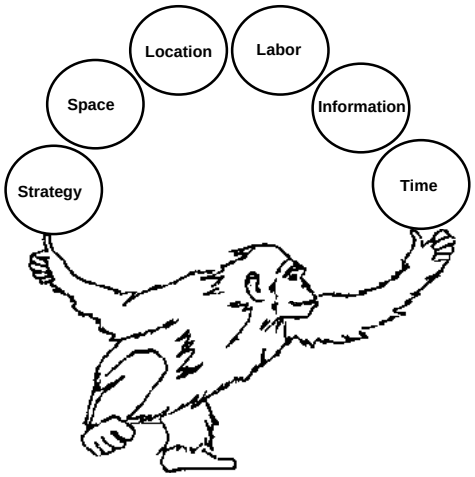
Warehouse Layout and Design

A warehouse is a warehouse. It's a big box in which you store inventory. Well, today's warehouse isn't the warehouse that it was twenty years ago and it's going to be totally different in the future. The whole role and strategic purpose of warehousing is changing and it's changing very rapidly.



The warehouse is no longer a repository of inventory that comes to rest. Hopefully, we're turning our inventories more. We're expanding the number of shipments we make with less inventory. Therefore, the whole logic of the former design of the warehouse has changed. In the past, we needed large storage areas and small assembly areas for shipments. That's changed. Now we need larger assembly areas for the shipment and smaller storage areas. We need larger picking areas, more pick slots, and less backup inventory. The design effort is really a balance of the right amount of space, labor, and time along side an understanding of strategy, location, and all other business information. So if your warehouse's role has changed to become a cross-dock operation versus a storage of safety stocks and seasonal inventories, then the strategic purpose of the warehouse has changed and its design needs to change also.

Warning Signs of the Need to Re-design

In all too many warehouses we are now trying to do two and three times what they were designed for. So what happens? We have inventory sitting in the aisles. We have multiple SKU's on the same pallet. We have multiple pallets in the same pick spot. This plays havoc with our productivity. It plays havoc with everything that the warehouse was designed for. And unfortunately, it creates a whole lot of other problems, which are indicators of the need to re-design the warehouse.

The Strategic Role of the Warehouse Has Changed

Need for warehouse space has increased
Operating costs are rising faster than throughput
Labor costs have significantly changed
Space available to conduct warehouse activities has decreased
Congestion is increasing
Shipping errors and other service measurements have decreased
Order cycle time has significantly decreased
Outside facilities are being used
Short-term "fixes" are required
Inventory control/management issues are on the rise

Operating costs proceed to increase faster than throughput. As you run into storage problems or strategic changes in your warehouse and the design no longer fits the need, your operating costs are going to go up. Your costs per unit rather than going down based on higher volumes through a fixed cost operation, will go up. Your labor costs will also go up on a per unit pick basis. Why do your labor costs go up? Because you have to move those pallets of goods that are sitting in the aisles, right in the way of where you need to go to pull stock or to put stock away.

Your space availability to conduct warehouse activities will decrease. For example, the assembly area for shipments had been 2,000 sq. feet, but because the number of SKU's has doubled, you've now turned part of that area into quick-pick storage or dead storage space. So consequently the space available to conduct those all-critical warehouse activities decreases at a time when, because of the strategic change, it probably needed to increase.

Shipping errors increase and other service measurement decline. Not only do efficiency and productivity go down, but probably more importantly from a customer service standpoint, shipment errors go up and those other service measurements, such as line fill, tend to go down.

Line fill goes down at a time when you have more inventory than you need but, because you can't find what you need, you ship it out in less than a complete shipment.

Order cycle time increases. Just the opposite of what we should be trying to achieve lower productivity, higher shipping errors, and increased cycle time.

Congestion is increasing. You have to move things. You're going to have to double and triple stack in your staging area. Which means that when the carrier comes in, it's going to take longer to load them, which means that you're going to get less carriers to the dock in the prescribed period of time. You're going to have to expand your shipping time or you're going to have to find some other way to be able to handle that efficiently, like adding more dock doors or adding more staging areas.

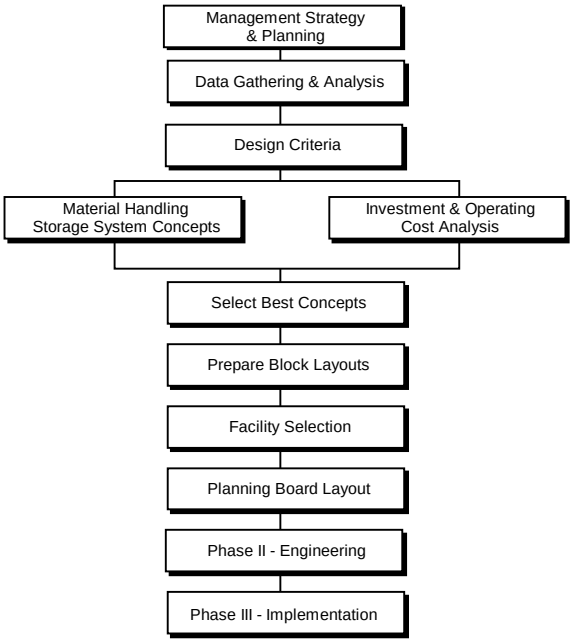
More outside space and facilities will need to be used. When you reach the point of saturation you go to the outside to store slow moving goods, obsolete goods, excess inventory and seasonal goods. The theory is very good but let's look at those slow moving goods. They are the ones that are going to guarantee that if they are not in your warehouse, you are not going to get 100% fill rate, because you are probably not going to ship them in the order. And those are the ones that are going to lengthen your order cycle time if you have to go to another facility and bring them back to combine them. Thus, it just slowed down your cycle time.

Short-term fixes are required. Most all warehouses require some short-term fixes, but when the fix becomes standard procedure in your warehouse it's definitely time to re-design your warehouse. You've reached the point where you are no longer making efficient use of the facility instead what you are doing is making the exception the rule.

Inventory control and management problems increase. When you have a warehouse that's not functioning as it was designed to function you're going to have shipping errors. As soon as you start having shipping errors, it is inevitable that you are going to have inventory control and inventory management issues. You send somebody to a location to pick something and it isn't there because they made a shipping error on the last shipment and shipped that item to someone thinking it was something else. This guarantees multiple errors. A congested, crowded, over-capacity, improperly designed warehouse assures you of such inventory control issues and that, in turn, will assure you of other management issues such as shipping errors, complaints, and damage. These are some of the telltale signs that you need to re-design your warehouse.

Design Approach

The overall approach to a good warehouse design is heavily impacted by the collection of data, the understanding of business issues, and the development of concepts.



Data Collection

The most important aspect of warehouse design or re-design is data collection. The major problem is generally the lack of good data on which to base a design. People often don't know how much the SKU's will expand, nor the size or cube, or weight of what they are going to store. If you don't have that kind of information, it is extremely difficult to design any degree of accuracy into your facility. It does not make it impossible to develop a good warehouse design. It does though require that you collect whatever data and information is available and make some assumptions and use those assumptions to replace the information that is not available.

What data do you need to have in order to do a warehouse design? You need to know how many SKU's you have. Not only today, but what are the future projections of the number of SKU's you will have? Are you in an industry that is dynamically changing? Are you in a business where you are going to continually expand the number of SKU's? The number of SKU's is going to define how many pick-face locations you need and how many overflow stock locations you need. It is going to define the characteristics of your order picking. How many products are you going to have? How many SKU's are you going to have in 3 years or 5 years? Will you be

adding new lines? Will you be making acquisitions? Will there be a proliferation of package sizes, or colors, or flavors, or styles? What you generally do is to start with the current number of SKU's and look at some of the changes which are to be anticipated, and forecast a rate of growth based upon those changes.

Design specification of the SKU, such things as how big are they? What do they weigh? What are their cubic dimensions? You can't design a warehouse for one size SKU's when you have many different sized SKU's.

Number of SKU's
Design Specifications of SKU's
Throughput Annually, Monthly, Seasonally
Growth Projections
Receiving Characteristics
Order Characteristics
Shipping Characteristics
Storage Characteristics

Throughput - annually, monthly, or seasonally? Is there seasonality to your production lines? Do you have an end of the month peak? Do you have an end of the quarter peak? Do you get 60% of your volume in the last week of the month and the other 40% spread out evenly in the third week of the month and nothing in the first and second? You have to design a facility to handle the peak, not the average.

Receiving characteristics - how much, how often, how large? Does it all come in on Friday? Does it all come in on Monday? Does it all come in one month a year?

Shipping characteristics - how much, how often, how large? Does it all go out on Friday? Does it all go out on Monday?

Storage characteristics –how many, what size, weight, etc.?

Inventory Turns

All of us would like to see at least 6 turns on most inventory, in some cases more than that. If you're in the replacement parts business you may have parts that are going to sit on the shelves for maybe 2 or 3 years before you sell one. As long as you're making adequate margin on them there is nothing wrong with that, but it does impact how you're going to design the facility to handle those items. You may have items that are going to fly off the shelf. Maybe they are going to turn 30 times a year or even more. Well, if they are going to be stored in the same facility as those replacement parts for the 1952 Studebaker, you will need different storage methods or layouts for each. So consequently, you're going to have different zones in the warehouse and you are going to have a facility that is designed differently for the different types of products. So you must understand the storage characteristics of all of the SKU's. What can you expect out of those products from an inventory standpoint and from a storage standpoint? Do they need refrigerated storage, frozen storage, low humidity storage? Can they be stored outdoors, etc.?

Receiving and Shipping

You need information on daily activity regarding receiving and shipping. You need to know the number and the type of receipts. Are you dealing with full pallets or full truckloads of goods?

Are there multiple SKU's per shipment or are there a lot of parcel shipments? It is extremely important to know, not only what are you doing today, but what are the future projections of what your company will be doing. More shipments are being made to customers in a shorter period of time today than before, and this will only increase. That means customers are ordering smaller quantities, which means the direction is to more frequent orders, but smaller shipments. Some companies, which were truckload shippers, are now LTL shippers. You need to know what's going to happen to your shipping operations.

Customer location and service

How many ship-to points do you have on an average day, on a peak day, on a typical day? Are you shipping to a thousand customers or are you shipping to 10 customers?

Receive-from vendors and locations

How many receive-from vendors do you have? How many received-from locations do you have? This is going to determine how much inbound staging area you will need. This is going to determine how many truck docks you will need. This is going to help you understand how many inbound receipts you're going to have to handle.

Operational costs and assumptions

What is it that your company bases its operational costs on and what kind of assumptions do they make? Do they assume that any location you have will be a union operation and that it will have set work rules? Do they assume that a benefit rate will amount to a particular percentage of your actual paid wages? Do they make assumptions as to what your labor rate is going to be and what the labor rate increases are going to be? All of that is important to determine if there will be an adequate return on the investment you want to make.

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Warehouse design typically involves three distinct phases:
I. Pre-engineering
II. Engineering
III. Implementation

I. PRE-ENGINEERING

The first thing you have to do is to understand what is management's strategy. What is the strategic purpose of the facility today and tomorrow and the future direction of your organization, division, group, and facility? Is it going to be a storage facility or is it going to be a cross-dock facility? Will it become a reverse logistics depot?

The next step is information and data collection. Once you have collected that data you have to do some statistical analysis. You know how many cartons you are going to handle. You know how much cube each SKU is. You know how many SKU's, how often you are going to turn the inventory, now you can calculate how much storage space you need, at least in gross terms.

Conceptual design

Once you know how much gross space you need, you can begin doing a conceptual design. It doesn't tell you the details of how you're going to store goods. It doesn't give you any specifics, but it gives you gross calculations. So you can decide how big this facility needs to be, so that you can begin to determine how much it is going to cost.

Layout planning

You can then start doing the layout planning of where those different activities should exist in relationship to one another. Once you do that, you can begin determining how much manpower the facility will require if you lay it out that way. If you have storage at one end of the building and receiving at the other end of the building, then it is going to take "x" number of people to move the product from one end of the building to the other end of the building. Once you have done that, you can start doing the investment and the operating costs analysis of the different alternatives that you have developed. The concept phase developed each of these alternatives. Now you'll need to do the evaluation of what those alternatives will cost. For instance, are you going to use pallet jacks or guided trains loaded with pallets, or are you going to use fork trucks to move the product? You need an economic evaluation of each operational design to determine which will be the most economical. Which would be more practical for the type of layout and operation you're going to design? Then you can begin developing the general management and information system requirements. You can put together a prospective rendition of what this facility will look like.

Trade-off principles

When you have various alternatives to look at, you need certain rules to determine which is the best. There are certain financial evaluations you can make, but there are some general trade-off principles you want to consider in any design. The larger the item, the less you want to handle and move it. It's all right to move smaller parts that require less labor, but if you have large items, you don't want to have to have multiple handling of them.

You want the shortest path, the shortest travel distance, thus the lowest labor and equipment to move things from one point to the other. That's the reason you have the basic concept of the fastest moving goods closest to the door because that limits the amount of travel time to take out and put away inventory and ship it back out again.

Smallest space - the smaller the space that you can put the inventory into, by definition, the less the travel distance will be because if you can put all your SKU's in just one room, then you can pick in this one room and don't have to travel amongst multiple rooms.

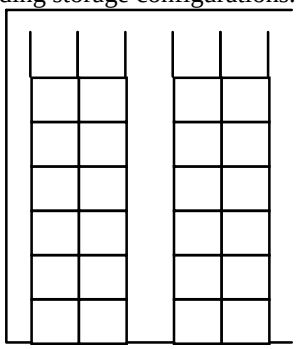
Less handling, less labor - the less times you have to move an item the less handling, the less labor, the less cost. Of course as soon as you start having less handling, less labor, less cost, you start having larger storage spaces and therefore you have violated the previous rule which had to do with smaller space, shorter travel. So you have to balance between these multiple principles.

Stock groupings - you want to take a number of items that are similar and put them into a single area.

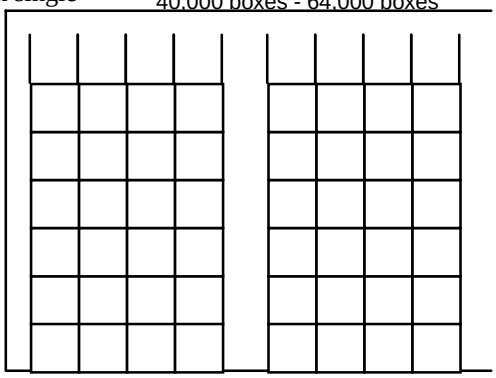
Longer run times - if you are picking a particular type of item you want to pick all of that item before you go from one area to another.

Balancing activities - if you have multiple activities like shipping, picking, receiving, and packing, you want to balance the time requirements of each of those so that you reduce the amount of time spent on each activity on a per unit basis by getting longer run sizes, so to speak. If you have separate people picking the order, then packing the order, then shipping the order you will have less set up time and less interruptions, but greater travel times in between each station.

There are trade-offs regarding storage configurations. The diagram is an example of a facility with an 18 ft. ceiling height where you have single-deep racking with a narrow aisle and another with double deep racking. The difference has to do with the amount of inventory you can store within the same amount of floor space. So the difference in single deep and double deep. in this case is that if you are storing 40,000 cases you can save 15,000 sq. ft of facility with a double deep configuration.



Single Deep Configuragion
18" clear stack height
38,000 sq. ft. - 48,000 sq. ft.
40,000 boxes - 64,000 boxes



Double Deep Configuragion
18' clear stack height
23,000 sq. ft. - 31,000 sq. ft.
40,000 boxes - 64,000 boxes

Floor space measurement on different applications - standard width aisles use a counter balance fork-lift which require a 10 ft. aisle. Narrow aisle equipment requires a 7 ft. aisle or 30% less space. This will vary depending on the specific equipment and the design of that equipment.
In most warehouses, you will find traditional fork lifts and two types of storage: bulk storage without racks and rack storage with a lot of single deep racking. The opportunities for improving space utilization will be particularly applicable in re-designing such a warehouse. By going from single-deep racking to double-deep racking or from a traditional wide aisle application to a narrow aisle application, the size and number of aisles will be reduced, therefore eliminating the square footage you've devoted to aisle. Therefore it increases the utilization you get from the same square footage of facility.

Another issue is height. The higher you go, the less square foot footage you need. So why not always go to 60', for instance? Because as you go higher two things happen. Your racking and handling equipment become more expensive and your operating costs go up, even though your cost per square foot goes down.

Economic tradeoffs need to be looked at - the cost of equipment, the cost of maintenance, the cost of the labor, the total investment in the equipment and parts, and the recoverable or scrape value of that equipment. In addition to economic tradeoffs, you will also need to look at things such as what impact is it going to have on your cycle time? Will you be able to get out orders quicker if you have an automated operation or a manual operation? What will it do to your flexibility in case your product line changes?

Trade-off issues:
Economic
Environmental
Safety and health
Flexibility

Which is cheapest is only a portion of the design criteria. You also have to consider qualitative factors such as:
flexibility of the layout,
reliability of the layout – for example if you have a highly automated system what happens if you have power failure,
serviceability,
customer service,
safety,
housekeeping,
noise.

In fact, all these factors and more, that influence the investment, design, service, implementation and ongoing operation of your new facility must be understood. If each has been adequately considered the new facility will offer significant benefits and minimal risk.

II. ENGINEERING

In the detailed design or engineering phase, you will do the engineered system layout drawings. Before you knew you needed 100,000 sq. ft. Now you need to determine where the aisles are going to be, where the racks are going to be, how much space each is going to take, and what does that do in regards to the columns that support the building?

At the same time you do the engineered system layout drawings, you have to start to determine electrical, lighting, and computer wiring requirement drawings. Where do you need terminals? Where do you need lights? You will need to make equipment drawings. Depending upon the degree of sophistication in the material handling equipment, those drawings may

become very detailed. You're going to need to design and engineer equipment and control specifications. You will need to do an outline of building criteria or alterations.

To build or to modify
In most cases, you're going to move into a warehouse that is a pre-existing building. And in many cases that pre-existing building may need certain alterations to be able to fit with the design of the facility you have put together. If you're given the opportunity to design from scratch, you will want to outline what the building requirements should be.

Operating procedures manuals
This is probably one of the most overlooked areas. You have designed a facility, an operating system, and the material handling equipment, now the next step is developing a detailed operations procedure that says how you are going to do what, when, where. How many people are going to do it? What is the type of equipment? How do you use the equipment? Where will the equipment be stored? How do you service the equipment? If you are going to have an efficient long-running operation, somewhere along the line, somebody has to develop such operating procedures. It makes a lot more sense to develop this at the time you are designing the facility, then to try to develop it later based upon bad practices or misuse of operations or facility design.

III. IMPLEMENTATION PHASE

Now you are ready for the implementation phase in which you are going to issue requests for proposals to equipment suppliers based upon your needs. These will specify exactly what is needed, such as what the weight capacity must be, how long the battery has to hold a charge, etc. Then you can review and analyze the responses because you have sent out the same proposal based upon the same specifications to multiple vendors so that you can actually compare apples to apples.

A good warehouse design depends on how well you understand your business. The facility must ultimately support your company's strategic logistics plan, customer service objectives, and bottom line target. Unless it meets all of these objectives and your organization's unique needs, both now and over the planning horizon, the best "state of the art" facility may not solve your real requirements.

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Thomas L. Freese is principal of Freese & Associates, Inc. a management and logistics consulting firm in Chagrin Falls, Ohio. Mr. Freese received his B.S. in business administration and marketing, and an M.B.A. with a concentration in business logistics, from The Ohio State University. His experience spans a wide spectrum of products and industries, from bulk chemicals to consumer goods, frozen fruit, and fresh poultry. He has consulted to numerous manufacturers, wholesalers, and retailers.
He is an active member of the Association of Transportation Law, Logistics and Policy (ATLLP), the Council of Logistics Management (CLM), and Warehousing Education and Research Council (WERC). He is a frequent speaker at professional conferences and seminars and has contributed articles to the *Journal of Business Logistics*, *Traffic Management*, *Food Business*, and *Distribution Center Management*. His chapter on "Warehouse Site Selection" appears in The Logistics Handbook published by Free Press and his chapter on "Third Party Warehousing" is a part of The Warehouse Management Handbook, Tompkins Press

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