Interpreting the Numbers: From Data to Design

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Abstract. The design of a distribution center in a supply chain network depends on the proper analysis of the storage and handling requirements of the products to be stored. The best way to determine these requirements is through an extensive analysis of the historical data for the company, including inventories, movements, and receiving and shipping characteristics, as well as accurate projections for future growth of individual company product lines. Many steps can be taken during this analysis to convert the information into design criteria which will be used to determine how, when, and where each product will be stored and handled. In this way, the resulting distribution center can be used to effectively fulfill customer orders with the most efficient method.

Data Collection and Analysis. The first step in designing a warehouse is the collection of historical data for the company's products and customers. This is the one of the most essentials step in effective warehouse design, as the best designs come from the gathering of the most accurate data and information.

Product Characteristics. Product characteristics refer to the shape and size of the product to be stored. They determine the types of storage methods and modules suitable for different products. For example, palletized loads with good stackability can either be stored on the floor or in a variety of racks. But pallet loads with poor stackability may not be suitable for floor storage since available building height will not be fully utilized. Long loads such as steel bars and tubes can be stored on the floor or in cantilever racks. Small items are best stored in bins, rack shelves, totes, storage cabinets, or similar equipment. Product characteristics also influence the type of handling equipment to be used. While pallet loads can be handled by a wide variety of lift truck mechanisms, long loads may require side loaders or bridge cranes. Smaller loads can be handled manually.

Classifying the entire product line into product categories and establishing their shape, size, weight, and special storage or handling characteristics is the first step in the analytical process. Many companies do not have this information readily available, but since it is essential for appropriate design, these companies need to make a concerted effort to gather this information. Automatic product sizing machines can be useful in accomplishing this task.

Inventory Profile. The second step in the data analysis process is to establish an inventory profile for each product group. This profile will include average and peak levels of inventory for each item in the product group. These should be expressed in cubic inventory units, which

can be easily converted into units of storage such as number of pallets, bins, or other defined units of measure. These profiles should next be calculated in terms of unit loads per item, which will have an impact of what type of storage modules will be best suited for each product. For example, items with single pallet lots will be stored best in single deep pallet racks, while items with lots of 20 pallets or more may be more suitable for bulk floor or drive-in rack storage. The total inventory levels will influence the space requirements for each type of module and the total storage space.

Movement Analysis. Data of individual product movement or sales for a period of at least 3 months must be gathered next. Product movement should be defined by the number of product picks or "hits", which are the number of times a picker must go to a particular location to make a pick. In most companies, the conventional Pareto rule applies to the movement of material, with 20% of the items normally accounting for 80% of the movement. Developing a periodic movement profile for each item will classify them as fast, medium, or slow movers. This classification helps determine the location of specific items for faster picking, as well as which processes and equipment should be used to pick and store them. Movement data for at least one full year must be gathered for companies which exhibit dramatic seasonal characteristics, such as apparel distributors.

Order Characteristics. The most labor intensive components in any distribution operation are the order picking, checking, and packing activities. How efficiently these are performed will depend upon the arrangement of the pick/pack lines and workstations and the methods of work employed. These methods depend on an analysis of the order characteristics. The number of orders shipped per day can vary during days of the week and months of the year. Orders may consist of a single line item or multiple line items. Units on a line will vary from one to many, from one product to another. Order characteristics for a sufficient period should be carefully gathered and analyzed to create accurate profiles. These profiles will indicate whether orders should be picked as single orders, in batches, by zones, or a combination of these.

Receiving and Shipping Characteristics. Data regarding these characteristics must be gathered and analyzed to assist in the design of the dock areas, including the number of dock doors needed and the staging space to be provided. The profiles will include truck arrival and departure patterns, the number of inbound and outbound shipments, the composition of loads in terms of units, cartons, and pallets, the dock time per truck, and the documentation requirements.

Forecast Factors. A planning time horizon must be determined during the data analysis phase in order to gauge how much room for an expansion of products and categories will be required. A 5-year design horizon is typically used, since forecasts beyond that level are generally inaccurate. A determination of growth or retraction for specific product lines, as well as expected future product line acquisitions or development must be made by the company's sales and planning department and used in the creation of the warehouse design.

Interpreting the Data for Design. Once all the data has been gathered, it must be organized into summary statistics that can be utilized to determine specifics of the warehouse design, from the number of racks required to the types of conveyor needed and which products will be stored in which modules. Space requirements, picking methods, and even workforce levels can all be determined from an accurate interpretation of the historical data and projections.

Storage Requirements. In a typical warehouse or distribution center, the bulk of the space, perhaps as much as 75 percent, is devoted to the storage function. In designing the storage space, the three principal factors which directly influence space requirements are the load characteristics of the product (what to store), the storage modules (where to store), and the material handling equipment in use (how to store) [1].

For a design year, requirements for each product or category must be stated in terms of a unit load, such as pallets in inventory, which will lead to the creation of an inventory profile. An inventory profile is the frequency of items that correspond to a specific range of pallet or case inventory per item. Items with high inventories are more suited for storage in dense systems such as floor storage, drive-in, drive-through, pallet flow, or push-back racks. Items with low or medium inventories are best suited for single or double deep pallet racks. Items with volumes that are significantly less than a pallet are recommended for storage in shelving, bin drawers, case flow rack, carousels, or automated mini-load systems. Table 1 shows the applicable storage modules for various ranges of pallets per item [2].

Range of Number of Pallets per SKU	No. of SKUs	Total No. of Pallets	Average No. of Pallets per Item	Applicable Storage Module X = Preferred Storage Module O = Workable But Not Preferred						
				Pallet Load				Less than Pallet Load		
				Floor Storage	Drive-In Racks	Double Deep Racks	Single Deep Racks	Case Flow Racks	Shelves	Bin Drawers
>100	2	350	175	X	X	O	O			
51 to 100	18	1,100	61	X	X	O	O			
21 to 50	40	1,000	25	X	X	X	O			
11 to 20	160	2,200	14	X	X	X	O			
6 to 10	330	2,300	7	O	O	X	X			
2 to 5	500	1,600	3			O	X			
0.5 to 1	750	750	1				X	X		
0.25 to 0.49	900	270	0.3					X	X	
0.24 or less	1,300	65	0.05					X	X	X

Table 1. Inventory Profile and Corresponding Storage Modules

Inventory data alone cannot determine the storage configuration that applies to the warehouse design. Product movement in and out of the warehouse also influences the space and equipment required. This data shows trends, cycles, peaks, consistency and opportunities for smoothing. Inventory data should be adjusted for peaks evident in the movement data, especially for companies with seasonal storage requirements. Peak inventory overflow may be a candidate for outside storage.

Movement or sales data will also show which products are the fastest and slowest movers. The products with the highest movement should generally be stored in dense storage closest to the shipping areas. Products with slow movement can be situation further from the docks. If inventory data is not available or reliable, the movement data can be converted to inventory data by dividing by the number of turns per year. Turns is the number of times per year that the inventory has been converted to sales. Care must be taken not to use turnover rates expressed in dollars ($) when calculating inventories in units.

Order Processing Requirements. The order processing area is where product, equipment, labor, and operating systems come together to complete orders for customers. Order processing is the sum of elements required to assemble the correct quantity of each product or line item specified on an order in a form that is convenient for shipping. As in the storage area, the space required to accommodate this function in a distribution center varies significantly based on the requirements.

An order profile must be developed from the data collected on the historical orders and used to determine design year requirements. Statistics collected from the order profile include line items per order, units per order, units per line item, total weight per order, and number of orders to process per day. These statistics will assist in the determination of whether a forward pick zone is required as well as the type of picking required, particularly whether items will be picked by order or in batches. A high concentration of one-line orders suggests the use of batch picking, where multiple orders are picked in the same pass by a group of storage modules into a tote or a cart and separated by orders in a consolidation area near the docks. This is a faster picking method than order picking, since the employee does not need to pass by the same storage module multiple times while making his picks. The speed of picking may be offset by the level of complexity in the consolidation area, though. Most facilities will end up with a combination of order and batch picking.

Based on the characteristics of the order, picking can be additionally classified into (1) full pallet picking, (2) full case picking, (3) broken case picking, and (4) special handling requirements picking for hard to handle item picking. Full pallet picking entails retrieving items in full pallet quantities. For full case picking, the picker picks products in minimum full case quantities. Broken case picking consists of breaking up a case quantity of an item and picking individual pieces. Using these classifications along with the movement data on fast, medium, and slow moving items, a picking plan for each SKU can be determined.

For full pallet picking, fast-movers should be picked from pallet flow racks or bulk storage closest to the docks. In some companies, such as computer distributors, the fastest movers like new monitors should be cross-docked, or stored right at the docks for immediate shipment, without entering an inventory storage module. Slower moving pallet loads can be picked from pallet racks further from the docks, at elevated rack positions.

For full case picking, the fastest movers can be picked directly from pallet flow racks onto a central take-away conveyor, or from bulk positions or pallet racks at floor level onto pallet jacks. Slower movers can be picked from pallet racks by stock picker trucks at higher elevation levels. Fast movers for broken case picks may be located in case flow racks, or often from more advanced, such as a pick-to-light system or automated broken case order selector like an A-frame. Medium and slower moving broken case picks are typically made from standard shelving, bin drawers, or carousels. As opposed to pallet racks, though, most of these forward picking modules such as flow racks and shelving have significant size and weight limitations, usually requiring reserve, or backup, storage in pallets in another area of the warehouse.

Shipping and Receiving Requirements. A substantial part of warehouse operations is concentrated in the receiving and shipping area, also known as the dock area. Receiving and shipping operations have to be designed for the peak load estimates of the design year.

These requirements are expressed in following expected terms regarding the frequency of receipts and shipments:

- Number of trucks arriving
- Times of arrival
- Loading and unloading times
- Volume by product lines
- Volume by mode of transportation

Other questions which need to be addressed in the data analysis are the number and location of suppliers shipping to the facility, the carriers supplying the transport, the modes of transportation used, and the typical shipment sizes, which can vary between full truckloads, less than full truckloads (LTL), or parcel shipments (UPS, FedEx, etc.).

Depending on the layout of the facility, the receiving and shipping dock doors can be in the same area as in a U-shaped product flow, or in different areas of the warehouse, as in an L-shaped or I-shaped product flow. Having the shipping and receiving doors close to each other allows for more flexibility for dock usage, promotes faster cross docking capability, and permits consolidation of the supervisory function for the two operation. Conversely, separating them may improve security and reduce congestion.

The number of dock doors required can be determined based on the data patterns of truck arrivals and departures, the length of time it takes to load or unload the trucks, and the total number of pallets to be handled in a typical day. For example, if a company expects up to 20 carriers in an 8-hour day and each carrier spends an average of 3 hours at the facility, a door can only be used twice per day. Therefore, a minimum of 10 doors would be required. Other increasingly complex formulas can be used for more accurate results when more detailed information is available.

Conclusion. Since the operation of a company's distribution centers has become such an important part of its supply chain network, it is essential that these facilities are designed to perform most effectively and efficiently with respect to the product lines and customer base. The only way to accurately design a warehouse is to gather and utilize the best appropriate data and statistical for the company's historical sales and inventories, and to make the most accurate forecasts for future business operations. This will lead to a design that helps the company fulfill customer orders, instead of impeding its prospects for the successful operation of its distribution centers.

References

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