**Designing a Warehouse**

**Overview**

Warehouses, defined here, are facilities that provide a proper environment for the purpose of storing goods and materials that require protection from the elements. Warehouses must be designed to accommodate the loads of the materials to be stored, the associated handling equipment, the receiving and shipping operations and associated trucking, and the needs of the operating personnel. 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.



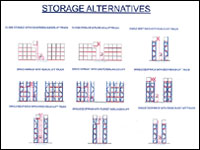
Features already now common in warehouse designs are higher bays, sophisticated materials-handling equipment, broadband connectivity access, and more distribution networks. A wide range of storage alternatives, picking alternatives, material handling equipment and software exist to meet the physical and operational requirements of the warehouse. Warehouse spaces must also be [flexible](http://www.wbdg.org/design/design_change.php) to accommodate future operations and storage needs as well as mission changes.

**Building Attributes**

Being utilitarian facilities, warehouse designers should focus on making the warehouse spaces [functional](http://www.wbdg.org/design/func_oper.php) and efficient, while providing a [safe](http://www.wbdg.org/design/secure_safe.php) and [comfortable](http://www.wbdg.org/design/provide_comfort.php) environment for the workers to increase [productivity](http://www.wbdg.org/design/productive.php) and control, [reduce operating costs](http://www.wbdg.org/design/optimize_om.php), 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.

**A. Types of Spaces**

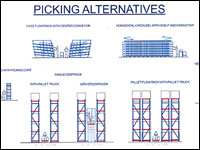
Depending on the program of the warehouse being designed, space types may vary dramatically.

* [Storage Space](http://www.wbdg.org/design/warehouse_st.php)
* [Office Space](http://www.wbdg.org/design/office_st.php)
* [Loading Docks](http://www.wbdg.org/design/loading_dock.php) for shipping and receiving
* [Light Industrial Space](http://www.wbdg.org/design/light_industrial.php)
* Computer Centers

**B. Space Configurations**

Warehouses should:

Be designed based on current and future needs.

* Be designed based on current and future needs. [View detailed storage alternatives](http://www.wbdg.org/images/media_img.php?m=warehouse_2lg.jpg&w=502&h=372)
  + Facilitate changes in business/agency growth, and size/population of office and warehouse spaces within the building. Warehouse space should be easily adapted to new functions such as office (on ground or upper levels), computer centers, or light industrial/fabrication.

[View detailed picking alternatives](http://www.wbdg.org/images/media_img.php?m=warehouse_3lg.jpg&w=502&h=291)

* + Accommodate need for future loading docks, truck space, and car parking spaces if space configuration changes through effective site design.
  + Address material handling technologies and business practice, such as "just-in-time" storage, which have fundamentally changed operation of warehouses and distribution centers, and will continue to do so.
  + Include roof design with built-in extra structural capacity to handle addition of future rooftop equipment.
  + Be designed with fire protection capacity to accommodate storage of materials with a greater fire hazard, especially needed with high plastic product content or packaging, and plastic shrink-wrapped pallets.
* 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 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.

**C. Durable/**[**Functional**](http://www.wbdg.org/design/func_oper.php)

* Be planned to accommodate loads of stored materials as well as associated handling equipment.
  + Design of warehouses is to be based on the dead and live load requirements of the structure as it will be built. [Snow, wind, and seismic loads](http://www.wbdg.org/design/resist_hazards.php) shall be considered where they are applicable. Racking in seismic areas must be built stronger and be better braced.
  + Wind uplift can cause great damage to roofs and metal roof copings at the roof edge. Building codes recognize that wind velocity is greater across open areas, typical for warehouse zones.
  + Wind-driven rain can easily penetrate the vast surface areas of the warehouse walls. Design walls to permit any infiltrating water to evaporate harmlessly without collecting in the wall cavities or damaging stored product.
  + Proper floor types are an important consideration in the design. General warehouse space should be floored with a concrete slab to carry wheel loads and withstand the abrasion generated by the continual use of hard rubber and steel-wheeled forklift trucks. Consider adding hardeners and dustproofers to protect the concrete. Consider using epoxy coating on concrete floors near battery charging areas.
  + Floor flatness and levelness requirements are critical, especially for high ceilinged space and safe operation of high-lifting equipment.
  + Adequate space must be provided on-site for truck maneuvering, truck storage if the business owns a fleet, car parking for employees and future office space/population expansion (which might be driven by higher rent for center-city office space), and landscaped areas.
* Be designed to ensure that no structural member will interfere with the spacing of rail car doors or truck berths at dock spaces. Dock heights on the truck side of the terminal should be approximately 4'-4" above the pavement, with appropriate ramps at each truck berth to bring the height of the truck bed in line with the dock height. Dock heights on the rail side of the terminal should be approximately 3'-9" above the top of the rail to ensure that the rail car floor is even with the dock floor. Dock widths and areas inside exterior doors leading to dock space must be planned for maneuverability of forklift trucks and other expected types of material handling equipment.
  + Dock heights on the truck side of the terminal should be approximately 4'-40" above the pavement, with appropriate ramps, scissor lifts, or dock levelers at each truck berth to safely bring the height of the truck bed in line with the dock height.
  + Tops of doors should be high enough to accommodate full height pallet handling from the highest trucks.
  + Dock heights on the rail side of the terminal should be approximately 3'-9" above the top of the rail to ensure that the rail car floor is even with the dock floor.
  + Dock widths and areas inside exterior doors leading to dock space must be planned for maneuverability of forklift trucks and other expected types of material handling equipment. Consider using a non-slip finish on the concrete floor near loading areas for safety.

**D.** [**Energy-Efficient**](http://www.wbdg.org/design/minimize_consumption.php)

* Be designed with [passive solar concepts](http://www.wbdg.org/resources/psheating.php?r=warehouse), solar geometry, and [building load requirements](http://www.wbdg.org/design/minimize_consumption.php) in mind.
* Possess [light colored roof](http://www.wbdg.org/design/site_potential.php) 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 wroker 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](http://www.wbdg.org/resources/greenproducts.php?r=warehouse), e.g., [motion sensor instant-on lighting systems](http://www.wbdg.org/resources/electriclighting.php?r=warehouse), wherever feasible.

**E.** [**Safety/Security**](http://www.wbdg.org/design/ensure_health.php) **of Personnel and Material**

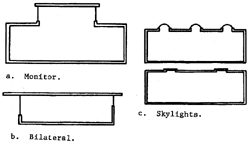
* Address the traditional [life-safety and health](http://www.wbdg.org/design/ensure_health.php) concerns common to all buildings, including measures to prevent occupational injuries and illnesses (work-related musculoskeletal disorders (WMSD), trips, falls, etc.), ensure electrical safety, and eliminate 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](http://www.wbdg.org/design/fire_protection.php) 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](http://www.wbdg.org/design/provide_security.php) incorporated into the overall warehouse design.

**F.** [**Health/Comfort**](http://www.wbdg.org/design/ensure_health.php)

* Provide [proper ventilation](http://www.wbdg.org/resources/hvac.php?r=warehouse) 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](http://www.wbdg.org/resources/daylighting.php?r=warehouse) with the [electric lighting system](http://www.wbdg.org/resources/efficientlighting.php?r=warehouse).
* Allow for natural lighting where possible. Provide [lighting controls](http://www.wbdg.org/resources/electriclighting.php?r=warehouse) 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](http://www.wbdg.org/design/promote_health.php) 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.

**G. Example Design and Construction Criteria**

For GSA, the unit costs for this building type are based on the construction quality and design features in the following [table](http://www.wbdg.org/pdfs/gsa_usc_shell_utility.pdf) (PDF 187 KB, 14 pgs). This information is based on GSA's benchmark interpretation and could be different for other owners.

**Emerging Issues**

Examples of natural lighting designs for warehouse structures

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.

Forces outside the parameters of the normal building project can generate great changes in warehouse design. Examples include accelerated tax write-offs in the 1980's, which enabled speculative construction of much larger buildings; again 1980's federal regulations to permit much larger over-the-road trucks, which required commensurate changes to site space given over to truck space; local real estate market prices, which often makes it economically attractive for companies to relocate much of their corporate back office space at their regional distribution center; increasingly tighter environmental and permitting processes, which leaves the market to the larger developers, resulting in usually larger projects; and the reclamation of former "brownfields" industrial sites for either new industrial or other uses.

**Relevant Codes and Standards**

Warehouses must be designed to meet all local building, fire, and life-safety codes. When in doubt, consult with the local building official. The [Occupational Safety and Health Administration (OSHA)](http://www.osha.gov/) also provides guidance for warehouse safety.

* 29 U.S.C. § 651 et seq.; 29 C.F.R. Part 1903.1 et seq.—Occupational Safety and Health Act 1970

Several design criteria and guidelines exist for federal warehouses:

* Department of Defense (DOD)
  + [*UFC 4-440-01A Storage Depots*](http://www.wbdg.org/ccb/browse_doc.php?d=6867)
  + [*UFC 4-442-01N Design: Covered Storage*](http://www.wbdg.org/ccb/browse_doc.php?d=2861)
* National Fire Protection Association
  + [*NFPA 230 Standard for the Fire Protection of Storage*](http://www.wbdg.org/references/ihs_l.php?d=NFPA%20230)
* Veterans Administration (VA)—Veterans Health Administration
  + [*VA VHA Acquisition and Materials Management Service—Warehouse*](http://www.wbdg.org/ccb/browse_doc.php?d=4797)

Acker, E. (2011). Whole Building Design Guide. Retrieved from http://www.wbdg.org/design/warehouse.php