A FRAMEWORK FOR INTEGRATION OF FORWARD AND REVERSE
LOGISTICS INTO A SINGLE FACILITY

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1 INTRODUCTION

There are many reasons that items sent to a customer are returned to a distribution center (DC), especially in a DC that is filling electronic commerce and catalog orders. Items may be returned because of errors either by the DC or the customer; the product may be damaged in transit; or the customer may not want the product or be able to use the product, especially with electronics. The management of returns and implementation of reverse logistics into a DC is a key to the success of a company that has catalog and/or internet sales. The return rate on both catalog orders and electronic commerce orders can range anywhere from 25% to 50% according to Willoughby and Tucker [16].

1.1 Reverse Logistics

Many distribution businesses often ignore reverse logistics, not realizing its importance to their business. Reverse logistics is a vital part of a successful business in warehousing and distribution. It is important for the manager of this type of facility to understand that there is a strong possibility that items will be returned, especially in e-commerce or catalog sales. By acknowledging that items may be returned and preparing for returns can make a distribution business run more efficiently. Recognizing that both the forward and reverse channels of the supply chain can be combined and doing this correctly will save a significant amount of money for the business.
Johnson [6] classified some of the reasons that items may be returned. These included defects, recycling at the end of the normal life, or a government mandated recall. Meyer [7] described reverse logistics as a “new frontier” for retail requiring consideration of both the handling and the disposition of items that have been returned. Due to the factors involved in reverse logistics it can be very complicated. These factors include the life cycle of products, warehousing, transportation, record keeping of the products returned, among others.

In reverse logistics there exist two ways to process returns: reuse or dispose. Four activities are classified under reuse. These four are:

- Remanufacture (major re-work)
- Repair (minor re-work)
- Recycle (returned to ordinal components)
- Direct Reuse (as is)

1.2 Forward Logistics

Van Den Berg and Zijm [12] discussed the functions performed in a forward logistics DC. The first of these functions is receiving. After the product is received it is usually inspected for damage. Next, it is moved to storage where it is held until it is
needed to be picked. After the items for the order have been retrieved from storage, it
will then be packed. Then the order is complete and can be shipped.

The forward channel of the supply chain refers to items moving through the supply
chain going from the manufacturer to the warehouse and then to the customer. The
reverse channel refers to items flowing from the customer to the warehouse and then
of the manufacturer. Looking at the functions involved in these channels receiving,
inspection, and storage are the areas that would vary from the forward to the reverse
channel. For example in the forward channel the inspection percentage might be low,
but in the reverse channel the inspection must be 100% because the items are coming
back from the customer and every item coming back can be different and the
company does not know the types of items or the condition of the items being
returned. Both receiving and storage would be different because the reverse channel
deals with smaller quantities since items are usually returned on an individual basis
and not in large quantities. After the storage function in the reverse channel, channels
would then merge and all the items would follow the forward channel.

1.3 Objectives

The objective of this thesis is to demonstrate the labor savings of a combined
distribution and return center versus separate centers. The forward and reverse
channels of a distribution center will be compared. However, this thesis will
demonstrate that using a combined center requires less overall labor therefore lowering the total operating cost of the DC. This thesis will attempt to show that the operations of the forward and reverse channels have many similarities and are easy to combine.

This thesis will define the operations that are needed for each step in the reverse and forward channel. There will also be equations developed that will calculate the time required to perform each operation and the total time required to complete each step of the two channels. There will also be another set of equations that will calculate the number of workers need to perform the operations and the number of workers needed to complete each step. Which help in to demonstrate that a combined center should be used instead of two separate centers.
2 LITERATURE REVIEW

This section of the thesis will look at some of the work that has done by others in the area of reverse logistics.

2.1 Reverse Logistics

According to the website for 180commerce.com [1] reverse logistics is, "...the science of moving goods back through the supply chain." They further stated that most companies "...tend to ignore reverse logistics due to inadequate systems and cost." They also claimed that this could affect profit margins without proper management of reverse logistics.

2.1.1 Importance of Returns

It is important for a warehouse and distribution center to not overlook the processing and handling of returns. It is inevitable that items will be returned. The reasons why items are returned can vary from the item not being the right size to the item not being in line with the consumer's taste. Since items will inevitably be returned, it is important that the distribution center develop a plan to deal with this issue.

If there is not plan by the management to deal with returns it could be damaging for the company. If the returns are not handle correctly it could cause the company to lose money. If the problem becomes massive it could even cause the company to go
out of business. Since returns are inevitable and there is really no way around them a plan needs to be developed to handle them.

2.1.2 Remanufacture

Remanufacturing is one of the ways that returned items can be reused. Fleischmann, Bloemhof-Ruward, Dekker, Van Der Lann, Van Nuen, and Van Wassenhove [3] viewed remanufacturing as the ability of a manufacturer to recoup some of the value out of an already used or sold product. The key to this approach is knowing whether a product should be remanufactured or scrapped. It is also possible to use remanufacturing to develop spare parts or products to be sold in a secondary market with little cost to the manufacturer. The goal of remanufacturing is to bring old and non-functioning products back to use through an overhaul of the item. Some of the typical items that are remanufactured are engines and machine tools.

Van Der Lann and Salomon [14] examined a Dutch copier manufacturer to gain insight on the interaction of manufacturing and remanufacturing. This company only manufactures copiers when their demand is too high to be met by remanufactured copiers. All of the old copiers are remanufactured and if they meet the standards, they are sold as new copiers.
Van Der Lann and Salomon also discussed the use of a push-pull strategy for remanufacturing. In the push strategy, products are pushed through remanufacturing regardless if they are needed to meet demand or not. In the pull strategy, products only go through remanufacturing, as they are needed to satisfy demand which keeps inventory low and holding cost down.

Van Der Lann, Dekker, and Salomon [15] looked at the operations management and the consequences of remanufacturing. They also examined different analytical models that deal specifically with remanufacturing. They explained that a spare parts model cannot be used because there is not a perfect correlation between demands and returns. They also observed that a spare parts model cannot be used because the number of parts in inventory is not constant and will fluctuate over time.

Muckstadt and Isaac [8] developed one of the first analytical inventory models that includes returns. The goal of their model was to determine the reorder time and quantity to minimize cost. Their model assumed that demands and returns were independent of one another and followed a Poisson distribution. They also assumed that outside procurement lead-times were constant. A queuing model was applied with multiple servers available for remanufacturing and stochastic lead times. A continuous review strategy controlled the inventory level and the outside procurements and does not allow for disposal. They concluded from this model that
the optimal strategy is to place an order of a certain size to reach the inventory capacity when the inventory level falls below its capacity.

Considering this analytical model, Heyman [5] noted that remanufacturing all of the returned products would result in extremely high inventories and progressive holding costs. So, Heyman developed a model that allows for disposal when inventories are too high. Items returned when the inventory level is greater than the inventory capacity are disposed of. In this model Heyman does not take into account remanufacturing lead times, fixed cost outside of procurement or outside procurement lead times. In this case, Heyman suggested that it is optimal to set the reorder point at inventory capacity equal to minus one and the outside procurement quantity at the size to reach the inventory capacity equal to one. All returned products should be disposed if the inventory level exceeds or is equal to the inventory level at which disposal is profitable.

Salomon, Van Der Lann, Dekker, Thierry and Ridder [11] and Van Der Lann, Dekker, Ridder, Salomon [13] looked at procurement, remanufacturing and disposal simultaneously. Salomon et al [11] used the inventory level at which to reorder, the size of the order to reach the inventory capacity and the inventory level at which to dispose to determine when an item should be ordered. The next model, developed by Van Der Laan and Salomon [14], showed an alternate disposal strategy where
remanufacturing and disposal are controlled by the queue length of returned products waiting to be remanufactured. The variables in this model were the inventory level at which to reorder, the size of the order to reach the inventory capacity, and the remanufacturing capacity. This model stated that items should be disposed of on arrival when the number waiting to be manufactured is equal to the remanufacturing capacity. Both Salomon et al. and Van Der Lann et al. looked at the reorder point and the quantity to be reordered with the option to dispose but Salomon et al. based disposal on the inventory and Van Der Lann et al. based disposal on the number of items waiting to be remanufactured.

Van Der Lann, et al. [15] then developed a model that considers both items waiting to be remanufactured and inventory. In this model they created a maximum capacity for items waiting to be remanufactured and items in inventory. Once the capacity is reached all other items are disposed.

2.1.3 Other Reuse Methods

Recycling is another method of reuse. Fleischmann, et al. [3] defined recycling as material recovery without conserving any product structures. Some products that can be recycled are glass, paper, plastic and some metals. The next type of reuse discussed is repair. Fleischmann, et al. [3] stated that the goal of repair is to restore non-working products to a working status, although there may be a possible loss of
quality. Some examples of products that can be repaired are domestic appliances, industrial machines and electronic equipment. Repair differs from remanufacturing because the work required for repair minimal compared to the overhaul done in remanufacturing.

2.1.4 Direct Reuse and Disposal

Fleischmann et al. [3] further stated that most direct reuse products do go through some maintenance and cleaning before they are reused. Some examples of things reused are bottles, pallets, and other containers. Direct reuse is possible when the item needs very little maintenance and not an overhaul (remanufacturing).

The disposal of products in reverse logistics is a key concept. As discussed earlier, in some cases it may be more beneficial to dispose of a particular product than to remanufacture it. In addition to considering inventory levels, Van Der Lann et al. [15] stated that used products may still be disposed of after they are returned from the market if testing shows that the product does not meet the standards for remanufacturing or if disposal is more profitable.

Heyman [5] examined disposal. One situation occurs when the inventory level of a SKU (stock keeping units) is so high that the repair or remanufacture and the holding cost of a product is greater than the savings that can be obtained from selling the repaired or remanufactured item rather than a new item. His model assumed that both
repair and purchase lead times are negligible. This is assumed because both can be expedited. In this model there is a maximum number of items allowed in inventory. Returns that raise the inventory level above that maximum number of items allowed in inventory are disposed of, all other items are kept and placed in inventory. However, once an item is placed in inventory, it can not be removed in the all steps except for picking.

2.2 Forward Logistics

Forward logistics is the process items undergo to reach the customer in a distribution center. An item will typically go through six steps in the distribution center before it reaches the customer. These steps are receiving (when the item comes from the manufacturer to the distribution center), inspection, storage, picking, packing and shipping. The steps in the forward logistics process are the same six steps of the reverse process. However, in the reverse process the task of receiving, inspection and storage are different.

2.3 Reverse Logistics in a Central Return Center

Many of the experts who have done research in this area state that in order to be efficient the two processes must remain separate [2], [10]. They say that there should be two buildings—a returns center and a distribution center—and that they should never be combined. Their reasoning for this is that the forward channel will take
preference over the reverse channel and that it is very likely that the reverse channel will become neglected if both operations are combined.

Rogers and Tibben-Lembke [10] claimed that a central return center (CRC) is needed in reverse logistics to process returned items to maximize efficiency of the reverse channel. This may be true if the only process being considered is returns. However, this neglects the combination of both the forward and reverse channels as an efficient and cost effective method of handling items. A CRC separate from the DC is not necessarily needed if managed properly; the problem is the DC’s focus and not the act of integrating. The authors here felt the DC has the main focus of getting products to the customers and not managing any items being returned.

At a CRC, the employees should have expertise in specific areas and will be able to quickly determine where each returned item should be routed. One of the benefits of a CRC is the consistency gained by this expertise, which may be a problem if integration occurs. Rogers and Tibben-Lembke believe that the expertise will be lost in a DC since everyone will not be familiar with both forward and reverse channels. Other problems with the integration of the forward and reverse channels are space and cycle time requirements. Space is an issue because of the possibility of mishandling and the postponed handling of products in the DC in order to free up dock doors (the area semi-trucks use for loading and unloading) or other areas of
limited space. The cycle time for a DC is increased when the reverse channel is added because the concentration is not solely on the forward channel, but on both channels.

DiMaggio [2] noted that a Dallas reverse logistics provider thought that if forward and reverse channels are integrated, employees would be occupied with the task of getting product out the door and the reverse channel would fall by the wayside. This is similar to the argument presented by Rogers and Tibben-Lembke.

2.4 Integration of Forward and Reverse Logistics

Fleischmann et al. [3] also noted that different levels of integration are possible for the forward and reverse channels. A major issue in reverse logistics is whether the forward and reverse channels can be completely integrated, partially integrated, or completely separated, and if integration is possible, how is this accomplished. A complicating factor is in the high degree of uncertainty in the quantity and quality of used products returned by consumers.

Fleischmann et al. also stated that there are no models that consider the combined routing of items from the forward and reverse channels. However, a separate reverse logistics channel can be created. In the creation of an efficient reverse logistics channel Fleischmann et al. named three things that need to be identified: i) the actors in the reverse channel; ii) which functions have to be carried out in the reverse
logistics channel; and iii) the relation between the forward and reverse distribution channel.

2.4.1 Actors

The actors are any members or special parties involved in the forward and reverse channels. Examples of these members are traditional manufacturers, retailers, logistics service providers, secondary material dealers and material recovery facilities.

2.4.2 Functions of Reverse Logistics

Receiving, inspection, storage, picking, packing, and shipping are the functions in reverse logistics [9]. The location for the inspection inside the system is a vital concern in reverse logistics. It is possible that early inspection can reduce the handling cost by quickly disposing of items of no use to the company. While inspecting items, they can be sorted into various reusable groups (remanufacturing, recycling, reuse, and dispose) which may prove to be less expensive at an early stage close to receiving.

2.4.3 Relationship

Looking at the tasks in each activity, one must identify the similarities and the differences in the reusable groups. Determining whether the reverse logistics loop is
open or closed is the key to understanding the relationship the reusable groups. Whether the product is going to be recycled, remanufactured or reused will determine if the loop is closed or open.

In an open loop system the product does not return to the original manufacturer, but goes elsewhere. An example of this type of system is recycling. In an open loop system it is not always feasible to integrate the forward and reverse processes because of the different actors involved.

However, the integration process in a closed loop system is easier since the product is returning to its original manufacturer. The majority of the actors are the same, but there may still be difficulties in the collection and delivery because there may be different handlers for those operations.

However, Fleischmann, et al. [3] stated that there are no models that have integrated both channels, but they implied that it can be done if the actors in both channels are the same and it is in a closed loop system which is true for the combined center being considered.
3 METHODOLOGY

This section will discuss how and why the spreadsheets were used to calculate the results. The methodology used IDEF0 (Integration Definition for Function Modeling) models [4] to show each function involved in the forward and reverse channels and the inputs, outputs, controls and mechanisms in each function. This chapter will also show the tables and variables used in each step to calculate the workload and the number of employees needed per function.

3.1 Functions

The operations in both forward and reverse logistics are very similar. The basic steps in each process are receiving, inspection, storing, picking, packing and shipping. However, reverse logistics may have one extra phase, remanufacturing, after items are inspected. Also, reverse logistics has more variability since the number of items returned cannot be predicted, and operations are performed on a smaller scale because items are evaluated and handled on an item-by-item basis instead of a pallet-by-pallet basis as in forward logistics. If the two systems are integrated the last three steps (picking, packing, and shipping) in both forward and reverse logistics are identical.

In this section there are IDEF0 models [4] used to illustrate the activities involved in both the reverse and forward channels. Each stage has an input and output as well as
parameters that can be controlled and mechanisms that are used to perform each activity. Figure 3.1 shows the basic concept of an IDEF0 model.

![Diagram](image)

**Figure 3.1: A Basic IDEF0 Model**

An IDEF0 model consists of four parts. The first part is the input, which is what goes into the function or activity to make it work. Another part is the controls. The controls are the items that can be controlled by the person (or object) performing the actual function or activity. The third part of an IDEF0 model is known as the mechanism. The mechanism is the objects that carry out the function but cannot be controlled. The fourth part of an IDEF0 is the output where the final goal or outcome is shown.

In this chapter several tables are delineated for the first three steps of the forward and reverse processes. For the calculations herein it is assumed that each employee is capable of doing 450 minutes of work per day.
3.1.1 Receiving

Receiving is the first stage in the process. In the forward channel, items are received from a manufacturer or supplier. The handling of these items is usually done by forklift, but a conveyor may also transport them if the items are removed by case and not on pallets. The number of employees needed in this area is based on the number of trucks scheduled to make deliveries and the quantity of product received, both of which can be controlled by the facility. Other factors that need to be considered in this stage are the number of dock doors (the area semi-trucks use for loading and unloading) dedicated to receiving, and the number of transporters needed to efficiently unload the trucks as shown in Figure 3.2. After items are received, they move to the next step in the forward process, inspection.

Figure 3.2: IDEF0 Model for Receiving (Forward)
In reverse logistics, the receiving process is very similar, but since the items being returned are typically individual items instead of cases or pallets, the handling of the items is different and must be done on a much smaller scale. Items can be put in carts and most of handling can be performed manually.

The items returned will also need to be identified as returned items, so for tracking purposes each item will receive a barcode label. In receiving returned goods, the number of dock doors used is based on the flow of the returns. The number of items being returned (which is not controlled by the company) also determines the number of workers and the number of transporters. Once the items have been received they will become received product and will move on to the next phase, inspection. The IDEF0 diagram Figure 3.3 shows the controls, mechanisms and inputs and outputs for receiving in the reverse channel.

3.1.2 Inspection

In the next stage of forward logistics, some of the product is moved from receiving to inspection. Visual inspection is performed in the receiving area, as items are unloaded. A sample of these items is taken if they don’t pass visual inspection and move to a detailed inspection. If the pallet looks undamaged, the product will often be moved on to the storage area. For inspection, the number of employees should be
Figure 3.3: IDEF0 Model for Receiving (Reverse)

low since there is not a 100% item-by-item inspection and the sample rate is likely to
be low.

The size of the sample area is usually just the area by the dock doors (the area semi-
trucks use for loading and unloading) when the product is coming off the truck. The
inspection takes place as the forklift driver is transporting or putting away the items.
The only mechanism in this phase is the people who perform the inspections. Once
the inspection is done, the item is then moved to the storage area. In Figure 3.4, the
IDEF0 diagram shows the controls, mechanisms and inputs and outputs for inspection
in the forward channel.
In reverse logistics, the inspection process is where the forward and reverse logistics differ the most and where integration will be the most complicated. One complication is that the items come in randomly (meaning both the time and the SKU) and another is that every item that comes in has to have a complete inspection. Some items that come in may require testing, for example, if the item is electronic. Other items (like clothing) may have a thorough visual inspection, where the inspector is looking for damage to the item.

This area will have a higher number of workers per item than in the forward channel since the inspection is very detailed for each item. The sample size of the area will
also be larger than in the reverse process. There should be an area that is set aside for just inspection with testing capabilities (if necessary) for the returned items.

Once the inspection of each item is completed there four areas that the item could travel to: storage (where the item is being directly reused), disposal, recycle, or remanufacturing. The things that are needed in this phase are the people who do the inspection and the equipment needed to assist in the inspection. In Figure 3.5, the controls, mechanisms, inputs and outputs are shown below for the inspection step of the reverse channel.

![Figure 3.5: IDEF0 Model for Inspection (Reverse)]
3.1.3 Storage

In this step all of the components for the forward and reverse process are the same, which is shown in Figure 3.6. Items returned are placed in active or reserve storage.

![Diagram of Storage Process]

**Figure 3.6: IDEF0 Model for Storing (Forward and Reverse)**

Active storage will mainly be used for the items that are returned. In active storage it will be easier to store items that are received item-by-item and are not in whole pallet form. These will be the next items used to fill the outgoing orders. In reserve, storage pallets or cases are usually used to store the items and once the active storage becomes empty, these are the items used to replenish the active storage. When the
items from the reserve storage (cases) are taken to the active storage they are used on an item-by-item basis, just like those items in the reverse process.

In this stage the number of workers needed will depend on the number of items received and that pass inspection. The transporters being used in the phase will be both those from the forward and reverse process, so they should be cross-functional, for example, forklifts. However, the size of the load being transported will vary depending on from which process the items are coming from.

3.1.4 Pick

The next part of both the reverse and forward logistics processes is the picking function. The IDEF0 below in Figure 3.7 shows the control, mechanisms, inputs and outputs for this step. In this step there are employees known as order pickers who are assigned to an order and are responsible for the filling of that order, or they can be assigned to a zone where they pick part of the order. Workers are assigned to a wave that goes to all pickers.

In this stage there are many things to consider. The number of transporters is important, and a decision needs to be made about the type of transporters used. Forklifts should be used in the case of large quantity orders or carts for smaller a more individual quantity orders. The number of workers also depends on the type of picking being done: the larger the quantities and the lower the variety, the smaller the
number of employees. Another decision to be made is the type of picking strategy that will be the most efficient. The final output from this stage is a filled order that is moved to the packing phase.

![IDEF0 Model for Picking (Forward and Reverse)](image)

Figure 3.7: IDEF0 Model for Picking (Forward and Reverse)

3.1.5 **Pack**

The next phase in this process is the packing of the orders that were just picked. In this stage, both the forward and reverse processes are fully integrated and there is no
difference in the procedures and products in this area. The picked order is assembled and is prepared to be shipped out. In this stage it is important to have enough workers to be able to pack the order efficiently and carefully so that no items will become damaged in transit. After the product is packed and ready to go, it is moved into the final phase of this process, shipping. Figure 3.8 shows the IDEF0 diagram for the packing function.

![Diagram of IDEF0 Model for Packing](image)

**Figure 3.8: IDEF0 Model for Packing (Forward/Reverse)**

3.1.6 Ship

This is the last phase in the forward and reverse processes, and like the previous two sections, this phase also is the same for both channels. The main goal of this phase is
to get the product out of the building with no damage. The number of workers is also key in this phase. It is important to have enough workers to get the orders loaded and out the door. The type of shipping that is required to satisfy the customer is important, should the product be sent overnight, through UPS, an overnight delivery service, or by another means of shipping. The output from this phase is the shipped product to the customer. Below in Figure 3.9, the IDEF0 diagram shows the controls, mechanisms and inputs and outputs.

Figure 3.9: IDEF0 Model for Shipping (Forward and Reverse)
3.2 Facility Requirements

There are two options that exist when discussing the implementation of a forward and reverse logistics process. One option is to have a separate distribution and returns center [2], [10]. The second option, which is a feasible option, but has not been considered, is to have one combined center with the operations of both. Both of these options are being analyzed and compared in the sections to follow.

3.2.1 Distribution Center and Return Center (Separate)

For separate facilities, each will require a building to house the operations. Each facility will also have its own workers and equipment for handling and testing. There will also be overhead expenses at each facility to support operation. Also, with separate facilities, outside transportation will be needed to transport the items to the appropriate destination after the inspection.

3.2.2 Distribution/Return Center (Combined)

A combined facility will have some of the same requirements for the separate centers, such as a building, employees, transporters, and overhead cost. Although the requirements are the same, the quantity is different: fewer employees will be needed in a Distribution/Return Center (D/RC). Also, a combined facility has the same overall requirements (such as utilities, restrooms, and office space), but there is less total space in one facility than two. The two separate facilities may each be smaller
than the combined facility. However, the size of both facilities together will be can bigger than the D/RC. There is a lesser need for any outside transportation because most items will be moved into the forward process. Only those items that are moved to recycling or disposal will need transportation. Another thing that may be different is the size of the facility.

3.2.3 Advantages/Disadvantages

In using a combined facility there are many areas where the company can save money:

- Direct labor
- Support staff
- Overhead of two buildings
- Equipment
- Non-manufacturing areas (office space, restrooms, locker rooms, etc.)
- Transportation

The first reason that having a combined center is more advantageous than having a separate center is that two buildings cost more than one to both build and to operate. An example of this is the number of managers needed. Only one management staff will be needed instead of two if the facility is a combined one. Also, workers in the two separate buildings may have a lot of idle time, especially in the returns center,
since their utilization depends on the flow of returns. In a forward process, the flow of the products is known while in the reverse process it is random, and if there are no returns then there is no work, which results in idle time for the employees. In a D/RC, since there are two operations being performed in one building, the employees will be cross-trained. If in a particular day the number of returns is low in a combined center, the workers can then be utilized in the forward operation.

The equipment that will be in both the DC and the RC can also be shared if it is located in one facility instead of purchasing the same equipment for two buildings. Also, there is not a lot of outside transportation needed in the combined facility, which in separate facilities is required to get the products from one facility to the other. All items that are incorporated into the forward process from the reverse channel can be integrated through conveyors or other methods of transportation within in the particular facility. Non-manufacturing areas such as: office space, restrooms, and cafeterias, do not have to be duplicated in a combined center versus a separate center.

The main disadvantage of the combined facility stated by the experts [2], [10] is that the main focus may be the forward process and the reverse process may get neglected. Although this is seen as a disadvantage, this will not occur in a combined center if there is a specific section in the center that is dedicated solely to the returns.
If there is a low volume of returns, the employees in the returns area could be moved to the forward logistics area and will not be idle.

3.3 Facility Comparison Spreadsheet

To test the impact of combining the forward and reverse channels on the number of employees needed, a spreadsheet was developed to calculate workload in other conditions. The types of employees that are being compared are direct labor employees. This spreadsheet will help demonstrate that it is economical to have a combined distribution and return center instead of a separate returns center and distribution center.

The spreadsheet includes the variables that describe the operations of a distribution center. The two options that will be covered in the testing will be separate centers and a combined center. The spreadsheet contains variables that pertain to receiving, inspection, and storage in the forward and reverse channels.

3.3.1 Receiving Elements

In receiving there are six elements that make up this stage: unloading the truck, putting on barcodes (only in the reverse channel), scanning barcodes, inspecting items, moving items and scanning the location that the item will be placed in. These elements are described in Section 3.3.3.
3.3.2 Inspection Elements

In the inspection stage, there are a total of four elements that are important in either reverse or forward logistics. These elements are move items to storage, detailed inspection, move items to remanufacture, recycles or disposal, and remanufacture as shown in section 3.3.4. In the storage stage, items are put either in reserve or active storage as shown in Section 3.3.4.

The next sections discuss the first three steps (receiving, inspection and storage) in both the forward and reverse channels. Tables are included to show the calculations for workload in each area. In the center of each table are the elements of each step that are represented in minutes. On the left side of the table are rows for the output of the minutes spent to accomplish the task in the forward process. On the right side of the table are the output spaces for the reverse process. The shaded blocks in each table mean that the specific element being represented is not performed in that channel. The last row of each table shows the total amount of time for all of the elements under each step. Following each table are formulas that show how each number that will be given in Chapter 4 derives both the calculations of the workload and the number of employees needed in each type of facility.
3.3.3 Receiving

Table 3.1 shows the elements needed to complete the receiving step. The elements of inspection and storage also have similar tables.

<table>
<thead>
<tr>
<th>Forward</th>
<th>RECEIVING</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Unload Truck</td>
<td>R1</td>
</tr>
<tr>
<td></td>
<td>Unload Truck from RC</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>Put On Bar Codes</td>
<td>R2</td>
</tr>
<tr>
<td>R3</td>
<td>Scan Barcodes</td>
<td>R3</td>
</tr>
<tr>
<td></td>
<td>Inspect Items</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Move items</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scan Location</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

R1, R2, and R3 represent the tasks that can be accomplished by one person in the receiving step.

3.3.3.1 Receiving Formulas for the Forward Channel

\[ Time \ to \ Unload \ Truck = \]

Number of trucks per day ×
Number of cases per truck ×
Time required per case (move) +
Number of trucks per day ×
Set up truck for unloading
Time to Scan Barcodes =

Number of trucks per day \times \text{Number of cases per truck} \times \text{Time required to scan barcodes}

Time to Inspect Cases =

Number of trucks per day \times \text{Number of cases per truck} \times \text{Time required per item (inspect)}

Time to Move Cases =

Number of trucks per day \times \text{Number of cases per truck} \times \text{Time required per case (move)}

Time to Scan Locations =

Number of trucks per day \times \text{Number of cases per truck} \times \text{Time required to scan barcodes}

Total Time =

Unload truck +
Scan barcodes +
Inspect cases +
Move Cases +
Scan Locations
3.3.3.2 Receiving Formulas for the Reverse Channel

Time to Unload Truck =

Number of items per case x
Percent of returns x
Time required per case (move) +
(Number of trucks per day x
Number of cases per truck x
Number of items per case x
Percent of returns) / (Returns per truck) x
Set up truck for unloading

Time to Unload Truck from RC =

Percent of remanufactured x
Percent of returns x
Time required per case (move) +
(Number of Trucks per day x
Number of cases per truck x
Number of items per case x
Percent of remanufactured x
Percent of returns) / (Returns per truck) x
Set up truck for unloading

Time to Put on Barcodes =

Number of trucks per day x
Number of cases per truck x
Percent of returns x
Time required to put on barcodes

Time to Scan Barcodes =

Number of items per case x
Number of trucks per day x
Percent of returns x
Time required to scan barcodes
\[ Time\ to\ Move\ Cases = \]
\[ \text{Number of cases per truck} \times \text{Number of trucks per day} \times \text{Percent of returns} \times \text{Time required per case (move)} \]

\[ Time\ to\ Scan\ Location = \]
\[ \text{Number of trucks per day} \times \text{Number of cases per truck} \times \text{Time required to scan barcodes} \times \text{Percent of returns} \]

\[ Total\ Time = \]
\[ \text{Unload Truck} + \text{Unload Trucks for RC} + \text{Put on Barcodes} + \text{Scan Barcodes} + \text{Move Cases} + \text{Scan Location} \]

3.3.3.3 Number of Employees Needed

R1- gives the results for the number of employees needed in both the combined and separate facilities where it is assumed that one person can do the job of unloading the truck and unloading of the trucks from the RC

\[ Separate = \]
\[ \text{Unload truck (Forward)/ 450 minutes} + \]
\[ (\text{Unload truck (Reverse)} + \text{Unload truck from RC (Reverse)})/ 450 \text{ minutes} \]
\[ \text{Combined} = \]
\[
(\text{Unload truck (Forward)} + \\
\text{Unload truck (Reverse)} + \\
\text{Unload truck form RC (reverse)})/ 450 \text{ minutes}
\]

**R2**: gives the results for the number of employees needed in both the combined and separate facilities where it is assumed that it takes one person to put on and scan the bar codes.

\[ \text{Separate} = \]
\[
\text{Scan Barcodes (Forward)/ 450 minutes} + \\
(\text{Put Barcodes (Reverse)} + \\
\text{Scan Barcodes (Reverse)})/ 450 \text{ minutes}
\]

\[ \text{Combined} = \]
\[
(\text{Scan Barcodes (Forward)} + \\
\text{Put Barcodes (Reverse)} + \\
\text{Scan Barcodes (Reverse)})/ 450 \text{ minutes}
\]

**R3**: gives the result for the number of employees needed in both the combined and separate facility where it is assumed that it takes one person to inspect the cases, move the case and scan the locations.
\[ \text{Separate} = \]

\[
\frac{(\text{Inspect Cases (Forward)} + \text{Move Cases (Forward)} + \text{Scan Location (Forward)})}{450 \text{ minutes}} + \frac{(\text{Move Cases (Reverse)} + \text{Scan Locations (Reverse)})}{450 \text{ minutes}}
\]

\[ \text{Combined} = \]

\[
\frac{(\text{Inspect Cases (Forward)} + \text{Move Cases (Forward)} + \text{Scan Location (Forward)} + \text{Move Cases (Reverse)} + \text{Scan Locations (Reverse)})}{450 \text{ minutes}}
\]

\[ \text{Total Separate} = \]

\[
\text{R1 (Separate)} + \text{R2 (Separate)} + \text{R3 (Separate)}
\]

\[ \text{Total Combined} = \]

\[
\text{R1 (Combined)} + \text{R2 (Combined)} + \text{R3 (Combined)}
\]

3.3.4 Inspection

Table 3.2 shows the elements needed to complete the inspection step.

<table>
<thead>
<tr>
<th>Forward</th>
<th>INSPECTION</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>Detailed Inspection</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>Move Items to Remanufacture</td>
<td>I2</td>
</tr>
<tr>
<td></td>
<td>Remanufacture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>
I1 and I2 represent the group of tasks that can be done by one person.

3.3.4.1 Inspection Formulas for the Forward Channel

\[ \text{Time to Perform Detailed Inspection} = \]
\[
\text{Number of trucks per day} \times \\
\text{Number of cases per truck} \times \\
\text{Number of items per case per truck} \times \\
\text{Percent of samples taken} \times \\
\text{Time required per item to inspect} \\
\]

\[ \text{Total Time} = \] \hspace{1cm} (23)

Detailed Inspection

3.3.4.2 Inspection Formulas for Reverse Channel

\[ \text{Time to Perform Detailed Inspection} = \] \hspace{1cm} (24)

\[
\text{Number of trucks per day} \times \\
\text{Number of cases per truck} \times \\
\text{Number of items per case per truck} \times \\
\text{Percent of returns} \times \\
\text{Time required per item to inspect} \\
\]

\[ \text{Time to Move Items to Remanufacture} = \] \hspace{1cm} (25)

\[
\text{Number of trucks per day} \times \\
\text{Number of cases per truck} \times \\
\text{Number of items per case} \times \\
\text{Percent of returns} \times \\
\text{Time required per item to move} \\
\]
\[ Time to Remanufacture = \]
\[
\text{Number of trucks per day x} \\
\text{Number of cases per truck x} \\
\text{Number of items per case x} \\
\text{Percent of returns x} \\
\text{Percent to remanufacture x} \\
\text{Time to remanufacture}
\]

\[ Total Time = \]
\[
\text{Detailed Inspection} + \\
\text{Move Items to Remanufacture} + \\
\text{Remanufacture}
\]

3.3.4.3 Number of Employees Needed

**I1** - gives the results for the number of employees needed in both the combined and separate facilities where it is assumed that one person can do the job of detailed inspection.

\[ Separate = \]
\[
\text{Detailed Inspection (Forward)/ 450 minutes} + \\
(Detailed Inspection (Reverse) + \\
\text{Move items to remanufacture (Reverse) +} \\
\text{Remanufacture (Reverse))/ 450 minutes}
\]

\[ Combined = \]
\[
(Detailed Inspection (Forward)+ \\
\text{Detailed Inspection (Reverse) +} \\
\text{Move items to remanufacture (Reverse) +} \\
\text{Remanufacture (Reverse))/ 450 minutes}
\]
I2-gives the results for the number of employees needed in both the combined and separate facilities where it is assumed that one person can do the job of moving the items to remanufacture, repair, dispose and remanufacturing the items.

\[ Separate = \]
\[
\text{(Move items to remanufacture (Reverse) + Remanufacture (Reverse))}/ 450 \text{ minutes}
\]

\[ Combined = \]
\[
\text{(Move items to remanufacture (Reverse) + Remanufacture (Reverse))}/ 450 \text{ minutes}
\]

\[ Total \: Separate = \]
\[
I1 \text{ (separate)} + I2 \text{ (separate)}
\]

\[ Total \: Combined = \]
\[
I1 \text{ (combined)} + I2 \text{ (combined)}
\]

3.3.5 Storage

Table 3.3 shows the elements needed to complete the storage step.

<table>
<thead>
<tr>
<th>Forward</th>
<th>STORAGE</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Place items in reserve storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Place items in active storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>
3.3.5.1 Storage Formulas for the Forward Channel

\[
\text{Time to Place Items in Reserve Storage} = (34)
\]

\[
\text{Time required per item (move) } \times \\
\text{Number of items per case } \times \\
\text{Number of cases per truck } \times \\
\text{Percent of cases per truck } \times \\
\text{Percent of items in reserve storage}
\]

\[
\text{Total Time} = (35)
\]

\[
\text{Place items in reserve storage}
\]

3.3.5.2 Storage Formulas for the Reverse Channel

\[
\text{Time to Place Items in Active Storage} = (36)
\]

\[
\text{Time required per item (move) } \times \\
\text{Number of items per case } \times \\
\text{Number of cases per truck } \times \\
\text{Percent of returns } \times \text{Percent in active storage}
\]

\[
\text{Total Time} = (37)
\]

\[
\text{Place items in active storage}
\]

3.3.5.3 Number of Employees Needed

\[
\text{Separate} = (38)
\]

\[
\text{Place items in reserve storage/450 min } + \\
\text{Place items in active storage/450 min}
\]

\[
\text{Combined} = (39)
\]

\[
(\text{Place items in reserve storage } +
\text{Place items in active storage})/450 \text{ min}
\]
Total = Combined storage + Separate storage
4 FINDINGS AND RESULTS

This chapter will discuss the results from Microsoft Excel spreadsheets that were described in Chapter 3. The sections in this chapter will be divided by each step in the process for both the forward and reverse channels. In each section, the variables will be explained and results analyzed.

4.1 Comparison of Workers Required

The purpose of this section is to report the findings and results based on the workload calculations (Chapter 3) and the employees needed. The results will demonstrate that it can be more economical and more orders per worker can be processed with a combined facility of both the forward and reverse processes. The values used for the variables and times in this chapter were taken from time studies performed at a distribution center that specializes in e-commerce and catalog sales. The times used from the distribution center are results from time studies of facility operations.

4.1.1 Receiving

The variables used to determine the element times for the receiving step are shown in Table 4.1.
Table 4.1 Variables for Receiving

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trucks per day</td>
<td>14</td>
</tr>
<tr>
<td>Number of cases per truck</td>
<td>400</td>
</tr>
<tr>
<td>Number of items per case</td>
<td>40</td>
</tr>
<tr>
<td>Returns per truck</td>
<td>8000</td>
</tr>
<tr>
<td>Percent Remanufactured</td>
<td>12%</td>
</tr>
<tr>
<td>Percent of returns</td>
<td>30%</td>
</tr>
</tbody>
</table>

The number chosen for the number of trucks per day was based on numbers taken from a distribution center, which was their volume of trucks per day. For the percent remanufactured, 12% was chosen based on the distribution center numbers. Based upon previous research done, 30% for the percentage of items returned is reasonable especially in an e-commerce or catalog sales business.

Table 4.2 shows the actual times to perform each operation.

Table 4.2 Times for Receiving (minutes)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set up truck for unloading</td>
<td>7.25</td>
</tr>
<tr>
<td>Move case</td>
<td>0.0203</td>
</tr>
<tr>
<td>Scan barcode</td>
<td>0.017</td>
</tr>
<tr>
<td>Put on barcode</td>
<td>0.27</td>
</tr>
</tbody>
</table>

The setup time of 7.25 minutes for the truck unloading, taken from a time study done by a distribution center, includes the time for the trucks to pull up to the dock and for
the employees to lock the truck to the dock and get ready to unload the items from the truck. The setup time is only used once per truck while the other times are used once per case or per item.

Table 4.3 shows the times required in the forward and reverse channel to perform the task that make up the receiving step.

<table>
<thead>
<tr>
<th></th>
<th>Forward</th>
<th>REceiving</th>
<th>Reverse</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>1238.3</td>
<td>Unload Truck</td>
<td>13702.5</td>
<td>R1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unload Trucks from RC</td>
<td>1644.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Put On Bar Codes</td>
<td>453.6</td>
<td>R2</td>
</tr>
<tr>
<td>R2</td>
<td>95.2</td>
<td>Scan Barcodes</td>
<td>2.856</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>373.3</td>
<td>Inspect Cases</td>
<td></td>
<td>R3</td>
</tr>
<tr>
<td>1136.8</td>
<td>Move Cases</td>
<td>341.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95.2</td>
<td>Scan Location</td>
<td>28.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700.5</td>
<td>TOTAL</td>
<td></td>
<td>2470.4</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4 shows the results from the comparison done between a combined facility and a separate facility. The table shows the number of employees needed for the elements grouped together that form R1, R2, and R3 and for the entire process.

<table>
<thead>
<tr>
<th></th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>R2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>R3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>41</td>
</tr>
</tbody>
</table>
The total number of workers needed is less in the combined center than in the separate center. This is because the separate center has an element of double handling the same product because it is handled once at the return center and again at the distribution center. There are also people needed to transport the items between the two centers which adds a between center transportation time, which is not necessary for a combined center.

4.1.2 Inspection

The variables used to determine the element times for the receiving step are shown in Table 4.5. The sample percent taken refers to the items in the forward channel that are selected for a detailed inspection. This percent is normally low because a DC will have confidence in the items received from vendors.

<table>
<thead>
<tr>
<th>Table 4.5 Variables for Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tucks per day</td>
</tr>
<tr>
<td>Number of cases per truck</td>
</tr>
<tr>
<td>Number of items per case</td>
</tr>
<tr>
<td>Percent Remanufactured</td>
</tr>
<tr>
<td>Percent of returns</td>
</tr>
<tr>
<td>Percent of samples taken</td>
</tr>
</tbody>
</table>

The times used to determine the element times for the receiving step are shown in Table 4.6.
Table 4.6 Times for Inspection (minutes)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time required per item (inspect)</td>
<td>0.4</td>
</tr>
<tr>
<td>Time required per item (move)</td>
<td>0.173</td>
</tr>
<tr>
<td>Time to remanufacture</td>
<td>2</td>
</tr>
</tbody>
</table>

In Table 4.7, the actual time required to perform each task is shown in minutes for both the forward and reverse channels. I1 (detailed inspection) and I2 (move items to remanufacture and remanufacture) represent tasks that can be performed by the same person.

Table 4.7 Inspection Workload Calculations (minutes)

<table>
<thead>
<tr>
<th>Forward</th>
<th>INSPECTION</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>3584.0</td>
<td>I1</td>
</tr>
<tr>
<td>Detailed Inspection</td>
<td>26880</td>
<td></td>
</tr>
<tr>
<td>Move Items to Remanufacture</td>
<td>11625.6</td>
<td></td>
</tr>
<tr>
<td>Remanufacture</td>
<td>16128</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>54633.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.8 shows the results from the comparison done between a combined facility and a separate facility. The table shows the number of employees need for the total step and for the elements grouped together that form I1 and I2.
Table 4.8 Employees Needed in Inspection

<table>
<thead>
<tr>
<th></th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>I2</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td>104</td>
</tr>
</tbody>
</table>

Table 4.8 also shows that the number of employees needed in a combined or separate center is the same. This is because there is no outside transportation element in this step. The total number of employees needed in either center are one hundred and four.

4.1.3 Storage

The variables used to determine the element times for the storage step are shown in Table 4.9.

Table 4.9 Variables for Storage

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases per truck</td>
<td>400</td>
</tr>
<tr>
<td>Number of items per case</td>
<td>40</td>
</tr>
<tr>
<td>Percent of items (reserve storage)</td>
<td>75%</td>
</tr>
<tr>
<td>Percent of returns</td>
<td>30%</td>
</tr>
<tr>
<td>Percent of active storage</td>
<td>25%</td>
</tr>
</tbody>
</table>

The times used to determine the element times for the storage step are shown in Table 4.10.
Table 4.10 Times for Storage (minutes)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time required per item (move)</td>
<td>0.173</td>
</tr>
</tbody>
</table>

In Table 4.11 the actual time required to perform each task is shown in minutes for both the forward and reverse channels.

Table 4.11 Storage Workload Calculations (minutes)

<table>
<thead>
<tr>
<th>Forward</th>
<th>STORAGE</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>2076.0</td>
<td>Place items in reserve storage</td>
<td></td>
</tr>
<tr>
<td>2076.0</td>
<td>Place items in active storage</td>
<td>207.6</td>
</tr>
<tr>
<td>2076.0</td>
<td>TOTAL</td>
<td>207.6</td>
</tr>
</tbody>
</table>

Table 4.12 shows the results from the comparison done between a combined facility and a separate facility. The table shows the number of employees needed in the storage area. Once again the numbers for the combined and separate centers are equal due to the transportation element.

Table 4.12 Employees Needed in Storage

<table>
<thead>
<tr>
<th></th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
4.2 Totals for All Operations (Employees Needed)

Table 4.13 gives an overview of the total number of direct labor employees needed to run each type of center efficiently. The results show that there are fewer employees required to run a combined center than separate facilities. The reason for this is in the receiving step where the items that go to both centers are handled twice and there are additional employees needed to transport items between the two buildings. However, in the inspection and storage step there is no benefit gained from a combined center.

<table>
<thead>
<tr>
<th>Functions</th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving</td>
<td>46</td>
<td>41</td>
</tr>
<tr>
<td>Inspection</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td>Storage</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>156</td>
<td>151</td>
</tr>
</tbody>
</table>

4.3 Sensitivity Analysis

The purpose of the sensitivity analysis is to see if there are any significant effects when the values of the variables change. These graphs were done to also see what trends were visible in each parameter.

Figure 4.1, Figure 4.2, and Figure 4.3 show that as the percentage remanufactured gets larger, the number of trucks per day increases, and as the percentage of items remanufactured gets larger, the gap gets wider between the combined and separate
facilities. This is because the transportation time and the number of people used to transport the products from one building to the next increases in the separate facility as the percent remanufactured, the number of trucks per day, and the amount returned increases. Also, the more items that are remanufactured, delivered or returned, the more people are needed to man that part of the reverse channel in a separate facility. However, in a combined facility it is possible for the employees to be cross-functional, so fewer total employees are needed in the combined facility than the total number of employees needed in two buildings.

Figure 4.1 shows the impact of changing the percent of returns on the employees needed in the separate and combined centers.

Figure 4.1: Impact of Changing Percent of Returns on Employees Needed
Figure 4.2 shows the impact of changing the number of trucks per day in the separate and combined centers.

![Figure 4.2: Impact of Changing Number of Trucks per Day](image)

Figure 4.3 shows the impact of changing the number of trucks per day in the separate and combined centers.

![Figure 4.3: Comparison of Facility With Increasing Percent Remanufactured](image)
Figure 4.1 and Figure 4.2, the slopes are steep, which shows that they have significance. In Figure 4.1, the number of employees needed more than doubles when the percent of returns goes from 10 to 50%; the number of employees increase from 68 or 64 to 243 or 236. In Figure 4.2, when the number of trucks per day is doubled from 8 to 16, the number of employees needed increased by about 81 or 84 people.

Table 4.14, Table 4.15, and Table 4.16 show the number of employees that would be required looking over the range of input variables that were examined. Below are the values that were used for Figure 4.1, Figure 4.2 and Figure 4.3. The numbers in bold represent the values used to calculate the results in the workload calculations.

<table>
<thead>
<tr>
<th>Percent of Returns</th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>68</td>
<td>64</td>
</tr>
<tr>
<td>20</td>
<td>111</td>
<td>107</td>
</tr>
<tr>
<td>30</td>
<td>156</td>
<td>151</td>
</tr>
<tr>
<td>40</td>
<td>200</td>
<td>193</td>
</tr>
<tr>
<td>50</td>
<td>243</td>
<td>236</td>
</tr>
<tr>
<td>60</td>
<td>288</td>
<td>279</td>
</tr>
<tr>
<td>70</td>
<td>332</td>
<td>321</td>
</tr>
<tr>
<td>80</td>
<td>376</td>
<td>363</td>
</tr>
<tr>
<td>90</td>
<td>421</td>
<td>408</td>
</tr>
<tr>
<td>100</td>
<td>464</td>
<td>451</td>
</tr>
</tbody>
</table>
Table 4.15 Effect of Number of Trucks per Day of Employees Needed

<table>
<thead>
<tr>
<th>Number of Trucks per day</th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>94</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>113</td>
<td>110</td>
</tr>
<tr>
<td>12</td>
<td>135</td>
<td>131</td>
</tr>
<tr>
<td>14</td>
<td>156</td>
<td>151</td>
</tr>
<tr>
<td>16</td>
<td>178</td>
<td>171</td>
</tr>
<tr>
<td>18</td>
<td>199</td>
<td>192</td>
</tr>
<tr>
<td>20</td>
<td>219</td>
<td>212</td>
</tr>
<tr>
<td>22</td>
<td>240</td>
<td>233</td>
</tr>
<tr>
<td>24</td>
<td>260</td>
<td>253</td>
</tr>
</tbody>
</table>

Table 4.16 Effect of Percent Remanufactured of Employees Needed

<table>
<thead>
<tr>
<th>Percent Remanufacture</th>
<th>Separate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>123</td>
<td>121</td>
</tr>
<tr>
<td>4</td>
<td>129</td>
<td>127</td>
</tr>
<tr>
<td>6</td>
<td>136</td>
<td>133</td>
</tr>
<tr>
<td>8</td>
<td>142</td>
<td>139</td>
</tr>
<tr>
<td>10</td>
<td>149</td>
<td>145</td>
</tr>
<tr>
<td>12</td>
<td>156</td>
<td>151</td>
</tr>
<tr>
<td>14</td>
<td>162</td>
<td>157</td>
</tr>
<tr>
<td>16</td>
<td>169</td>
<td>163</td>
</tr>
<tr>
<td>18</td>
<td>175</td>
<td>169</td>
</tr>
<tr>
<td>20</td>
<td>182</td>
<td>175</td>
</tr>
</tbody>
</table>
5  CONCLUSIONS AND RECOMMENDATIONS

The results of this research show that it is less expensive to have a combined center to handle both forward and reverse logistics rather than having two separate buildings. In each step evaluated (receiving, inspection and storage), the number of employees that are needed in a combined center is either equal to or less than that of the separate center, even when the numbers are changed in the for the percentage remanufactured, the number of trucks per day, and the percentage of returns.

The main reason why the combined center always needed equal or fewer employees than the separate center is due to the transportation element that is created with two separate buildings. When there are two separate buildings that handle the reverse process, there will have to be transportation to and from each of the buildings for the products.

Other benefits in having a combined facility include the cross training of the workers and the cross functionality of the equipment used. This will allow higher utilization rates for the employees and the equipment in the center.

5.1  Relevance and Applications

This research is extremely beneficial for warehousing and distribution e-commerce and catalog businesses or any other business that has a high percentage of returns.
The spreadsheets developed can be used to estimate staffing for a facility that handles returns or that handles both the forward and the reverse processes in one building. Based on knowing some key variables that play a major part in the operations of one of these companies it is possible to use this work to justify the cost of a combined operation and staffing as well. This also demonstrates that there is potential savings from combining the forward and reverse processes as opposed to claims from others. The combined centers have savings in the areas of direct labor (the area of focus for this thesis), staff support, overhead of two buildings, equipment, non-manufacturing areas (office space, restrooms, locker rooms, etc.) and transportation.

Other advantages of a combined facility are space and flexibility. The combined center has the opportunity to save space by having all operations under one roof. A combined center is better equipped to deal with variation because workers and equipment can be cross-functional and can handle whatever channel has the most work.

5.2 Further Research

This research can be used to further evaluate the advantages of a combined distribution and returns center. Although the size of the building was discussed, the actual layout was not considered in the calculations. The size of each department could be quantified and used in the evaluation of a combined or a separate facility,
which may have a negative impact on the workload calculations. This could be looked at by examining the travel times involved in transporting the items to the departments.

The work done by Van der Lann about the decision between disposal and remanufacturing can also be integrated into deciding whether a center should be separate or combined. Adding the element of disposal and when to dispose can make a difference in the results as far as the workload calculation and the number of employees needed. Consideration of transportation times can be added to making the decision to dispose, which could be added into the workload calculations to see if that has any effect on the number of employees needed for each type of facility.

Another area of further research is to look at using a distribution for the times used to determine the number of workers and the workload calculations instead of numbers time standards. This would give a range of times to perform different tasks. This range would then be used to look at determining if it is better to use a combined or separate facilities.
REFERENCES


