost • Wasted labor time in looking for items at the job site	a) Yes
3) Loss of items at the job site	a) Human error in picking items b) Items being stolen c) Items being damaged by contractors	• Loss of inventory • Need to manufacture new items • Additional manufacturing costs	a) Yes[1] b) No c) No

[1] As long as the item is in the reading range of the handheld

4) Emergency trips to Austin and Waco for inventory	a) Inaccurate / unavailable information on usage rates and usage variability	• Increased operational costs due to the need of requesting inventory from Austin and Waco: transportation cost, labor cost, workers overtime cost.	a) Yes
5) Inventory shortage	a) Inaccurate / unavailable information on usage rates and usage variability	• Potential delay on jobs. • Increased manufacturing and or transportation cost. • Potential loss of a counter job. • Suboptimal safety stock • Suboptimal cycle stock	a) Yes[2]
6) Excess inventory	a) Inaccurate / unavailable information on usage rates and usage variability	• Suboptimal safety stock • Suboptimal cycle stock • Opportunity cost tied up in excess inventory.	a) Same as problem 5

[2] RFID does not solve this problem, but helps in obtaining better usage information

7) Added expenses due to slow processing	a) Manual counting b) Paper based information flow	• Increased operational costs • Increased labor costs	a) Yes b) Yes
8) Need to perform inventory counts.	a) Paper based information flow	• Increased operational costs • Increased labor costs	a) Yes

Chapter 5: Process Mapping

Process Mapping refers to activities involved in defining exactly what a business entity does, who is responsible, to what standard a process should be completed and how the success of a business process can be determined. Once this is done, there can be no uncertainty as to the requirements of every internal business process.

Process mapping enables us to clearly and simply record existing processes, examine them thoroughly and develop improvements by: (11)

- Eliminating unnecessary tasks
- Clarifying roles within the process
- Reducing delays and duplication
- Reducing the number of staff required
- Establish what is currently happening, how predictably and why
- Measure how efficiently the process is working
- Develop new improved processes to reduce or eliminate inefficiency

What is process mapping/flowcharting? (11)

1. Flowcharts show people what their jobs are and how they should interact with one another as part of process. Everybody should be able to see from the chart what their job is and how their work fits in with the work of others in the process.
2. Processes are simply sequences of actions designed to transform inputs into outputs. For instance, baking a cake will involve taking various ingredients (inputs) and producing the cake

(output) using the recipe (process), Similarly, the steps required to deal with a prosecution file from receipt to disposal will involve a process, or series of processes.

3. Process mapping is an exercise to identify all the steps and decisions in a process in diagrammatic form which -

    - Describes the flow of materials, information and documents
    - Displays the various tasks contained within the process
    - Shows that the tasks transform inputs into outputs
    - Indicates the decisions that need to be made along the chain
    - Demonstrates the essential inter-relationships and interdependence between the process steps; and reminds us that the strength of a chain depends upon its weakest link

4. There are many different types of chart, each designed to capture particular aspects of work, such as travel charts that can record movement of people or materials in a process. However, for the purposes of this guide we concentrate on two of the most common techniques –

    - Flowchart or Outline Process Map - which provides a basic 'birds eye' view of all the actions undertaken; and
    - Deployment Charts - which not only provide the basic overview above but also indicate where or by whom the actions are performed?

5. It is important to remember that although there are many types of chart and numerous charting conventions, you should not be drawn into a technical maze. Make the charts work for you and keep them as simple as you possibly can. The primary objective is to make the chart as clear as

possible, so that the process under review can be readily understood and improvements identified by almost anyone, even someone unfamiliar with the process.

Why process map?

1. Making system changes without truly understanding how the process is working today, and why, can lead to costly mistakes. It can also create conditions that make it difficult for staff to work effectively, and often create further problems.
2. If you do not measure a process, you will not be able to manage it effectively and if you cannot manage a process, you cannot improve it.
3. It has been estimated that people working in organizations can waste about 15 – 20% of their time by re-doing things that are wrong, chasing things without result, querying incomplete instructions, doing other people's jobs and so on.
4. Process mapping enables us to clearly define the current processes in chart form, identifying problem areas such as bottlenecks, capacity issues, delays or waste. Once identified, this knowledge provides a solid basis from which to develop solutions and introduce and plan new improved processes.

Construction of Process Maps (16)

1. Types of process map

There are two basic types of chart that you may find useful:

Process Flowchart

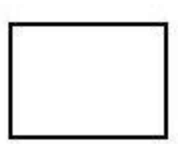
This chart simply sets out the sequence of activities and decision points. These are useful for capturing the initial detail of the process. Labels showing the grade/level of staff doing each step can be added if required.

Deployment Flowchart

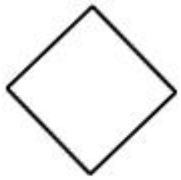
This shows who does what along with the interactions between people and departments (e.g. Between Case Preparation and Witness Warning or between Police and CPS). This is sometimes known as a "swim lane" chart as the page is divided into vertical lanes showing the various actions and how the process moves from person to person or agency to agency.

The two most important symbols are:

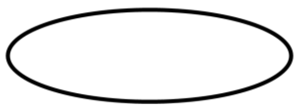
a. A rectangle, representing an activity or task:



b. A diamond, representing a decision:

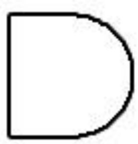


c. Ellipse , representing start / end of the process

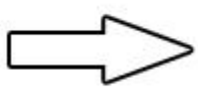


d. You may also find it useful, when considering process improvement to label certain actions on your chart to highlight -

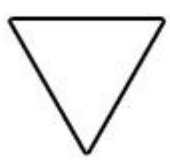
Delays



Transport/movement



Storage/Filing



2. **Preparation for process mapping**(16)

   a. Involve those who work IN and AROUND the process. All the following need to be involved:

      - Those who DO the work
      - The SUPPLIERS to the process
      - The CUSTOMERS of the process
      - The SUPERVISORS / MANAGERS of the process

   b. It is essential to involve operational staff in any process mapping exercise. Only by asking the people who do the work will you be able capture the information required. There may be some suspicion from staff about the ultimate aims of a process improvement exercise and how change will affect individuals. Communication and openness about the exercise, its aims and expected outcomes is therefore critical in reassuring staff and securing co-operation.

   c. Assemble a small team ideally comprising representatives from ALL agencies or sections involved in the exercise, who have a good overview of the processes under examination. Key points to ensure are that:

      - Terms of reference are agreed and clearly understood by all participants – what are we trying to achieve with this work?
      - Sufficient time is provided to do the job properly – set sensible deadlines;
      - There is clear, visible Management commitment and support to the exercise;

- All staff are made aware of the exercise, terms of reference and likely impact on them, together with an invitation to contribute or voice any particular anxieties;
- Team members receive some basic guidance on process mapping /charting techniques;

d. Staff, supervisors and managers will need to be assured that the process mapping exercise will help them to work SMARTER rather than HARDER by enabling them to:

- Learn much more about their processes by pooling their knowledge and working together both internally and externally to perfect them;
- Work out how to do their jobs excellently and consistently without procedures being forced on them from above;
- Visualize various kinds of changes likely to produce improvement;
- Focus on the most troublesome aspects of their processes;
- Demonstrate where processes fit into the overall system;
- See where they as individuals fit into the overall system and to recognize their internal customers and suppliers;
- Explain simply and easily the nature and detail of the processes to interested parties and new staff;
- Identify any existing (and new) skills needed by those involved in the process;
- Effectively help to plan implementation of proposed changes;

e. All parties should be clear and agree on what they wish to achieve through a process mapping exercise. It is unlikely that time and resources will permit a detailed examination of everything, and it may be sensible to identify key processes and concentrate on those. Examples might be interfaces with the Police, or elements where ownership of a process may change, such as file preparation or witness care

3. **Gathering information**(16)

   a. If more than one Agency or organization is involved in the exercise, try to have a member of the OTHER agency who is familiar with the process under consideration present during process mapping sessions. This will give the other agency a 'hands on' practical understanding of your process and will hopefully facilitate future stages when considering combined or improved processes. It can also be useful to have the "blindingly obvious" question posed by someone not too close to the process.

   b. Observe the Process in Operation and talk to the staff involved. Walk through the process in sequence, asking how the work gets done. Try to obtain a clear overview without too much fine detail at this stage. If it proves difficult to get people to think sequentially it may help to ask the following types of questions at various steps in the process:

      - What are the inputs to your task which are relevant to the process under consideration?
      - Where does your work come from? (Your SUPPLIER)
      - What do you do with it?
      - Where do you send your output? (Your CUSTOMER)
      - What form does that output take? (This output then becomes the input for the next box (Process Step) in the flowchart

   c. Roughly and simply sketch the Process (without too much detail) describing the sequence of tasks and decision points ***as they actually happen***. The sketch should indicate:

      - WHO does WHAT

- WHAT is done and WHEN
- What DECISIONS have to be taken and
- What possible paths follow from each decision

d. It can be helpful to use 'POST-IT' notes on a large whiteboard (or just sick them on the wall!). Each note can represent a 'step' in the process and save a lot of pain when it comes to re-shuffling the sequence to get it right!

e. Draw the flowchart initially to represent the operation, ***as it actually happens*** - NOT what you might prefer it to be! Use a flip chart or whiteboard to produce your initial charts

f. Keep it simple to facilitate broad understanding of the OVERALL process. Too much detail early on can be overwhelming and/or lead to confusion. If you agree that more detail is required on a particular action, it is easy to highlight that box and produce a separate chart showing the process taking place within.

g. Leave the flowchart on the board / wall if possible. This enables reflection and re-thinking between meetings. Continue until consensus is reached. Rarely is the flowchart complete without re-work.

4. Constructing a process flowchart (13)

a. Try to lay the sequence out by working in a downward direction rather than across. This will help later if you want to convert your process chart to a 'deployment flowchart'.

b. Having thought through the main 'steps' of the process, flowchart them in sequence as they are performed using rectangles for 'tasks' and diamonds for ‘decisions’. Use connecting arrows between boxes to represent the direction of the sequence.

c. Concisely describe each task or decision in its own box. You may sometimes wish to number (some of) the boxes and provide a key to where the activity is described in more detail.

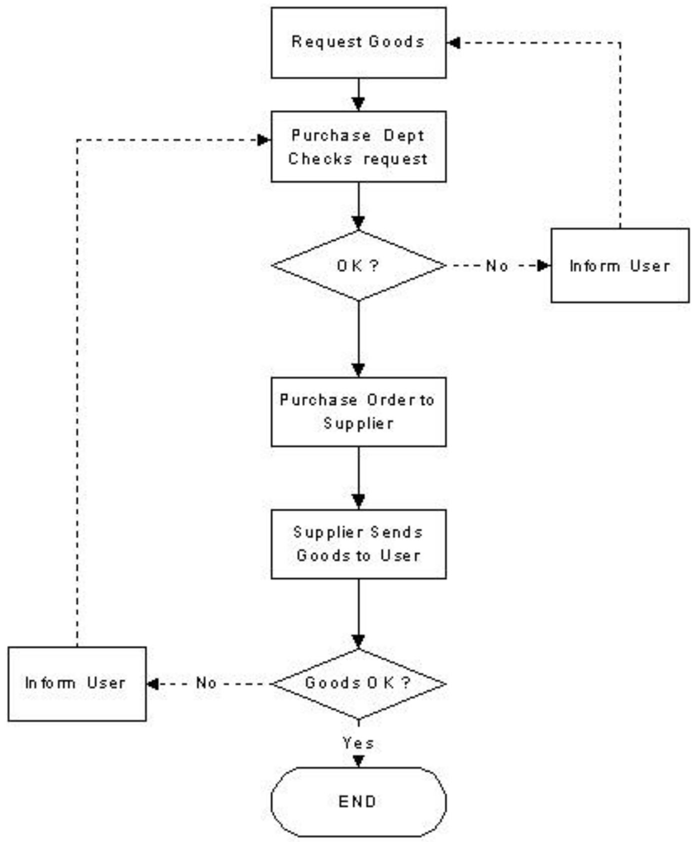
d. If the process includes decision points, this will normally imply some 'return-routing' causing some boxes to have more than one input. In the example below the “return routing” or "loops" indicate an inefficiency or waste.

e. Decisions often (but not always) pose questions answerable by YES or NO. It can be convenient to structure the questions so that the preferred answer is 'YES' whereas 'NO' leads to re-routing etc. In our example overleaf the most efficient process takes the form of a straight line down the page.

f. Useful conventions that then follow are to draw:

- The 'YES' route out of the bottom of the diamond (i.e. normal flow downward through the chart)
- The 'NO' route as a line out of the side of the box

A simple example (13)



Simple Process Flow chart

5. Constructing a deployment flowchart

Here a "department" dimension is added horizontally along the top of the chart. You may use individuals, groups, departments, agencies, and functions etc - whatever kinds of 'units' play major roles in the process.

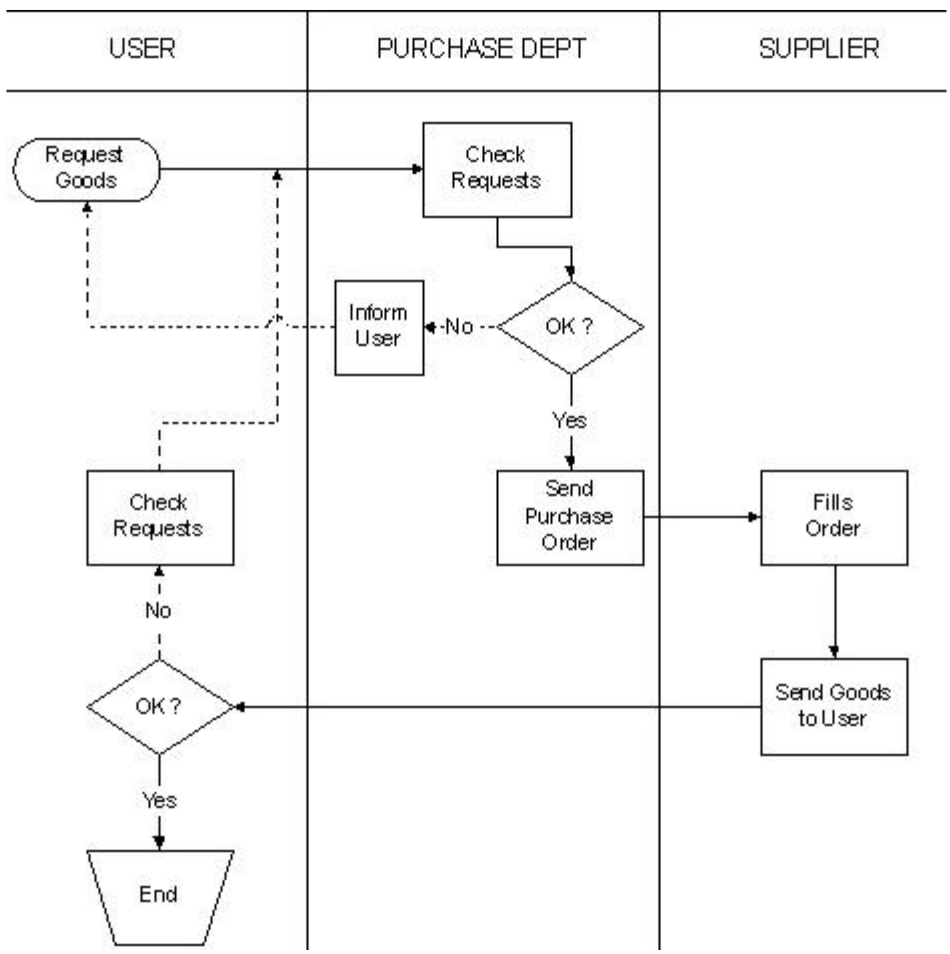
a. Draw vertical lines to separate the functional boundaries

b. When the flow moves from one function to another, this is ideally denoted by a horizontal line.

c. Apart from the ideally horizontal moves between functions, aim when possible to draw the sequence of activities from top to bottom.

d. Use the task and decision-making symbols as before and always connect symbols with arrows indicating the direction of flow. An example of a simple Deployment Chart is shown overleaf.

Example of a simple deployment flowchart (13)



As refinements to the deployment flowchart, it may be useful at this stage to indicate any delays in the process, particularly at the interface or boundaries between agencies or sections.

Process improvement

Critical examination (15)

1. Having selected and recorded key processes, the next stage is to critically examine them and develop new processes where necessary. This may well take the form of combining, for example, existing Police and CPS processes and deciding who will take responsibility for various actions.
2. In many instances the thoughts and discussions required to chart existing processes will lead to easy identification of improvements. These should be noted and retained for the improvement stage. Many improvements will "leap off the page" once an existing process is charted.
3. Analyzing your process maps in a structured way, known as Critical Examination, can identify process improvements. This basically involves the use of primary questions – WHAT, HOW, WHEN, WHERE, and WHO. Firstly define what is actually happening, (DOES), before moving onto identifying alternatives, (COULD), and finally deciding (SHOULD). The table below outlines the approach taken. A more detailed summary is shown at Annex 3.

Critical Examination summary(15)

Examine your process maps and ask the following questions –

PRIMARY QUESTIONS	WHY?	SECONDARY QUESTIONS	SELECTION
PURPOSE - What is achieved	WHY?	What else could be achieved?	WHAT SHOULD be achieved?
MEANS - How is it achieved?	WHY THAT WAY?	How else could it be achieved?	HOW SHOULD it be achieved?
SEQUENCE - When is it achieved?	WHY THEN?	When could it be achieved?	WHEN SHOULD it be achieved?
PLACE - Where is it achieved?	WHY THERE?	Where else could it be achieved?	WHERE SHOULD it be achieved?
PERSON - Who achieves it?	WHY THAT PERSON?	Who else could achieve it?	WHO SHOULD achieve it?

4. In essence we should be asking:

- Why are we doing it?
- Is it essential to do this?

In doing so you should also consider the:

- Implication of not doing parts of the process
- Impact on Customers/Stakeholders
- Why we needed the old process

- What do we want to change
- What are the requirements of the new process
- What needs to change

5. Rather than adopting the critical examination method and examining the whole process in the way outlined above, you may decide to focus on "wasted work".

What is wasted work? (15)

Wasted work is:

- Spending time doing things again which have not been done right first time;
- Duplicating effort;
- Doing things that add no value to the customer or the organization

Wasted work should be evident from your process maps, and often from any discussions you have with staff, when you:

- re-work something not done right first time;
- complete unnecessary forms/paperwork/reports;
- do not have access to the right equipment;
- work from unreliable or inaccurate information;
- do things that you've found others are doing/have done;
- deal with problems caused by other departments not doing their job correctly first time;
- encounter "bottlenecks" of work, or excessive delay/movement of work;
- fire fight and deal with symptoms rather than causes;

- have to obtain unnecessary authorization;
- attend unnecessary or poorly managed meetings;
- Have to handle issues that others should have dealt with.

What are the characteristics of an efficient and effective process? (15)

1. To help you identify some of the characteristics in an efficient process the following should always be apparent:

    - several tasks/jobs combined into one;
    - workers making decisions at the lowest possible level and monitoring their own progress;
    - steps in the process following a natural order;
    - work being performed where and when it makes sense (with the fewest possible people involved);
    - single points of contact and case managers;
    - the fewest possible interfaces and handling points;
    - the fewest backward movements;
    - The fewest possible activities.

2. Having completed the initial process examination and improvement stage, you should be in a position to chart the new processes.
3. It is important to chart any new improved process that you develop as this can be used as a training aid for all staff and should clearly define who is responsible for each action. These charts should also form the basis of any future work aimed at improving processes further.

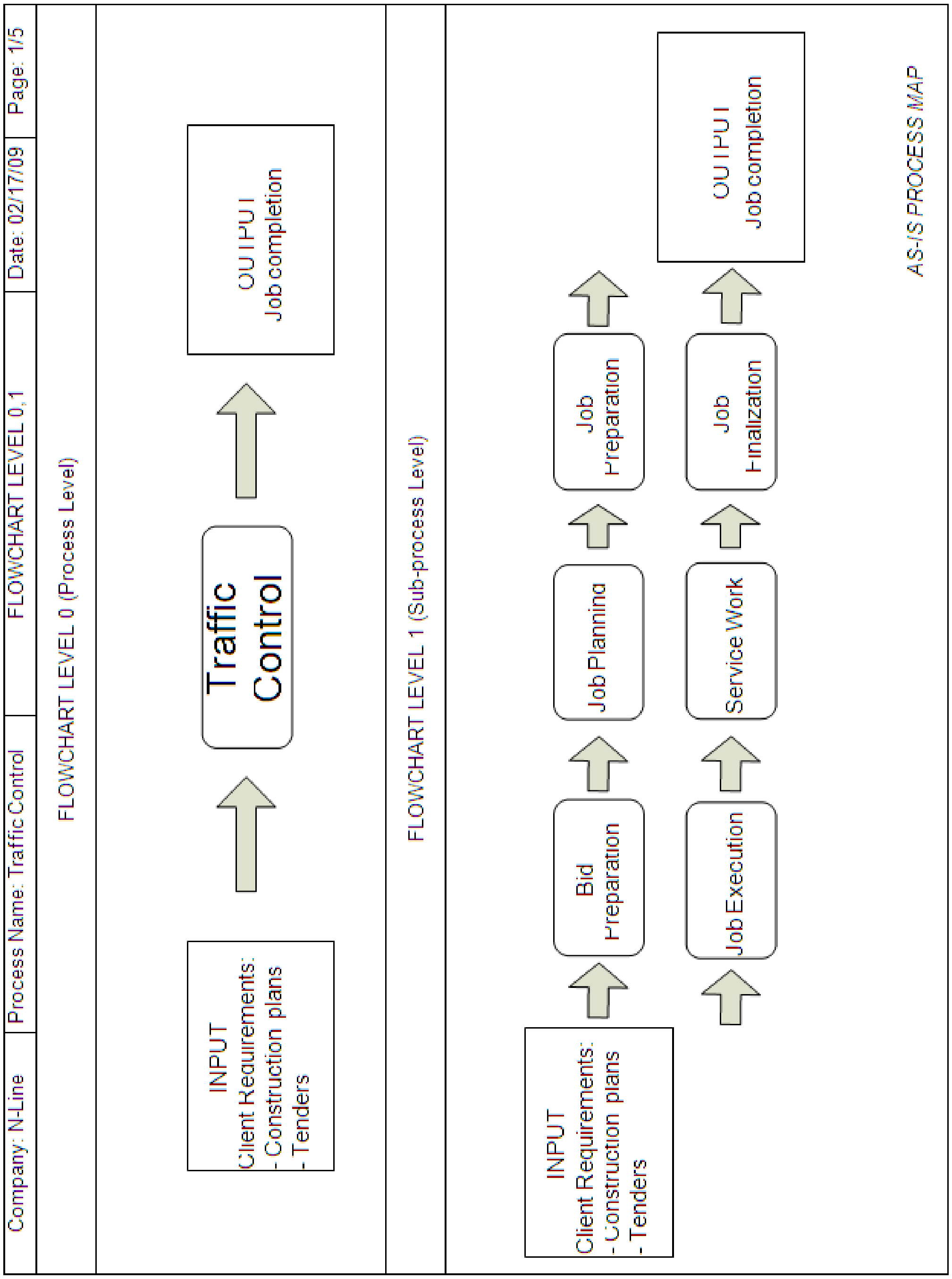
4. If the process examination covers more than one agency, an agreed combined process map may also be useful in supporting any Service Level Agreements which are developed by agencies for joint working.
5. It is also important to remember that a process mapping exercise as described in this guide is merely the first stage in a **CONTINUOUS** cycle of **INCREMENTAL** improvement and refinement of processes which is ultimately aimed at:

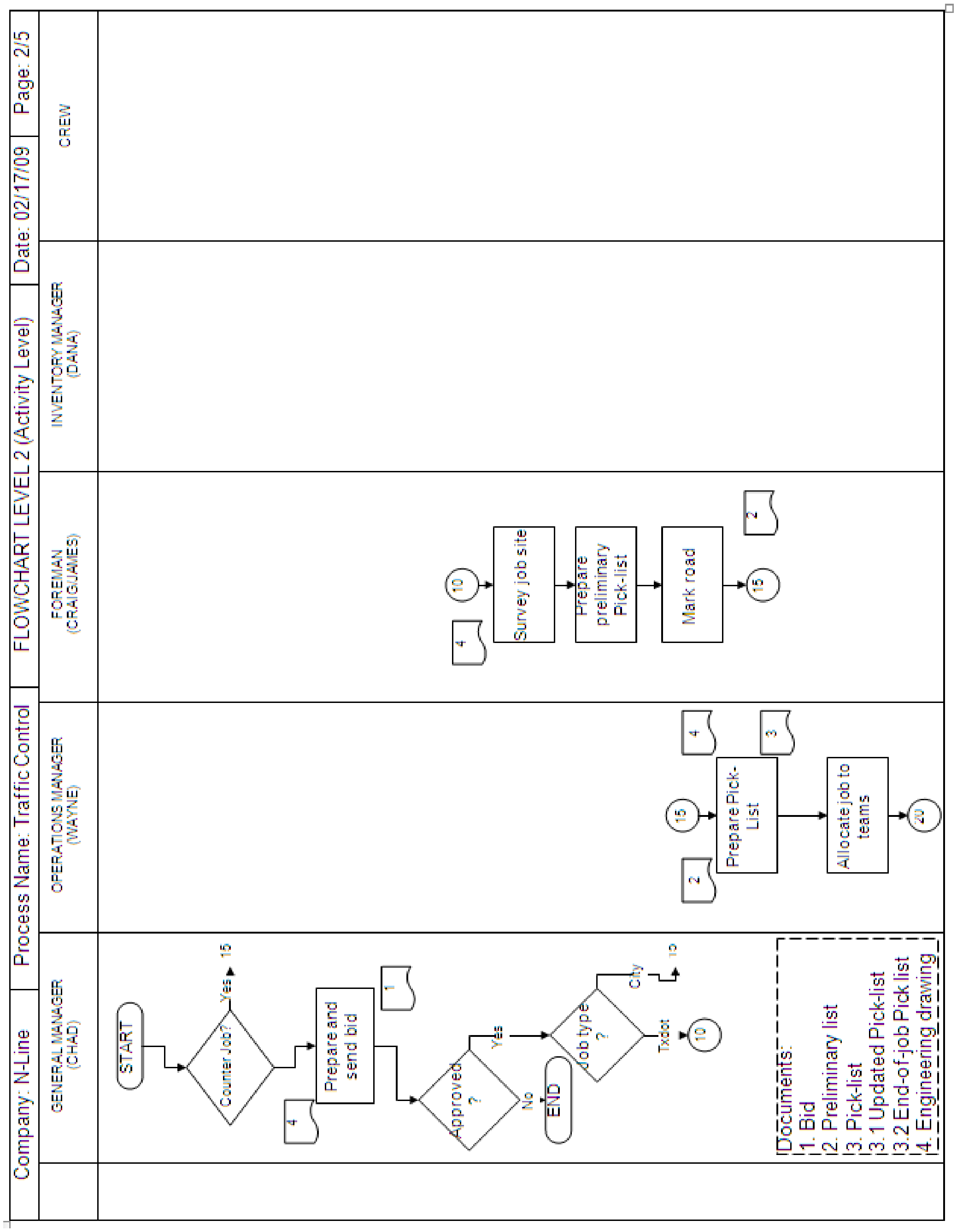
- Eliminating duplication of tasks and to reduce costs
- Improved efficiency and co-ordination of working practices
- reducing the transportation of materials e.g. files between locations
- improved quality and timeliness in the organization
- improving the effective deployment of staff
- Improved relationships between agencies e.g. Police, CPS and Courts
- reduced delays
- improving the service to victims and witnesses (or Customers/stakeholders)

Process Maps for N-line

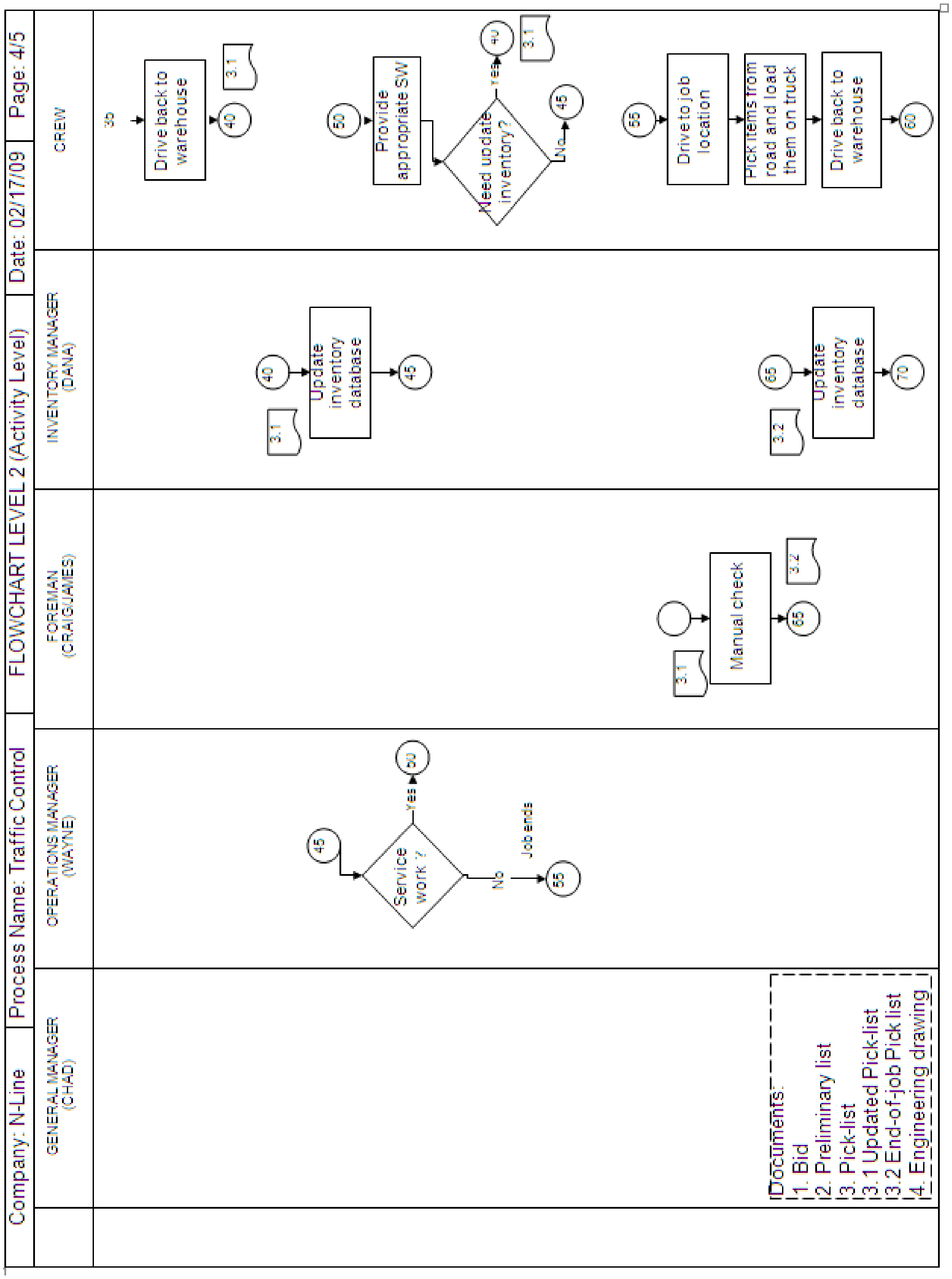
1. ASIS Process Map

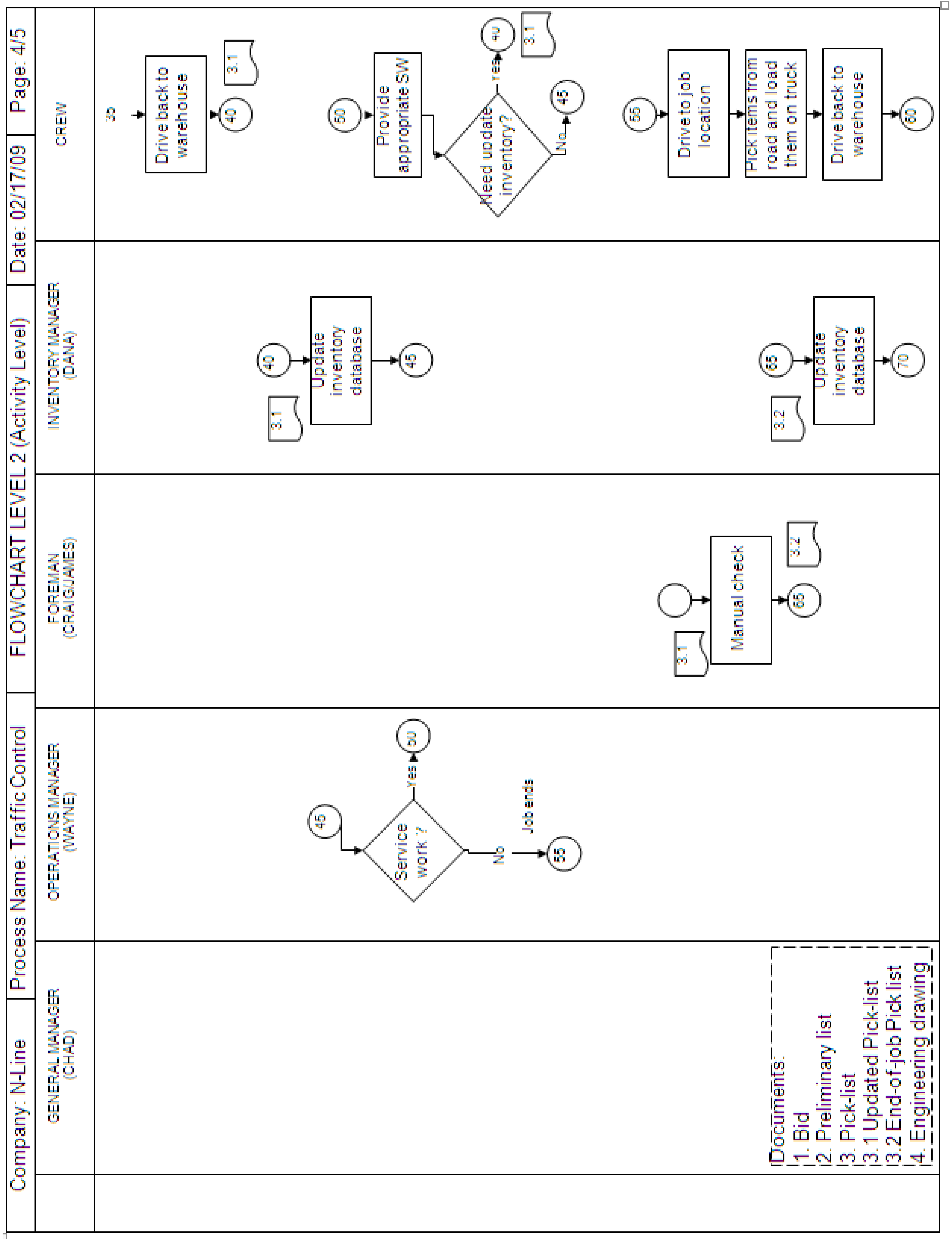
The below process map gives the diagrammatical illustration of the process of managing the retail jobs and Inventory by N-Line employees

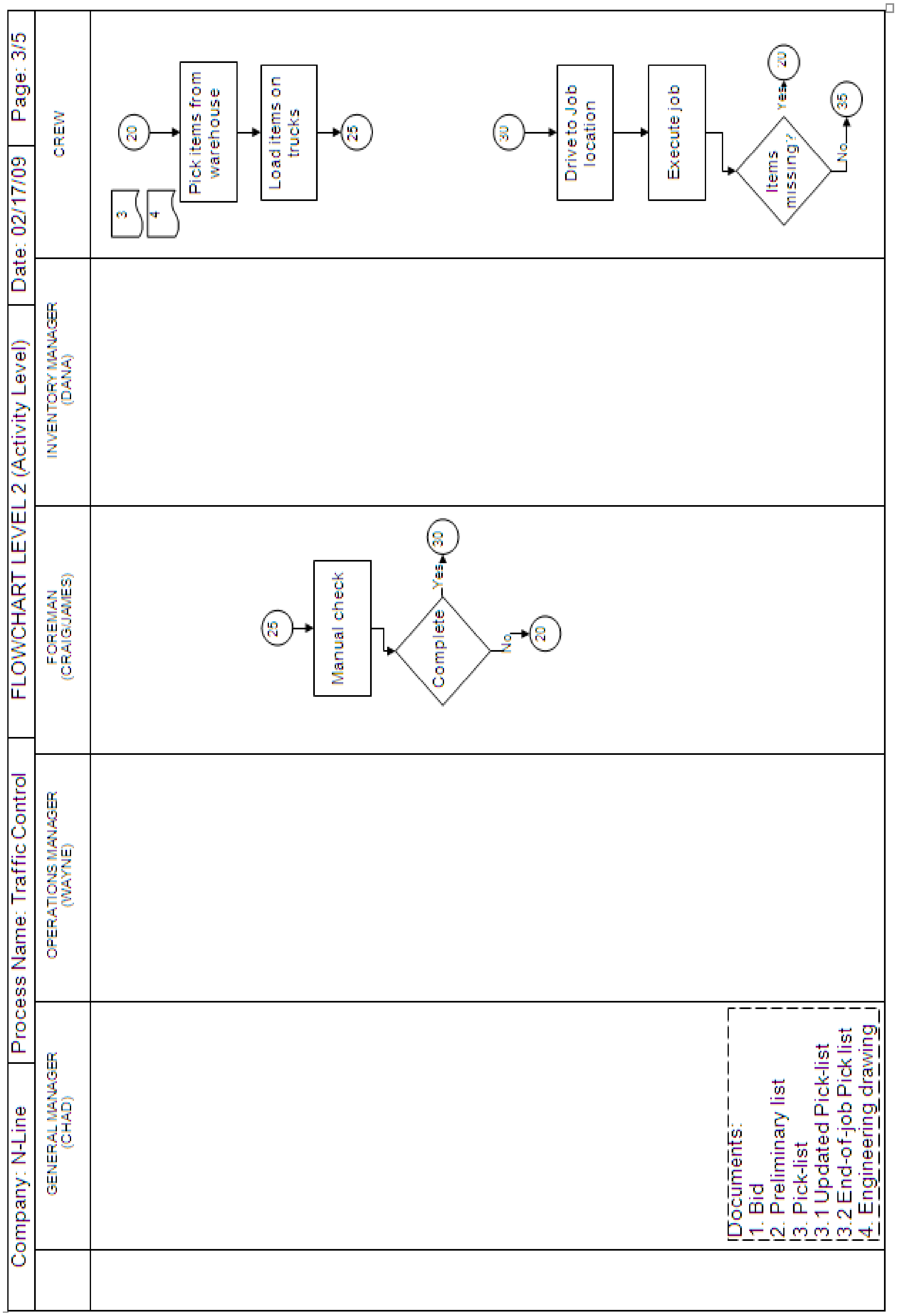

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 0,1
Date: 02/17/09
Page: 1/5
FLOWCHART LEVEL 0 (Process Level)
INPUT
Client Requirements:
- Construction plans
- Tenders
Traffic Control
OUTPUT
Job completion
FLOWCHART LEVEL 1 (Sub-process Level)
INPUT
Client Requirements:
- Construction plans
- Tenders
Bid Preparation
Job Planning
Job Preparation
Job Execution
Service Work
Job Finalization
OUTPUT
Job completion
AS-IS PROCESS MAP

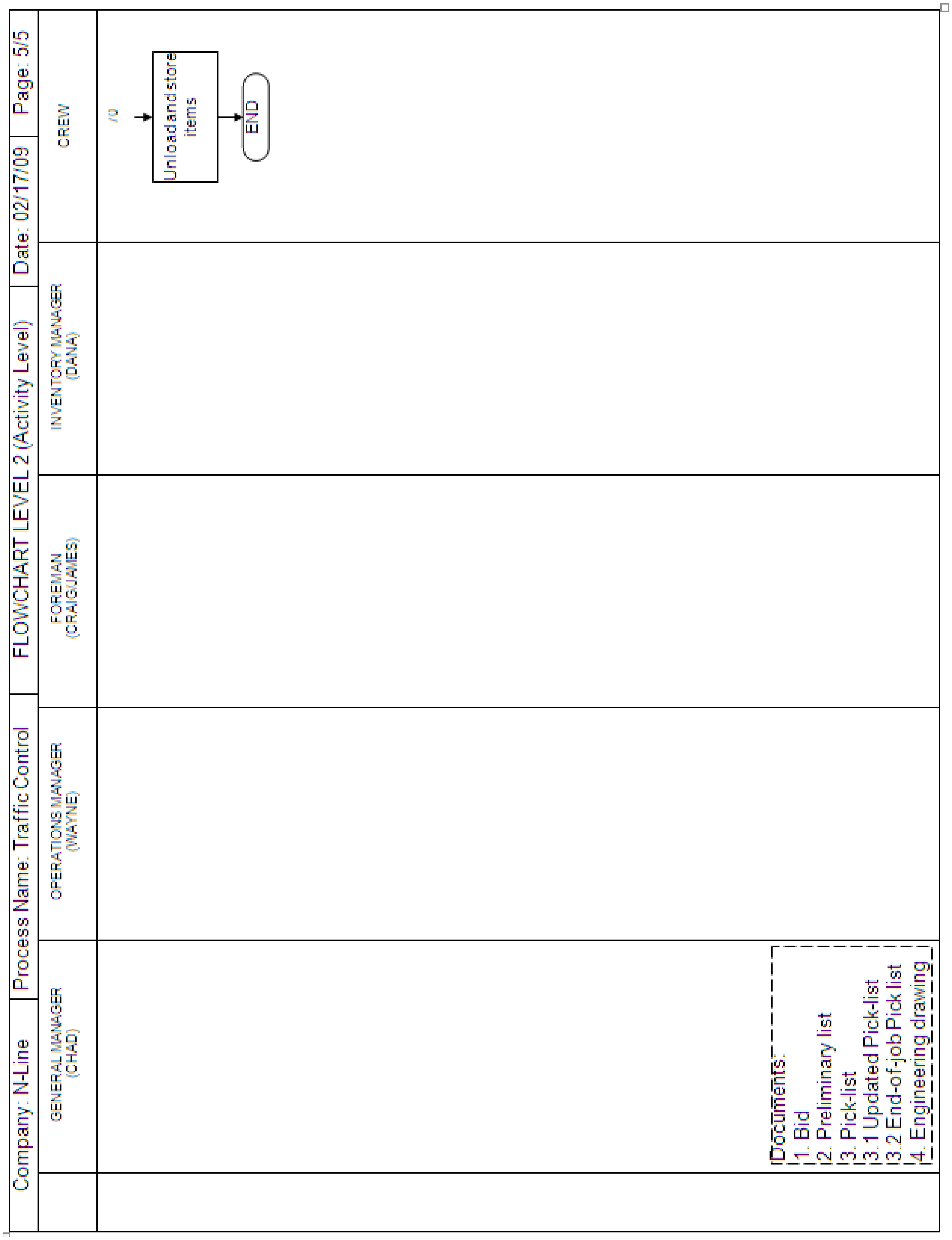


Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/17/09
Page: 2/5
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
INVENTORY MANAGER (DANA)
CREW
START
Counter Job?
Yes
15
Prepare and send bid
1
4
Approved ?
No
END
Yes
Job type ?
City
15
Txdot
10
Survey job site
Prepare preliminary Pick-list
Mark road
2
Prepare Pick-List
3
Allocate job to teams
20
Documents:
1. Bid
2. Preliminary list
3. Pick-list
3.1 Updated Pick-list
3.2 End-of-job Pick list
4. Engineering drawing


Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/17/09
Page: 4/5
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
INVENTORY MANAGER (DANA)
CREW
Drive back to warehouse
Provide appropriate SW
Need update inventory?
Yes
No
Drive to job location
Pick items from road and load them on truck
Drive back to warehouse
Update inventory database
Manual check
Service work ?
Job ends
Documents:
1. Bid
2. Preliminary list
3. Pick-list
3.1 Updated Pick-list
3.2 End-of-job Pick list
4. Engineering drawing

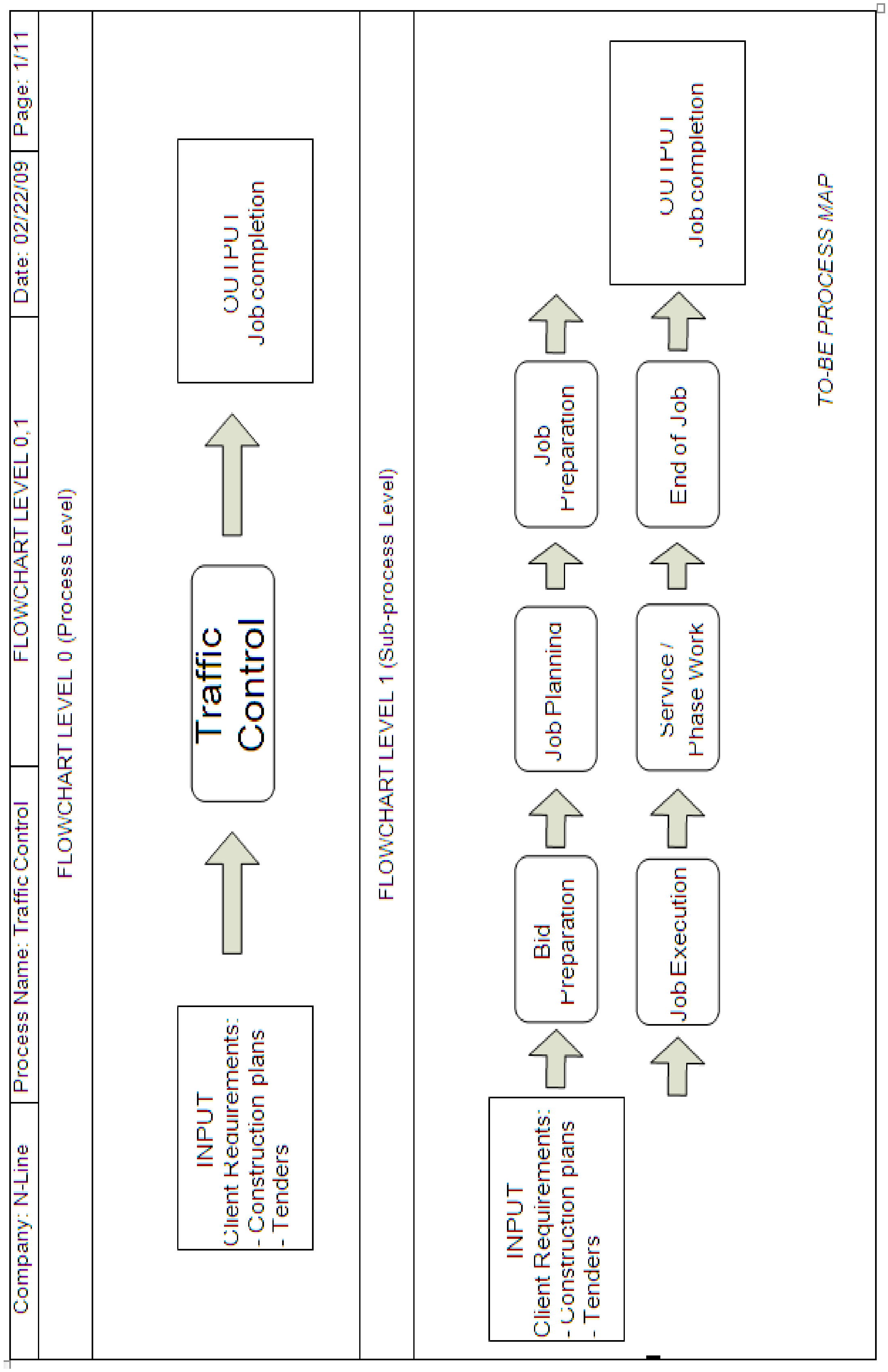

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/17/09
Page: 4/5
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
INVENTORY MANAGER (DANA)
CREW
35
Drive back to warehouse
40
3.1
50
Provide appropriate SW
Need update inventory?
Yes
No
45
40
3.1
55
Drive to job location
Pick items from road and load them on truck
Drive back to warehouse
60
40
Update inventory database
45
3.1
65
Update inventory database
70
3.2
Manual check
3.1
3.2
65
45
Service work ?
Yes
50
No
Job ends
55
Documents:
1. Bid
2. Preliminary list
3. Pick-list
3.1 Updated Pick-list
3.2 End-of-job Pick list
4. Engineering drawing

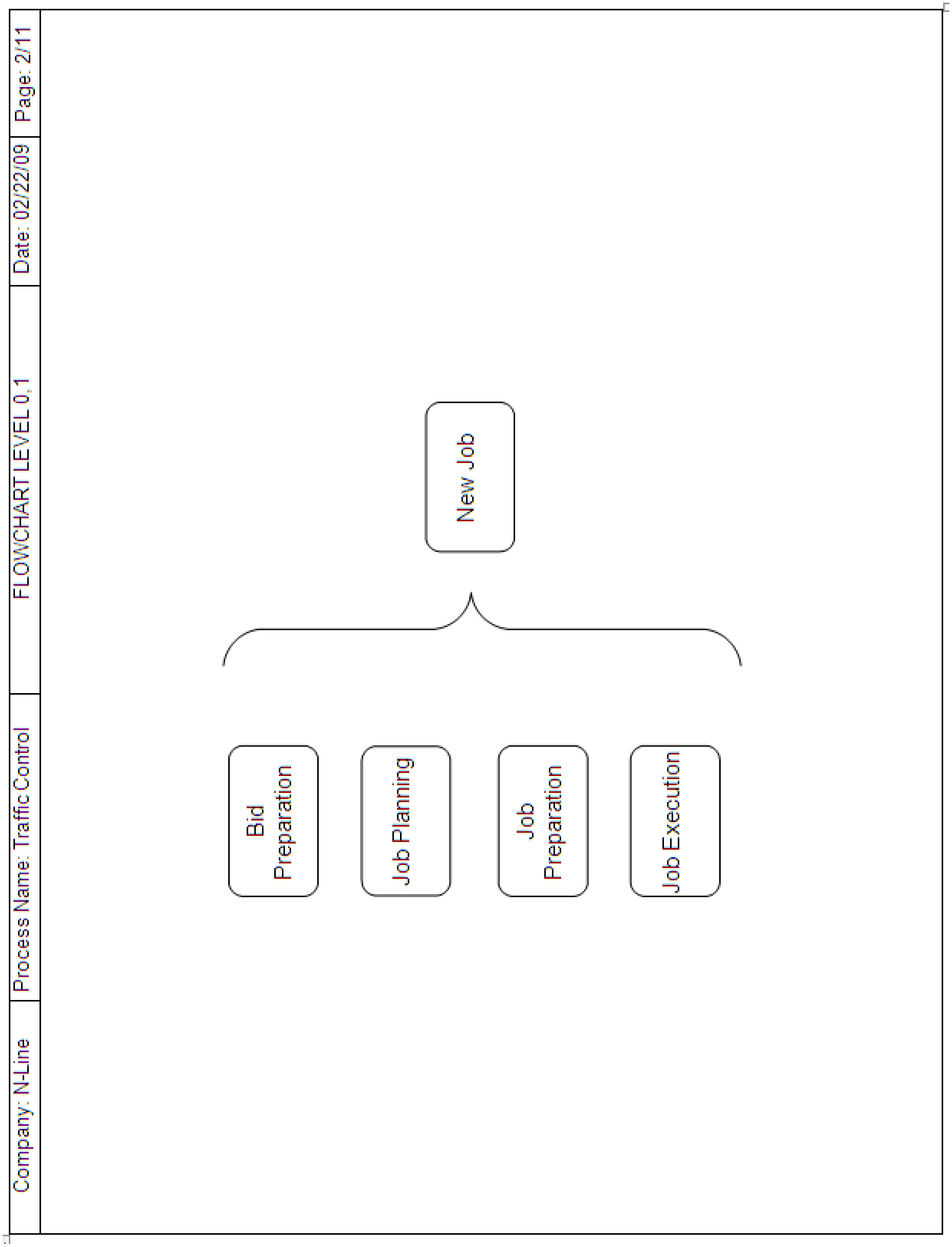

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/17/09
Page: 3/5
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
INVENTORY MANAGER (DANA)
CREW
20
3
4
Pick items from warehouse
Load items on trucks
25
30
Drive to Job location
Execute job
Items missing?
Yes
20
No
35
25
Manual check
Complete
Yes
30
No
20
Documents:
1. Bid
2. Preliminary list
3. Pick-list
3. 1 Updated Pick-list
3. 2 End-of-job Pick list
4. Engineering drawing

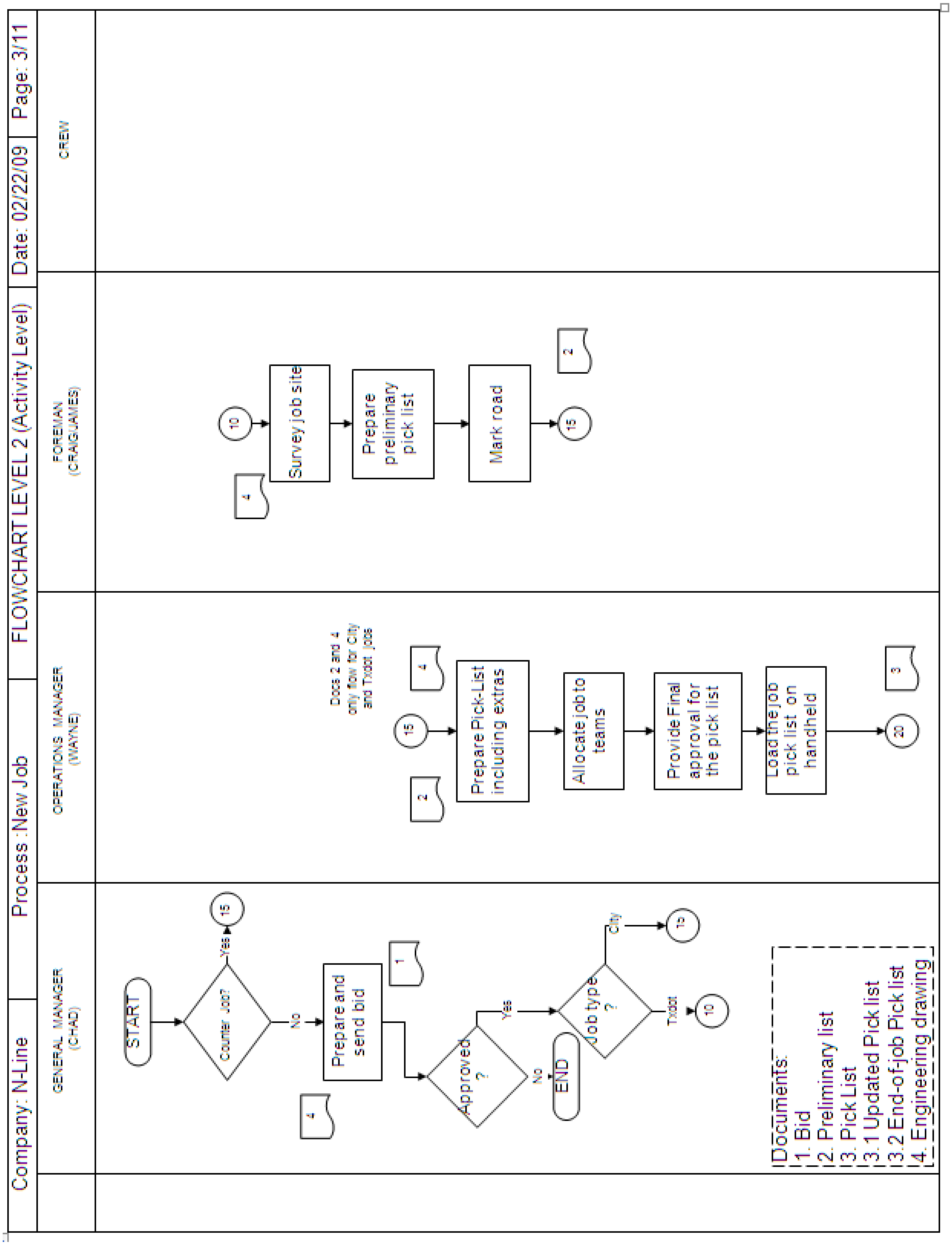

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/17/09
Page: 5/5
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
INVENTORY MANAGER (DANA)
CREW
Unload and store items
END
Documents:
1. Bid
2. Preliminary list
3. Pick-list
3.1 Updated Pick-list
3.2 End-of-job Pick list
4. Engineering drawing

2. TOBE Process Map

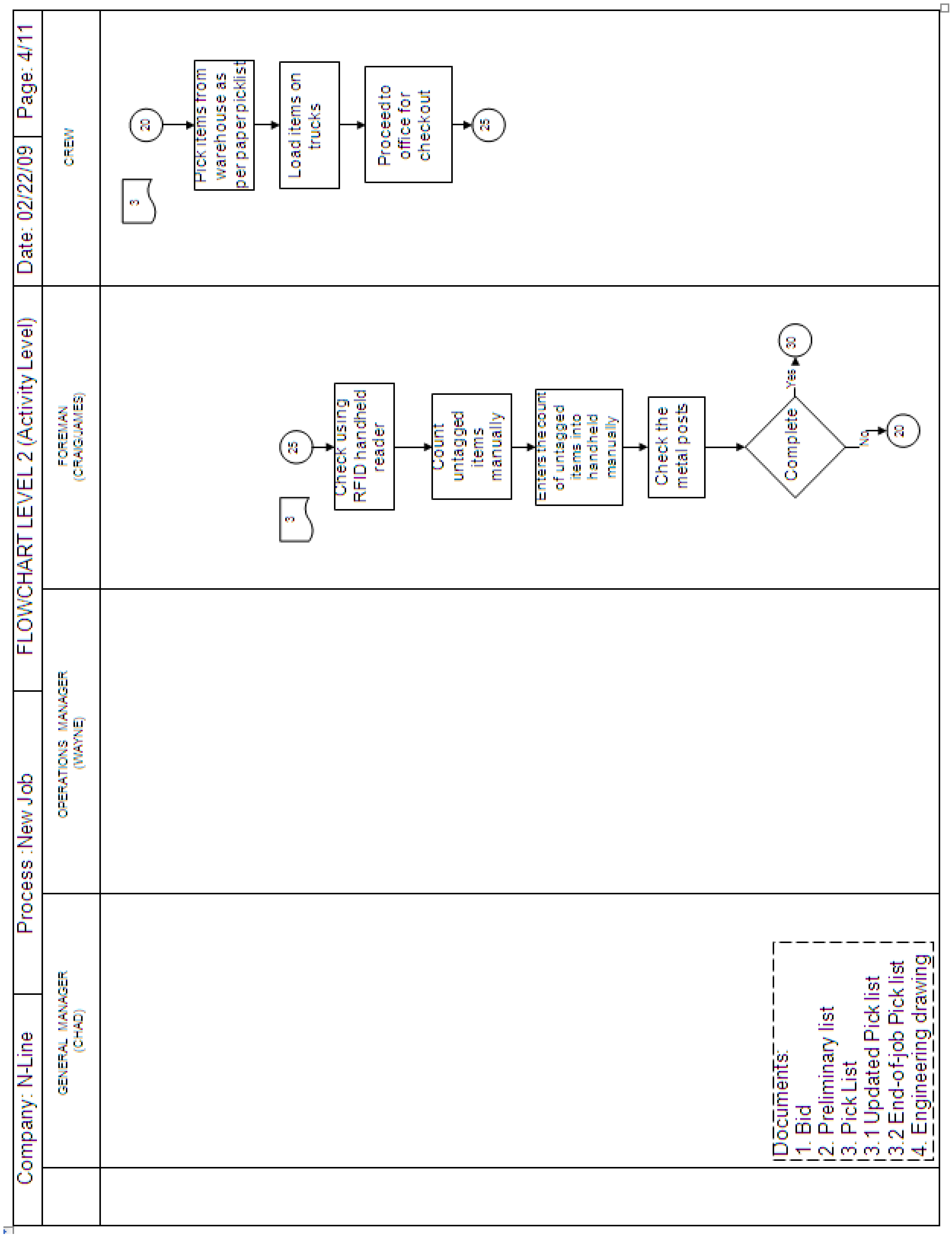
The below process map gives the diagrammatical illustration of the process of managing the retail jobs and Inventory by N-Line employees**.**

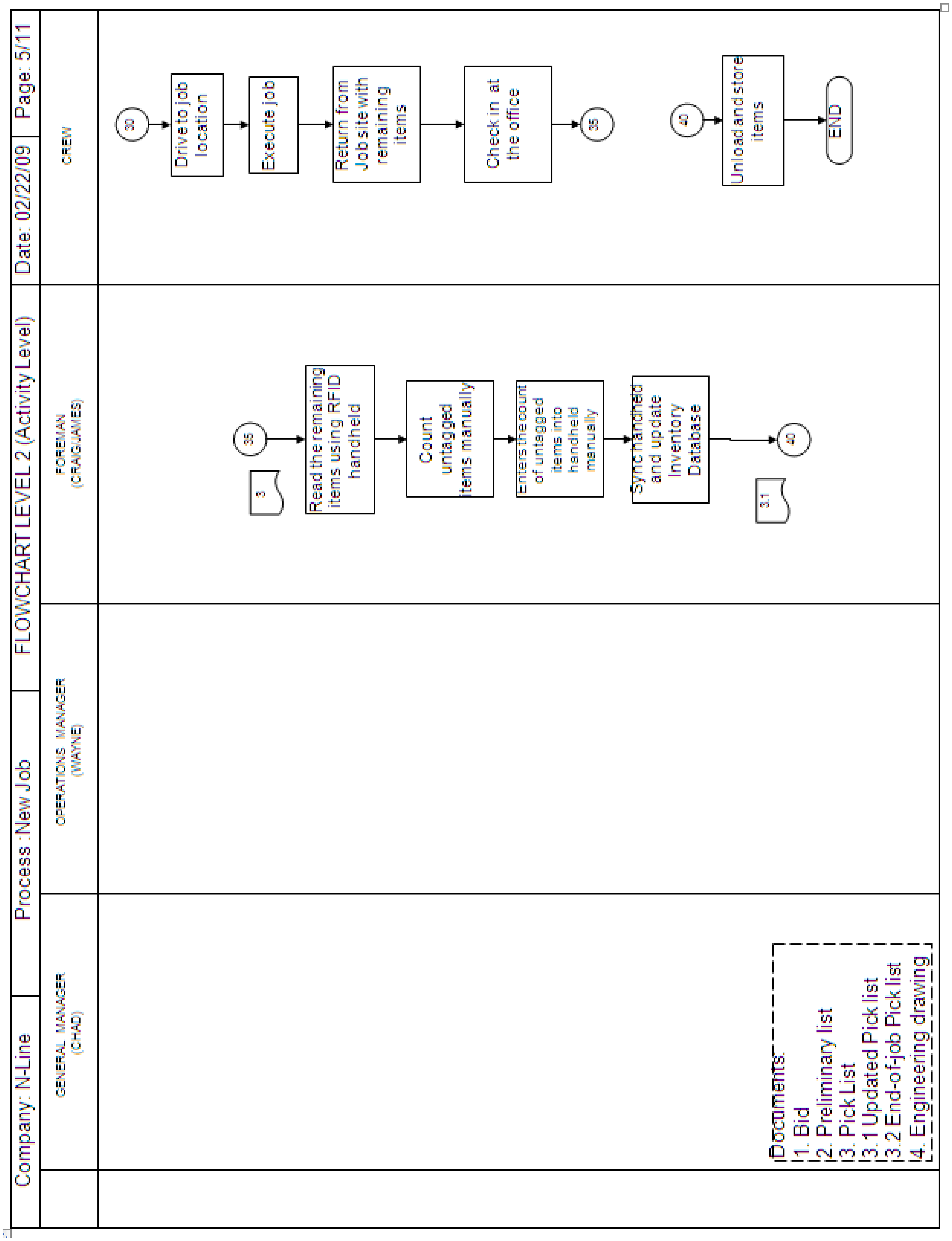

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 0,1
Date: 02/22/09
Page: 1/11
FLOWCHART LEVEL 0 (Process Level)
INPUT
Client Requirements:
- Construction plans
- Tenders
Traffic Control
OUTPUT
Job completion
FLOWCHART LEVEL 1 (Sub-process Level)
INPUT
Client Requirements:
- Construction plans
- Tenders
Bid Preparation
Job Planning
Job Preparation
Job Execution
Service / Phase Work
End of Job
OUTPUT
Job completion
TO-BE PROCESS MAP

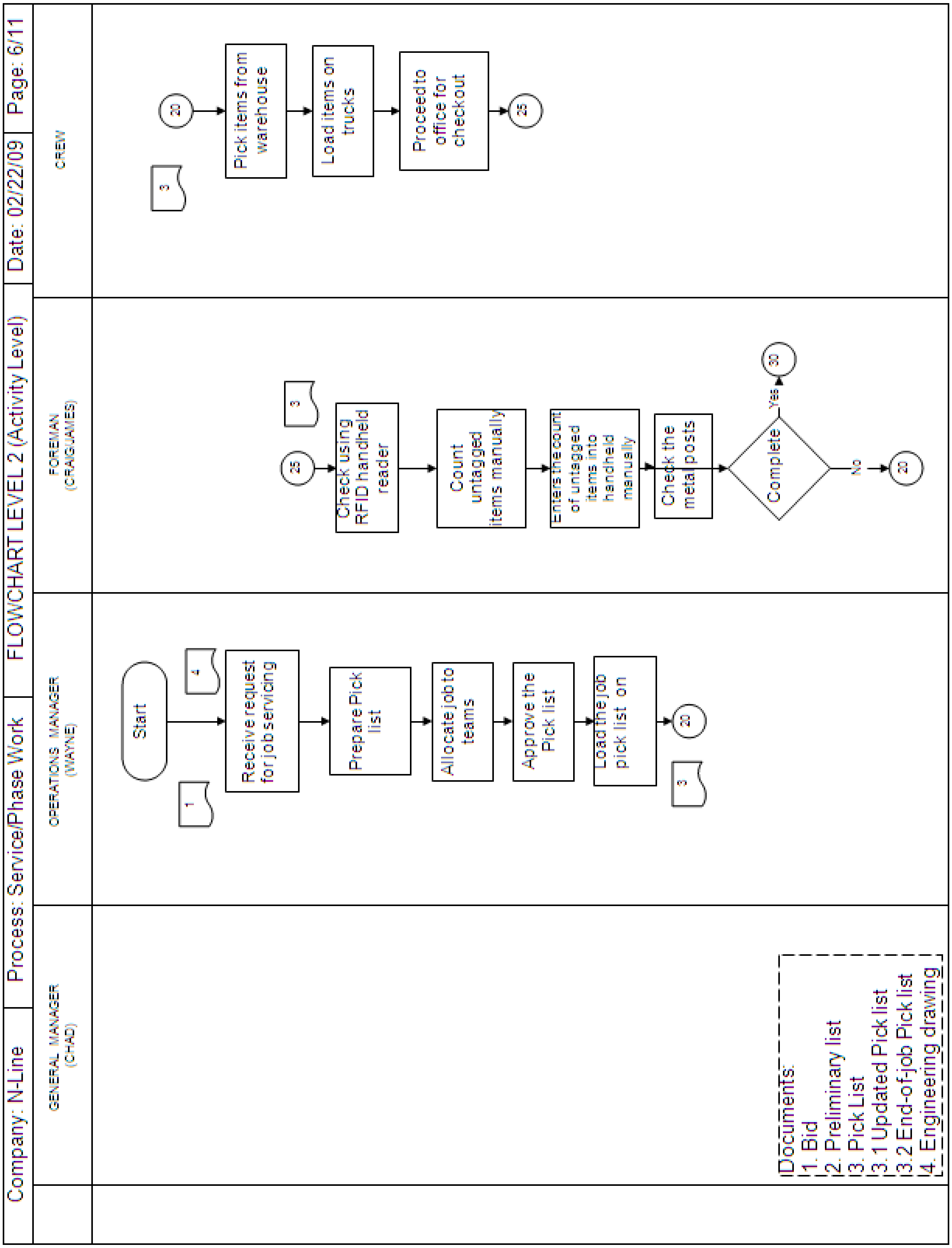

Company: N-Line
Process Name: Traffic Control
FLOWCHART LEVEL 0.1
Date: 02/22/09
Page: 2/11
New Job
Bid Preparation
Job Planning
Job Preparation
Job Execution

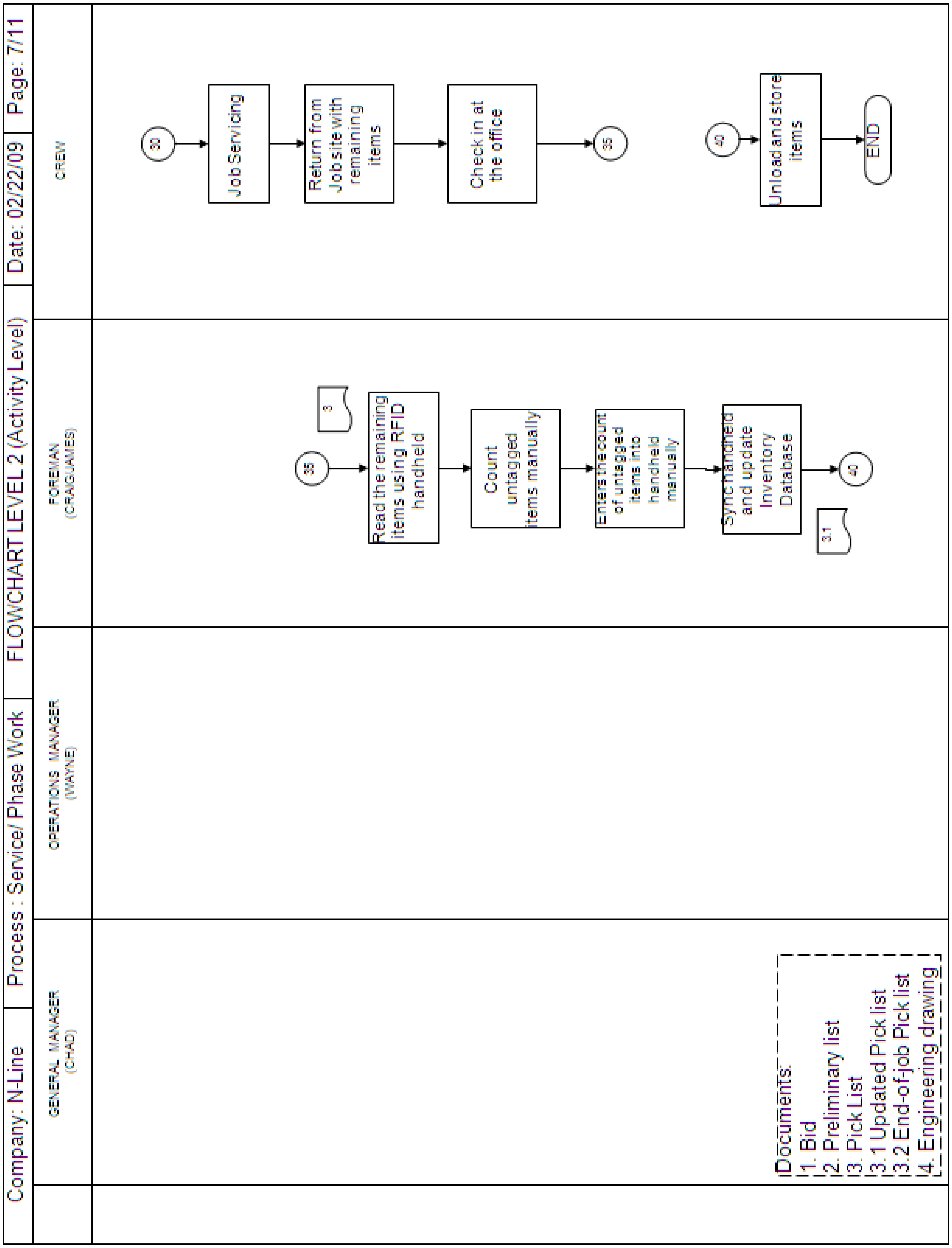


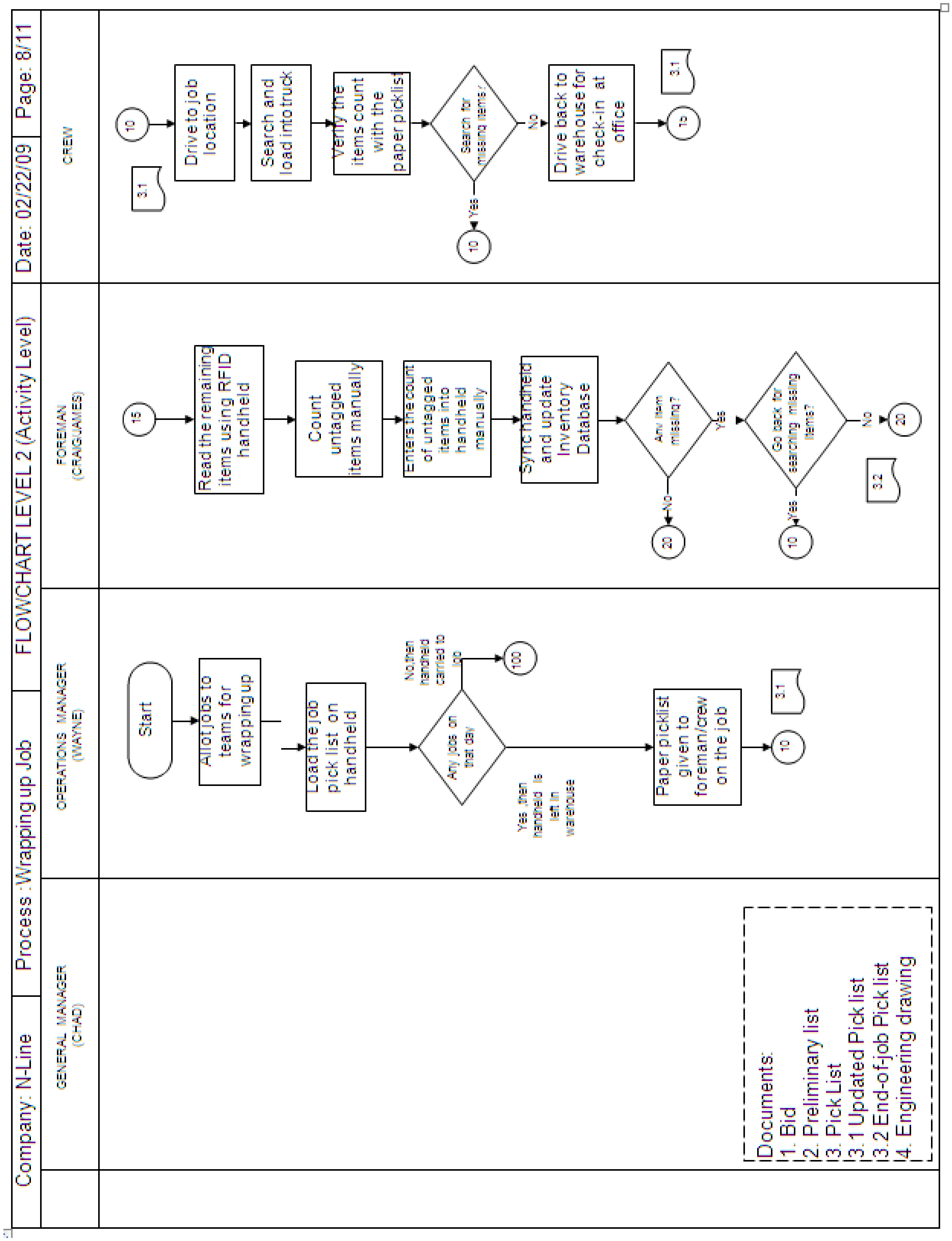
Company: N-Line
Process :New Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 3/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
START
Counter Job?
Yes
15
No
Prepare and send bid
1
4
Approved ?
Yes
No
END
Job type ?
City
15
Txdot
10
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing
Docs 2 and 4 only flow for City and Txdot jobs
15
2
4
Prepare Pick-List including extras
Allocate job to teams
Provide Final approval for the pick list
Load the job pick list on handheld
3
20
10
4
Survey job site
Prepare preliminary pick list
Mark road
2
15


Company: N-Line
Process :New Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 4/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
3
20
Pick items from warehouse as per paper picklist
Load items on trucks
Proceed to office for checkout
25
3
25
Check using RFID handheld reader
Count untagged items manually
Enters the count of untagged items into handheld manually
Check the metal posts
Complete
Yes
30
No
20
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing

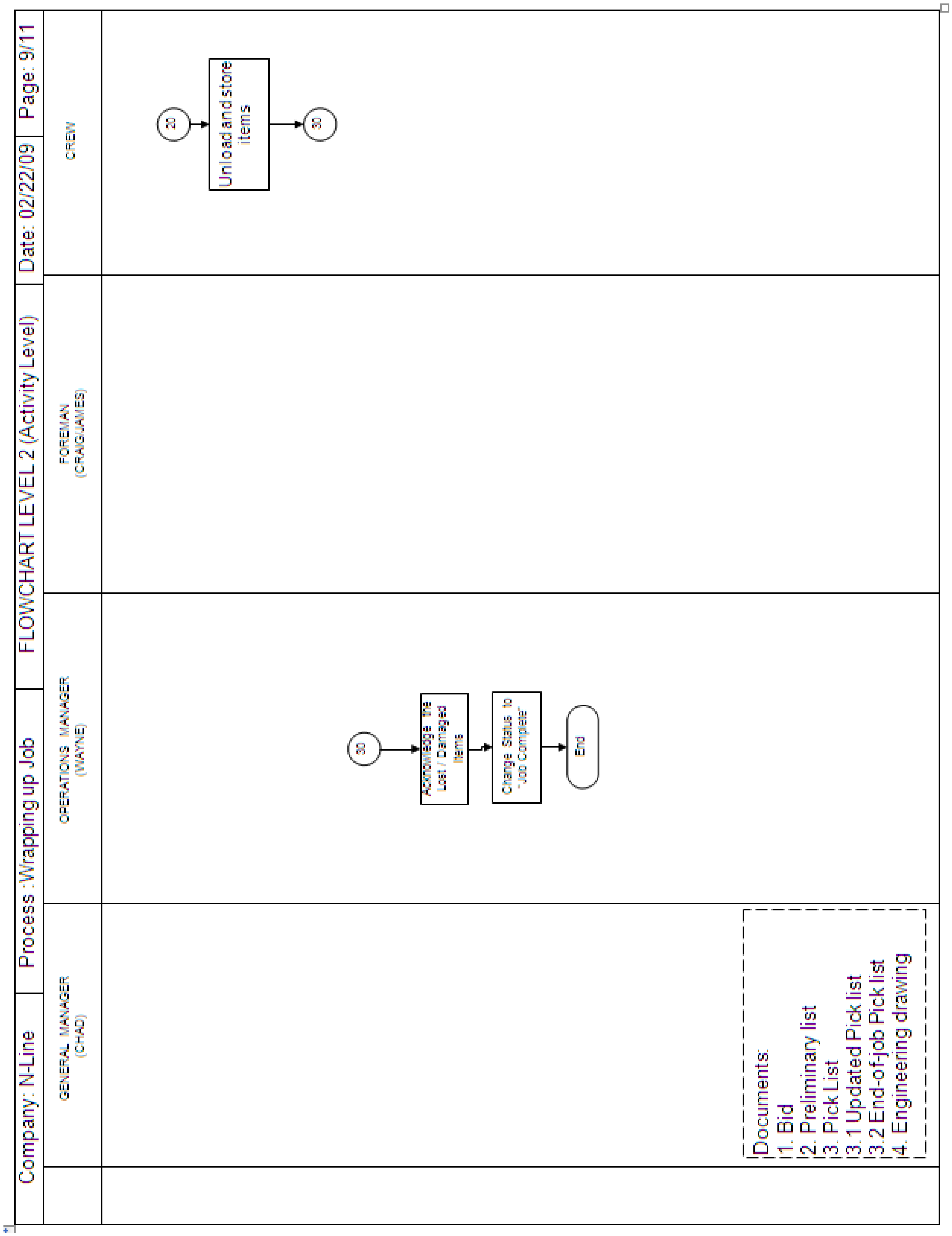

Company: N-Line
Process :New Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 5/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
30
Drive to job location
Execute job
Return from Job site with remaining items
Check in at the office
35
40
Unload and store items
END
35
3
Read the remaining items using RFID handheld
Count untagged items manually
Enters the count of untagged items into handheld manually
Sync handheld and update Inventory Database
3.1
40
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing


Company: N-Line
Process: Service/Phase Work
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 6/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
Start
Receive request for job servicing
Prepare Pick list
Allocate job to teams
Approve the Pick list
Load the job pick list on
Check using RFID handheld reader
Count untagged items manually
Enters the count of untagged items into handheld manually
Check the metal posts
Complete
Yes
No
Pick items from warehouse
Load items on trucks
Proceed to office for checkout
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing

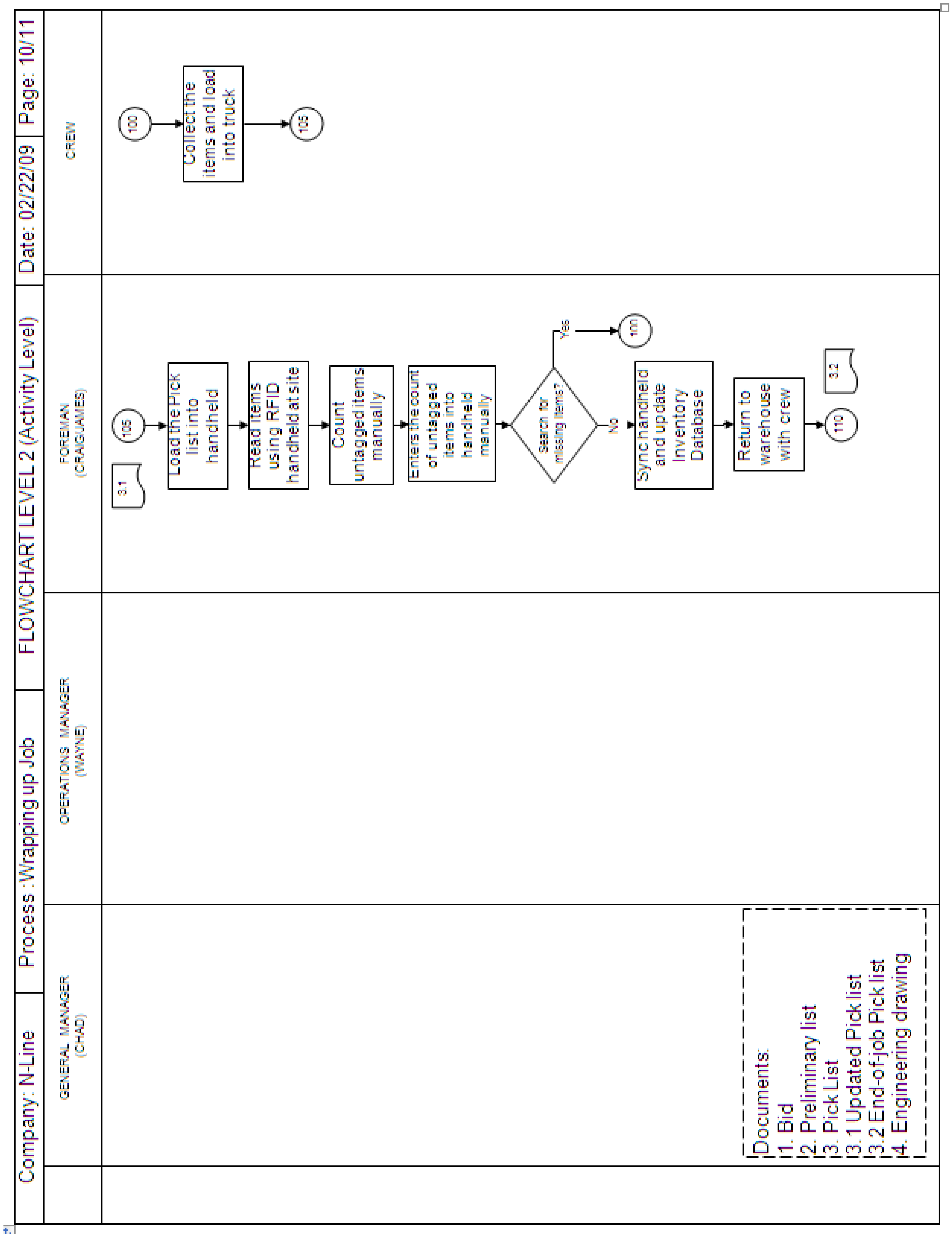

Company: N-Line
Process : Service/ Phase Work
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 7/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
30
Job Servicing
Return from Job site with remaining items
Check in at the office
35
35
3
Read the remaining items using RFID handheld
Count untagged items manually
Enters the count of untagged items into handheld manually
Sync handheld and update Inventory Database
3.1
40
40
Unload and store items
END
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing

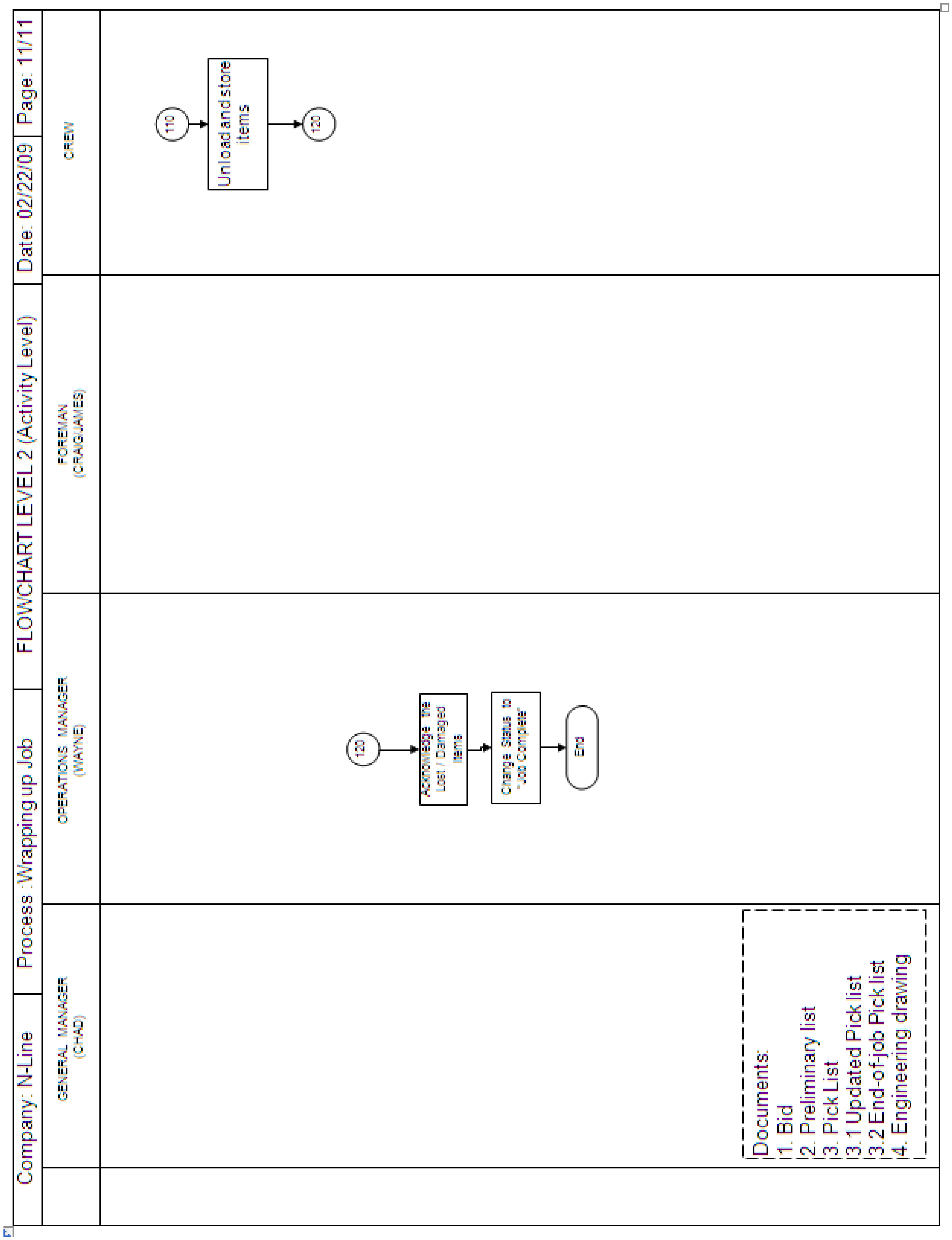


Company: N-Line
Process : Wrapping up Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 8/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
Start
Allot jobs to teams for wrapping up
Load the job pick list on handheld
Any jobs on that day
No,then handheld carried to job
100
Yes ,then handheld is left in warehouse
Paper picklist given to foreman/crew on the job
3.1
10
15
Read the remaining items using RFID handheld
Count untagged items manually
Enters the count of untagged items into handheld manually
Sync handheld and update Inventory Database
Any item missing?
No
20
Yes
Go back for searching missing items?
Yes
10
No
20
3.2
10
3.1
Drive to job location
Search and load into truck
Verify the items count with the paper picklist
Search for missing items
Yes
10
No
Drive back to warehouse for check-in at office
15
3.1
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing



Company: N-Line
Process :Wrapping up Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 9/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
20
Unload and store items
30
30
Acknowledge the Lost / Damaged items
Change Status to "Job Complete"
End
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing


Company: N-Line
Process :Wrapping up Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 10/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
100
Collect the items and load into truck
105
3.1
105
Load the Pick list into handheld
Read items using RFID handheld at site
Count untagged items manually
Enters the count of untagged items into handheld manually
Search for missing items?
Yes
No
Sync handheld and update Inventory Database
Return to warehouse with crew
110
3.2
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing


Company: N-Line
Process :Wrapping up Job
FLOWCHART LEVEL 2 (Activity Level)
Date: 02/22/09
Page: 11/11
GENERAL MANAGER (CHAD)
OPERATIONS MANAGER (WAYNE)
FOREMAN (CRAIG/JAMES)
CREW
110
Unload and store items
120
120
Acknowledge the Lost / Damaged items
Change Status to "Job Complete"
End
Documents:
1. Bid
2. Preliminary list
3. Pick List
3.1 Updated Pick list
3.2 End-of-job Pick list
4. Engineering drawing

3. Improvements in TO BE process over AS IS process

1) Automation of several manual processes

In the AS IS process (step # 25 and step # 60 of AS IS process map) , a worker would manually count the items and write them on the sheet of paper. This was read by Donna (Inventory manager) and entered manually into the database. There is a chance of error at each steps of this process.

In the TO BE process (step # 25 , step # 35in TO BE process) , the counting is automatically done by the RFID handheld. This data is automatically transferred to SQL server and displayed on screen.

2) Introduce Accountability

The AS IS process does not track the person (Step # 10, 15, 20, 25) who is executing the tasks or the person who made changes to the pickup list. This gave rise to miscommunications at multiple occasions and losses to the company. For e.g. Wayne would (Step # 15) make some changes to pick list based on communication with clients while the workers still have old version. Hence the worker will end up taking items according to old list. Also at many times, workers would not take all items by mistake (Step # 25). There was no way to track who checked the items when the truck left the warehouse.

In the TO BE process (Step # 15, 25) , we require people to login with their credential when they need to access the data in the system. We also have several categories of users with different levels of access according to their job profile. By this we can ensure , we track every change in the system to the user who was responsible for it.

3) Reduce the decision making by the workers

In the AS IS process (Step #25), a worker would take several decisions like carrying excess items , not carry few items based upon his understanding of the job. N-Line management has faced several issues because of the worker's attitude.

In the TO BE process (Step # 25, 30), the system would not allow the truck to pass if it is carrying extra items. In case it is carrying lesser items it gives a warning to the user. The reason we did not enforce the worker taking less number of items is that few times the job may be executed in parts; and all items are not carried at once.

4) Real time status display

The AS IS system does not provide a real time status display to N-Line management. Chad or other senor employees have to call Donna and ask for same.

In the TO BE process, we have a desktop application installed on each employee's PC. Everyone can log in and check the data to which they have access.

5) Fore casting

The AS IS process does not provide much information to the inventory usage trends over annual / monthly terms.

As a part of Phase –II in TO BE process, we plan to introduce the functionality to allow managers to forecast the demand and thus optimizing the inventory in warehouse.

6) Penalize customers for loss of items

The AS IS process does not allow N-Line to provide evidence to prove when the clients loose items from the job site. Thus N-Line has to bear the loss of items without penalizing the customer.

In the TO BE process (Step # 120), each item has unique ID (RFID tag ID). Thus N-Line can easily track the items with respect to the clients and penalize if they lose it.

Chapter 6: N-line System design

Approach

The project to design the Inventory Management system was completed through the following stages:

1. Requirement gathering / Process mapping
2. System Design
3. Software Development
4. Selection / Testing of RFID tags
5. Implementation Planning
6. Item tagging
7. Software Installation
8. Employee Training sessions
9. Onsite Trouble Shooting
10. Post Implementation Support

Stages 1-4 are explained in this chapter while remaining are elaborated in next chapters.

1. Requirement gathering / Process mapping

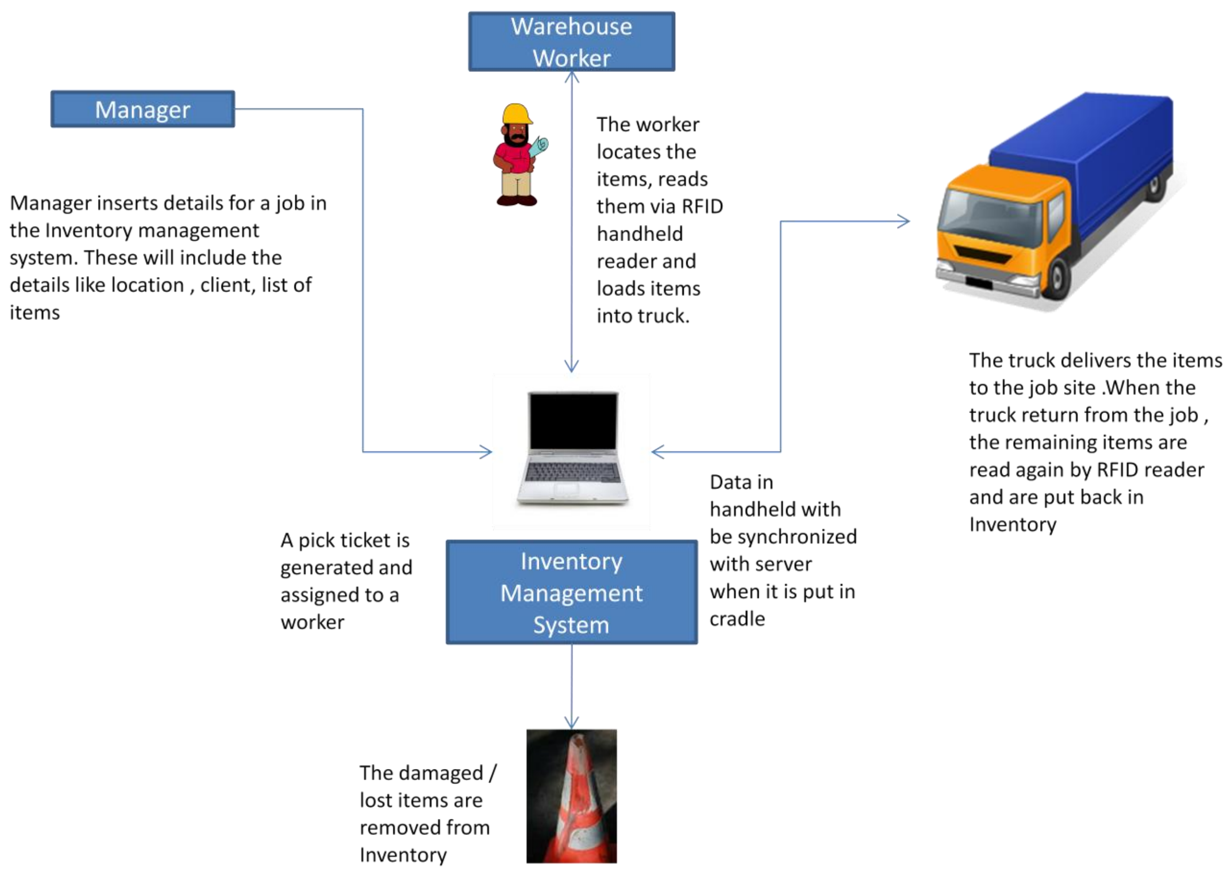
This was the first stages when we tried to understand the business of N-Line Traffic. We had visited the company several times to observe the way of daily operation. I had also been with the workers on a job to understand the complete cycle of working.

After several meetings with the clients and internal discussion, we came up with a draft AS-IS process which was reviewed internally within the team. Later we also got the AS-IS process map signed-off by Chad (co-owner of N-Line Traffic)

We followed the same process for designing the TO-BE process. This was also agreed with the clients. The process maps are explained earlier in detail.

2. System Design

Once the process mapping was complete, then we started with the system design. The below picture gives a high level idea of the Inventory Management System.



3. Software Development

Designing software for the Inventory System was a major part of the project. A large part of this was handled by another graduate student (Mahesh Babu). We also are grateful to Dr. Danso (Construction Management Department) for his expertise in programming on mobile devices. He helped us in the programming on handheld and synchronization between PC and handheld.

Attached below is the N-Line Software documentation with the following details:

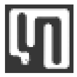
- DETAIL SYSTEM ARCHITECTURE
- DESKTOP APPLICATION
- HANDHELD APPLICATION
- SYNCHRONIZATION MODULE
- N-LINE SERVER DATABASE DESIGN
- N-LINE COMPACT (HANDHELD) DATABASE DESIGN
- TRAINING/ ITEM TAGGING MANUAL

4. RFID Tag Selection and Testing

The main tags we used in the process of testing were the AD-223, 805, 814, 824, 833, and 840 tags from Avery Dennison.

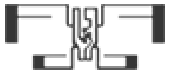
- AD-223 

- Slender form factor
- Write ranges nearly equivalent to the read ranges

- AD-805 
    - Small form factor
    - Excellent edge-on read ranges
    - Low stackable read range (not good with signs).

- AD-814 
    - Excellent for tagging small items
    - Edge on readability was not good with signs.

- AD-824
    - Excellent read ranges
    - Not foolproof with single-pass reading
    - Excellent stackable readability



- AD-833
  - Best tags for our applications
  - With a unique antenna design that enhances readability
  - Readable through brick walls
- AD-840 
  - Extremely durable
  - Good read range

We had shortlisted the following tags for the final testing:

- AD-223
- AD-833

We decided to go with Inlay with AD-223 with".002" White polyester label with standard adhesive" for cost considerations. (14)

Tag	Number of tags	Features					
		Only Inlay	Encoding	Inlay with .002" White polyester label with standard adhesive	Inlay with .002" White polyester label with standard adhesive and 10 mil rigid vinyl for waterproofing	Printing	Price
AD 223	7500	Yes	No	No	No	No	0.129
		Yes	Yes	No	No	No	N/A
		No	NO	Yes	No	No	0.22
		No	Yes	Yes	No	Yes	0.43
		No	Yes	No	Yes	No	0.48
		No	Yes	No	Yes	Yes	0.48
Tag	Number of tags	Features					
		Only Inlay	Encoding	Inlay with .002" White polyester label with standard adhesive	Inlay with A200 Acrylic white label with Cold adhesive	Printing	Price
AD 833	6600	Yes	No	No	No	No	.258*
see note below		Yes	Yes	No	No	No	N/A
		No	No	Yes	No	No	0.38
		No	Yes	Yes	No	Yes	0.83
		No	NO	No	Yes	No	0.44
		No	Yes	No	Yes	Yes	0.95

Chapter 7: N-Line System Implementation

The implementation involved the following:

1. Implementation Planning
2. Software Installation on Server and user machines
3. Tagging of items
4. Training of employees at N-Line
5. Resolving Post Implementation issues (Software + hardware)

The implementation of N-Line project was planned on weekend of 05/01/09. But since the tags delivery from the supplier was delayed, we had software deployment only.

As a part of software deployment, the following activities were carried out:

- Pre-requisite framework and softwares like (.Net framework, SQL Server Studio 2008, etc) were installed before installing N-Line application.
- MS SQL Server 2008 was installed on a dedicated machine to act as Database server.
- N-Line application was installed at following machines
    - Server
    - Chad England
    - Raymond Alvarado
    - Wayne Culpepper
    - Tammy (a month later)
- The handheld was connected via USB to the server for synchronization.

The tagging of items was initially planned with ENTC462 students only.

The time required for tagging was highly under-estimated. Moreover it involved several complications where we needed extensive inputs from N-Line employees.

Following issues were faced during the actual implementation

1. The time required for tagging was highly under-estimated. It took around 25 working days to complete tagging while the estimate was around 2-3 days.
2. The summer heat was one of the reasons for the slow pace of tagging.
3. We had only one RFID reader and it was required that we need to associate the items with the RFID tags IDs after sticking the tag onto the item. Thus, the RFID reader was one of the bottle necks.
4. Most of the signs were not listed in the initial product list provided by Chad. Hence these had to be added as new products. Also we needed extensive inputs from N-Line employees and managers to identity various constructions signs and decide a common nomenclature for them.
5. We had to manage the task of tagging considering the continuous inflow and outflow of the jobs. This required the N-Line workers to go to jobs and hence we had to halt the work at times.
6. During the period of tagging without the system being fully operational, when the workers took tagged items on the jobs they wrote the tag-ids on a paper which we had to manually update into the system. This took considerable time to set the correct values across the database for the items taken out.

Training of N-line Employees

We provided hands-on training to N-Line employees during May-June when we visited their Bryan warehouse daily. We also had several training sessions in their meeting room when we needed the entire crew to be available for a major change.

We also had created one page manual that we had pasted on employees desks to provide help in their daily activities.

Manual on Desktops

Steps for Creating New Job

1. Open the application and login
2. Click on “New Job”. Enter the job details like Job-name, client-name etc.
3. Allocate required number of items as per product. Save the job.
4. Job Saved popup- Click No.
5. Enter Crew, Vehicle details, Instructions for crew, lease ticket # (if any) and untagged items (if any).
6. Print the pick ticket on Orange Paper.
7. Give the pick ticket to foreman.

Steps for Editing / Viewing Existing Job:

1. Open the application and login.
2. Click on <Job Management> -> <Planned or Current Jobs >.
3. Click on Edit job for the required job.
4. Make required changes and save.
5. Edit Crew, Vehicle details, Instructions for crew, lease ticket # (if any) and untagged items (if any).
6. Print the pick ticket. Give the pick ticket to foreman.

Steps for Closing Existing Job:

1. Open the application and login.
2. Click on <Job Management> -> < Planned or Current Jobs >.
3. Click on delete / close job for the required job.
4. Acknowledge lost inventory (if any). Then Save.

Steps for adding new products:

1. Open the application and login.
2. Open <Setup> -> <Add Product>.
3. Enter the product details along with image (if any). Save the product.

Steps for adding new Users:

1. Open the application and login.
2. Open <Setup> -> <Add User>.
3. Add User details.
4. Ask the user to enter personal password. Save.

Manual for Handheld

Add New Inventory

8. Attach the tags to the item as per the tags location document.
9. Open the handheld application and login with your initials.
10. Click on Add Inventory.
11. Select the product which is being added.
12. Click on “Next”.
13. Scan the tags by pressing the trigger.
14. Check if the number of items being added is equal to the items scanned. Else scan again.
15. Click on Save.

Check out Job

1. Ensure that all items have tags on them.
2. Open the handheld application and login with your initials.
3. Click on “Checkout “.
4. Select the required job and click on “Alloc Details” at bottom right.
5. Scan the items by pressing trigger.
6. Check if all items are scanned. Else scan again.
7. Click on “Checkout” at bottom corner.

Check IN Job

1. Ensure that all items have tags on them. Separate the tags without items and add them separately as new inventory.
2. Open the handheld application and login with your initials.
3. Click on “Check IN “.
4. Scan the items by pressing trigger.
5. Check if all items are scanned. Else scan again.
6. Click on “Check In” at bottom corner.

Post Implementation Issues

Issues related to RFID tags		
	Some of the RFID tags (new ones) do not work or have extremely less range. This is one of the reason the accuracy is less	Planned
	The read range of bare tags is lot more than the labeled tags	Planned
	The tags get wets in mornings due to dew and this further reduces the read range.	Planned
	As the tags for wooden signs do not have adhesive at back, they tend to curl at the corners. This increases chances of being damaged when loading the signs.	Planned
Software - Desktop		
	Change in order of product listing as well as product names to help quickly locate items.	Closed
	Allow user to type in the text boxes for the Pick list	Closed
	SQL express needs to be installed on machine for syncing to work. We are installing over all m/c to be on safer side. Setup issue with Chad's m/c	Rejected
	Replace the Job Creation date column in Edit job screen with Job Start date	Ongoing
	Issue with active sync for multiple users	Closed
	Job inventories are not correct. Ref: Job 10011 not showing correct items sent. 12 barrels are on the job but don't show in items sent. 1 do not enter and 2 road work ahead signs are not on the job but show as items sent.	closed
	Add a field on create new job for a Lease Ticket #	Closed
	Remove the End Date field on create new job	Rejected
	Remove the Date field on Report Details pop up	Closed
	The Report Details that were previously entered are erased when you edit an existing job.	Closed
	The job name and date line on the PIS printout is being cut off.	Closed
	Reduce the box size for items that print on the PIS so that only one sheet will print.	Closed
	Add "day" in the PI sheet date	Closed

	change date format in the edit job screen , so the jobs can be arranged in ascending order	Closed
	Remove delete tag functionality and use new table for trashed tags. This table will have 3 columns , tag-id , product , date of trashing	Closed
	Option to "Update tag-id" in the edit tag screen. This will replace the tag-id (whether assigned to job or not provided it exists in DB	New 6/18
	Edit job screen - The default value of the new allocation to be zero. Also this have to be the number of items added to original pick list	Closed
	Sync losing connection with Handheld .; Need to re start the Aps	Closed
	New screen for debugging of incorrect Tag IDs	New 6/5
	For "1A" work zone and "1" Begin work Zone signs in the new job and edit job , out a popup telling users to add "workers present here" signs also on the job.	Closed
	SQL procedure for closing jobs	Closed
	Combine similar jobs together.	Closed
	Software - Handheld	
	Increases text size.	Rejected
	Put special beep when all items in pick list are read.	Closed
	Load beep after reading	Closed
	Color coding for items returned on the handheld (check in and checkout)	Closed
	Continuous beep when the trigger is pressed.	
	Put voice for "Check in" and "Checkout"	Rejected
	Popup to detect any incorrect item on the truck while checkout. Also stop checkout	Closed
	On handheld as on now - when we read extra items all items are cleared. Make changes so only the items that have exceeded are cleared.	Closed
	During Checkout: 1/ Incase tag is not in Inventory, pop up error message with list of tags which are not in Inventory 2/ If a item is checkout on job and not checked in and we are trying to check it out on another job, then pop up error message with the tag-id details, product and job which it is associated. 3/ Incase item is associated with wrong product (not in PI sheet) popup message with tag-id and it product name.	Closed

	Add a small screen option on the checkout / check in screen to display the tag-ids, product names being scanned. This will help to track the damaged tags.	Closed
	Add customer and job name to the reader (next to job number) in case you don't know the job number that you're checking out.	Rejected
	Create different beeps for item complete/incomplete and job complete/incomplete.	Closed
	Show Raymond how to change the intensity of the reader power. Low to add inventory and high to check out jobs.	Closed
	Dialog box in checkout/check in screen for status of trigger and clear tag list when clear is pressed	Closed
	insert job-id column in check in tag list	Closed
	Report(Pick list) without pictures	Closed
	Multiple operations on the same job. Check out not functional.	Closed
	"Click" sound at all click on handheld	Closed
	Arrange the products in checkout / check in alphabetical order	Closed
	Instead of 2 columns in checkout screen. have 3 columns (# of items to be taken , sent , scanned)	Closed
	IN the ADD Inventory screen - increase the tag-id columns width so that the full tag-id is visible	Closed
	Operational Issues	
	Lack of Manpower for additional work of tagging items (new and those coming from jobs).	Out of scope
	Issue for jobs going on weekend as the planning of jobs needs to be completed by Friday , else Wayne / Raymond has to come over weekend to create new Pick list.	Out of scope
	Lack of initiative from managers, hence workers tends to neglect several steps like tagging items before keeping items back in inventory. Some items were tagged by workers and kept back in warehouse without adding it to Inventory using handheld. Now these items have tags but will not be recognized by our system.	Out of scope
	System cannot handle very large quantities like 400 items being read at once. We must limit it to 50 at one time, for speed and accuracy.	Out of scope

Issues to be handled in Phase II		
	Incorporate barcode reader: Use input of barcode reader directly into desktop application.	Planned
	Maintain total job history (# of items , item type, person , date activity , job ID)	Planned
	Create report of damaged/ lost items for tax purposes	Planned
	Incorporate functionality for sale of products.	Planned
	Incorporate functionality for transfer of items from one warehouse to another.	Planned
	Add search functionality for easily locating items.	Planned
	Add an auto fill product name drop down	New 6/5
	Create a form by which we can check the tag-ids associated with a particular job or product. If incorrect IDs are identified corrections can be made in the same form. This will help them to resolve issue when they have read wrong items and make necessary corrections. This screen will be only accessible to managers.	Planned
	Create a new screen to show the number of items on the job at any stage of job cycle (based on job history)	Planned
	Create a form for taking orders on phone. The operation of adding items in the Inventory system can be done later.	Planned
	Create a new pick list for getting items from the job to warehouse	Planned

Chapter 8: Financial Analysis

Financial analysis (ROI Calculation)

Our team comprising of Dr. Gaukler, Daniel Merchan, Venkat Pidikiti and myself had done extensive analysis to show the financial viability of this project.

We calculated the ROI (Return on Investment) through following steps:

1. Problem Formulation: Calculated the financial impact of the N-Line pain points.
2. RFID Savings analysis: Calculated the average annual saving through implementation of this project.
3. ROI calculation

PROBLEM FORMULATION

Based on the problems identified in the above section, a set of equations were formulated for each problem. These equations are included in the appendix. For each of the problem, the parameters were established and information was gathered to calculate the costs. These costs were used to calculate the net savings associated with the implementation of the RFID system.

Parameters used for the equations are tabulated below. (12)

Total Number of Jobs		**Units**
TX DoT:	48	/year
City:	48	/year
Counter[3]:	14	/year
Number of Second Drop-off Trips		
TX DoT:	6	/year
City:	18	/year
Number of Second Pick-up Trips		
TX DoT:	4	
City:	12	
Workers Needed per Second Trip	2	/trip
Time Taken per Second Trip		
TX DoT:	2.25	Hours
City:	0.75	Hours
Roundtrip Distance		
TX DoT:	120	Miles
City:	20	Miles
Truck Mileage	10	miles/gal
Emergency inventory trips to A&W	12	Year
Manufacturing request to Waco	52	orders/year
Total manual labor	6	Workers

[3] Estimated counter jobs is 28 but we use 14 since it takes less time for this type of jobs

Wages TX DoT:	$13.84	/ hour
City:	$12.15	/ hour
Inventory Counts		
Total counts:	110	Year
Workforce required:	1	Workers
Time taken:	0.25	hours/count
Estimated time saving per job:	1	Hour
Fuel Cost:	$2.50	Gal
Percentage of Tagged Items	80%	
Percentage of Lost Items	10.00%	
Average Time for an Emergency Trip	3	Hours
Average Distance Emergency Trip	170	miles

The parameters listed above were all based on historical data and estimations, some provided by N-line management and some based on our understanding of the process.

For clarification purposes, several parameters are explained below in greater detail.

Total Number of Jobs: Based on historical data. Estimated counter jobs/year are 28 but we use 14 since it takes less time to complete this type of jobs.

Number of second pickup trips; Number of second drop-off trips: Based on estimations provided by N-line managers. For TX-Dot, approximately 1 out of 5 jobs need a second trip. For City jobs, 3 out of 5 jobs need a second trip (expected since average distance for City jobs is significantly minor). Overall, second drop-off trips are more frequent than pickup trips.

Time taken per second trip: Estimated considering the average roundtrip distance per type of job.

Emergency inventory trips to Austin and Waco: On average, N-line needs one unplanned trip per month to the manufacturing locations for inventory replenishment purposes. Average time and distance for emergency trips are based on estimations having Austin and Waco as the emergency destinations.

Wages; Fuel cost: As of April, 2009.

Estimated time saving per job: Cumulative time saved per job with the use of RFID. This includes time spent looking around the warehouse for misplaced items, time spent checking the correct amount of signs after loading the trucks, time spent filling paper documents, others.

Percentage of Tagged Items: This is the percentage of items in the warehouse which are going to be tagged (80%). We need this information because the rest of the untagged items cannot be tracked by RFID and thus the costs involved for such items still exists, which needs to be taken into consideration.

Percentage of lost items: These are the items which are lost on the job site and not accounted for. We have assumed that, with the implementation of the RFID system, at least 10% of the lost items would be found.

Estimated time savings per job: A job on an average to be loaded into the truck takes 2 hours. Other than this, there are other activities like unloading, data entry, and paper based flow. We have estimated that RFID can save at least 1 hour per job. With this we calculated the productivity savings.

COST AND INVENTORY CALCULATIONS

COST CALCULATIONS:

Based on the parameters and the equations of different problems, the costs associated with each of these problems are calculated and the corresponding savings resulting from the RFID implementation are obtained. It is important to notice that not all the items are tagged, and thus the entire costs associated with the problems cannot be saved. However since we are tagging 80 % of the items, most of the costs of the problems would be eliminated.

COST EQUATIONS PER IDENTIFIED PROBLEM

The following equations set will allow us to calculate the cost incurred due to each one of the above identified problems (*as-is* state), and compare it with the cost after the RFID implementation (*to-be state*). Costs will be estimated on a yearly basis.

Again, the problems were:

Problem #	**1**	**2**	**3**	**4**	**7**	**8**
Description	2^{nd} Drop off	2^{nd} pick up	Items lost	Emergency trips to Austin and Waco	Slow processing	Cycle counts

Note: Problems 5&6 are not included as they are part of the inventory analysis.

Indexes:

i = Type of trip, i: {D (drop off); P (pick up); R (request from Austin or Waco)}.

j = Job type, j: {1(TX DoT); 2 (City); 3(Counter)}

t = Item type

Parameter definition:

T_{ij}: Average number of trips per year

NW_{ij}: Average number of workers per trip

WtT_{ij}: Average working time per worker per activity

WR_j: Worker wage rate ($/hour)

d_{ij}: Average roundtrip distance

m_j: Truck mileage

FC: fuel cost per gallon

L_t: Average number of items of type *t* lost per year

IC_t: Cost of item

NJ: Total number of jobs

NI_t: Number of items manufactured

I: Bank interest rate

CCt: Average time per inventory count

NCC: Average number of inventory counts per year

Variable Definition

f: Fraction of untagged items, $0<f<1$

f': Fraction of lost items that could be found with RFID.

RS: Estimated time saving. This accounts for the improvement in process efficiency due to the use of RFID.

The costs and savings calculations are tabulated below. The annual savings were **$ 6450.61**

Savings from use of RFID have been included based on fraction of tagged Items

All Costs and savings calculated annually

Problem 1: Second drop-off trip

After discussion with N-Line management, we found out that many times workers forget to carry all the required items to the job or they realize that they need additional items when they are at job site. Sometimes, the items are staged by workers near the trucks but are left behind at the warehouse. As a result, either the workers have to come back at warehouse to pick up items or someone from warehouse drive to the job site with the items.

The quantitative losses of N-line when the workers return to pick up items from warehouse are calculated below

Problems 1 : Calculation method

Problem Cost = Wage cost + Transportation cost

Without RFID

Wage cost:

Transportation cost:

With RFID

Wage cost:) f

Transportation cost: ( ) f

	COST		
AS-IS Cost	**Wage**	**Transportation**	**Total**
TX Dot	$373.61	$180.00	$553.61
City:	$328.05	$90.00	$418.05
		Total	$971.66
	Savings with RFID		**$777.33**

Problem 2: Second pick-up trip

This is exactly similar to first case except for the fact that here the workers from the warehouse drive to the job site to deliver the additional items.

Problems 2 : Calculation method

Problem Cost = Wage cost + Transportation cost

Without RFID

Wage cost:

Transportation cost:

With RFID

Wage cost:) f

Transportation cost: ( ) f

	COST		
AS-IS Cost	**Wage**	**Transportation**	**Total**
TX Dot	$249.08	$120.00	$369.08
City:	$218.70	$60.00	$278.70
		Total	$647.78
	Savings with RFID		**$518.22**

Problem 3: Items lost at job site

Many times, N-Line's items are lost from the job site. Sometimes, contractors move the items to different location without informing N-Line while at times, other traffic sign rental companies pick up N-Line's items assuming that they belong to them. At other times, they are lost without trace. According to the contract with N-line, contractor is liable to pay N-line for the damages. But N-Line cannot provide conclusive evidence about the items being lost as the all items look similar and each item do not have any unique identification. With RFID, every item has a Unique Identification Number, which would help N-Line to prove their case to contractors.

Problems 3 : Calculation method

Problem Cost = Cost of lost items

Without RFID

Cost of lost items:

With RFID

Cost of lost items (realistic case): ( ) f'

Total Cost of Lost items	$22,348.45
Savings with RFID	**$2,234.85**

Problem 4: Emergency trips to Austin and Waco

Before RFID implementation, N-Line management did not have accurate inventory figures. This resulted in several mistakes in planning for jobs. At many instances, the management would realize a day or two in advance that they do not have sufficient items at the Bryan's warehouse. In such cases , they would try to get the items from Austin/Waco 's warehouse. Either a worker from Bryan would drive to the other warehouse and pick up the items or someone from other end would drop the items at Bryan.

Problems: 4 Calculation method

Problem Cost = Wage cost + Transportation cost

Without RFID

Wage cost:

Transportation cost:

With RFID

Wage cost:

Transportation cost:

COST		
Wage	**Transportation**	**Total**
$996.30	$510.00	$1,506.30
Savings with RFID		**$1,205.04**

Problem 7: Added expenses due to slow processing

Before RFID implementation, all the activities related to Inventory and jobs were managed via papers and manual intention. This took more time than the electronic method using RFID.

Problems: 7 Calculation method

Problem Cost = Wage cost

Based on an estimate of time savings per each job.

With RFID

Cost Savings: NJ×RS×WR

Productivity Savings $1,429.31

Problem 8: Inventory counts

N-Line management had to ask workers to do inventory counts several times in one year to imprve the accuracy of their inventory figures. This effort required multiple workers around one week to do the counting. RFID implementation would scrap the need for multiple inventory counts. Moreover, if need be the inventory count could be done in couple of days with one worker.

Problems: 8 Calculation method

Problem Cost = Inventory count cost

Without RFID

Inventory count cost: CCt ×WR ×NCC

With RFID

Inventory count cost: CCt ×WR ×NCC× f

Cost of Inventory Counts	$357.33
Savings with RFID	**$285.86**

Total estimated Savings with RFID per year: $ 6450.61

There were no savings computed for problems 5 & 6. These are calculated in the inventory analysis.

INVENTORY ANALYSIS:

We analyzed Inventory Costs based on the following cost which are discussed above:

1. Material Costs of Inventory
2. Ordering Costs
3. Carrying cost
4. Internal Ordering Costs of inventory

The Material cost is used to calculate the total investment of N-Line in Inventory.

The ordering cost was included in the material cost as N-Line management did not provide us separate data regarding ordering costs.

Carrying cost mainly includes the cost due to damages to items when in warehouse , items becoming outdated along with the cost of funds being tied up with the Inventory. The traffic items get outdated with the changing state laws and standards. The Carrying costs are mainly due to items being damaged and funds being tied up in Inventory.

Internal Ordering Costs mainly relate to the cost of getting items from other N-Line warehouses. This will include mainly the gas costs along with crew salary. In addition to the gas cost , the depreciation of vehicles due to mileage and maintenance cost due to wearing out of tires and other parts adds to the cost.

Workforce level: Based on the information gathered from N-line management, we determined that the current workforce level is 30hours/worker/week, and the workforce level in summer (June through September) reaches 60 hours/worker/week. According to N-line management, the current period (March-April 2009) corresponds to a 75% capacity utilization scenario. Accordingly, the workforce level for summer period doubles up giving a capacity utilization of 150%. Summer is the period with highest demand.

Inventory levels: To determine total inventory levels per item two sources of information were used: current inventory levels at warehouse and job orders for each ongoing job. Whit this data, the total amount of current inventory per product was determined.

Capacity projections: Using this information, we estimated the inventory levels for two scenarios: moderate-high demand (100% capacity) and high demand (150% capacity). With these inventory requirements projections, the amount of overage/underage for each item was calculated.

Opportunity cost / Cost of funds tied up with Inventory: Finally, with the overage inventory amount and the cost per item, the annual opportunity cost of the inventory was calculated at an assumed 5% interest rate. The opportunity cost totals $7,842.84 is an estimate of the amount of money that N-line is losing in year 2009 due to excess inventory.

The inventory analysis is summarized in the table below. (12)

		Capacity 75%		**Projected Capacity 100%**	
PRODUCTS	**Inventory at Warehouse**	**Inventory at Job location**	**Current Total Inventory**	**Required Inventory**	**Inventory Overage/Underage**
A-Frame	11	0	11	2	9
Construction Signs	4,244	2,323	6,567	3,097	3,470
Barrel	905	400	1,305	533	772
Grabber Cone	2,175	2,875	5,050	3,833	1,217
Reflective Cone Type	45	0	45	7	38

I					
Reflective Cone Type III	31	0	31	5	26
Water Barrier	42	6	48	8	40
MESSAGE BOARD	1	0	1	1	0
Two-Way Traffic Vertical Panel	292	0	292	50	242
Total:	**7,746**	**5,604**	**13,350**		

Projected Capacity 150%				
Required Inventory	**Inventory Overage/Underage**	**% Inventory Overage/Underage**	**Purchase Cost**	**Overage Inventory Cost**
3	8	72.73	$9.45	$75.60
4,646	1,921	29.25	$63.00	$121,023.00
800	505	38.70	$33.00	$16,665.00
5,750	(700)	(13.86)	$13.50	$0.00
11	35	76.67	$32.00	$1,104.00
8	24	75.81	$137.50	$3,231.25
12	36	75.00	$271.00	$9,756.00
1	0	0.00	$14,900.00	$0.00
75	217	74.32	$23.05	$5,001.85
	Total Inventory Overage Cost			**$156,856.70**

Annual Opportunity Cost (5% Interest Rate):	**$7,842.84**

**This would be the opportunity cost for year 2009 given current operating conditions*

Since some of the items are not being used at the moment, we used information of an item with similar usage rate and current inventory levels to project demand.

The capacity information has been used to project inventory levels for current and future (high demand) scenarios. Based on the workforce level information provided, we have estimated that the present capacity is approximately 75%. Accordingly, the workforce level for summer period doubles up giving a capacity utilization of 150%. Summer is the period with highest demand.

ROI Calculation:

We have calculated ROI considering various scenarios

1. Implementation only at Bryan Office
    a. ROI after considering excess Inventory cost
    b. ROI without considering excess Inventory cost
2. Enterprise-wide Implementation across 3 warehouses
    a. ROI after considering excess Inventory cost
    b. ROI without considering excess Inventory cost

Bryan Office:

Initial Cost

This is the cost of implementation at Bryan's warehouse. It does not include any recurring cost like replacing tags. We have depreciated the cost of the scanner over 10years.

Development Cost	1	$16,585.00	$16,585.00
Est. Scanner Cost	1	$2,900.00	$2,900.00
Tag Cost	14049	$0.46	$6,462.54
Est. Setup Labor	200	$9.00	$1,800.00
			$27,747.54

Estimated Annual Cost:

We have considered following factors while calculating the annual recurring cost:

- The cost of the scanner is depreciated to zero over 10years.
- We assume that 10% of the tags would have to be replaced annually.

Scanner	1	$300.00	$300.00
Tag Replacement	600	$0.46	$276.00
Extra Labor	50	$9.00	$450.00
			$1,026.00

ROI Calculation for the Bryan Implementation:

	Without Excess Inventory Oppurtunity Cost	With Excess Inventory Oppurtunity Cost
Bryan Office # of Years for Payback	**5.11**	**2.09**

ADDITIONAL OFFICES

We have calculated the costs for implementation across other warehouses in similar as that for Bryan warehouse

Initial Cost

A large portion of the N-Line Inventory is based in Bryan, as a result we would require less tags for implementing the system across other warehouses.

Est Scanner Cost	1	$2,900.00	$2,900.00
Tag Cost	8000	$0.46	$3,680.00
Est Setup Labor	150	$9.00	$1,350.00
			$7,930.00

The recurring cost is considered to be same as of Bryan to be on a safer side. We calculate ROI based upon the above analysis.

	Without Excess Inventory Oppurtunity Cost	With Excess Inventory Oppurtunity Cost
Additional Office # of Years for Payback	1.46	0.60

Enterprise perspective (if system deployed at all location in this calendar year)

Set up cost

The table below gives the information about the costs for implementing the Inventory system across all 3 warehouses.

Bryan	$ 27,747.54
Location #2	$ 7,930.00
Location 3	$ 7,930.00
Total Setup cost	**$ 43,607.54**

The table below gives us a comprehensive view of ROI considering various factors like Inventory costs and recurring annual expenses.

	Without Excess Inventory Oppurtunity Cost	With Excess Inventory Oppurtunity Cost
Saving per Warehouse	-$6,451.00	-$14,293.84
Total saving	$19,353.00	$42,881.52
Payback without annual expense	2.25	1.02
Annual Expense per warehouse	-$1,026.00	-$1,025.00
Total Annual Expense	$3,078.00	$3,075.00
	Without Excess Inventory Oppurtunity Cost	**With Excess Inventory Oppurtunity Cost**
Payback with annual expense	2.68	1.10

Chapter 8: Feedback, Learning and Conclusions

Customer Feedback

We had conducted an employee poll at N-Line to understand what the employees perceived of the RFID Inventory System. We conducted this poll at all levels from Owner of company to the worker in warehouse. The below table gives summary of our discussion.

Name of N-line Employee	Role at N-line	Comments
Raymond	Assistant Operation manager	• Keep track of Inventory (IN / Out)
Jackson	Worker / Crew (Warehouse)	• No idea yet
Mario	Worker / Crew (Warehouse). Played a major role in tagging the signs	• Saves Money • Tagging has helped to keep sign bay in order as workers now have to place signs at correct location • No major issues with scanning since last 2 weeks
Tammy	Assistant to Managers. Responsible to scanning	• Loss prevention • Find out what is on the job • Cost analysis • Suggested improvements in PI sheet
Chad	Co-Owner	• Saves Money • Increase accuracy in inventory / billing

Wayne	Operation Manager	• Track Inventory • This system has increases workload , decreases efficiency , increases loading time by 30% • Does not have faith in system as system does not show correct inventory • Few suggestions to improve were provided
Aaron	Manager (Mechanical)	• Helps Chad to track inventory. • As owners take pride in their company / assets, they want to track each item to its location. It may be a bit of hassle but people must change to do better.
Shay	Receptionist	• Does not help me at all • Keep track of Inventory • Would help if leasing ticket is integrated in the Inventory system
James	Foreman	• Keeps better track of Inventory / on job • Issue – Service jobs require extra work • No issues otherwise
Tiffany	Receptionist	• Positive Inventory stuff

RFID Implementation Advantages

Direct

1. Inventory Visibility to all required people to those who have access to server
2. Can track the exact number of the items on job. Earlier the papers used to get misplaced and the correct numbers were never entered into the Inventory system
3. Elimination of human error while in counting the number of items taken on job, or returned and its entry into the system.
4. Excess items cannot be taken on job now as the handheld gives warning / error. This means that the person who makes the PI sheet has to put correct figures rather than approx ones.
5. Incorrect items (items not on pick list) cannot be taken. Check on handheld for same.
6. Introduced accountability into the system, as the person who makes / modifies the PI sheet is recorded in the system. At the same time every step like scanning in / out is also accounted to a person.

Indirect

1. Streamlined Warehouse. This was told by Mario.
2. No item can be thrown right away without scanning it first. Earlier people used to throw the items, decision were taken by the workers.
3. Alignment of company's goals / mission from everyone's perspective. (From owner, assistant Op manager, receptionist) EXCEPT Ops. Manager
4. Getting all employees involved in new technology deployment

RFID Implementation disadvantages

Direct

1. Extra step in loading.
2. Confusion / stress when tag does not read for any reason.
3. Originally we had full support/ commitment from co-owner (Chad) and Ops. Manager (Wayne). After our first meeting with all managers from 3 warehouses, Wayne had a ***toxic*** effect on everyone else. Expectation from Chad was to put off these negative emotions that Wayne had on other employees. This was also difficult on our team.
4. We were not given all requirements (different scenarios for jobs) prior to project.

Indirect

1. Since there was no pilot project, it created confusion/ stress.
2. Lack of internal communication (within N-Line)

Learning from the project (Development Team perspective)

- *Project contract separate from proposal*: Mention the success criteria as a part of contract. The contract should include high level design which determines the scope of the project. It should also contain a framework for communication between the team e.g. regular updates and feedback, planning etc.

- *Exhaustive requirement gathering – different from process mapping*: We need to capture detailed requirements in a functional requirement document. This document should be signed off by the clients before the project development is initiated. Any deviation from this document should be taken a new requirement.

- *Open communication channel / regular feedback from client in all phases of projects*: Need weekly or fortnightly meetings with clients to discuss any open questions. This would ensure that most of the issues that came up during post-implementation of N-line project would be handled in the development phase itself. It would also provide client better picture of the end product before the final delivery, thus reducing chances of unrealistic expectations.

- *Exhaustive testing of RFID tags*: The testing of RFID tags at the university was not exhaustive. The RFID tags were tested without the acrylic cover. This was a major flaw in testing as the performance of the tags deteriorated by almost 50% with the protective cover. A professional manual which gives the different testing methods would have been useful.

- *Document all communication especially with client*: We faced several instances where client held the development team responsible for a verbal comment / commitment. This could have been avoided had we documented all requirements / expectations in project contract.

- *Pilot implementation*: "A pilot implementation of the system would have ensured that the whole company does not go through beta-testing phase. It would have also reduced the stress level as well as increased the employees' confidence in system. I think the system was not ready for full scale implementation at start of May" – Chad England. A lot of post-implementation issues could have been resolved in a pilot project. One is not concerned with data integrity in case of system failure in pilot project while data integrity is of prime importance in full implementation. We faced numerous conditions in initial part of implementation where we lost the data integrity because system failed beyond recovery. This induced high level of stress amongst N-line employees.

- *Include all stakeholders in discussion for requirement gathering*: We had only Chad (Owner) and Wayne (Op. Manager) from N-Line for discussion till the day of implementation. In actual case, the system is used more by other employees like (Raymond, Tammy, workers, foremen ...etc). The upper management missed the subtle requirements / constraints during our project discussion. These small requirements came up as bugs in the post implementation phase. We could have avoided this by including all the stakeholders in the initial phases.

Learning from the project (N-line Management perspective)

- *Conduct ROI analysis before initiation of project*
- *Document all expectations from system*
- *Document all communication with Development team*
- *Include all relevant people in the discussion*

- *Keep all employees educated about the any new system that affects them*

- *Maintain clear communication amongst employees*: The N-Line management did not clearly convey the role of each employee in this system. This was a source of misunderstanding and stress. For E.g.: Wayne (Ops Manager) assumed that he is responsible for scanning in/out any item for all jobs using handheld, while we had agreed in process mapping that foreman will do the scanning. Even to this day, Tammy does the scanning rather than a foreman.

- *Ensure that pilot testing is successful prior to any full scale implementation*

Areas of further improvement

The prime concern for N-line is the quality/durability of the tags and the readers.

Tags: We have proposed new set of tags FT-1008. These tags have a higher price tag than the previous ones.

Reader: We have proposed use of circular polarized ACC RFID reader rather than Motorola MC9090. This reader is cheaper as well as a better performer.

Approach	New ROI	New ROI for Full Company Implementation
New tags for Barrels and cones	2.26	0.96
New tags for cones, Barrels and other items too.	2.53	1.05

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