Chapter 7

Facility Layout Design and Location Analysis

Facility location analysis and facility layout design is critical to the success of operations. The layout may dictate the profitability of the company and should be carefully considered during the product design and process selection/design decisions. The layout should not dictate the processes. However, in older facilities this may be the case. Ideally, the processes should dictate the layout. Customer locations may drive the decisions on the location of the facility and the site selection decisions dictate part of the layout plan.

The major goal of facility planning is to minimize material handling within the facility, regardless of the type of facility being planned. If material handling can be reduced, the opportunity to mishandle, mislead, or damage the product is minimized. If the material handling can be reduced, costs can be reduced and if costs can be reduced one of two things can happen: either the profits for the company can be improved or the price for the products can be reduced. Figure 7.1 shows a facility that was located near major interstate highways, major rail yards and near several major airports and seaports. There are advantages to locating facilities such as warehouses, distribution centers and cross docking facilities close to major supply chain nodes.

Figure 7.1: Cross Docking and Trans-loading Facility—Located near Major East-West and North-South Roads and Major Rail Yard

The next goal of the layout design process should be to layout the facility to improve the efficiency of the space and workers. In a distribution facility, the majority of the worker's time is spent moving from one location to the next picking location. If the layout can be designed to better utilize the space and use the employees' time more effectively, the amount of time spent walking from one location to the next can be reduced. This can be accomplished by storing fast moving items closer to the shipping and receiving areas or through the use of robotics such as the Kiva System used by Amazon.

One of the biggest complaints in the distribution and warehousing world is that is a shortage of space – "We don't have enough storage space!" Primarily because most facility managers measure their space on the square footage of the facility vice cube footage utilization. Almost everyone in the industry falls into this trap. Look at a *Modern Materials Handling* Magazine[39] and you will see articles about distribution centers—almost each one of them lists the square footage of the facility. Efficiently utilizing the space of the facility may mean utilizing the cube footage of the facility. Very few distribution centers or warehouses only stack supplies and materials one pallet high, therefore cube footage may provide more space. And, placing like

[3939] Go to http://www.mmh.com/ for more information on Materials Handling and facility layout models.

items close in the facility may very well reduce the movement in the facility, thus using employee time more efficiently. Using common sense in laying out the facility also helps produce more usable storage space.

To more efficiently layout the facility it is necessary to eliminate bottlenecks in the facility. This is much easier to do when designing a new facility than when inheriting an older facility. We will look at the Theory of Constraints in more detail in the discussion of Just-in-Time. However, it is imperative to get rid of all bottlenecks in the facility to produce a more efficiently run facility. Any bottleneck will reduce the efficiency and effectiveness of the operation. The principles of the Theory of Constraints and the principles of Just-in-Time—reducing waste—will improve the efficiency of the facility.

Early in the course we said that anything that does not add value is waste. We will see in future discussions that the goal of Just-in-Time is to eliminate waste. If waste is removed from the operations, there will be less movement. If there is less movement, we have achieved the primary goal of the layout design: reducing the need for material handling. If reducing material handling is achieved, the need for material handling equipment is reduced and therefore the costs of operations are reduced and again profits should be increased.

A good facility layout should consider the interaction and communications between the workers and management. If communication is improved, the quality of the outputs will improve. If the management can communicate directly with the workers, less will be lost in the communications process. One facility that I was in recently had all of the management on the second floor with two-way mirrored glass on the walls so that they could look down on the workers. This provided the management team with visibility of what was happening on the shop floor but violates the idea of facilitating communications.

The World Wide Operations Center for BNSF Railroads[40] has the same layout design. The BNSF facility is an awesome facility. From the floor (and from the windows on the second level) everyone can see the large screens that show the location of every train on the system and the contents of the trains as well as a weather screen and a listing of freight by commodity. The problem is that when on the operations floor, you feel like you are in an old

[40] For more on BNSF go to http://www.bnsf.com/

Western/Horror/Comedy where the eyes are cut out of the painting and you feel like someone is always watching you. This also impeded the ability to communicate face to face. Conversely, FedEx[41] has a World Wide Operations Center in Memphis, Tennessee that is similarly set up on the operations floor—large screens with tracking for every plane and the FedEx Weather Station. The difference is that the offices are on the operations floor to facilitate communications.

The final goal of the facility design process is to facilitate reduction of cycle time. In a distribution facility the goal of the layout design the goal is to reduce the processing times in the facility to reduce the customer wait times for the products the customers have ordered. If the facility is laid out for efficiency, it should also improve responsiveness to the customer.

In a service operation the goal should be to maximize the exposure of products to the customers depending on the type of operations. In some operations it may be better to design the process to minimize the travel and movement of the customer through the facility. Figure 7.2 shows the entrance to Ron Jon Surf Shop in Cocoa Beach, Florida. There are three ways to enter the store and at every entrance is the display of the newest shirt designs to encourage the impulse buy.

[41] For more on the operations of FedEx go to fedex.com

Figure 7.2: The South Entrance to Ron Jon Surf Shop – T-Shirt display to expose products to the customers

Grocery stores have the concept of maximizing exposure of the products to the customer. Almost every grocery store has the same layout. You go into the store and the fresh fruits and vegetables are on one end of the store, the meats and seafood are along the back, the frozen foods and breads are in the middle, and the dairy products are at the other side of the store. Even the Wal-Mart Supercenter grocery layout concept has the same basic layout only from front to rear rather than left-right or right-left orientation.

Starbucks stores are laid out to maximize the exposure of the products such as cups, accessories, coffees, and teas to the customer before reaching the counter to order a drink or pastry. Another coffee chain needed assistance with their layouts in 2005. This West Coast chain was looking for suggestions from consultants to improve the sale of the complementary items to their coffees and teas. Figure 7.3 shows their typical layout and analysis of the layout.

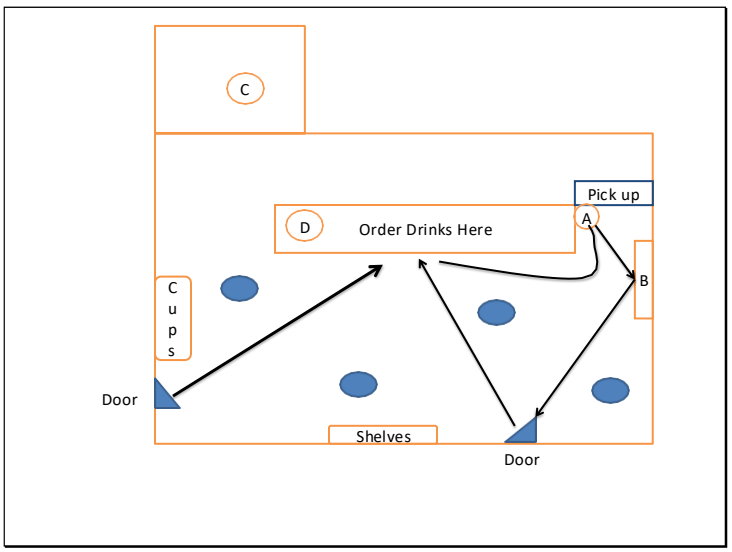


Figure 7.3: Coffee Shop Layout

The first observation of this layout is that the customers could enter either of the doors without ever seeing the cups and mugs for sale or the coffees and teas for sale on the shelves. This violates the idea of maximizing exposure to the products. The next problem with this layout is that after ordering the drink, the customers go to the pickup area to get their drinks. Located by the pickup area at A was the menu of what drinks were available. This probably should be placed in clear view of the ordering area and not where you pick up the drinks. After picking up the drinks and getting cream and sugar at B, the customer could leave without seeing the other items for sale.

If the customer came in the door on the bottom of the diagram, they could reach the ordering area without ever seeing the pastry area at D. The area shown at C was actually a tasting area that featured the newest flavors and the coffees of the day. This area was not clearly marked and was not obvious to the customers and therefore not really utilized, thus losing the marketing value of the area. Compare this to a typical Starbuck's layout (see figure 7.4) where cups and bags of coffee are exposed to the customer to encourage the impulse buy while waiting in line.

Figure 7.4: Starbuck's layout to expose products to the buyer

Other Considerations for Layout Planning

Safety and Security

Safety always must be a consideration in the design of the facility or the layout of the facility. A company can design the most efficient production layout but if it places the employees at risk or places the product at risk from the layout, it cannot be implemented. Granted providing a quality product with the least amount of movement and material handling is important, but the most important asset that any company has is its employees. If the safety of those employees is put at risk, the design is a no-go.

In California, the Occupational Safety and Health Administration (Cal OSHA) has certain rules and regulation that may or may not be applicable in other areas of the country. But these rules to protect the workers may be applicable in other states and to other countries that have Earthquake threats. Cal OSHA requires distribution centers that stack materials more than two pallet positions high to be bolted to the ground for Earthquake protection. This is important when designing a distribution center or warehouse layout. Why? Once the pallet racks are bolted down it is not only not practical but possibly not cost effective to move the racks—so, it is important to get the racks in the right place the first time.

It is also important to consider security of the facility and controlled access for visitors and employees as part of this design process. Most facilities have a controlled entrance and may have security guards at the entrance to ensure that employees are coming and going from the

controlled access point. The other reason for this controlled entry point besides the safety and security of the employees is to ensure that a dishonest employee is discouraged from taking stuff out of the facility.

Product Quality

Obviously, as the process design is for producing a quality product, the layout of the facility has to support that goal. If the layout design's primary goal is to minimize material handling, the corollary benefit of this goal is that the chances of producing a quality product are improved if the product is handled as little as possible. The fewer times a product is moved the smaller the probability that it will be damaged or misrouted, thereby reducing the impacts on the quality of the product.

If a product needs a certain environment for production such as a painting facility or the manufacture of computer chips, there may be impacts to the layout and/or the location of the facility. For example, when the Harley-Davidson Plant was in Kansas City, Missouri, the painting of the gas tanks was accomplished in a controlled environment that contained an air dam to blow particles off the workers to prevent defects in the paint. This process also has restrictions on the foods that the workers can eat to prevent defects in the painting of the tanks as a result of oils from the foods.

Flexibility for Future Operations

Every plan should include a consideration for the future of the operations. Whether it is a manufacturing facility that needs to consider future products or variations of the same product or a distribution center that needs to consider future storage requirements and product configurations, as well as the ability to expand capacity in the future, the company has to consider posturing for the future. This is an example of facility planning linked to capacity planning.

In the mid-1990s, Grainger designed and built a new distribution center in Ontario, California. By 2001, this facility had outgrown its capacity and needed to expand the operations. However, in the 5+ years that the facility was open, the facility had become blocked in—there was no place to expand the facility. Grainger decided to design and build a new facility a few miles down the road in Mira Loma, California. This time the facility was built larger than the current capacity by about 1.5 times. This allowed the company to slowly expand into the facility

as the need arose. The other flexibility that Grainger built into this facility was to buy the land around the facility to allow for the flexibility of future expansion and prevent being blocked in again.

Types of Layouts

Process Layout

A process layout places all of the like machines in the same area of the facility. As processes are completed the products are moved to the next process. In the facility diagram below (Figure 7.5), each of the areas shown represents the groupings of like machines or processes.

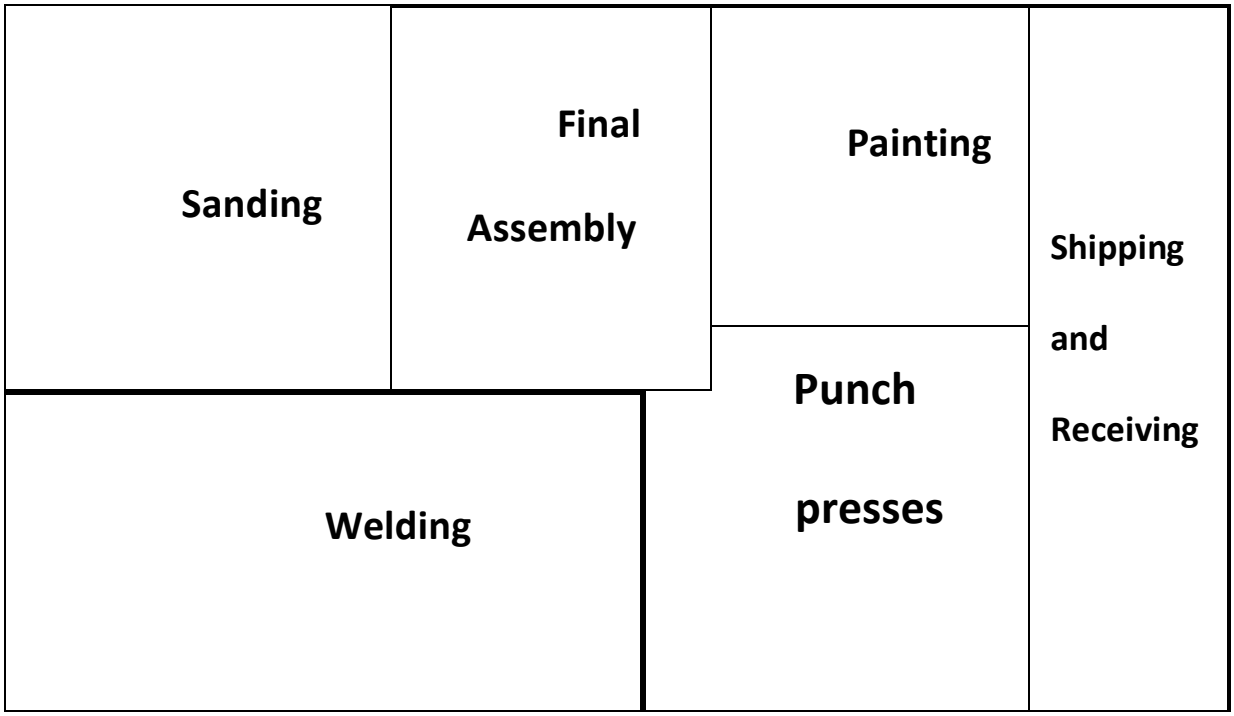


Figure 7.5: Process Layout Example

In order to improve the layout of a facility it is necessary to analyze the flow of materials or work in process from one process to the next. This flow analysis may show that the layout is flawed and not producing an efficient use of personnel and is causing an inordinate amount of moving of the materials and work in process. Take a look at Figure 7.6. This example shows a similar process layout that may not be as efficient. Look at the flow of the materials and work in process through the facility. This analysis shows that the layout may not be as efficient as it

could be and may be requiring more material handling and movement as is necessary or should be necessary. This layout has work in process moving across other process sectors. This is not an efficient layout. The goal of the process layout analysis is to find the optimal layout that will meet the goals of layout design.

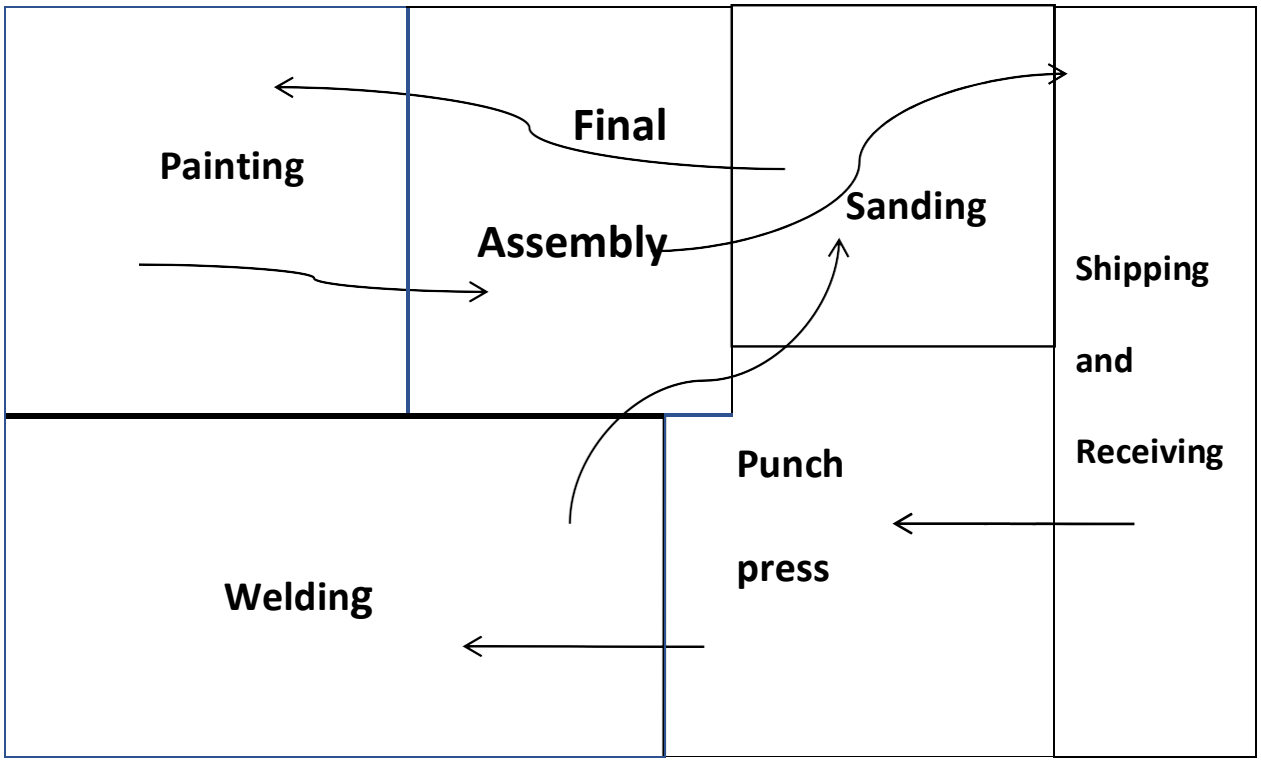


Figure 7.6: Process Layout with flow analysis

Product Layout

The product layout is the traditional linear manufacturing layout. Raw materials or subassemblies enter at one end of the manufacturing line and a finished product comes out the other end of the product layout.

The first thing that has to be considered in designing the product layout is to know or determine the assembly order or precedent of activities. This is important to make sure the layout is in a logical format based on what needs to be done first. (We will see this same methodology when we look at the Critical Path Method and Project Evaluation and Review Technique for Project Management.)

The next step in the product line design is to consider if work stations or work cells will be used for the product line. Either way the design has to consider how much work will be

assigned to the workstation or work cell to ensure a smooth flow through the line without delays or a buildup of work in process. In order to do this, it is important to measure the cycle time for the entire line (For example: Harley-Davidson knows it takes 54 minutes for one bike to be made on one of their product lines). Then the cycle time for each work station or cell must be calculated.

Cellular Layout

What is a cellular layout? A cellular layout is an attempt to balance the line and reduce material handling through a facility. This can only be accomplished by measuring the cycle times for each cell to ensure that the cells are balanced internally and externally. A cellular layout groups like machines into a cell. This sounds a lot like the definition of a process layout and may very well be a process layout within a product layout. Parts families may be grouped together within the product line and passed from one process cell to the next process. This produces a hybrid layout or a line within a line production.

The advantages of a cell are all based on proper planning and analysis. To achieve the benefits of cells requires balancing within and between cells. When properly designed the cell will minimize the need to constantly change set ups along the product line by grouping the like activities together much like the process concept.

Cellular layouts, although perceived by some advocates of Just-in-Time as the best way to produce goods and services, may not be appropriate for all products or services. If there are not enough processes or enough parts families in the operation, it may not be feasible to move to a cellular layout. Computer models are great for analyzing the available data to determine whether cells are right for the product or service.

Cellular layouts are not just for manufacturing. Cells can be seen in services and retail operations. When I lived in Hawaii there was a family-owned store in Waipahu, Arakawa's, that was broken into cells based on the "family member" that ran that particular department. The family saw this as efficient, but from the customer perspective the need to pay for items at every cell was seen as a bit inefficient.

In the fast food industry cells play a big part. In hamburger fast food restaurants there are cells that focus on the making of French fries, a cell that focuses on "grilling" the burgers, another cell that focuses on putting the burger together and another cell that is focused on taking

the customers' orders. The goal is to reduce the customer wait time and improve efficiency of the operations.

Project Layout

Project layouts are fixed position layouts. Remember back to the discussions on projects earlier in the text, projects are onetime operations. In a project layout it is not feasible to have a product layout. The manufacture of airplanes is an example of a fixed position or project layout. It is not feasible to have an assembly line for such a large product. Usually in a fixed position layout the largest costs are the variable costs associated with bringing highly skilled labor into the operation and then taking them back out after they have completed their work. The materials are brought to the product assembly area in time for the laborers to apply them. Conversely, the fixed costs for the production are relatively low.

Hybrid Layout

When Harley-Davidson had their assembly plant in Kansas City, Missouri, they had a hybrid layout. The manufacture of the gas tanks was a process layout—from the cutting of the blanks to the forming of the gas tank halves to the welding to the paint operations. Once the fuel tanks and the powertrains were complete the remainder of the assembly was a product line with four assembly lines—three basic models (V-Rod, Sportster, and Dynaglide) and one custom made (Screaming Eagle) assembly line.

Concerns and Issues to Consider

Balance. The assembly line needs to be balanced – every station in the line must have the same amount of work taking place (time wise) or else there will be a buildup of work in process at a workstation.

Flexibility. Part of the problem with the Kansas City Harley Davidson Assembly Plant was the lack of flexibility. This may be one of the underlying reasons that it was closed down. The three product assembly lines were not flexible. Each line could only produce one model of motorcycle. When the demand went up for one model and down for another model, they could not shift work to one of the other lines. Product lines need to be flexible. For example, Toro uses the same assembly line for lawn mowers (in the fall and winter) that it does for snowblowers (spring and summer).

Process Design

Now that we have the basic layouts defined, it is time to look at the methods for determining the optimal layout.

Block Diagramming

Look back at Figure 7.7. A block diagram could be applied to the layout. The goal of the block diagram is to establish with **quantifiable data** the number of items moving from one process or machine to the next process or machine and what if any is moving backward to be redone. Figure 7.7a shows a facility looked at recently that could have used a block diagram to determine the optimal layout based on flow analysis and quantifiable data to determine which processes should have been placed adjacent. This particular facility was "focused on Lean initiatives." However, the primary goal of Lean as we will see later is to reduce waste. One of the wastes that Lean seeks to reduce or eliminate is the waste of movement. This particular facility could have improved operations by using the data that they had available and the use of a block diagram.

In this particular aircraft parts repair and rebuild facility items came in through each of the three doors and went to Area A, Area B, or Area C for initial analysis and repair. Then items moved from the initial area to one of the other two areas for additional work and then to one of

the other areas for more work before being shipped out to the customers.

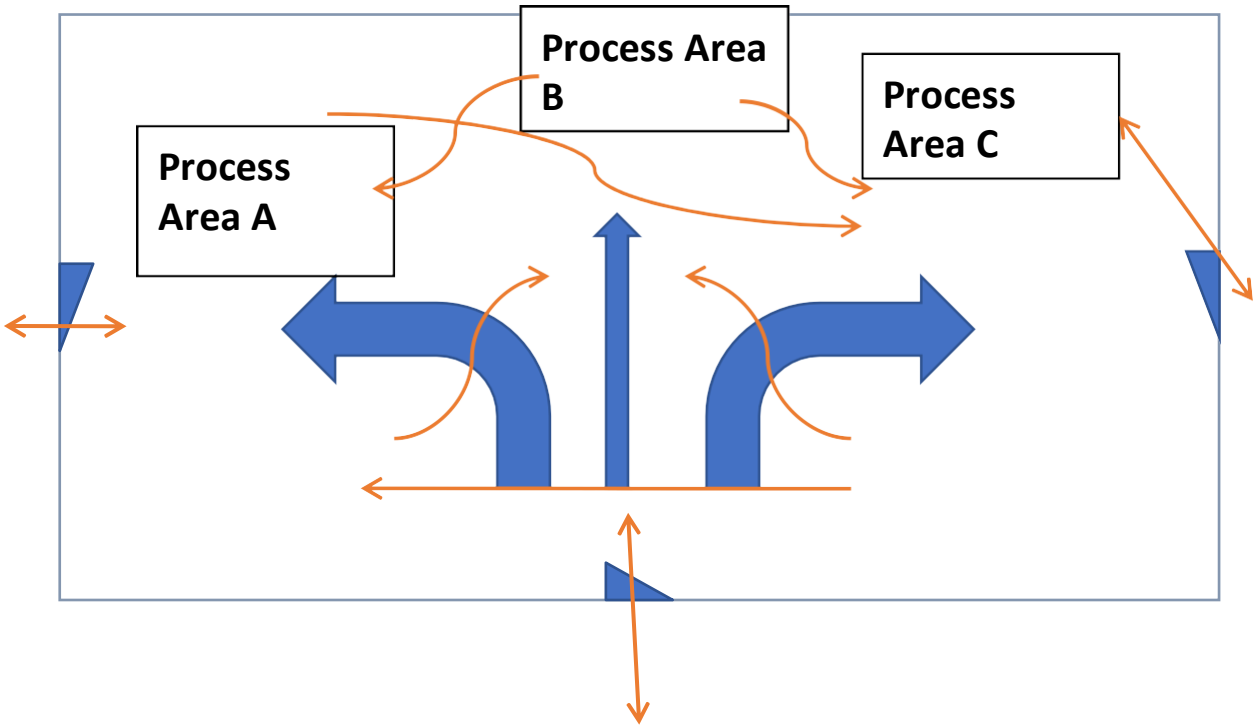


Figure 7.7a: Flow Analysis Using Block Diagramming

Using the quantifiable data of the movements from one area to the next and analyzing the data to determine the movements between adjacent areas a more optimal layout is possible. Look at Figure 7.7b and the redesign based on adjacent sector movements. This new layout not only allows for movement from each area to the other areas without passing through Area B in the middle which slowed operations. Also the new design provides an area strictly for Quality Assurance and Shipping Area which was handled throughout the facility in the previous design.

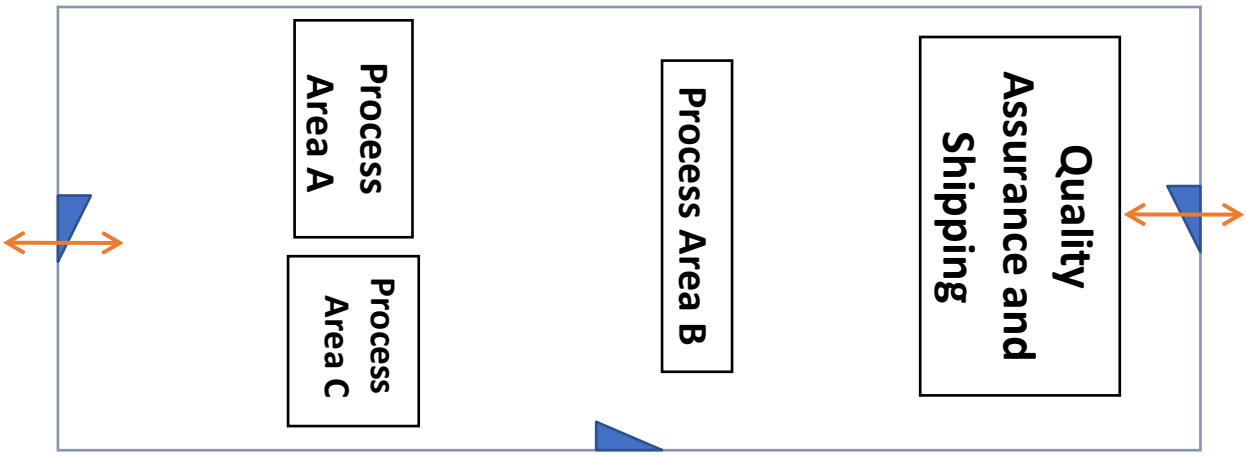


Figure 7.7b: Redesigned Facility Using Block Diagramming

Figure 7.8 shows the US Navy's methodology for determining the flow of materials between departments in a distribution center. The chart allows the organization to create an easy to understand methodology to establish the flow from department to department.

ACTIVITY FROM \ ACTIVITY TO	RECEIVING	INSPECTION	AS/RS	BULK STORAGE	PALLET RACK STORAGE	RACKABLES ORDER PICKING	BINNABLES ORDER PICKING	SHIPMENT STAGING	EMPLOYEE SERVICES	DATA PROCESSING	TOTAL
RECEIVING	–	30	5	2	10						47
INSPECTION		–	15		8	3	4	3			33
AS/RS			–		7	4		9			20
BULK STORAGE				–	1			1			2
PALLET RACK STORAGE					–	6		20			26
RACKABLES ORDER PICKING						–	7	4	1	1	13
BINNABLES ORDER PICKING							–	11			11
SHIPMENT STAGING		3						–			3
EMPLOYEE SERVICES									–		0
DATA PROCESSING										–	0
TOTAL		33	20	2	26	13	11	48	1	1	155

NOTE:
Activity units expressed as frequency factor equal to units moved (pallets, pounds, cu. ft. etc.) times distance per move (usually feet).

Figure 7.8: US Navy Methodology for Establishing Flow of Materials between Activities

Figure 7.9 shows another method from the US Navy to establish activity between departments. This chart shows the affinity between departments: The activities with three lines have strong movements between the departments meaning they have to be in close proximity, the activities with two line have substantial movement and therefore should be in close proximity to each other, the activities with one line have some movement and those activities not connected at all have no movement and therefore have no need to be closely located in the facility.

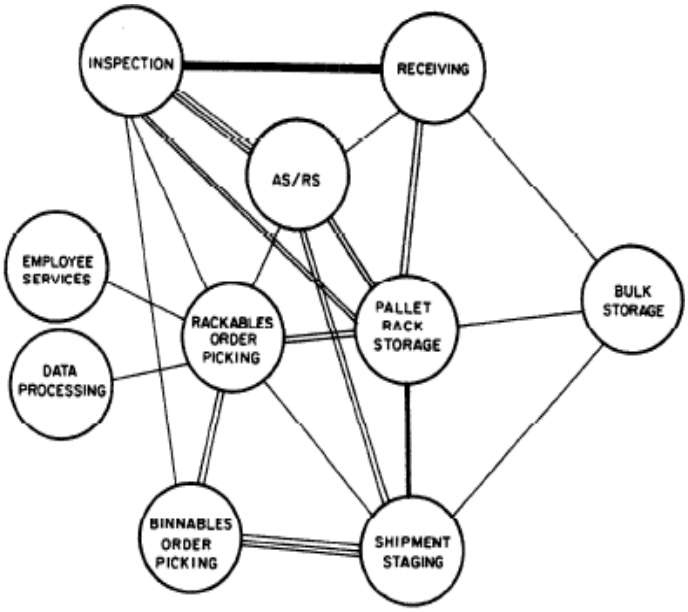


Figure 7.9: Activity Diagram

Relationship Diagrams

One of the most common relationship grids is the Muther's Grid. This technique was originally developed by Richard Muther. The relationship grid is designed to be used if when

quantifiable data are not available. Therefore, this technique is not used if the data shown for the block diagram or the affinity diagram are available. A relationship diagram is based on someone's opinion of what should be located close to other activities. In 1980 the warehouse that I was responsible for was destroyed by a large tropical storm in Hawaii. Although this warehouse was a showplace warehouse that was included on every distinguished visitor tour in Hawaii, there were some areas that could be improved. The data was not available to show what moved from where to where. So my smart guys developed a rough draft relationship diagram. We were not aware of Muther's work but used the same ideas of what we thought should be close to which when designing the new facility. The problem with a relationship diagram is that it is subjective. It is someone's opinion or best guess. A Muther's Grid when blank looks like Figure 7.10. Notice that it looks a little like the old mileage charts on a paper map shown in Figure 7.11—and is read the same way. The intersection of the lines is the relationship and shows what should and should not be placed close to other activities.

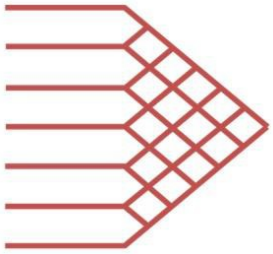


Figure 7.10: Blank Muther's Grid

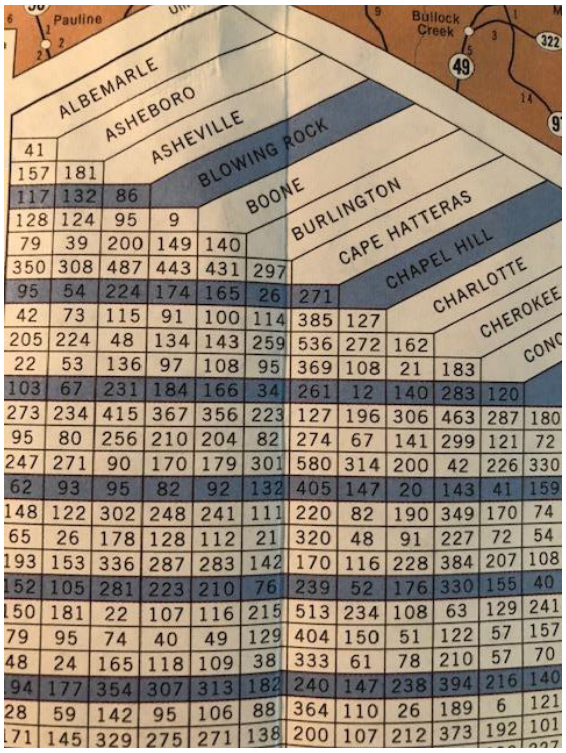


Figure 7.11: Example of Grid from Old Paper Maps

In Figure 7.11, if you are travelling from Chapel Hill, NC to Cape Hatteras, NC, you find the two cities and at the intersection you can find the mileage. Reading a Muther's Grid is the same methodology. You find the two areas that you are concerned about and at the intersection you can find the recommendation for the location of those areas or activities.

Using the Muther's Grid

There are three methods of analysis using the Muther's Grid to establish relationships for improving the layout design that I have seen used. The first methodology I call the "Vowel Method"—for obvious reasons. The relationships are shown using the following scoring system:

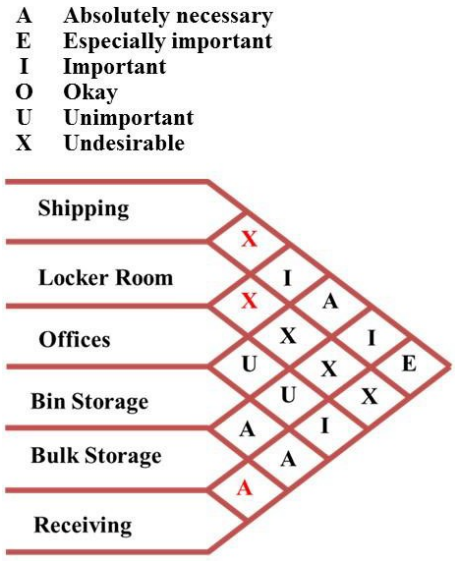


Figure 7.12: Vowel Methodology Muther's Grid

In Figure 7.12 the Vowel Methodology is applied to the Muther's Grid. Using this Grid it is easy to see that the subjective analysis deems the relationship between the shipping department and the offices is Undesirable (X)—the rationale for this decision is because the need to have privacy in the offices to talk to potential employees and talk with current employees is critical to operating a business. At the same time it is important to have privacy in the locker room to talk among the employees.

Bulk storage and Receiving is deemed to be Absolutely Important (A) because of the desire to reduce material handling costs and the waste of unnecessary movement. The same is true in this example for bin storage (small items) and shipping. The rationale for determining that shipping and locker rooms should not be close (Undesirable—X) is to prevent the temptation to move nice to have items to the locker room vice the shipping dock.

Figure 7.13 shows the same rationale using the "Numbering Methodology." This methodology is very similar except that instead of using letters or vowels, numbers are used. The importance with using this method is to make sure the decision maker and the recommender understand the numbering system. This is why it is important to have the scale close by when looking at the grid. This is important because the decision maker needs to know the scale—is a 1

good or bad? The rating scheme of one system may have 1 as good and 6 as bad (the lower the better, like a golf score) or may have 6 as good and 1 as bad (the more points the better, like a good basketball game). The intersection between bulk storage and receiving is a 1—Absolutely Important to reduce movement.

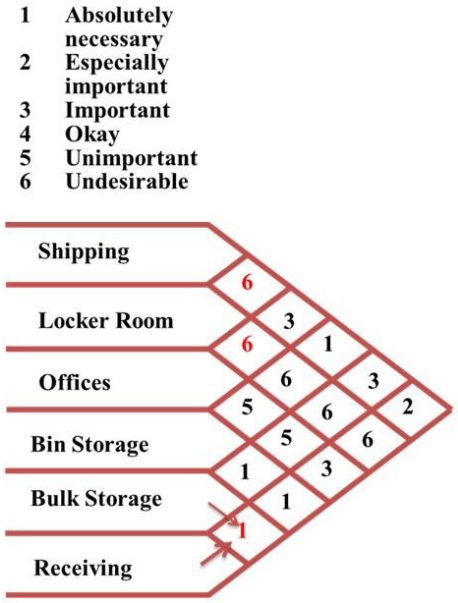


Figure 7.13: Muther's Grid Using Numbering Methodology

Hybrid Methodology

The Hybrid Methodology comes from the US Navy's Manual for Warehousing Layout.[42] This methodology combines the two previous methods to provide a much better relationship diagram. The hybrid method not only shows what the recommendation is but the rationale of the recommender and the thought process for the recommendation. Figure 7.14 shows this

[42] Navy Supply Publication 529, Warehousing Modernization and Layout Planning Guide, 1985. Although this publication is almost 40 years old, it is still considered by many to be the best publication available to guide a planner to design the most optimal warehouse or distribution center layout.

methodology. Looking at Data Processing and Employees Services, the recommendation is Absolutely Necessary and the rationale is because they share office space.

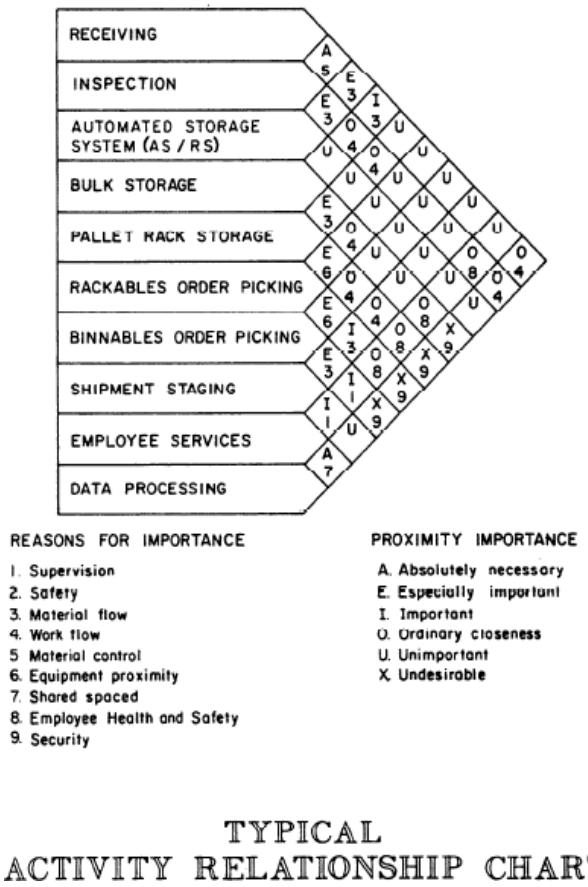


Figure 7.14: Hybrid Methodology for Relationship Planning

Layout Summary

The layout of the facility may provide a competitive advantage and improve efficiency of the operations. The facility layout will determine capital expenditures and flexibility, and may constrain the capacity of the company.

Layout design is just as important in services as it is in manufacturing. If quantifiable data is available a block diagram may be the best tool to improve the layout design and efficiency. When **quantifiable data is not available** a Muther's Grid or Relationship Diagram may be more useful to design or redesign the operations. A process walk is necessary to determine what operations precede other operations based on the walk and the process charts.

The layout for a facility may be constrained by the location and what is available in a location. This is why location and site selection are critical to good layout designs.

Location Analysis and Models

Whether a company is involved in heavy manufacturing such as automobile manufacturing and high tech manufacturing or distribution centers, there are some considerations that are common to the process and some considerations that are unique to certain industries. Land costs, utility costs, and construction costs are common to any facility.

In **Heavy Manufacturing** decisions and considerations to be analyzed before choosing a location for a new facility include:

- **What is the availability of labor in the desired area?** Is there sufficient labor available and is there sufficient skilled labor to staff the facility or will the companies have to bring employees in from other locations. Although there is currently almost 10% unemployment throughout the United States it does not mean that the skills necessary for operations will be available.
- **Raw Materials**. Is it better for the company to locate the manufacturing facility closer to the source of the raw materials or is it better to locate the facility closer to the customers? If the raw materials have a short shelf life, it may be more advantageous to the company to have the manufacturing plant close to the source of the raw materials. If the raw materials can only be delivered by rail, the facility must be located near or on a rail siding.
- **The mode of shipping the finished product may dictate the location of the facility**. Certain products must be shipped by rail, therefore the manufacturing facility should be located on a rail siding or rail spur. Access to transportation networks is a requirement for

all facilities—the type of network is driven by the raw materials and the finished product. Several years ago there were sufficient potatoes in the field in Russia to feed the entire country and make all the Vodka the country could drink only to have the produce rot in the field because a lack of sufficient transportation networks to get the produce to the factories.

In **Light or High Tech Manufacturing** the biggest concern after the land, construction and utilities costs is the education base of the area. There is a good reason why the Research Triangle Park (RTP) area in North Carolina is located where it is and has a large number of high tech firms in the RTP. Within a little more than an hour of the RTP are four world class research universities providing a well-educated workforce. North Carolina State University, Wake Forest University, Duke University, and the University of North Carolina are all nearby. The Silicon Valley area in California provides the same education-rich environment to support the high tech needs of the industry. There are several areas that I have been stationed during my military career that will never be high tech hubs because of the lack of quality secondary and post-secondary education programs.

The driving factor for the location of a warehouse or distribution center should be proximity to the customer or to the manufacturing facility. A decision has to be made as to whether or not it is better for the company to locate their storage facility close to the manufacturing plant or close to the customer. Wal-Mart has a good model for where to place distribution centers to support its "more than 8,446 retail units under 55 different banners in 15

countries."[43] The purpose of warehouses and distribution centers is to put the product closer to the customers and reduce the customer order cycle time. This being the case, the distribution center or warehouse should probably be placed as close to the customer base as possible.

Chicago Consulting Company provides an annual survey of warehouse locations to best meet the population base of the United States. This study is available at http://www.chicago-consulting.com/10best.shtml and is updated every year. The study bases its recommendations on the road networks and the population centers of the United States. This study is based on the center of gravity location model. This model is based on plotting the customer locations on a grid and placing the facility as close to all of the customers as possible to reduce travel time to the customers. This model can be weighted to place the facility closer to higher priority or higher volume customers. This model can be used for retail locations or for distribution centers. A center of gravity calculation using Excel looks like Figure 7.15. This example shows a non-weighted example. Figure 7.16 shows the same information using weights to favor the stronger customer locations.

[43] http://walmartstores.com/AboutUs/. "We have more than 40 Regional Distribution Centers. Each one is over 1 million square feet in size. They operate 24/7 to keep our fleet of tractors and trailers rolling. Inside each DC, more than five miles of conveyor belts move over 9,000 different lines of merchandise. Each DC supports between 75 and 100 stores within a 250-mile radius."

Center of gravity

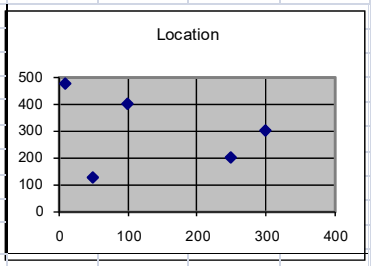
Enter the weights and coordinates in the data area.

Data

	Weight	X coord	Y coord
Location	0.2	100	400
Location	0.2	250	200
Location	0.2	50	125
Location	0.2	300	300
Location	0.2	10	475

Results

Sum	1	710	1500
Average		142	300
Weighted Average		142	300



Distance table

			X coord	100	250	50	300	10
			Y coord	400	200	125	300	475
X coord	Y coord			Location	Location	Location	Location	Location
100	400	Location 1		0	250	279.5085	223.6068	117.1537
250	200	Location 2		250	0	213.6001	111.8034	365
50	125	Location 3		279.5085	213.6001	0	305.1639	352.2783
300	300	Location 4		223.6068	111.8034	305.1639	0	338.7108
10	475	Location 5		117.1537	365	352.2783	338.7108	0
		Total		870.269	940.4035	1150.551	979.2849	1173.143
		Weighted Total		174.0538	188.0807	230.1102	195.857	234.6286

Figure 7.15: Center of Gravity Example

Center of gravity

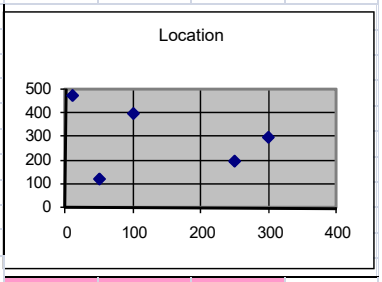
Enter the weights and coordinates in the data area.

Data

	Weight	X coord	Y coord
Location	0.3	100	400
Location	0.25	250	200
Location	0.1	50	125
Location	0.2	300	300
Location	0.15	10	475

Results

Sum	1	710	1500
Average		142	300
Weighted Average		159	313.75



Distance table

			X coord	100	250	50	300	10
			Y coord	400	200	125	300	475
X coord	Y coord			Location	Location	Location	Location	Location
100	400	Location 1		0	250	279.5085	223.6068	117.1537
250	200	Location 2		250	0	213.6001	111.8034	365
50	125	Location 3		279.5085	213.6001	0	305.1639	352.2783
300	300	Location 4		223.6068	111.8034	305.1639	0	338.7108
10	475	Location 5		117.1537	365	352.2783	338.7108	0
		Total		870.269	940.4035	1150.551	979.2849	1173.143
		Weighted Total		152.7453	173.4707	251.1271	176.3559	229.3661

Figure 7.16: Weighted Center of Gravity Example

In addition, there is now a regular publication, *Site Selection,* that is dedicated to helping companies determine where to place a facility. The magazine is basically a marketing tool for regions to help promote the capabilities and advantages of an area for companies considering relocation or expansion.

Distribution Center/Warehouse Considerations for Layout and Location

The considerations for location for the distribution center should include the location proximity to the customers besides other factors in the layout. These include:

- **Cross-docking—**will the facility use cross docking as a technique? Cross-docking has been discussed in greater detail under supply chain management. Cross-docking is simply planning the inbound shipments to the facility in coordination with the outbound shipments so that the items never go on the shelf but from the inbound truck to an outbound truck within 24–48 hours. From a layout perspective this requires a holding area to be designed but may mean less shelf storage space will be needed in the design and layout.

- **Dock doors—how many?** If moving into a current facility this may not be a consideration; however, if the company is designing a new facility this may be a consideration that will drive the layout. Is it possible to have inbound on one side of the facility and outbound on another side of the facility? If so, this may impact the layout as well as the traffic flow pattern.

- **Vehicle flow—**how will the trucks come into the facility and leave the facility? This is an important consideration to the layout. The optimal solution would be to have one way traffic flow; however, because of land constraints and security issues this may not be always feasible.

- **Picking techniques—**how will the items be picked in preparation to shipping to the customer? There are various picking techniques used in distribution centers to include the use of Automated Storage/Automated Retrieval (AS/AR) systems that do not have any human involvement with the put away and picking operations. Pet Foods in Topeka, Kansas uses a total AS/AR system for their state of the art facility. The Defense Logistics Agency uses AS/AR systems for their small high volume items. The type of picking technique and the analysis of fast moving items will drive the layout of the facility.

- **Bulk storage—**how much bulk storage will be kept and will it be kept close to the other storage areas or in a separate facility will drive the layout of the distribution center.

- **Safety/backup stocks—**safety stocks are a level of stocks above the normal stockage levels to cover variations in demand patterns. Will the company have safety stock at each location for every item or will there be a central location with the safety stocks? This will drive the layout and size of the facility needed. (We will cover safety stock in greater detail under the discussions on inventory management.)

- **Customer proximity –** obviously, if the goal of distribution centers is to put the product closer to the customer, the location has to be in close proximity to the customer base.

Other Location Factors

Just as there are common factors to the different industry locations, there are some common factors to the choosing the global or regional locations.

For companies considering locating overseas—whether that overseas is Asia, Europe, South America, Africa, or North America, depending on the location of the corporation—there are certain areas that need to be considered before relocating operations.

- **Culture**—obviously, or at least it should be obvious, that countries have different cultures and what are the norms and mores in one country are not necessarily the social norms and mores in other countries. Even Wal-Mart found this out when they tried expanding to Germany. Wal-Mart bought Wertkauf as the point of entry into Germany. Wertkauf was the German equivalent of Wal-Mart and would appear to be a good match. However, Wal-Mart discovered that there were cultural differences between the shoppers in Germany and the shoppers in the United States; now there is no Wal-Mart in Germany and no Wertkauf either.

  Wal-Mart learned the same lesson again when they moved into China. Shoppers' behavior in China is apparently different from shoppers' behavior in other areas served by Wal-Mart. According to my students from China, they go to the store more often and buy what they need. One student reported that his family would go to Wal-Mart up to four times a day to get fresh foods. Wal-Mart also learned that the culture/laws in China dictated that a certain percentage of the items in the stores had to come from the local area—which should not have been a problem as most of what is in the Wal-Mart stores in the United States is from China.
- **Language**—the typical American attitude is that everyone will speak English. And if they don't seem to understand English the first time the typical American attitude is SPEAK SLOW AND SPEAK LOUD and they will understand. When I was stationed in Germany the common attitude was: "If you speak three languages, you are tri-lingual; if you speak two languages, you are bi-lingual; and if you speak only one language, you are probably American." Companies have to ensure that employees

that they are sending overseas understand the native language and can communicate in the native language.

- **Exchange rates**—how stable is the Dollar against the local currency and what is the exchange rate? Or, if a company outside the United States is looking to expand, how stable is the company's native currency against the Dollar or the Euro or other foreign currency. The wine makers in South Africa are very concerned about the stability and the exchange rate of the Rand against the Dollar. The wine makers are working hard to eliminate waste in their systems in order to compete cost-wise head-to-head with the California Wineries.

- **Trade agreements or blocks—**if the company tries to expand into another country, will they have to compete against protections from trade agreements or trading blocs such as the recent US Canada Mexico Agreement the European Union? If so, will that include tariffs or duties for importing products or can the company take advantage of Free Trade Zones to reduce tariffs or duties? *The APICS Operations Management Body of Knowledge* defines a Free Trade Zone (or Foreign Trade Zone) as: "an area considered outside of the host country's territory but supervised by its customs department. Material may be brought in to the FTZ without paying import duty taxes and assembled or manufactured into a finished product. Duties and taxes are then paid when the finished good is moved outside the FTZ for retail sale."[44] Figure 7.17 is just

[44] *APICS Operations Management Body of Knowledge*, APICS The Association for Operations Management, 2nd edition, 2009, p. 26.

a part of the Free Trade Zone, Colon in Panama. In the FTZ, Colon, there is a commercial area with store fronts for businesses to make purchases and then there is a warehousing district for the storage of products without having to pay customs and taxes.

Figure 7.17: Part of the Commercial Area, Zona Libre, Colon, Panama

- **Commercial travel—**this is an area that is often overlooked when making the analysis for off-shoring operations. The cost of flying employees and management back and forth to distant locations and the time involved in the travel is a critical component of the analysis that should not be overlooked.

- **Supply chain/Transportation costs—**one of the critical areas that should be considered in the off-shoring analysis is the cost of moving products around the globe. For example if a company with a primary market in North America, moves operations from North Carolina to China, there is now a cost of moving the products from China back to North America. In 2009, Maersk Lines announced that they were going to save $1 billion a year in fuel costs by cutting shipping speeds in half. From a

manufacturing perspective, this just doubled the shipping times and doubled the inventory in motion.

Hilton Hotels has a goal of making the furnishings in each of its chains look the same for each room in the chain regardless of the location. For example, if customer is a loyal Hampton Inn guest, the goal is for every Hampton Inn room to look the same so the guest feels at home. After a very detailed analysis, Hilton determined that it was actually cheaper to buy the materials in the United States, ship them to Southeast Asia, have the furniture made, and shipped back to the United States than they could have the furniture made in the United States.

One issue surfacing in 2020 is the increased dependence on other countries to supply critical products to the USA and other parts of the world. This became an issue with the rise of the coronavirus pandemic. One consideration has to be what is critical to national survival? And how much of these critical items should be made in the USA as opposed to overseas?

However, recent studies have shown that it is only about 5% more expensive now to make products in the USA than it is to make them in Asia and ship them to the USA. Part of this is based on the rise of transportation and part of it is based on the rise in the cost of labor in other countries.

- **Labor—**unfortunately, this is the only aspect considered in too many off-shoring analyses. When the cost of oil rose to $140 a barrel in 2008, many companies started questioning the analysis that based the off-shoring on labor alone. Recent studies show that the cost of labor increases in some Asian Countries coupled with fuel costs now put the difference between producing in Asia and producing in North America at

approximately only 5%. With the steep decline in oil prices in 2020, one has to wonder why the costs of transportation have not decreased as well. The answer may be tied to long term price contracts for fuel – leaving companies paying way too much for fuel based on the 2020 prices.

Regional Location Considerations

Many of the considerations for overseas location analysis impact regional decisions as well. However, a few other considerations must be taken into account for regional location decisions.

- **Quality of Life—**when considering other locations for operations this must be taken into account. In 1972, Amoco Oil Company decided to move its credit card operations from Chicago. The location decided upon was Raleigh, North Carolina. The primary reason given for the selection was the quality of life in the Raleigh area which included cost of labor, cost of housing, better education, and the overall cost of living in the Raleigh area. Quality of life also included better Bar-B-Que in the Raleigh area and closer proximity to the beach.

  Amoco knew when they moved into the area that they would probably move in approximately ten years based on their models. One of the things that Amoco did was work with the State of North Carolina on the location and **incentives** to move into the Raleigh area. Amoco received local incentives to move into the area and in exchange the State of North Carolina was promised the facility when Amoco moved on. The facility was ahead of its time with its own cooling ponds, lots of trees around the building and parking lots, and tinted windows that reflected sunlight to reduce the

cooling requirements during the day and reflected lights in at night to keep reduce lighting requirements and heating requirements.

Another example of local/regional incentives is the Wal-Mart in Kansas City, Kansas. Twenty years ago, the Kansas City, Kansas area was a relatively depressed economic area and did not merit a new Wal-Mart. Then the Kansas Speedway was built, Nebraska Furniture Mart opened, Cabela's opened and quickly became the number one tourist attraction in the State of Kansas, followed by the opening of the Legends Shopping Center. All of this made the Kansas City, Kansas area the fastest growing shopping and economic district in the Midwest. However, Wyandotte County and Kansas City, Kansas had to offer tax incentives to the largest company in the world to move into the area.

- **Local/regional regulations—**are there environmental concerns or local tax concerns such as in California? The tax rates, environmental regulations and OSHA regulations are driving companies into Nevada. More and more companies are moving operations into the Reno/Sparks, Nevada area for distribution centers. This location provides rapid response to California customers and the Interstate 80 corridor without paying California taxes or having to comply with California environmental regulations. The same trend is becoming a reality in Las Vegas, Nevada. The proximity to Southern California and the lack of state taxes makes it a logical choice for distribution centers.

- **Transportation networks—**just like the previous discussion about distribution center location analysis, the availability and access to rail, air, and road networks is important to the decision of where to locate a manufacturing facility. This is why Ontario, California is such a popular place for distribution centers – it is close to the

ports of LA and Long Beach, close to LAX and Ontario airports, and at the intersection of Interstates 10 and 15 while not far from Interstate 5.

- **Income levels—**deciding to put a high-end retail operation such as Nordstrom's will or at least should have as part of the decision process a consideration of the income levels of the area. In Kansas City a high-end company called Digi's Karma opened in an area that was not economically postured to support the company and the store closed its doors less than three months later.

- When all else fails and relaxed government oversight or incentives are not available, you can always start your own government. This is what Disney did in Florida. They could not get incentives or full support for infrastructure improvements, so they started the Reedy Creek Development Authority and formed their own government, police, fire, sewage, and infrastructure. Amazing that in 1967 when Disney World was announced that no one in Florida wanted anything to do with it and now the state depends on the Disney tourist trade for survival.

Summary

Location analysis is a complicated process that enables the company's decision makers to balance costs of off-shoring such as building a new facility and increased inventory costs with cost savings from incentives, labor savings, and potential entry to new markets. The basics of location analysis and layout design can be used for any operation from a small gym to a large multimillion square foot distribution center.

Discussion Questions and Thought Questions on Layout Design and Site Selection

1. Go to a retail activity and look at their layout. What is the store trying to do with their layout? Is there an obvious pattern to their layout?
2. Based on your visit to a retail facility, is there a better way to layout the facility to maximize exposure to products?
3. Visit a Home Depot or Lowe's and look at the warehouse layout that they have. Is there a pattern to their layout?
4. Create a Muther's Grid to improve the layout of the Home Depot that you visit.
5. What is the difference between a product, process, and fixed facility layout?
6. What is a hybrid layout and what advantages does it provide?
7. When should you not choose to use a cellular layout?
8. Can the layout of the facility become the bottleneck for the company?
9. Why is site selection so important to the success of the company?