Supply chain efficiencies depend upon the efficiency of logistics including transportation and warehousing operations. Warehouse efficiencies depend upon a combination of warehouse design, layout, infrastructure, systems, process and people. In cases where one is able to design a warehouse and implement the complete project from ground zero, gives the Supply Chain Manager a good scope to create a tailor made solution design matching the exact requirement, thereby increase efficiency as well as reduce transactional cost. However this may not be the case all the time. In an ongoing situation, often Supply Chain Manager’s are forced to take up available facilities and work around the available design and try to get the best results.

Warehouse Design element aims to maximize the utility of space, equipment and efficiency of operations. We will briefly cover the various elements of a warehouse design and understand their importance. In basic functional aspects, a warehouse function consists of - Material receipts including unloading, unpacking and inspection, put away and Storage of materials in various categories of storage locations, systems updating, pull materials for dispatch and delivery of materials after processing.

The design of the warehouse space should be planned to best accommodate business service requirements and the products to be stored/handled. The economics of modern commercial warehouses dictate that goods are processed in minimal turnaround time.

The Different Types of Warehouses Include
- Heated and unheated general warehouses—provide space for bulk, rack, and bin storage, aisle space, receiving and shipping space, packing and crating space, and office and toilet space;
- Refrigerated warehouses—preserve the quality of
perishable goods and general supply materials that require refrigeration. Includes freeze and chill space, processing facilities, and mechanical areas; and

- Controlled humidity (CH) warehouses—similar to general warehouses except that they are constructed with vapor barriers and contain humidity control equipment to maintain humidity at desired levels.

Special-designed warehouses meeting strict requirements can also provide liquid storage (fuel and nonpropellants), flammable and combustible storage, radioactive material storage, hazardous chemical storage, and ammunition storage. Features already now common in warehouse designs are higher bays, sophisticated materials-handling equipment, broadband connectivity access, and more distribution networks. A wide range of storage alternatives, picking alternatives, material handling equipment and software exist to meet the physical and operational requirements of the warehouse. Warehouse spaces must also be flexible to accommodate future operations and storage needs as well as mission changes.

A. Warehouse Location, Layout and Building

The location of a warehouse should ideally be situated in a flat ground. The location should be easily approachable and in an area suited for this nature of business. Locations closer to markets or to national highways would be ideal. Public transportation and communication infrastructure should also be available. The layout of the building should be designed to accommodate fleet parking, and enable containers to drive in and drive out easily. Any time two containers should be able to pass through on the path without any interruption. There should be enough free space for vehicles to maneuver. The layout should also provide for other utility, safety and security operations. Building is normally constructed using galvanized metallic sheets mounted on C Section girdles. The flooring should be RCC concrete with weight bearing capacity as per requirement of the load to be calculated in each case. The ground should be flat, even and smooth surface to facilitate MHE movements and dust free. The roof height would be a major consideration to be able to install multi vertical storage racking installation. The walls and roof should be designed with suitable lighting panels and ventilators for air exchange fitted with bird cages. The number of loading and unloading docs and placement of these docs play an important role in the design of operations and efficiency of operation. All weather docks and the facility should enable 24 hours operations of dock levels. The docks should be equipped with dock levelers and all these have to be installed during construction phase itself. Ramps have to be provided to facilitate movement of workers to increase productivity and control, reduce operating costs, and improve customer service. Even warehouses have to maintain a corporate image and provide for worker satisfaction. Building image and aesthetics, landscaping, and worker safety and comfort, become important issues in competitive real estate markets.

Design Considerations:-Following are the design considerations to be made for constructing a warehouse.

Figure 1: A Typical Refrigerated Warehouse

Being utilitarian facilities, warehouse designers should focus on making the warehouse spaces functional and efficient, while providing a safe and comfortable environment for the workers to increase productivity and control, reduce operating costs, and improve customer service. Even warehouses have to maintain a corporate image and provide for worker satisfaction. Building image and aesthetics, landscaping, and worker safety and comfort, become important issues in competitive real estate markets.
forklift etc. Lighting design will depend upon the layout and the racking design.

B. Internal Layout

Internal layout design will be built taking into account the operational process, nature of goods, volumes of transactions both inbound and outbound, storage types, in house operations involving put away and pull sequences and process requirements including packing, kitting etc. and the availability of floor space coupled with building layout design of inbound and outbound docks. The design aims to maximize space utilization, minimize MHE movement and Manpower movement.

C. Types of Storage

Types of storage are determined by the nature of cargo. Depending upon the cargo whether finished goods, raw material parts etc, the types of storage can vary from bulk stock, block stock, racking, pallet racking, shelf racking, binning, unit pick or loose pick face, carton pick etc. The storage types vary with nature of materials with different types of storage designs for drums, pallets, tires, cartons, tube and rods etc.

D. Racking Designs & Material Handling Equipment

Racking Design takes into account the storage type, storage unit, volume and weight coupled with the available floor space and roof height to design system which maximizes the storage capacity. Put away and picking process and transactional volumes are also taken into consideration. The inventory profile study would include detailing of number of SKUs in each category of fast moving, slow moving or other criteria as per the nature of business and the storage type would be designed as per the inventory profile and the process.

Racking designs are very many and varies with the type of industries and nature of inventory. Normal racking designs include pallet racking on multiple levels. You can have shelving, binning or combination of bulk stock and forward pick face racking designs. Block stack racking and other types of high density racking can be found in FG warehouses. Mezzanine store binning and shelving rack designs are normally designed for spare parts and small parts. Highly automated racking designs can have automatic retrieval systems and conveyors in the warehouse. Material Handling Equipments are specified based on rack design coupled with pallet design, nature of cargo, weight and the warehouse layout etc. Forklifts, reach trucks, hand pallet jacks, trolleys are normal Material handling equipments in normal warehousing operations.

E. Space Configurations

Warehouses should:

- Be designed based on current and future needs.
- Maximize utilization of space while providing adequate circulation paths for personnel and material handling equipment such as forklift trucks. Use higher bays to take advantage of height allowances in the space.
- Optimize layout and configuration for the warehouse operation, including efficient circulation and material handling and storage processes.
- Relate interior and exterior receiving and shipping operations to the process flow of goods through the warehouse.
- Receiving and shipping are best separated to avoid congestion at the loading dock areas in the building, and in the truck maneuvering areas.
- Alternative material handling methods will determine other

![Figure 2a, 2b: (a) Warehouse Storage Alternatives, (b) Picking Alternatives](image)
building aspects, such as aisle widths, lighting design, need for mezzanine space, fire protection, and egress design. Businesses will often use different methods of storage handling simultaneously for different products.

Refer Figure 2a and 2b for storage and packing alternatives.

F. Durable/Functional Aspect

Warehouse should be

- Planned to accommodate loads of stored materials as well as associated handling equipment.
- Designed to ensure that no structural member will interfere with the spacing of rail car doors or truck berths at dock spaces.

G. Energy-Efficient Aspect

Warehouse should

- Be designed with passive solar concepts, solar geometry, and building load requirements in mind.
- Possess light colored roof to reflect a large percentage of solar radiation, reducing HVAC loads, and energy consumption. First cost is also reduced, due to the smaller plant size required. When a large roof area is anticipated, this effect can be significant, especially for temperature controlled warehouses. Greater heat reflection will increase worker productivity in the summer.
- Be planned with interior dock space in colder climates to reduce energy consumption and provide more tolerable winter working conditions for dock workers.
- Use ceiling mounted fans to reduce heat stratification and provide air movement, thus increasing worker comfort in both summer and winter. Mount fans above highest forklift level for worker safety.
- Consider specifying white painted metal roof decking, thereby increasing ceiling surface reflectivity, lighting efficiency, and worker comfort without any added energy cost.
- Use energy-efficient fixtures, systems, and appliances, e.g., motion sensor instant-on lighting systems, wherever feasible.

Refer Figure 3 for energy efficient warehouse.

H. Safety/Security of Personnel and Material- A very important aspect

- Address the traditional life-safety and health concerns common to all buildings, including measures to prevent occupational injuries and illnesses (work-related musculoskeletal disorders (WMSD), trips, falls, etc.), ensure electrical safety, and eliminate exposure to hazardous materials. The following operations have historically contributed to significant numbers of warehouse injuries and are considered to be the most hazardous: docks, powered industrial trucks, conveyors, materials storage, manual lifting/handling, roof ladders and hatches, and charging stations. Other serious operational safety problems include inadequate fire safety provisions, improper blocking of exits and egress paths, chemical exposure, improper use of lockout procedures, lack of ergonomics, and failure to wear personal protective equipment.
- Incorporate proper signage to clearly warn of hazards or to direct personnel to take precaution. The specific strategy for the warehouses signs must be determined early in the facility design process.
- Possess non-slip surface treatments on floors subject to wetting, such as outdoor docks, to eliminate slips and falls to personnel.
- Be designed with fire sprinkler systems engineered to cover the specific commodity classification in the specific storage configuration for the planned warehouse. The adequacy of the sprinkler system must be evaluated when changes occur that can increase the hazard classification, such as introducing a new product line, using a different packaging material, or changing from wood pallets to plastic pallets.
- Include appropriate security systems incorporated into the overall warehouse design.

Refer Figure 4.
I. Health/Comfort of the workers

The designer should

- Provide proper ventilation under all circumstances.
- Provide local exhaust for restrooms, kitchens, janitor’s closets, copy rooms, battery-charging areas, etc.
- Consider installing CO2 sensors to provide real time monitoring of air quality.
- Integrate daylighting with the electric lighting system.
- Allow for natural lighting where possible. Provide lighting controls that turn off lights when sufficient daylight exists. Consider dimming controls that continuously adjust lighting levels to respond to daylight conditions.
- Consider the different natural lighting designs for warehouses.
- Minimize HVAC system noise in occupied space.
- Use furnishings, chairs, and equipment that are ergonomically designed and approved for that use.
- Design equipment and furnishings reflective of healthy work practices in an effort to eliminate repetitive motions as well as prevent strains and sprains.
- Strive to create a ‘sense of place’ such that the warehouse has a unique character that engenders a sense of pride, purpose, and dedication for individual workers and the workplace community.

Emerging Issues in Warehouse construction

Automated Storage and Retrieval Systems (AS/RS) are reshaping the ways in which goods and services are manufactured, stored, and distributed. AS/RS have become a means to control and immediately report the movement of material, providing a critical link in the chain of information systems that control work-in-process, manufacturing schedules, and distribution. AS/RS warehouses are designed for maximum storage and minimum personnel on site. They are built for lower temperature operation with minimal heat and light needed, but require a tall structure with super level floors. In the private sector, competition, technology and e-commerce are forcing distributors to look for ways to move larger quantities of their products more quickly and efficiently to the consumer.

Clustering distribution centers in a single geographic area is among the new trends. There is also a move towards transportation specialization, such as companies that depend on substantial parcel air transport, locating near Memphis, TN, while Columbus, OH rates higher for companies focused on overland distribution.

Labor availability and technology advances are factors driving many companies to consolidate their distribution systems into fewer but larger, regional facilities. However, not all companies are consolidating their distribution centers: in many areas, the consolidation trend itself is producing a new generation of smaller, local distribution centers. Experts say that new logistical handling systems and greater outsourcing—in particular, the increased use of third-party logistics providers—seem to be driving this trend. New “flex” warehouses in well landscaped industrial park settings for smaller businesses is a growing trend. These buildings accommodate small businesses such as contractors, light industrial fabricators, and mechanics that do not need exposure to heavy retail street traffic. In older industrial areas, small warehouse buildings with low roofs, no longer suitable for large single commercial users, are being repositioned and renovated as multi-tenant “flex” warehouse buildings.

Benefits of Warehouse

- Effective Utilization Of Space
- Easy To Assemble And Dismantle
- Automated Storage

Apart from this, there are special industrial racking units too. There are wide range of shelf styles like flat metal, plain shelves and wire mesh. There are special shelves too that are covered with rubber to serve as cushion for delicate items. Not just that, you could also include drawers and special locking system depending on your needs.

Conclusion

Warehouse is meant for commercial storage needs, and not for individual needs and hence its design has to be given due consideration of the needs of all the stake holders / users. The Warehouses must be designed to meet all local building, fire, and life-safety codes. The Occupational Safety and Health Administration (OSHA) also provides guidance for warehouse safety.

Reference

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