Warehouse Redesign

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1. Executive Summary

A young, growing biomedical company is expanding its warehouse space to keep up with the increasing production. This project's goals were to recommend a layout and improve a process that would minimize the distance traveled by the material handlers, increase the safety of the warehouse by implementing visual controls, implement ergonomics to reduce chance of injury, and save money for the company. To achieve this first I familiarized myself with their current processes and department and the space required for their current and future production levels. Next I created two alternative layouts, the first (Layout A) to minimize distance and the second (Layout B) to minimize distance while also minimizing cost. Both layouts removed an area that exposed the material handlers to an increased risk of back injury and reduced time moving items by keeping lots together until final shipping. In this stage I also created a proposal to implement visual controls in order to clearly designate quarantine areas and improve the visibility of the operation to auditors and people from corporate. Then I evaluated both layouts on time savings versus the cost of implementing the new layout, Layout A saved $50 more per year but cost an additional $3,000 to implement. The economic evaluations showed that both layouts paid off in 4 years but Layout B had a higher net present value and internal rate of return and a lower payback period so I decided to recommend Layout B.

2. Introduction

2.1 Project Origin

Over winter break I visited Corinne who works at Company X to get a tour of the facility in Sunnyvale, California. While I was on the tour, she told me how their company was going through a buyout and their operation was expanding and how as a result of that they were expanding their warehouse space to the other side of their building. They were just about to begin designing the new layout of the warehouse. I explained that I was currently in the process of looking for something to work on for my senior project and maybe I could help work on this new layout. She agreed and introduced me to the team who would be working on redesigning the warehouse portion of the extended facility: Bill, Rick, and Jorge.

2.2 Problem Statement

Company X's current warehouse is too small for their rapidly growing operation, which has created crowding and disorganization. This causes poor ergonomic conditions for the material handlers transporting the goods. The crowding and lack of visual controls increases the chance of cross contamination between sterile and non sterile items which could possibly be disastrous if this was seen during an audit or if an unsanitary product was released on to the market. The flow is scattered which cause the material handlers to have to traverse back and forth costing the company time and money.

2.3 Deliverables and Scope

2.3.1 Project Plan

One of the deliverables for this project will be to create a project plan. The form of the project plan will be a Gantt chart that is updated throughout the project to make sure that the project is up to date and allocates the responsibilities between the team members. It will also function as a work breakdown structure. This project plan will assure that the entire project stays on track and it will make sure that all the stakeholders have the same expectations on when each aspect of the project will be completed. The Gantt chart is all that the official project plan will consist of.

2.3.2 Current Layout and Assessment

For this deliverable, I will create a current layout on Visio then I will insert the current shelving layout on top of this. I will also create a spaghetti diagram of the flow of workers through the system for both generator and catheter material handling. This will enhance my understanding of the system and enable me to recommend a layout that will minimize the material handler's travel time and which departments need to be close or far from others. I will not include anything to do with the generator or catheter manufacturing; as far as this project is concerned the raw materials are dropped off then picked up in the same place as finished goods. Then I will create a written assessment first explaining then pointing out the strengths and weakness of the current layout and material handling process, including the distance and therefore time travelled per item and per year.

2.3.3 Recommended Layouts and Assessment

For the recommended layout I will create two new layouts on Visio of recommended changes to the current side of the building and the newly acquired side of the building to optimize flow and ergonomic ease of use. One layout will be the ideal situation with more changes and therefore more money spent, the other layout will have fewer changes in the actual building to minimize cost while still optimizing the flow. For both of these layouts I will layout out the necessary shelving then add on a spaghetti diagram of the workers for both generator and catheter material handling. I will not include anything to do with the generator or catheter manufacturing; as far as this project is concerned the raw materials are dropped off then picked up in the same place as finished goods. Then I will create an economic assessment and explain the changes in the material handling process that would go along with it, including the distance and therefore time travelled per item and per year and the time saved due to the change in distance.

2.3.4 Racking Sizing and Target Inventory Guidelines

For this deliverable I am only responsible for estimating how many carts will be need for the post-sterile quarantine catheters (both Product Family A and Product Family B) at the current time, with their projected growth, with 50% growth, and with 100% growth. . I will not be responsible for figuring out how much space each type of raw material takes up, this will just be a rough estimate so that I will be able to take into account that space on the new layout. I will not be responsible for the racking size of any intermediate, packaging, or shipping materials. I will also not be responsible for the generator raw material or finished goods. For everything besides the catheter finished goods, I will assume that the shelving needed will be 150% of the current usage and I will use this footprint on my recommended visio designs.

2.3.5 Visual Factory

I will use human factors techniques to create signage the will clearly designate areas. This includes painting lines on the floor to designate where pallets and carts should go and creating signs so that you will know what is in that area without having to open boxes.

2.4 Main Steps to Completion

First I need to gather all the necessary data to understand the current system. Once I understand the current system I need to research ways to improve the current system. Then I will find the space that will be required in the expanding system. After I know the dimensions of the current and future system then I will work on creating my recommended layouts. After we have finalized which layout I am going to do then I will figure out what type of visual tools we should use in the new layout. Then I will write up the final report.

3. Background

3.1 Information about Company X

Company X is a company that creates the Ablation Technology for Barrett's Esophagus. This system is designed to remove Barrett's epithelium in a quick endoscopic procedure. Barrett's esophagus is a change of the epithelial lining of the esophagus due to chronic reflux of stomach acids, enzymes, and bile, which can cause cells to become cancerous. By treating Barrett's esophagus you are able to halt the progression toward esophageal cancer. The products they produce are the Product A Ablation Catheter, which treats the entire circumference of the esophagus, the Product B Ablation Catheter, which is used to treat smaller areas of unhealthy cells, and then a generator to power these two types of catheters.

3.2 Current Layout

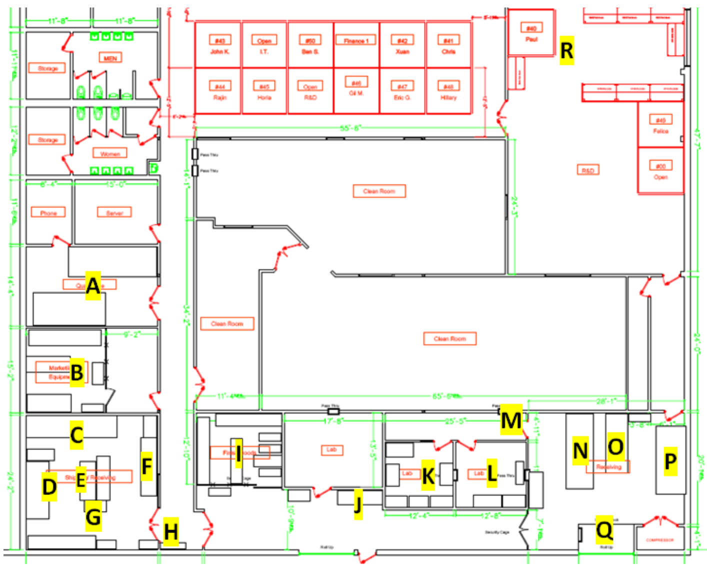

Figure 1: Current Layout with labeled departments

A. Quarantine Room (Biohazard and Non Conforming)
B. Generator Raw Materials
C. Catheters Finished Goods
D. Ready to Ship F.G., oldest according to FIFO
E. Packing Area
F. Shipping/Receiving Computer Desk
G. Waiting for Pick up
H. Just Received
I. Finished Goods Generators and Overflow Catheters F.G.
J. QC Quarantine
K. Catheter Packaging Room
L. Catheter Raw Material (small item storage)
M. Pass through window
N. Non-sterile quarantine
O. Catheter Raw Materials
P. Post-sterile quarantine
Q. Loading Dock
R. Generator Manufacturing

3.3 Current Process

3.3.1 Current Catheter Material Handling Process

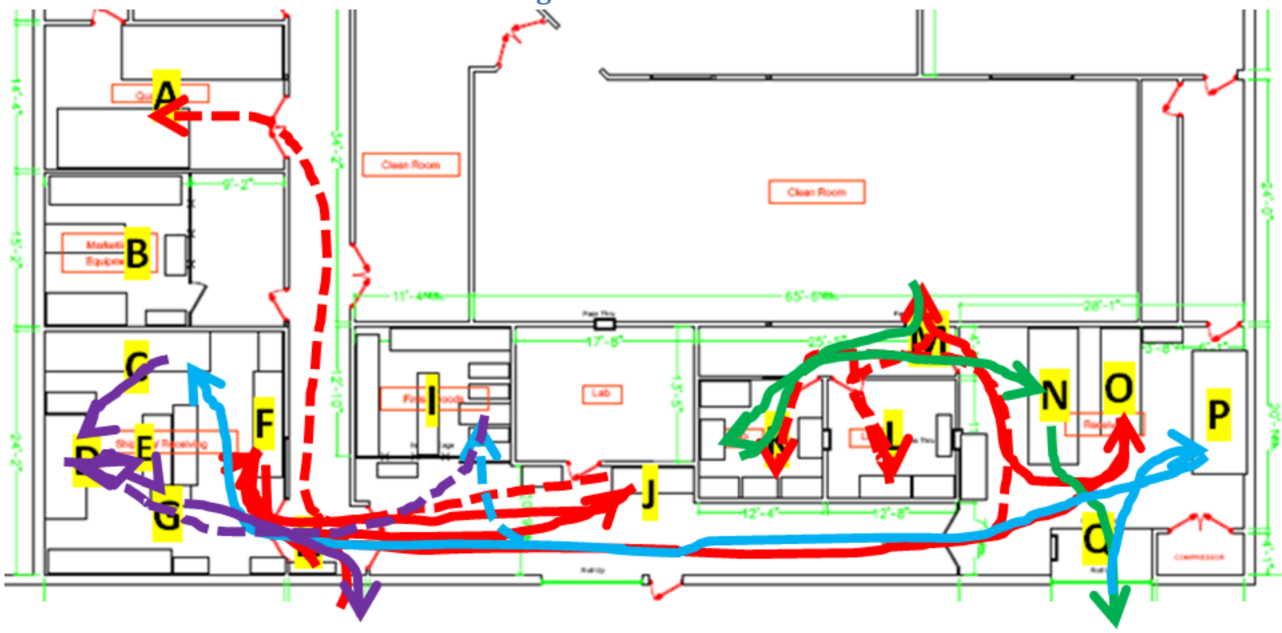

Figure 2: Current Catheter Material Handling Process on Layout

3.3.1.1 Catheter Raw Material Receiving Process (Red)

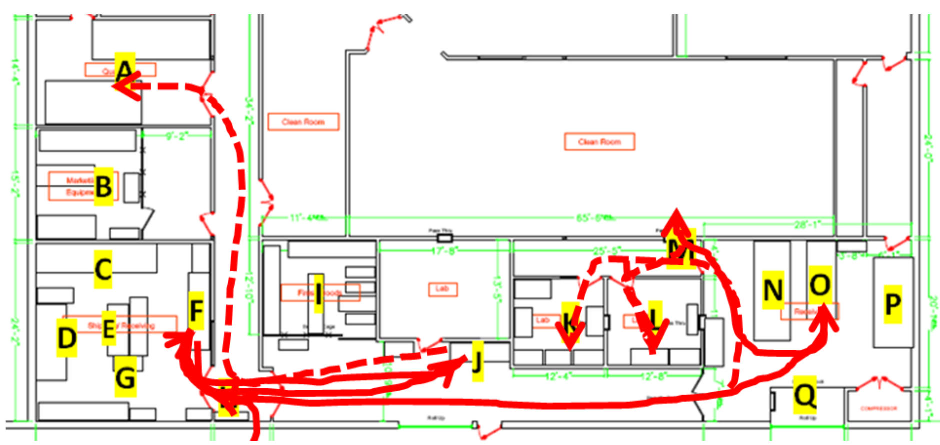

Figure 3: Current Catheter Receiving Process on Layout

1. Delivered (comes in door near shipping)
2. Put on cart (H)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (H)
4. Match qty in packages with qty stated on packing list. (H)
5. Non-inventory items without P.O. are delivered to recipient. (H)
6. Inventory items and or items under a PO are entered into computer system (F) and tag box (leave box on cart near door(H))

7. Go to QC or recipient (there for about 24 hours, then if approved it moves on) (J), if rejected by QC goes to Quarantine (A)
8. Released on computer (F)
9. Placed with raw materials (O), some of the raw materials are placed in a lab room (L) and labels and packaging supplies are placed in a lab room (K)
10. Picked up from Raw Materials (O or L)
11. Moved through pass through window into clean room then assembled in clean room (M)

3.3.1.2 Catheter Packaging (Green)

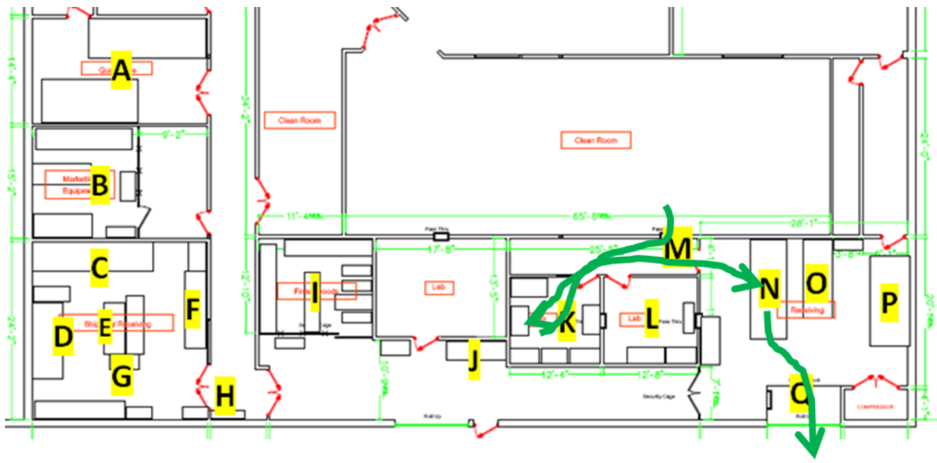

Figure 4: Current Catheter Packaging Process on Layout

1. Passed through window (M) from clean room to packing area (K) (room near the pass through window with the desks in it)
2. Moved to desk (K)
3. Instruction manual, filter and catheter placed in boxes (K)
4. Boxes repacked into coffin boxes in packing room (K)
5. Coffin boxes are then palletized and strapped (N)
6. Put into non-sterile quarantine (will be shipped through loading dock) (N)
7. Print labels for each pallet; complete the order forms for Sterigenics and Nelson labs. (F)
8. Shipped through loading dock (Q)

3.3.1.3 Catheter Receiving Post Sterilization (Blue)

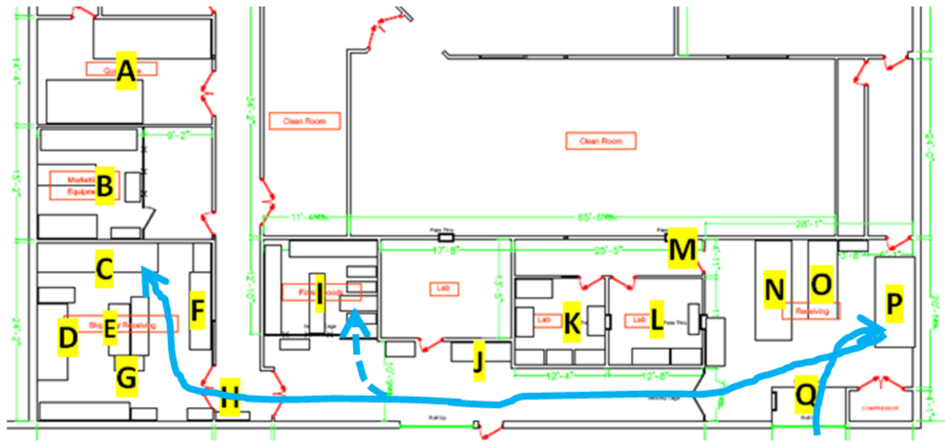

Figure 5: Current Catheter Receiving Post Sterilization Process on Layout

1. Delivered through loading dock (Q)
2. Waits a week for results in Post Sterile Quarantine (P)
3. QC releases (QC does some type of inspection on all catheters) (near P and O)
4. Release on system (F)
5. Unpack every catheter box from coffin boxes, bring into shipping room on cart, unload every catheter box into finished goods shelves (C), some overflow finished goods go to generator finished goods (I)

3.3.1.4 Catheter Shipping (Purple)

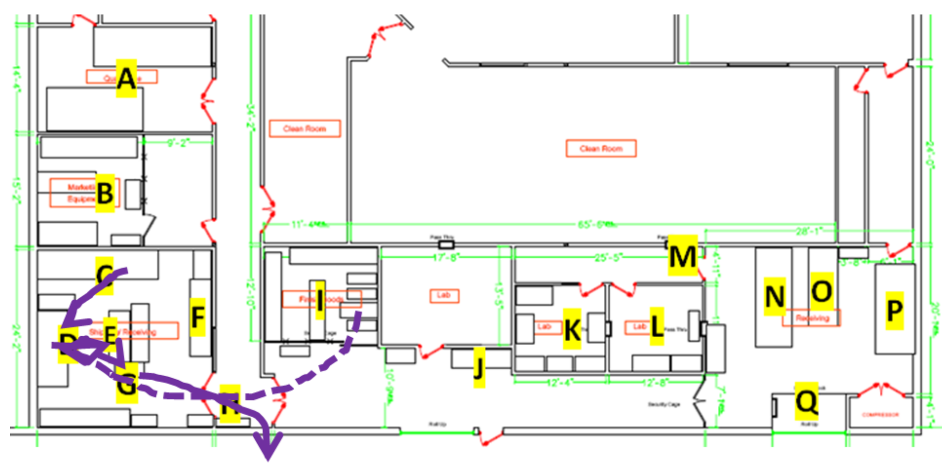

Figure 6: Current Catheter Shipping Process on Layout

1. Move the oldest catheter boxes off finished goods shelves (C)
2. Put into the shipping stock area to keep with FIFO practices (D)
3. Wait for order (about 60 orders/day) and transact sales order packing list in ERP system.(F)
4. Pull order. (D)

5. Box (E), if international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
6. Print shipping label (F)
7. Put in waiting area (G) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door near shipping room (H)
8. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

3.3.2. Current Generator Material Handling Process

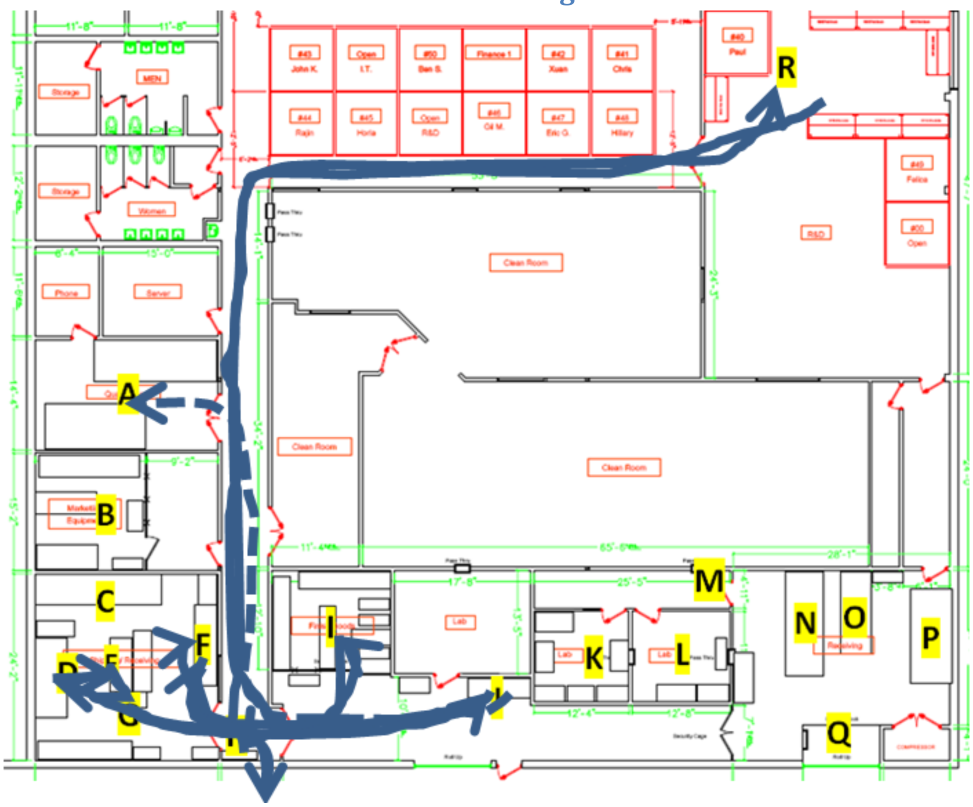

Figure 7: Current Generator Process on Layout

1. Delivered (comes in door near shipping)
2. Put on cart (H)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (H)
4. Match qty in packages with qty stated on packing list. (H)
5. Non-inventory items without PO are delivered to recipient. (H)
6. Inventory items and or items under a PO are entered into computer system (F) and tag box (leave box on cart near door(H))
7. Go to QC or recipient (there for about 24 hours, then if approved it moves on) (J), if rejected by QC goes to Quarantine (A)
8. Released on computer (F)
9. Placed with generator raw materials (B)
10. Take materials to generator manufacturing to be assembled (R)
11. Move to finished goods, take oldest items out of finished goods(I)

12. Wait for order, transact sales order packing list in ERP system.(F)
13. Pull order. (D)
14. Box (E), If international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
15. Print shipping label (F)
16. Put in waiting area (G) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door near shipping room (H)
17. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

3.4 Assessment of Current Layout and Process

When I was shown around the plant by Jorge, the lead material handler, he pointed out several weak features in the current process. The first thing he pointed out as a waste of time was unpacking and restacking of the catheters after they come back from Steregenics. He suggested a way of using a "bakery tray" to only stack the catheter packages once then you can just move the trays from one area to another in one motion instead of 20. Another suggestion was to have the catheter boxes standing up like bottles of milk on a slanted platform so that they would fall forward like cartons of milk at the grocery store, then one could simply load the newer ones in the back and the oldest one would come forward to keep in accordance with FIFO. By keeping the catheters together from the time they are packed to go out to Steregenics to the time they are shipped to the end customer then we would be able to save the material handler's time and therefore the company money.

When I talked to Jorge about the disarray the raw materials shelving was in, he said they don't have trouble finding the things they need and having set areas would actually be inconvenient because the orders come in different sizes every time. I think we should look into having standard shelving spots for different raw materials because it would help keep to visual factory principles and while it might not be difficult for Jorge to find the material he is looking for someone who wasn't as involved in receiving and putting it into the raw materials would find it very difficult. To remedy this I recommend going to a class based storage system, which is a combo between random and dedicated storage. The materials are put into different "classes" and there are dedicated spaces for each class but within the dedicated space the storage is randomized. This cuts down on space used compared to dedicated storage and time spent looking for items compared to randomized storage.

Another thing that took up a more of his time was writing labels to be placed on each of the raw materials boxes. He said that sometimes he will have to write up to 30 of these labels with the same information. I don't know about your receiving system capabilities but I feel like there should be some way to print these type of labels, which would give him more time to work on things he is really needed for and reduce the chance of errors.

The main reason items and people are traversing across the warehouse is because of QC and the computer stations needed for shipping, receiving, releasing, material handling, etc. I would like to look into more detail what processes QC needs to take the items into their lab and when they just need to do an "on site" inspection like for the Post-Sterile quarantine. I would also like to get more details on what

processes need a computer and if they need a computer do they need a printer or do they just need something printed and no computer.

I would also like to see if in the new space we could have a loading dock like the one we have in the current space so that the non-sterile loads and post-sterile loads would never have to be in the same room together, also the current space where we are keeping the non-sterile and post-sterile loads is to0 small to keep a total of 10 pallets in it (assuming 5 pallets each). I assume having that much walking space in a room that size violates some sort of fire code.

For the catheter flow you want receiving to be near QA then raw material storage and that to be near the pass through into the clean room. Then once it comes out of the clean room you want it to be near the packaging center and then you want that to be near to non-sterile quarantine. Once it comes back sterilized you want the post-sterile quarantine to be nowhere near the non-sterile quarantine, but you want it close to finished goods and shipping.

For the generator flow you want receiving to be near QA then generator raw material storage and the raw materials to be closer to generator assembly. After assembly you want it to be near to finished goods which should be really close to shipping.

To find out the distances traveled by the material handlers for catheter and generator manufacturing, I interviewed Jorge how many times he or the other material handlers traveled a certain route in a day, week, or month. Then I calculated how many trips there were between certain departments per month, assuming 5 days a week and 4 weeks a month. In Appendix A Table 1 you can see these calculations for generators which shows us that if in a given month they produce approximately 28 generators per month then the material handlers move about .1737 miles per generator. For catheters you can see Appendix A Table 2 these calculations that show that if in a given month they produce approximately 3000 generators per month then the material handlers move about .002841 miles per generator. Then I used the information given in Table 3 of Appendix A of projected production to find out how many hours the material handlers would spend transporting materials in 2012 to get about 67 hours spent just moving materials assuming the material handlers work at 3 miles per hours as shown in Appendix A Table 4.

4. Literature Review

4.1 Literature Review Approach

For my literature review, I was looking for information on designing a warehouse and how to use improve the material handling process and use visual factory principles. The places I used to search for information were the Cal Poly "Poly Cat" library catalog where I checked out books that met my search criteria. For finding articles I used the Web of Science database and the Engineering Village 2 database. For my search criteria I entered:

Warehouse (or) Facility (or) Factory	with	Planning (or) Design (or) Layout (or) Visual	Other searches:	"Material Handling" MRP "Process Flow" "Visual Tools"

First I would sort my results by "Times Cited—highest to lowest." To narrow down my search I would first choose the year 2000 to the present, if I still had over 200 results then I would mark the categories of "Engineering Industrial" and "Engineering Manufacturing." Then I would read the abstract to see if it had any bearing on my project.

4.2 Visual Factory

4.2.1 Why Visual Factory is Important

In Greif's book The Visual Factory he discusses principles of communicating visually with workers to maximize performance. He suggest to develop a visual mode of organization in which employees feel a sense of ownership, the visual communication should be set up in a location that is not exclusively held property. Greif shows that for effective visual communications are a mixture of personal involvement and public access. Grief states the ate visibility of a message within an area of activity implies public sharing of responsibility by everyone who is at all involved in the activity and that the display of messages within a given territory embodies the presumptions that those who perform actions are capable of distancing themselves from visually portrayed information. One of the necessities for visual communication according to Greif is that participants and observers must be able to approach one another on an equal plane, confronting objective realities that do not convey blame. He goes on to say that this can be done by providing a communication area. Firstly to facilitate group work, be able to hang messages pertaining to the team, general info, status of current projects, performance indicators. Secondly, the act of demarcating an explicit communication area symbolically reinforces the team's new responsibilities for control. Grief tells us not to convey information without first determining whether it generates interest, production of information should always be preceded by development of needs and create an information system that is directly relevant from the outset everyone must be well informed about the immediate environment. (Greif 1991)

4.2.2 Five Pillars of the Visual Workplace

Hirano and Ruben define the five pillars as organization, orderliness, cleanliness, standardized cleanup, and discipline. Organization, according to Hirano and Ruben, means removing from the workplace all

items that are not needed for current production or clerical operations; it means leaving only the bare essentials: when in doubt, throw it out. Orderliness is defined by Hirano and Ruben as arranging needed items so that they are easy to use and labeling them so that they are easy to find and put away. Hirano and Ruben shows cleanliness to mean sweeping the floors, wiping off machinery, and generally making sure that everything in the factory stays clean, It is closely related to the ability to turn out quality products, and Saving labor by finding ways to prevent dirt, dust, and debris from piling up in the workshop. Discipline means making a habit of properly maintaining correct procedures, without discipline the five pillars will not last long according to Hirano and Ruben. (Hirano 1996)

4.2.3 Uses of Visual Controls

A visual control is any communication device used in the work environment that tells us at a glance how work should be done as defined by Hirano and Ruben. Once the best locations have been decided, Hirano and Ruben show the need a way to indentify these locations so that everyone will know what goes where and how many of each item belongs in each location. There are two interesting strategies described by Hirano and Ruben the signboard strategy and the painting strategy and are describe in the following. The signboard strategy uses signboards to identify what, where, and how many. The three main types of signboards are: locations indicators which show where items go, item indicators which show what specific items go in those places, amount indicators which show how many of these items belong there. Signboards are often used to identify: names of work areas, inventory locations, equipment storage locations, standard procedures, machine layouts. The painting strategy is a method for identifying locations on floors and walkways. It is used to create divider lines that mark off walking areas from operation areas. When mapping walkways and operation areas keep the following factors in mind: u-shaped cell designs are generally more efficient then straight production lines, in-process inventory should be positioned carefully for pest production flow, floors should be leveled or repaired if possible before divider lines are laid down, walkways should allow for safety and a smooth flow of goods by being wide enough and avoiding twists and turns, divider lines should be between 2 and 4 inches wide, paint colors should be standardized and the colors should be bright. Color coding can be used to show clearly which parts, tools, jigs, and dies are to be used for which purpose. (Hirano 1996)

In order to make a plant visit more effective an profitable Grief says that the company must announce visits in advanced, have a notification “We welcome Mr. Smith from Company Y”, they should also involve employees in explaining work areas, have visual descriptive panels that explain how the facility works, and also those giving the tour should take advantage of the visitor’s observations, since the visitors have a fresh set of eyes and a new way of looking around the plant. (Greif 1991)

4.2.4 Stages of Developing a Visual Factory

Grief states that the first stage in developing visual documentation is to define the fields being covered, define what sector of the plant will participate, and define what is the nature of topics being covered. Next Grief suggest one select the media you will be working in, for example symbols enhance mobility (stop sign or right turn only sign symbols allow you to react quicker), and one should always place information near where it will be used. The third step according to Grief is to make sure that the system you develop allows for rapid updating, ask yourself: who is responsible for updates, what is the procedure, what time interval will updates be provided, should be updated by someone within the

group or close to it? The final step is to promote employee participation, without it the entire system is worthless. Some other important things to consider while developing the visual factory according to Grief are: charts indication required and completed quantities should be situated in the teams space and visible to workers and anyone who passes through, Messages as clear as possible with colors used effectively, The process should be simplified a prearranged layout with predetermined columns, titles, and boxes, one should Choose acknowledgment indicators or symbols (gold star) to signify fulfillment of objective for positive reinforcement, also employees should participate in designing the carts and finally A team should enter its own figures on the charts to make them feel in charge and responsible. (Greif 1991)

4.3 Warehouse Systems and Solutions

4.3.1 Types of Warehouse Systems

Van Den Berg describes the three types of warehousing systems as follows. Manual warehousing systems or picker to product systems is when the order goes from location to location looking for items to pull with their carts or forklifts or whatever they require. Automated warehousing systems are product to picker systems an example of which would be a carousel, a computer controlled warehousing system that is used for storage and order picking of small to medium sized products and when the picker request an item the carousel rotates and brings the item. Another example of a product to picker system is the automated storage/ retrieval system (AS/RS), which contains one or many parallel rails with two high bay pallet racks around each side, within each aisle travels a storage/retrieval machine or automated stacker train which travels along rails and moves pallets to the picker. The final type of machine he described was an order accumulation and sorting systems that are used to establish order integrity when orders are not picked in a single order fashion, this system usually consist of a closed loop conveyer with diverter mechanisms and accumulation lanes to sort the orders. (Van Den Berg 1999)

4.3.2 Warehouse Processes and Policies

According to Rouwenhorst's article there are several distinct phases or processes in a warehouse, the receiving process, the storage process (which consist of two part: the reserve area where products are stored the most economical way and the forward area where the products are stored for easy retrieval by an order picker), it may have sorting and or consolidation process, and then it will have a shipping process. (Rouwenhorst 2000) The forward reserve problem is the problem of deciding which product should get stored in the forward and what should be stored in the reserve area. (Van Den Berg 1999) Anything not covered by that is not done by the warehouse. Each of these processes has their own unique and specific organizational policies defined by Rouwenhorst as follows. During the receiving process, an assignment policy determines the allocation of trucks to doors. During the storage process there are several storage policies, a dedicated storage policy assigns a specific location for each product, a random storage policy leaves the decision to the operator, and a class based storage policy assigns a zone to certain product groups usually based on their turnover rate. Yet another storage policy mention by Rouwenhorst is correlated storage otherwise known as family grouping, where items that are used together a place together. In the order picking process it requires a zoning policy and a sorting policy. Two zoning policies exist; parallel or sequential zoning and the items can be picked by single order picking and by batch picking. The two sorting policies that exist for the order picking process are pick

and sort, which is sequential, and sort while pick which is simultaneous. During the shipping process, orders and trucks are assigned to docks by a dock assignment policy. (Rouwenhorst 2000)

4.3.3 Class-based storage rationale

Class based storage is a compromise between randomized and dedicated storage. The material is assigned a class (demand, product type, size) and each class is assigned a block of storage location and within this block material is sorted randomly. Dedicated storage reduces material handling cost but increases storage space, randomized storage requires less storage space but the material handling cost is greater. (Larson 1997)

4.4 Waste Reduction

4.4.1 Reducing Waste

Goldsby and Martichenko say that Taiichi Ohno's seven basic forms of muda (waste) are: defects in production, overproduction, inventories, unnecessary processing, unnecessary movement of people, unnecessary transport of goods, and waiting by employees. Goldsby and Martichenko infer that by reducing these seven basic forms of muda then you are able to create a leaner and less wasteful organization. Another way of reducing waste according to Goldsby and Martichenko is to reduce the following rework, scrap, risk (at source quality reduces issues when product is being created, variation that disrupts flow, and complexity which generates defects. They also suggest improving the flow of people by asking workers: what is the purpose of the task being done, how does a worker know that a task is completed successfully, what is the best way to perform this task, and how does the individual's role influence the overall success of the company. In Goldsby and Martchenko's opinion, safety stock is among the biggest wastes in most companies. They argue that variation in supplier order to ship lead time and transportation lead time will increase the safety stock of raw materials and finished goods and that variation in customer demand leads to forecasting that result in safety stock due to spikes in demand. In reference to fixed resources (computers, office furniture, shelves, etc.), Goldsby and Martichenko suggest that one approaches the situation by asking: how can we eliminate the need for this space entire, how much space is actually required, is the need for this space correlated with need for similar spaces at other facilities, why do we have this resources, how would we run the operation if this resource was eliminated. Goldsby and Martichenko propose that just because you have more space doesn't mean you have to use it, being lean is about doing more with less and challenging the organization to be less reliant on fixed resources and focused more on flow and speed. A lean workplace is an organized workspace according to Goldsby and Martichenko and it can be organized by highlighting waste and finding their root causes, having standardized operations and setting priorities, reducing clutter and complexity that may lead to quality issues, supporting measurements, promoting safety in all operations. Goldsby and Martichenko define organization as a place for everything and everything in its place. One of Goldsby and Martichenko's suggestions for reducing clutter and therefore reducing complexity is the red tag initiative, which is an initiative in which the company gives workers red tags that can be placed on paper, boxes, inventory, equipment and anything that does not have value in the workplace, then the workers have 48 hours to justify keeping the item, unclaimed items are thrown away. Goldsby and Martichenko assert that for a leaner workplace you need focus on reduction of inventories, reduction of lead times, maintenance of scalable and flexible infrastructure,

and sustained planned network design and visibility to build flexibility. Goldsby and Martichenko state that capable logistics systems are predictable, stable, and visible (both understandable and measurable). Strategic sourcing of raw material suppliers and logistics suppliers, according to Goldsby and Martichenko, are analyzed by looking at supplier location, supplier order to ship lead time and reliability, transportation lead time and reliability, supplier quality of service compliance, and supplier quality of product compliance. (Goldsby 2005) Van Den Berg says that more than 60% of all warehouses operating cost can be attributed to order picking. (Van Den Berg 1999)

Hirano and Ruben show us that by increasing the organization in the factory we can reduce time wasted searching for tools and parts and the unnecessary inventory and machinery that make the factory crowded and difficult to work in and are costly to maintain and can even hide other problems in the production. They also show us that orderliness can decrease waste in following area: Motion waste, the person sent to get a cart could not find it, Searching waste, no one can find the key to the locked cabinet that contains needed tools, The waste of human energy, a frustrated worker gives up on finding a needed template after looking in vain for half an hour, The waste of excess inventory, desk drawers are crammed full of pencils, markers, and other stationery supplies, The waste of defective products, the storage locations of two types of parts are switched without telling the operator so he picks up the wrong part without noticing and uses it in the product, and finally The waste of unsafe conditions, boxes of supplies are left in a walkway, causing someone to trip and get injured. (Hirano 1996)

4.4.2 Kanban

The productivity press development team give the equation of the number of kanban necessary to be:

$$Number\ of\ Kanban = \frac{Demand \times (Run\ Frequency + Lead\ Time + Safety\ Time)}{Container\ Quantity}$$

They also say that moving to a kanban system may involve "turning off" an MRP system, which is more of a push system and you have to start relying on the pull system of the kanban. (Productivity Press Development Team 2006)

5. Design

5.1 Design Goals

My goals when designing were to:

- Remove the dangerous ergonomic situation of moving 4 foot long 50 pound coffin boxes of catheters through a narrow hallway, which could easily result in back strain or injury
- Separate non-sterile and post-sterile quarantine to minimize chance of cross contamination
- Keep biohazard quarantine away from all other areas
- Minimized the distance travelled by the material handlers

Layout A was just focused on minimizing distance regardless of cost, while Layout B also looked minimizing the removal and building of walls as to minimize the cost by sacrificing some distance savings.

5.2 Space Requirements

When determining the space required for post-sterile and non-sterile quarantine, I look the capacity needed if they were to have 100% growth and two shipments to Steregenics a month. They currently have 5 pallets shipped to Steregenics and back once a month. I dedicated 5 pallets worth of non-sterile quarantine space so that once packaged and palletized then the catheters would have a designated area until they went out once every two weeks. I designated 10 pallets worth of space to post-sterile quarantine because Steregenics takes about two weeks to send the "clean" results, which allows QC to release the product. The 5 extra pallets spots are so that if the two shipments are in the warehouse at the same time then there is enough space for them all.

I did not do an in-depth space requirement of raw materials or generators. The information about this item is still changing and I could not have completed the recommended layouts by the deadline Company X needed them by if I were to have included this in the scope. I assumed if we increased the shelving by 150% then it would be sufficient because now we have bimonthly shipments and items are going out faster.

I did a more in-depth analysis of how many carts for finished goods would be required with the current catheter production, 25% growth, 50% growth, and 100% growth. First I had to decide which boxes I was using for Product A and which boxes for Product B and what size carts so I could find out how many boxed catheters of each type could go into the boxes and how many boxes could go onto each cart. I decided to design the finished goods capacity to 75% of the monthly inventory, since in the current system about 75% of inventory is shipped out in the second half of the month.

Product Family A fit 44 boxed catheters per box, 3 boxes per shelf, and 4 shelves per cart and the current number of units produced each month is about 1250 (see Table 1 for results).

Product Family A	Units/ month	Max Inventory	Boxes (44 units/box)	Shelves (3 boxes/shelf)	Carts (4 shelves/cart)

Now	1250	937.5	21.3	7.1	1.8
25% growth	1562.5	1171.9	26.6	8.9	2.2
50% growth	1875	1406.3	32.0	10.7	2.7
100% growth	2500	1875.0	42.6	14.2	3.6

Table 1: Number of Shelves Calculation for Product A

Product Family B fit 26 boxed catheters per box, 2 boxes per shelf, and 4 shelves per cart and the current number of units produced each month is about 3000 (see Table 2 for results).

Product Family B	Units/ month	Max Inventory	Boxes (27 units/box)	Shelves (2 boxes/shelf)	Carts (4 shelves/cart)
now	3000	2250.0	83.3	41.7	10.4
25% growth	3750	2812.5	104.2	52.1	13.0
50% growth	4500	3375.0	125.0	62.5	15.6
100% growth	6000	4500.0	166.7	83.3	20.8

Table 2: Number of Shelves Calculation for Product B

Below in Figure 8, it shows how many carts would be needed for at each level of growth. The boxes that look more square are for the Product A Family catheters and even though they are on the same carts they will take up a larger footprint because the box will overhang on either side.

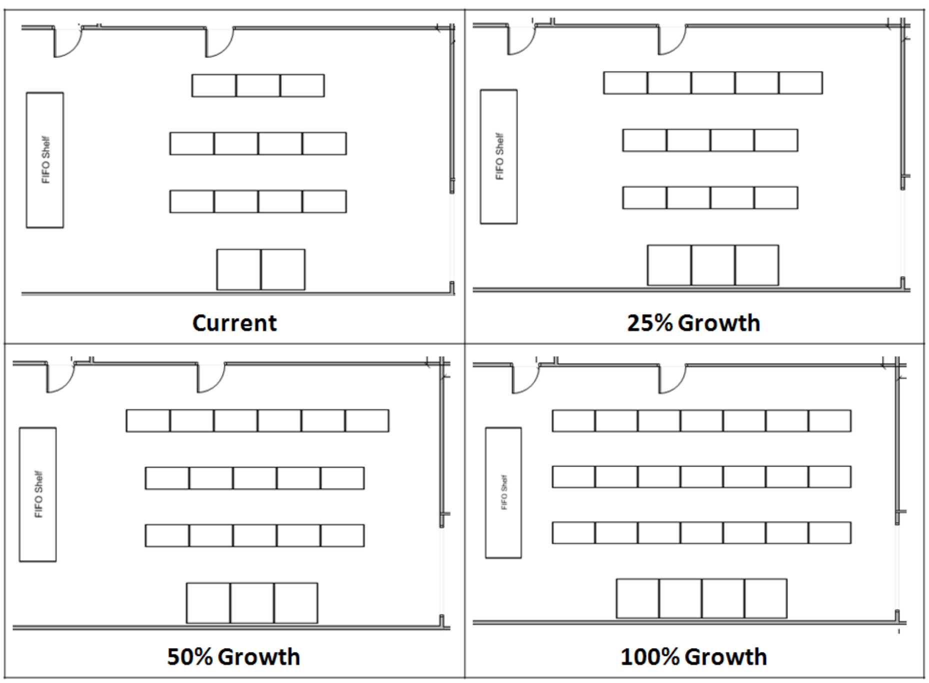

Figure 8: Layout of Catheter Finished Goods Carts at current capacity, 25%, 50%, and 100% growth

5.3 Proposed Layout A

5.3.1 Proposed Layout A Department Definition

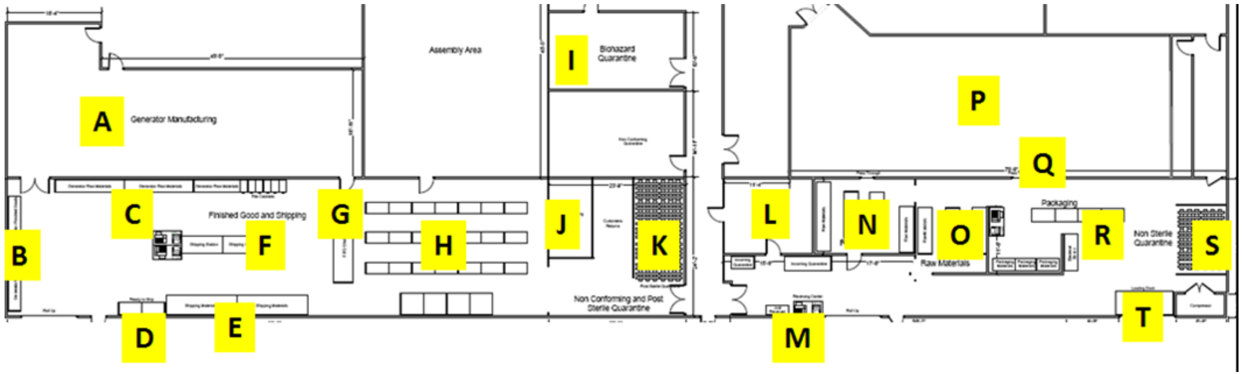

Figure 9: Layout A with Departments Labeled

A. Generator Manufacturing
B. Generator Finished Goods
C. Generator Raw Materials
D. Waiting for Pick-up by FedEx or UPS
E. Shipping Materials
F. Shipping Station
G. FIFO Shelf
H. Catheter Finished Goods Carts
I. Biohazard Quarantine
J. Non Conforming Quarantine
K. Post Sterile Catheter Quarantine
L. QC Lab
M. Receiving Station
N. Raw Material Storage
O. Excess Raw Material Storage
P. Clean Room for Raw Material Storage
Q. Pass Through Window
R. Packaging Station
S. Non Sterile Catheter Quarantine
T. Loading Dock

5.3.2 Proposed Layout A Catheter Material Handling Process

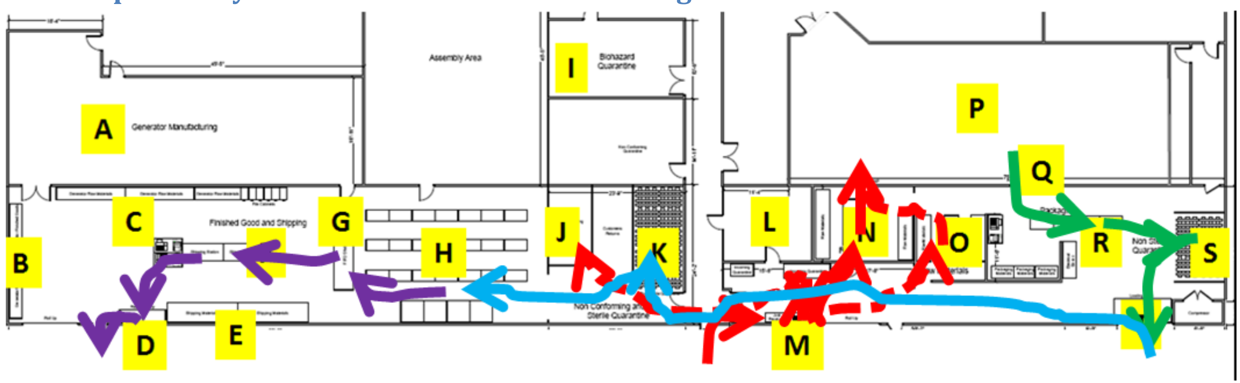

Figure 10: Proposed Catheter Material Handling Process on Layout A

5.3.2.1 Proposed Layout A Catheter Raw Material Receiving Process (Red)

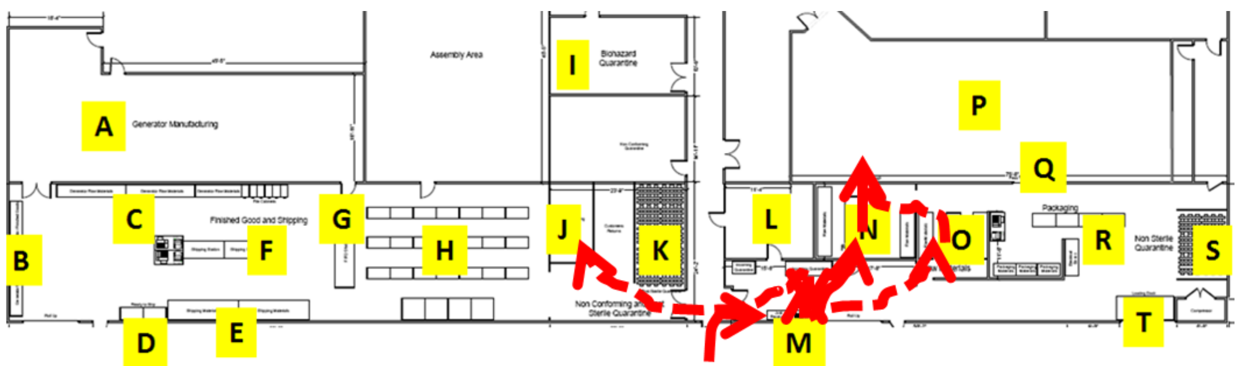

Figure 11: Proposed Catheter Receiving Process on Layout A

1. Delivered (comes in door in the middle of the back of the building)
2. Put on cart next to the Receiving Station(M)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (M)
4. Match qty in packages with qty stated on packing list. (M)
5. Non-inventory items without PO are delivered to recipient. (M)
6. Inventory items and or items under a PO are entered into computer system (M) and tag box (leave box on cart near door(M))
7. Go to QC (L) and is there for about 24 hours, then if approved it moves on , if rejected by QC goes to non-conforming quarantine (J)
8. Released on computer at the receiving station (M)
9. Placed with raw materials (N), overflow raw materials are placed in the other raw materials room (o) and labels and packaging supplies are placed in a lab room (R)
10. Picked up from Raw Materials (N or O)
11. Moved through pass through window in the raw materials room (N) into clean room (P) where they are manufactured

5.3.2.2 Proposed Layout A Catheter Packaging Process (Green)

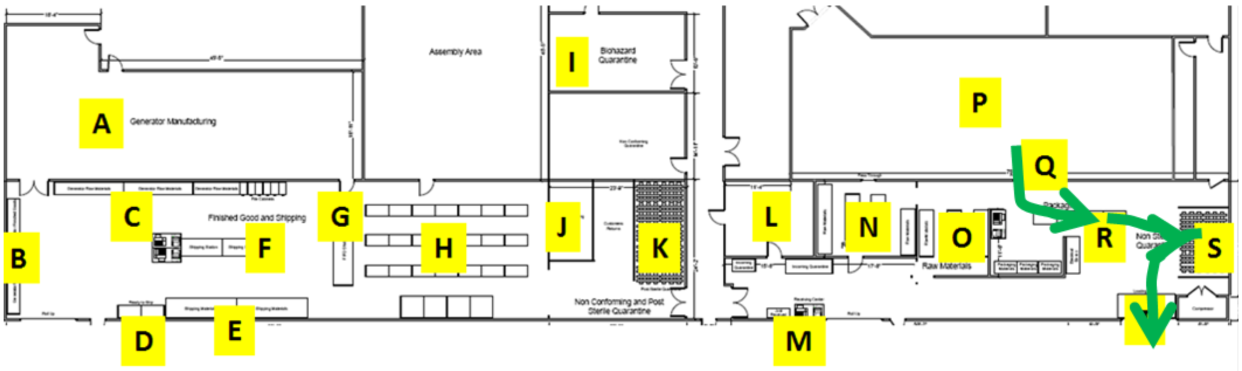

Figure 12: Proposed Catheter Packaging Process on Layout A

1. Passed through window (Q) from clean room to packing area (R)
2. Instruction manual, filter and catheter placed in boxes (R)
3. Boxes packed into coffin boxes in packing area (R)
4. Coffin boxes are then palletized and strapped (R)
5. Put into non-sterile quarantine (will be shipped through loading dock) (S)
6. Print labels for each pallet, complete the order forms for Sterigenics and Nelson labs. (M)
7. Shipped through loading dock (T)

5.3.2.3 Proposed Layout A Catheter Receiving Post Sterilization Process (Blue)

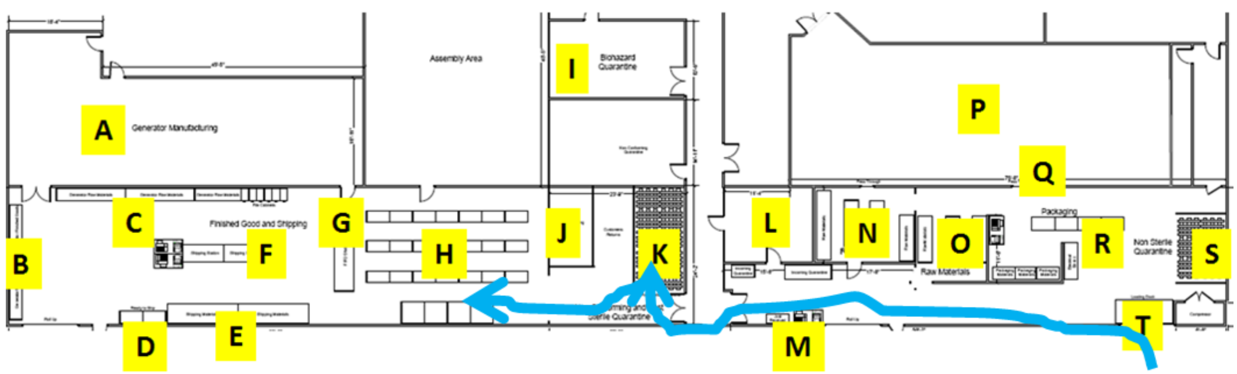

Figure 13: Proposed Catheter Post Sterilization Receiving Process on Layout A

1. Delivered through loading dock (T)
2. Waits up to two week for results in Post Sterile Quarantine (K)
3. QC releases (QC does no inspection and simply waits for results from Steregenics) (K)
4. Release on system in receiving area (M) once QC approves
5. Places coffin boxes with open ends to be able to see product information (SKU, Lot number, etc) at end of catheter box on carts which are wheeled into the catheter finished goods area (H)

5.3.2.4 Proposed Layout A Catheter Shipping Process (Purple)

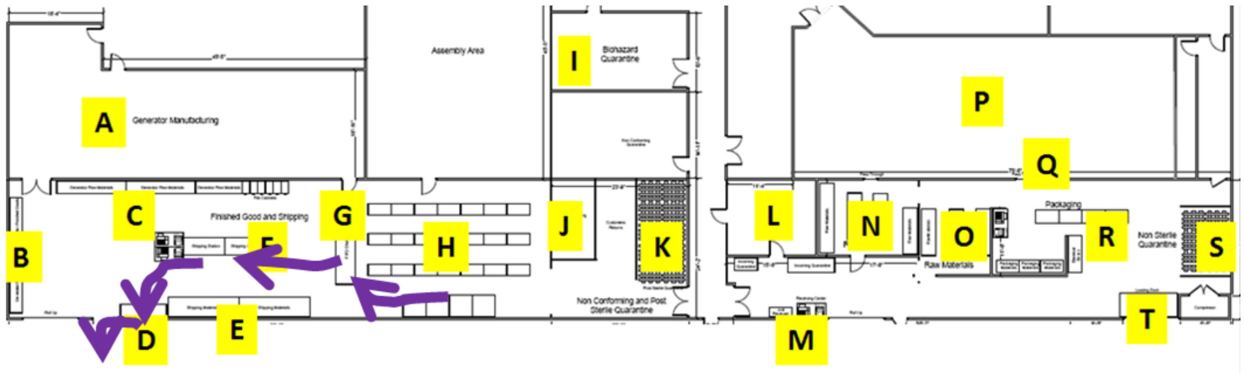

Figure 14: Proposed Catheter Shipping Process on Layout A

1. Move the oldest coffin boxes off finished goods carts (H)
2. Put into the shipping stock area to keep with FIFO practices (G)
3. Wait for order (about 60 orders/day) and transact sales order packing list in ERP system.(F)
4. Pull order. (G)
5. Box (F), if international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
6. Print shipping label (F)
7. Put in waiting area (D) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door on the left side of the back of the building (near D)
8. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

5.3.3 Proposed Layout A Generator Material Handling Process

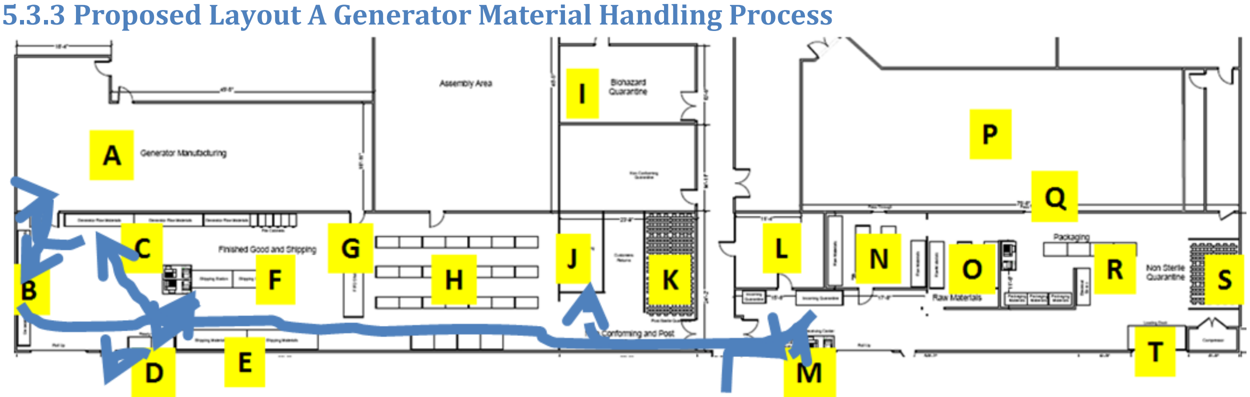

Figure 15: Proposed Generator Material Handling Process on Layout A

1. Delivered (comes in door near M)
2. Put on cart near receiving center (M)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (M)
4. Match qty in packages with qty stated on packing list. (M)
5. Non-inventory items without PO are delivered to recipient. (M)

6. Inventory items and or items under a PO are entered into computer system (M) and tag box (leave box on cart near door(M))
7. Go to QC (L) and is there for about 24 hours, then if approved it moves on, if rejected by QC goes to non-conforming quarantine (J)
8. Released on computer in receiving area(M)
9. Placed with generator raw materials (C)
10. Take materials to generator manufacturing to be assembled (A)
11. Move to finished goods, take oldest items out of finished goods(B)
12. Wait for order, transact sales order packing list in ERP system.(F)
13. Pull order. (B)
14. Box (F), If international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
15. Print shipping label (F)
16. Put in waiting area (D) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door on the right side of the building near the waiting area (D)
17. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

5.4 Proposed Layout B

5.4.1 Proposed Layout B Department Definition

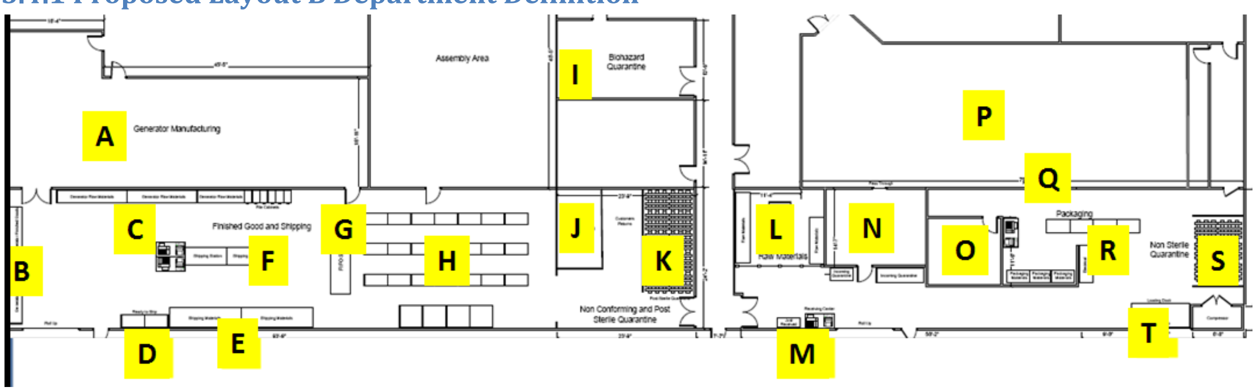

Figure 16: Layout B with Departments Labeled

A. Generator Manufacturing
B. Generator Finished Goods
C. Generator Raw Materials
D. Waiting for Pick-up by FedEx or UPS
E. Shipping Materials
F. Shipping Station
G. FIFO Shelf
H. Catheter Finished Goods Carts
I. Biohazard Quarantine
J. Non Conforming Quarantine
K. Post Sterile Catheter Quarantine

L. Raw Material Storage
M. Receiving Station
N. QC Lab
O. Excess Raw Material Storage
P. Clean Room for Raw Material Storage
Q. Pass Through Window
R. Packaging Station
S. Non Sterile Catheter Quarantine
T. Loading Dock

5.4.2 Proposed Layout B Catheter Material Handling Process

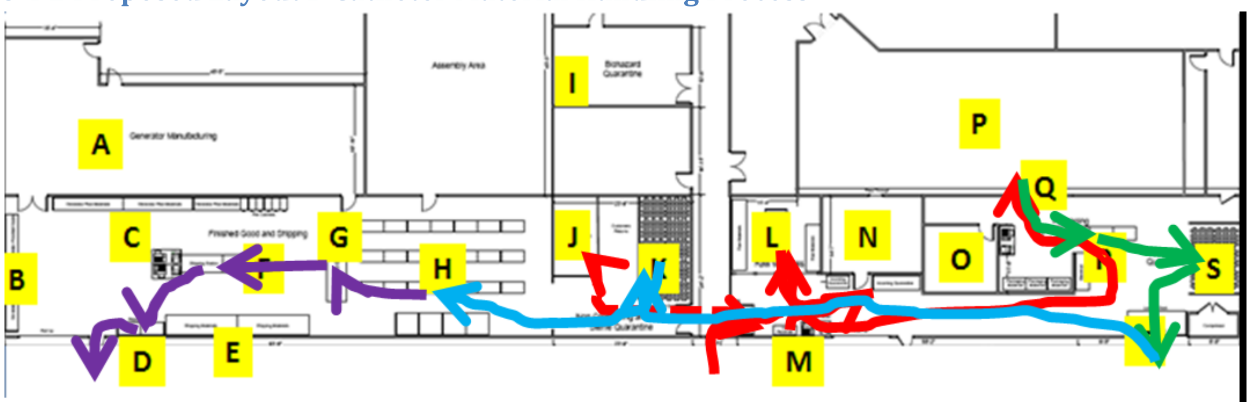

Figure 17: Proposed Catheter Material Handling Process on Layout B

5.4.2.1 Proposed Layout B Catheter Raw Material Receiving Process (Red)

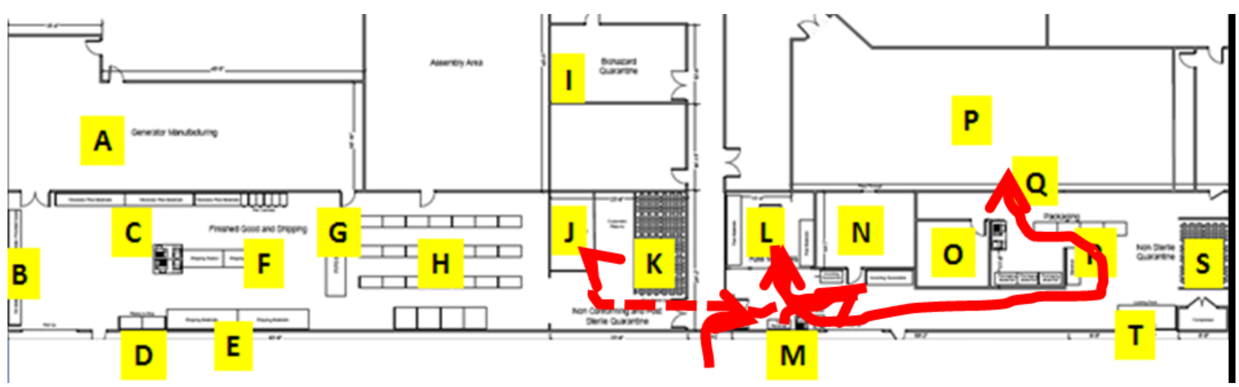

Figure 18: Proposed Catheter Receiving Process on Layout B

1. Delivered (comes in door in the middle of the back of the building)
2. Put on cart next to the Receiving Station(M)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (M)
4. Match qty in packages with qty stated on packing list. (M)
5. Non-inventory items without PO are delivered to recipient. (M)
6. Inventory items and or items under a PO are entered into computer system (M) and tag box (leave box on cart near door(M))

7. Go to QC (N) and is there for about 24 hours, then if approved it moves on , if rejected by QC goes to non-conforming quarantine (J)
8. Released on computer at the receiving station (M)
9. Placed with raw materials (L), overflow raw materials are placed in the other raw materials room (o) and labels and packaging supplies are placed in a lab room (R)
10. Picked up from Raw Materials (L or O)
11. Moved through pass through window in the raw materials room (L) into clean room (P) where they are manufactured

5.4.2.2 Proposed Layout B Catheter Packaging Process (Green)

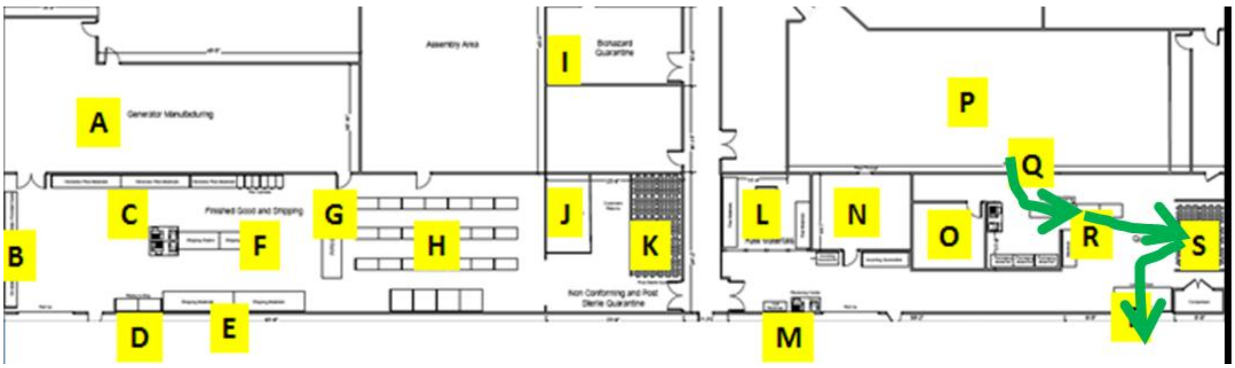

Figure 19: Proposed Catheter Packaging Process on Layout B

1. Passed through window (Q) from clean room to packing area (R)
2. Instruction manual, filter and catheter placed in boxes (R)
3. Boxes packed into coffin boxes in packing area (R)
4. Coffin boxes are then palletized and strapped (R)
5. Put into non-sterile quarantine (will be shipped through loading dock) (S)
6. Print labels for each pallet, complete the order forms for Sterigenics and Nelson labs. (M)
7. Shipped through loading dock (T)

5.4.2.3 Proposed Layout B Catheter Receiving Post Sterilization Process (Blue)

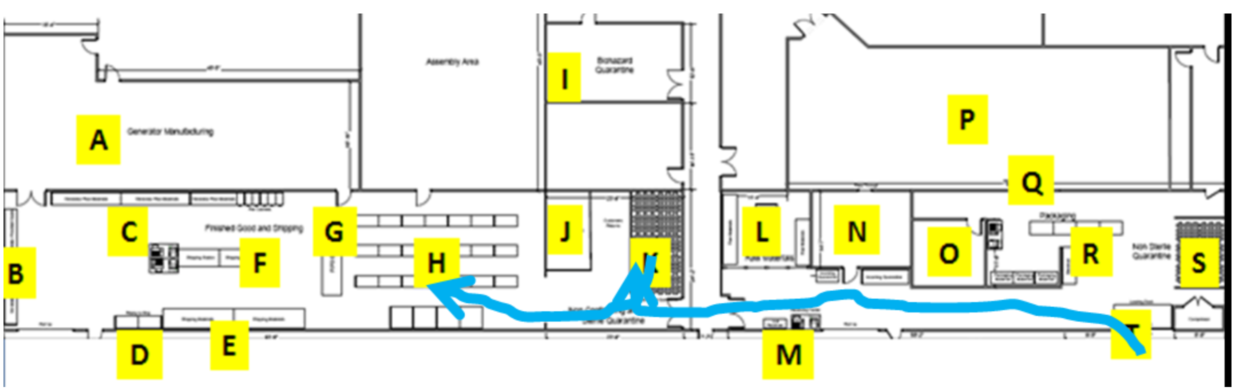

Figure 20: Proposed Catheter Post Sterilization Receiving Process on Layout B

1. Delivered through loading dock (T)
2. Waits up to two week for results in Post Sterile Quarantine (K)
3. QC releases (QC does no inspection and simply waits for results from Steregenics) (K)
4. Release on system in receiving area (M) once QC approves
5. Places coffin boxes with open ends to be able to see product information (SKU, Lot number, etc) at end of catheter box on carts which are wheeled into the catheter finished goods area (H)

5.4.2.4 Proposed Layout B Catheter Shipping Process (Purple)

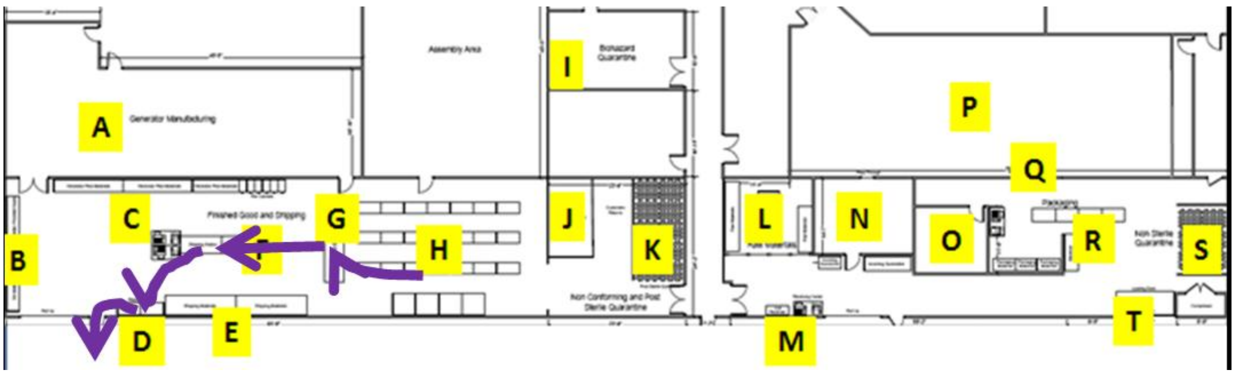

Figure 21: Proposed Catheter Shipping Process on Layout B

1. Move the oldest coffin boxes off finished goods carts (H)
2. Put into the shipping stock area to keep with FIFO practices (G)
3. Wait for order (about 60 orders/day) and transact sales order packing list in ERP system.(F)
4. Pull order. (G)
5. Box (F), if international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
6. Print shipping label (F)
7. Put in waiting area (D) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door on the left side of the back of the building (near D)
8. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

5.4.3 Proposed Layout B Generator Material Handling Process

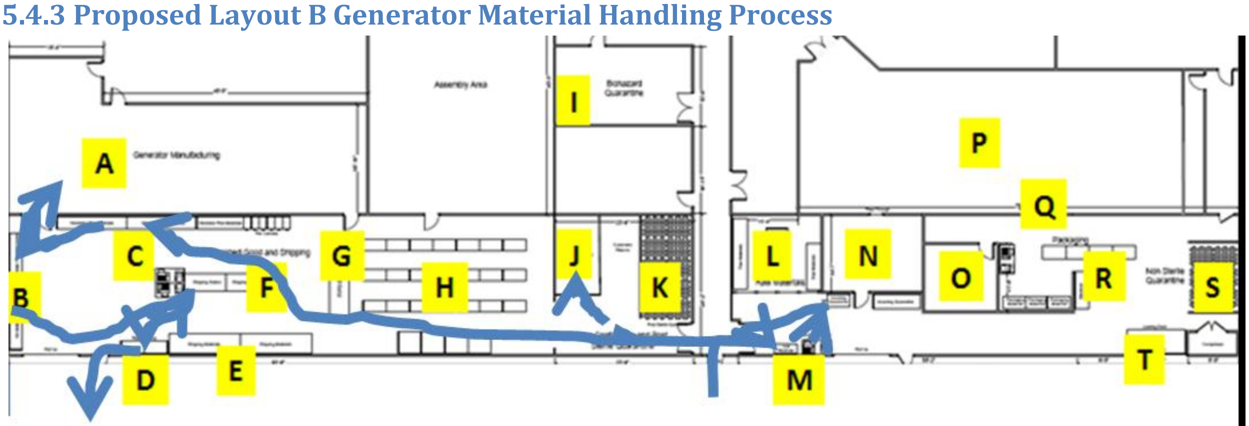

Figure 22: Proposed Generator Material Handling Process on Layout B

1. Delivered (comes in door near M)
2. Put on cart near receiving center (M)
3. Count and Inspect for damages, segregate inventory packages from non-inventory. (M)
4. Match qty in packages with qty stated on packing list. (M)
5. Non-inventory items without PO are delivered to recipient. (M)
6. Inventory items and or items under a PO are entered into computer system (M) and tag box (leave box on cart near door(M))
7. Go to QC (N) and is there for about 24 hours, then if approved it moves on, if rejected by QC goes to non-conforming quarantine (J)
8. Released on computer in receiving area(M)
9. Placed with generator raw materials (C)
10. Take materials to generator manufacturing to be assembled (A)
11. Move to finished goods, take oldest items out of finished goods(B)
12. Wait for order, transact sales order packing list in ERP system.(F)
13. Pull order. (B)
14. Box (F), If international order, there is packing rework and have to pull out catheter and filter about half way to put in new multilingual instruction manual (about 10% of orders)
15. Print shipping label (F)
16. Put in waiting area (D) for Fed Ex (about 80%) or UPS (about 20%) to come, leaves through door on the right side of the building near the waiting area (D)
17. Picked up by FedEx, UPS, or other 3rd party logistics supplier and shipped

5.5 Visual Communication

Figure 23: Color Coding for Visual Communication

For the visual communication portion of this project, I focused on creating signage so that anyone walking through the warehouse who was unfamiliar with the layout, whether it be an auditor or someone from corporate, would be easily identify the "departments" and potential hazards and quarantines. I used the color coding shown in Figure 23 to code the departments, this color codes came

from the company's website. Those departments without a designated color code, such as Shipping or Receiving, were put on a white background with the company colors.

Also I recommended that brown tape be placed down to designate where the catheter finished goods carts should be placed. This makes sure that there is always a designated aisle space and things do not get cramped together and using tape instead of paint allows there to be greater flexibility if the number of cart spaces needs to be changed.

6. Results and Discussion

6.1 Savings

6.1.1 Distance Savings

For both layouts I measured a rough distance on Visio and then used the data I had previously collected on how often trips are made to find out how often each of those distances are traveled for Layout A and Layout B. More detailed tables of these calculations are shown in Appendix B for Layout A and Appendix C for Layout B. All of the distance calculations use the forecasted unit production data for 2012.

Layout A													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Distance (mi)	7.12	8.38	9.66	9.40	8.35	10.55	9.41	9.08	11.35	10.38	10.24	10.66	114.56
Hours	2.37	2.79	3.22	3.13	2.78	3.52	3.14	3.03	3.78	3.46	3.41	3.55	
Total Hours traveled per year													38.185
Total Hours saved													28.915
% of time it now takes													57%

Table 3: Hours saved each year with Layout A

Layout B													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Distance (mi)	7.67	9.01	10.34	10.09	8.99	11.28	10.10	9.74	12.12	11.10	10.97	11.41	122.81
Hours	2.56	3.00	3.45	3.36	3.00	3.76	3.37	3.25	4.04	3.70	3.66	3.80	
Total Hours traveled per year													40.938
Total Hours saved													26.162
% of time it now takes													61%

Table 4: Hours saved each year with Layout A

As you can see in Tables 3 and 4, the hours saved per year, given this year's forecast data, is about 29 for Layout A and about 26 for Layout B. The current system is about 67 hours per year and you can see more details about the calculations that found this number in Appendix A.

6.1.2 Change of Coffin Boxes Savings

There are three points in the original process where the catheters are unloaded and reloaded from shelves and boxes costing the material handlers a lot of time. These instances are: they are unloaded after QC has cleared the post sterile quarantine to go to finished goods storage, and then reloaded onto the finished goods shelving, and then they are again reloaded into the FIFO shelving. One of the changes made in the new layout is that instead of doing the repetitive motion of unloading and reloading the catheters the material handler would only have to do one motion for every lot and the catheter boxes would be kept in larger boxes until they were shipped to the end customer. This involves changing the type of box to be front loading and unloading instead of top loading so that the material handlers will be able to just open the front and see the catheter boxes and their labels with the relevant information.

As you can see in Table 5 given the current data for this year's inventory it will save the material handlers approximately 41.6 hours this year for Product Family A and approximately 47.5 for Product Family B as shown in Table 6. This totals to be approximately 90 hours saved by switching the type of boxes.

Product Family A													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Without boxes(min)	158.5	189.4	209.2	229.1	193.7	240.6	218.2	182.6	250.1	222.8	224.6	237.5	
With boxes (min)	3.6	4.3	4.8	5.2	4.4	5.5	5.0	4.2	5.7	5.1	5.1	5.4	
Time saving (min)	154.9	185.1	204.4	223.9	189.3	235.1	213.2	178.5	244.4	217.8	219.5	232.1	
Time saving (hr)	2.6	3.1	3.4	3.7	3.2	3.9	3.6	3.0	4.1	3.6	3.7	3.9	41.6

Table 5: Time Saving for Product Family A

Product Family B													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Without boxes(min)	164.5	221	220.7	249.4	235.5	249.2	256.4	254.6	285.4	260.5	288.4	293.9	
With boxes (min)	7.3	9.8	9.8	11.1	10.5	11.1	11.4	11.3	12.7	11.6	12.8	13.1	
Time saving (min)	157.2	211.2	210.9	238.3	225.0	238.1	245.0	243.3	272.7	248.9	275.6	280.8	
Time saving (hr)	2.6	3.5	3.5	4.0	3.8	4.0	4.1	4.1	4.5	4.1	4.6	4.7	47.5

Table 6: Time Savings for Product Family B

6.1.3 Potential Cost of Back Injury

Work-place injuries and illnesses costs the U.S. an estimated $171 billion each year. It is important to every business to keep in mind good ergonomics for if no other reason just for economic reasons. Of the $60 billion paid out in annual compensation claims, back injuries account for more than 50% of the cost according to the National Compensation Insurance. A single injury will boost a company's workers compensation premiums by up to 100%. If a company creates an ergonomic workspace to avoid back injury then it can save a company an average of $24,000 to $26,000 per incident, according to www.ergotechinc.com and www.premierinc.com.

6.1.4 Total Savings

Most of the savings are given in hours for the warehouse redesign so I decided to place the cost per hour of a worker to the company, including worker's comp and all other benefits to be approximately $35 per hour cost to the company. Using this wage I was able see the total savings per year.   Layout A saved a total of 119 hours therefore $4,150 as shown in Table 7 while Layout B only saved 117 hours or $4,100 as show in Table 8.

Then the average cost of a back injury claim, not including how much the worker's comp premiums will go up, is conservatively $24,000. By removing the walls in the packaging area, we are able to reduce the un-ergonomic situation of maneuvering a 50 pound, 4 foot long box through two doorways no wider than 3 feet and a narrow hallway.

Savings - Layout A	Quantity	Unit Savings	Total Savings
Hours saved by shortened distance	29	$35	$1,000
Hours saved by keeping items in boxes	90	$35	$3,150

Average cost of back injury claim	1	$24,000	$24,000
Total			$28,150

Table 7: Total Savings of Layout A

Savings - Layout B	Quantity	Unit Savings	Total Savings
Hours saved by shortened distance	27	$35	$950
Hours saved by keeping items in boxes	90	$35	$3,150
Average cost of back injury claim	1	$24,000	$24,000
Total			$28,100

Table 8: Total Savings of Layout B

As you can see in Tables 7 & 8 the only difference between the savings is you save about $50 more per year with Layout A.

6.2 Costs

6.2.1 Catheter Finished Goods Redesign

This is the cost incurred by redesigning the catheter finished good's process so that the employee does not have to do repetitive motions and waste time. The boxes I chose I got prices for from www.uline.com. The Product A boxes are 16"x16"x24" and can fit 44 catheters. The Product B boxes are 14"x24"x18" and can fit 27 catheters. I got a quote for a shelf with a footprint of 24"x48" from www.grainger.com and chose to cost 21 of them because at 100% growth, the company will need 25 of them and they already have 4. I chose that number of boxes, which will be reused, since this would cover month to month and still have a buffer. I considered doing an economic analysis where new carts were added each year to meet projected growth but I did not want to complicate matters by predicting cart prices so all of the carts are bought at the beginning in this model but this needn't be true in practice. In Table 9, it shows that all of this will cost less than $13,000.

Item - Both Layouts	Quantity	Unit Cost	Total Cost
Product A Boxes	75	$4	$300
Product B Boxes	250	$2	$500
Cart	21	$570	$11,970
Total			$12,770

Table 9: Cost of Catheter Finished Goods Redesign

6.2.2 Implementing Visual Factory

These items were bought to implement Visual Factory by creating signs and marking the floors so the carts are put in the correct place. The possible savings created by this cost were not talked about in the Savings section, but are things like reducing the likelihood of quarantine items being moved from quarantine areas make things easier for an auditor, makes sure that carts remain safe distance apart, etc. This cost less than $300 as seen in Table 10 and using an inflated cost of printing and laminating an 8.5"x11" sign at FedEx Office and the rough cost of 2" wide brown duct tape at a home supply store.

Item - Both Layouts	Quantity	Unit Cost	Total Cost
Sign	50	$5	$250
Brown Tape	1	$10	$10

Total			$260

Table 10: Cost of Implementing Visual Factory

6.2.3 Removing Walls in Packaging Area

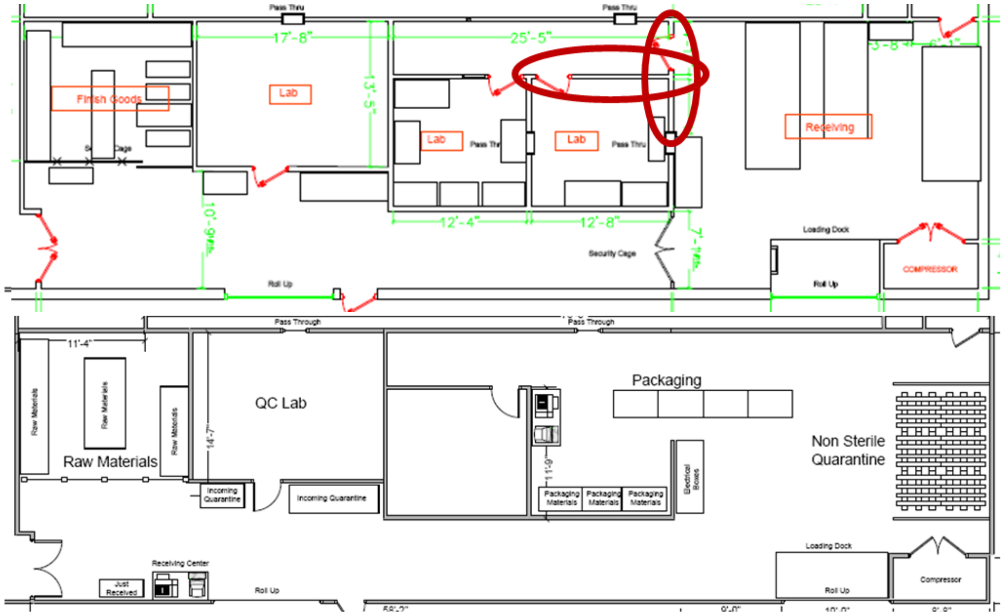

Figure 24: Layout Before and After Removing Walls in Packaging Area

You can see above in Figure 24 which walls are being removed to get rid of the dangerous ergonomic situation of maneuvering a large heavy box through narrow doors and a hallway. The lower layout in Figure 24 approximates how the area will look once those walls are removed. Both layouts remove these two walls as to create a more ergonomic working environment.

Also included in this calculation is the cost of removing the wall between the side of the building that is currently being utilized and the expansion space.

The cost of removing these three pieces of walls in this company's location was roughly estimated on the site www.homewyse.com based on the square footage of wall that needed to be removed and the area code the job was going to be done in. The total cost of removing these three pieces of wall is about $2,400 as shown in Table 11.

Item - Both Layouts	Quantity	Unit Cost	Total Cost
Remove 12' x 8' piece of wall	1	$1,000	$1,000
Remove 8' x 8' piece of wall	2	$700	$1,400
Total			$2,400

Table 11: Cost to remove walls

6.2.4 Moving QC

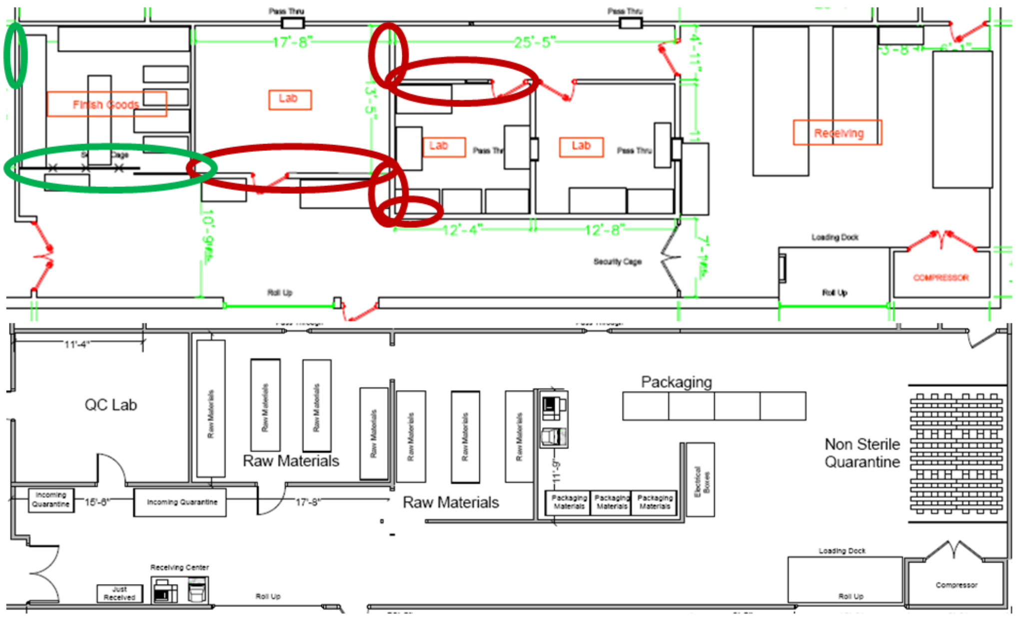

Figure 25: Layout before and after QC is moved

In Figure 25 about you can see the layout before with red circles around the pieces of walls that will be removed and green circles around either places where a door needs to be added or where a wall needs to be put in, below the current layout you can see what the proposed layout will look like. Only Layout A will have these changes. These changes minimize distance travelled by material handlers it also gives Quality Control a way to get into their lab without having to go through the material handling area.

Again these cost estimates came from www.homewyse.com and the total for moving QC and knocking down walls for the raw material storage and then the cost of the doors, knobs, and looks came from www.homedepot.com. The total for all this is just under $3,000 as shown in Table 12.

Item - Layout A only	Quantity	Unit Cost	Total Cost
Remove 3'x8' piece of wall	3	$300	$900
Remove 12' x 8' piece of wall	1	$1,000	$1,000
Frame 15'x10' wall	1	$300	$300
Drywall 15'x10' wall	1	$150	$150
Paint 15'x10 wall	1	$60	$60
Insert a door frame	2	$200	$400
Door	2	$30	$60
Lock and Door Knob	2	$20	$40
Total			$2,910

Table 12: Cost to move QC

6.2.5 Total Costs

Both Layout A and B change the process of the catheter finished goods, remove walls for the packaging area and between both sides of the building, and implement visual controls. They pay the cost for these

which totals to over $15,000 as shown in Table 14. In addition to all that Layout A moves Quality Control which cost approximately $3,000 totaling to $18,000

Layout A	Cost
Cost - Catheter Finished Goods	($12,770)
Cost - Remove Walls	($2,400)
Cost - Move QC	($2,910)
Cost - Visual Factory	($260)
Total Costs	($18,340)

Table 13: Total Cost for Layout A

Layout B	Cost
Cost - Catheter Finished Goods	($12,770)
Cost - Remove Walls	($2,400)
Cost - Visual Factory	($260)
Total Costs	($15,430)

Table 14: Total Cost for Layout B

7. Conclusion

For the economic analysis to choose the more economical layout I decided to disregard the savings from reducing the likelihood of a back injury claim. By avoiding just one back injury either one of these layouts pay for themselves, so I simply focused on the payback of the hours saved.

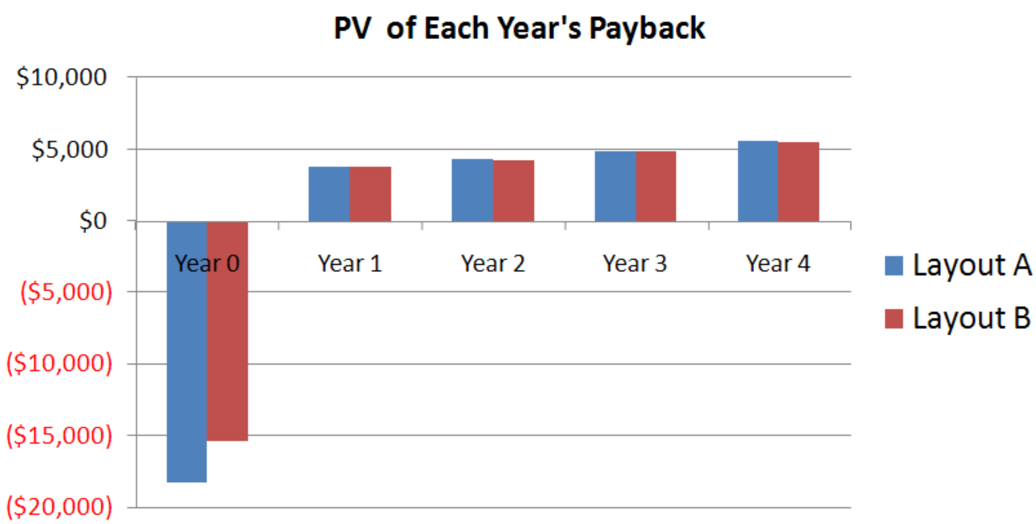

Figure 26: Present Value by year for Layout A and Layout B

	Year 0	Year 1	Year 2	Year 3	Year 4
Layout A	($18,340)	$3,773	$4,287	$4,872	$5,536
Layout B	($15,430)	$3,727	$4,236	$4,813	$5,469

Table 15: Present Value by year for Layout A and Layout B

To find the present value of each year's savings I used a 10% opportunity cost and a 25% growth rate, which is conservative considering that this company has been growing much more rapidly and has recently been bought out by a larger company who will help stimulate their growth. Figure 26 charts the data shown in Table 15. As you can see in Figure 26 each year the amount saved grows, with the savings from Layout B lagging behind those of Layout A which has material handlers travel shorter distances and therefore save more time.

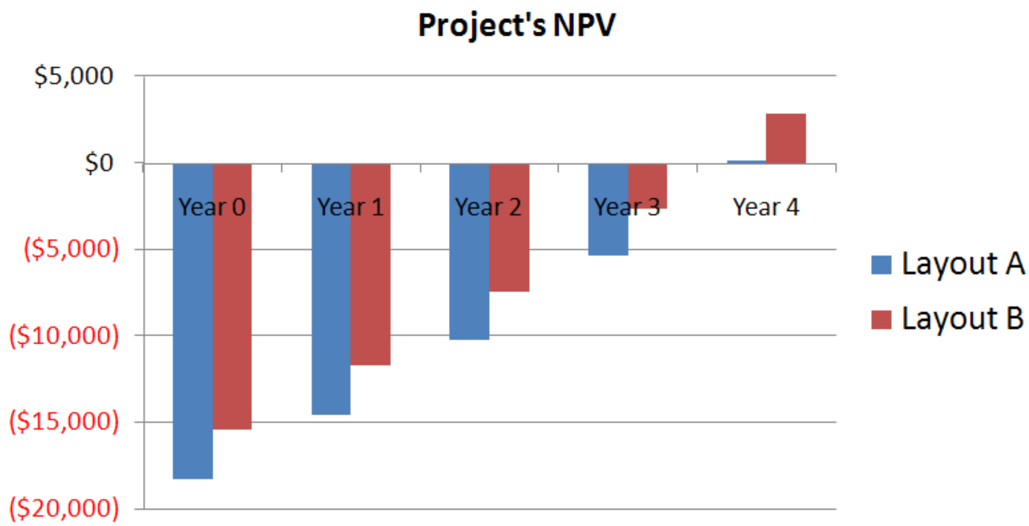

Figure 27: Net Present Value by year for Layout A and Layout B

	Year 0	Year 1	Year 2	Year 3	Year 4
Layout A	($18,340)	($14,567)	($10,280)	($5,408)	$128
Layout B	($15,430)	($11,703)	($7,467)	($2,654)	$2,815

Table 16: Net Present Value by year for Layout A and Layout B

The graph of the Net Present Value shown in Figure 27 illustrates the summation of the cost in year 0 and the saving in each year after that. Figure 27 charts the data shown in Table 16. This graph makes it more clear that even though you do not save as much each year with Layout B, the extra initial cost of Layout A makes it so that by the end of Year 4 Layout A's NPV is barely positive.

	NPV at end of Year 4	IRR	Payback Period
Layout A	$128	10.3%	3.98 years
Layout B	$2,815	17.3%	3.49 years

Table 17: Results of Layout A versus Layout B

Layout B has a higher net present value (NPV) at the end of Year 4, which means in 4 years the project of switching to Layout B will be more valuable. Also the internal rate of return (IRR) is higher for Layout B which means that this project is making you money at the same rate as a bank with a 17.3% interest rate. Also it has a lower payback period, which means that you breakeven almost half a year early with Layout B versus Layout A.

In conclusion I would recommend that this company implement Layout B.

8. List of References

"Back Injury Prevention." *Back Injury Prevention*. Web. Apr. 2012. <https://www.premierinc.com/safety/topics/back_injury/>.

"ErgoTech - Productivity through Ergonomics." *Ergonomic Factory Equipment Material Handling Ergonomic Work Positioners Ergonomics Products Lifts*. Web. Apr. 2012. <http://www.ergotechinc.com/why_ergonomics.htm>.

Goldsby, Thomas J., and Robert Martichenko. Lean Six Sigma Logistics: Strategic Development to Operational Success. Boca Raton, Fl.: J. Ross Pub., 2005. Print.

Greif, Michel. The Visual Factory: Building Participation through Shared Information. Cambridge, MA: Productivity, 1991. Print.

Hirano, Hiroyuki, and Rubin, Melanie. *5S for Operators: 5 Pillars of the Visual Workplace*. Portland: Productivity, 1996. Print.

Larson, T. Nick, Heather March, and Andrew Kusiak. "A Heuristic Approach to Warehouse Layout with Class-based Storage." *IIE Transactions* (1997): 337-48. Web. <http://www.springerlink.com.ezproxy.lib.calpoly.edu/content/v4lh05q0v528p1u1/fulltext.pdf>.

Mascitelli, Ronald. "Chapter 4 Visual Workflow Management." *Mastering Lean Product Development: A Practical, Event-driven Process for Maximizing Speed, Profits and Quality*. Northridge, CA: Technology Perspectives, 2011. 81-112. Web. 29 Mar. 2012.

Productivity Press Development Team. *Insights on Implementation: Visual Tools: Collected Practices and Cases*. New York: Productivity, 2006. Print.

Rouwenhorst, B., B. Reuter, V. Stockrahm, GJ Van Houtum, RJ Mantel, and WHM Zijm. "Warehouse Design and Control: Framework and Literature Review." *European Journal of Operations Research* 122.3 (200): 515-33. Web. 18 Feb. 2012. <http://www.sciencedirect.com/science/article/pii/S037722179900020X>.

Van Den Berg, J.P., and W.H.M Zijm. "Models for Warehouse Management: Classification and Examples." *International Journal of Prodcution Economics* 59.1-3 (1999): 519-28. Mar. 1999. Web. 18 Feb. 2012. <http://www.sciencedirect.com.ezproxy.lib.calpoly.edu/science/article/pii/S0925527398001145>.

"Visual Systems & Management." *Knowledge Fulcrum*. 6 Feb. 2009. Web. 29 Mar. 2012. <http://knowledge-fulcrum.com/category/visual-systems/>.

9. Appendices

9.1 Appendix A: Current Layout Distance Calculation

Generator											
From	To	inches			Trips/month	day	week	month		Weighted	
H	F	265		From where shipments arrive to the shipping computer area	100	5		100		26500	
F	J	580		From shipping computer area to QC	100	5		100		58000	
J	B	856		Post QC goes to generator raw materials	8		2	8		6848	
J	A	977		From QC to Non-Conforming Quarantine	2			2		1954	
B	R	1845		Generator raw materials to generator manufacturing	80	4		80		147600	
J	R	2198	(2x)	QC goes to check on generator manufacturing	8		2	8		35168	
R	I	2106		Generator manufacturing to generator finished goods	8		2	8		16848	
I	E	463		Generator finished goods to shipping packaging area	16		4	16		7408	
E	F	120		Shipping packing area to shipping computer area	16		4	16		1920	
G	OUT	297		From the shipping shelf out the door	20	1		20		5940	
										308186	in
										4.864047	mi
						assume	28	gen./month		0.173716	mi/gen.

Table 18: Distance traveled for Generator Material Handling in Current Layout

Catheter											
From	To	inches			Trips/ month	day	week	month			
H	F	265		From where shipments arrive to the shipping computer area	200	10		200		53000	
F	J	580		From shipping computer area to QC	200	10		200		116000	
J	A	977		From QC to Non-Conforming Quarantine	8		2	8		7816	
F	O	1251		Shipping computer area to raw materials area	40	2		40		50040	
F	L	1530		Shipping computer area to enclosed raw material area (next to packaging area)	20	1		20		30600	
O	M	494		Raw materials area to pass through window	8		2	8		3952	
L	M	233		Enclosed raw material area (next to packaging area) to pass through window	8		2	8		1864	
M	K	232		Between pass through window and packaging room	80		20	80		18560	
WITHIN K		84		Within the packaging room	80	4		80		6720	
K	N	405		Between the packaging room and non sterile quarantine.	64		16	64		25920	
N	Q	201		Between the non sterile quarantine & the loading dock	8			8		1608	
Q	P	193		Between the loading dock and the post sterile quarantine	8			8		1544	
P	C	1484		Post-sterile quarantines to finished goods in shipping	24			24		35616	
P	J	777	(2x)	QC goes to check on post-sterile quarantine	2			2		3108	
C	D	123		Transfer the finished goods to FIFO shelves	12		3	12		1476	
F	D	200		Go from shipping computers to FIFO shelves	600	30		600		120000	
D	E	64		FIFO shelf to shipping packaging area	600	30		600		38400	
E	G	20		Shipping packing area to ready to ship shelf	600	30		600		12000	
G	OUT	297		From the shipping shelf out the door	40	2		40		11880	
										540104	inches
										8.524	miles
						assume	3000	cath./month		0.00284	miles/cath.

Table 19: Distance traveled for Catheter Material Handling in Current Layout

Current Layout													
Distance (mi)	13.29	14.59	18.17	15.81	13.88	19.21	15.93	15.90	20.28	18.76	17.34	18.14	
Hours	4.43	4.86	6.06	5.27	4.63	6.40	5.31	5.30	6.76	6.25	5.78	6.05	
												Total Hours traveled per year	67.1

Table 20: Total Hours Traveled per year in Current Layout

9.2 Appendix B: Proposed Layout A Distance Calculations

Generator									
Inches			Trips/month	day	week	month		Weighted	
185		From where shipments arrive to the shipping computer area	100	5		100		18500	
110		From shipping computer area to QC	100	5		100		11000	
1807		Post QC goes to generator raw materials	8		2	8		14456	
318		From QC to Non-Conforming Quarantine	2			2		636	
150		Generator raw materials to generator mfg.	80	4		80		12000	
1742	(2x)	QC goes to check on generator manufacturing	8		2	8		27872	
249		Generator manufacturing to generator FG	8		2	8		1992	
260		Generator FG to shipping packaging area	16		4	16		4160	
60		Shipping packing to shipping computer area	16		4	16		960	
220		Out	20	1		20		4400	
								95976	in
								1.514772727	mi
						assume start generator	28	0.054099026	mi/gen.

Table 21: Distance traveled for Generator Material Handling in Proposed Layout A

Catheter									
inches			Trips/month	day	week	month			
185		From where shipments arrive to the shipping computer area	200	10		200		37000	
110		From shipping computer area to QC	200	10		200		22000	
318		From QC to Non-Conforming Quarantine	8		2	8		2544	
160		Shipping computer to raw materials area	40	2		40		6400	
300		Shipping computer area to Secondary RM	20	1		20		6000	
80		Raw materials to pass through window	8		2	8		640	
200		Secondary RM to pass through window	8		2	8		1600	
110		Between pass through window and packaging room	80		20	80		8800	
96		Within the packaging room	80	4		80		7680	
200		Between the packaging room and non sterile quarantine.	64		16	64		12800	
150		Non sterile quarantine and the loading dock	8			8		1200	
1150		Loading dock and the post sterile quarantine	8			8		9200	
300		Post-sterile quarantines to finished goods in shipping area.	24			24		7200	
425	(2x)	QC goes to check on post-sterile quarantine	2			2		1700	
70		Transfer finished goods to FIFO shelves	12		3	12		840	
60		From shipping computers to FIFO shelves	600	30		600		36000	
175		FIFO shelf to shipping packaging area	600	30		600		105000	
160		Shipping packing to ready to ship shelf	600	30		600		96000	
75		Out	40	2		40		3000	
								365604	inches
								5.770265152	miles
						assume start cath.	3000	0.001923422	miles/cath.

Table 22: Distance traveled for Catheter Material Handling in Proposed Layout A

9.3 Appendix C: Proposed Layout B Distance Calculations

Generator									
Inches			Trips/month	day	week	month		Weighted	
185		From where shipments arrive to the shipping computer area	100	5		100		18500	
135		From shipping computer area to QC	100	5		100		13500	
1400		Post QC goes to generator raw materials	8		2	8		11200	
500		From QC to Non-Conforming Quarantine	2			2		1000	
150		Generator raw materials to generator mfg.	80	4		80		12000	
1932	(2x)	QC goes to check on generator manufacturing	8		2	8		30912	
249		Generator manufacturing to generator FG	8		2	8		1992	
260		Generator FG to shipping packaging area	16		4	16		4160	
60		Shipping packing area to shipping computer area	16		4	16		960	
220		Out	20	1		20		4400	
								98624	in
								1.5565657	mi
						assume start generator	28	0.0555916	mi/gen.

Table 23: Distance traveled for Generator Material Handling in Proposed Layout B

Catheter									
Inches			Trips/month	day	week	month			
185		From where shipments arrive to the shipping computer area	200	10		200		37000	
135		From shipping computer area to QC	200	10		200		27000	
500		From QC to Non-Conforming Quarantine	8		2	8		4000	
190		Shipping computer area to raw materials area	60	2		40		11400	
0		Shipping computer area to packaging area	0			0		0	
1049		Raw materials area to pass through window	16		2	8		16784	
110		Between pass through window and packaging room	80		20	80		8800	
96		Within the packaging room	80	4		80		7680	
200		Between the packaging room and non sterile quarantine.	64		16	64		12800	
150		Between the non sterile quarantine and the loading dock?	8			8		1200	
1150		Between the loading dock and the post sterile quarantine?	8			8		9200	
300		Post-sterile quarantines goes to finished goods in shipping area.	24			24		7200	
425	(2x)	QC goes to check on post-sterile quarantine	2			2		1700	
70		Transfer the finished goods to FIFO shelves	12		3	12		840	
60		Go from shipping computers to FIFO shelves	600	30		600		36000	
175		FIFO shelf to shipping packaging area	600	30		600		105000	
160		Shipping packing area to ready to ship shelf	600	30		600		96000	
75		Out	40	2		40		3000	
								385604	inches
								6.0859217	miles
						assume start cath.	3000	0.0020286	miles/cath.

Table 24: Distance traveled for Catheter Material Handling in Proposed Layout B