Chapter 21. Warehousing Systems

This is an introduction chapter quotation. It is offset three inches to the right.

21.1. Introduction

In recent years many corporations have completely reengineered their supply chain to respond to increasing customer service demands and higher profitability requirements from their shareholders. While warehouses have become smaller, they remain a key component in the supply chain of most corporations. The requirements for the warehousing operations have significantly increased. Order accuracy, order response time, order frequency, and order size requirements are dramatically different from a decade ago. The advent of electronic commerce will introduce even more complications since a larger number of small and single-customer orders will have to processed on very tight deadlines.

Warehousing Definitions and Classification

There exists a large variety of warehousing systems, both with respect to the storage technology, the order picking technology, and the material handling equipment used. In the next few figures different warehouse types are shown to illustrate this variety.

Figure 21.1. Warehousing Example Using Floor Stacking and Pallet Jacks

Figure 21.2. Warehousing Example Using Block Stacking and Fork Lift Trucks

Figure 21.3. Warehousing Example Using Pallet Rack and Narrow Aisle Trucks

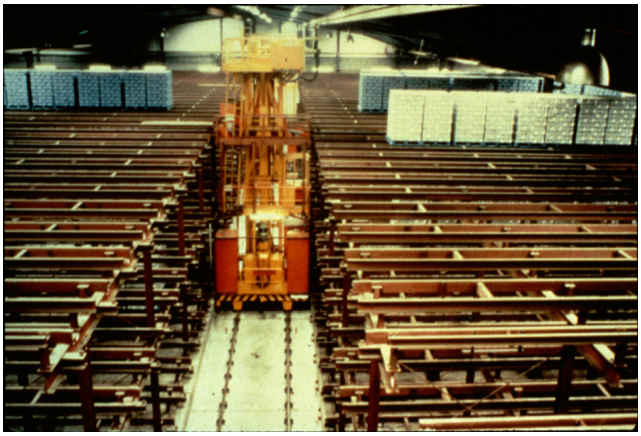

Figure 21.4. Warehousing Example Using Automated Deep Lane Storage

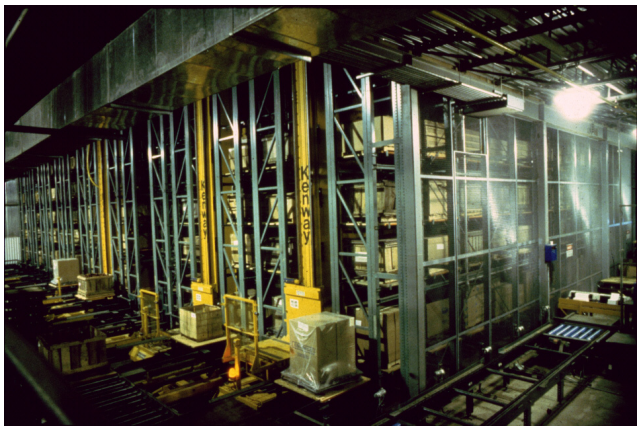

Figure 21.5. Warehousing Example Using Automated Storage and Retrieval System

Figure 21.6. Warehousing Example Using A-Frame Automated Order Picking

Main Functional Types of a Warehouse

We have identified four major functional types of warehouses.

1. Holding warehouse
2. Deconsolidation or distribution warehouse
3. Cross-docking or sortation warehouse
4. Work-in-process warehouse

Holding Warehouse

The main function of a holding warehouse is to store materials. Examples range from the mundane archival document storage of corporations and law firms to the planned underground storage facility to hold all the nuclear waste generated by nuclear electricity generation. The main capacity is storage capacity and throughput and response time are of lesser or insignificant importance.

Distribution Warehouse

The main function of a distribution warehouse is to receive a limited number of large shipments from suppliers, to hold products in inventory until they are requested by the customers, and then extract the products for customer orders from inventory and to ship them to the customers. The typical inventory pattern for a product is the classical saw tooth pattern. The throughput capacity, response time, and the storage capacity are all important performance measures. A common variant of the distribution warehouse is the finished goods warehouse for a manufacturing facility, where products arrive from the manufacturing lines.

One of the main functions of a warehouse that fulfills customers orders is the transformation of the large, relatively few, and homogeneous with respect to products input or arrival quantities to the many, small, heterogeneous with respect to products output quantities. The larger input quantities are caused by the desire to exploit transportation economies of scale, especially over larger distances. The small and frequent output quantities are caused by the fulfillment of customers orders that ever more diverse, smaller, and have a shorter response time.

Order picking is a prime component of labor and its associated costs in the warehouse. Two main layouts for this type of warehouse are common. The first layout executes the order picking operations directly from the storage locations for a product. When the number of picks for that product becomes

larger, this mode of operations becomes increasingly more expensive because the large storage area causes large travel distances for the order picker. A second layout executes the order-picking operations mostly from a concentrated forward picking area, while keeping the bulk of the inventory for a product in a larger reserve storage area. When the inventory is low in the forward picking area, it is replenished from the reserve storage area. The costs associated with this extra material-handling move must be traded off with the savings of picking the products from the smaller forward picking area.

Cross-docking or sortation warehouse

The main function of this type of facility is to receive a number of shipments from various sources, to sort the materials by their destinations, and to create and ship a number of shipments to the destinations. The prime example is the distribution and sortation facility of a less-than-truckload (LTL) or package carrier. A major characteristic is that in principle no inventory is held at the warehouse. The main performance characteristics are the throughput capacity and the throughput or flow time.

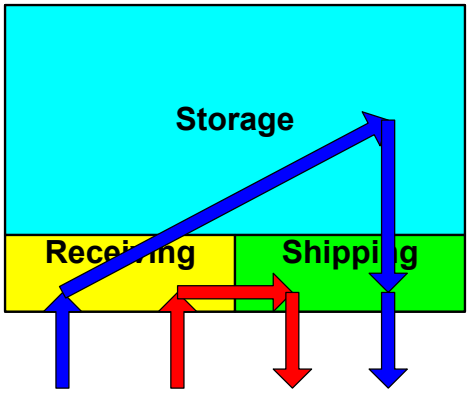

Figure 21.7. Schematic of Material Flows using Cross Docking versus Storage

Work-In-Process Warehouse

This warehouse holds sub-components and partially manufactured products. The components arrive from the manufacturing facility or vendors and are shipped back to the manufacturing facility.

Main Performance Characteristics of a Warehouse

We have identified six major performance characteristics of a warehouse.

1. Throughput capacity
2. Storage capacity
3. Response time

4. Cost rate
5. Other resource consumptions
6. Flexibility and robustness

Throughput Capacity

The throughput capacity indicates how much material flow can be processed through the warehouse per time unit. There may be a different capacity for receiving and for shipping. Typical units will be lines per day, piece per day, pallets per day, …

Storage Capacity

The storage capacity indicates how much material can be held in storage in the warehouse. Typical units will be number of unit loads such as pallets and cubic volume.

Response Time

The response time of a warehouse indicates the time between the arrival of an order at the warehouse until this order is shipped from the warehouse. The response time is part of the order lead-time. Typical units will be hours or days. A maximum response time bound is typically one of the customer service criteria, e.g. all orders will be shipped within 24 hours.

Cost rate

The cost rate indicates the cost per unit of material flow shipped from the warehouse. Typical units will be dollars per piece, dollars per carton, dollars per pallet…

Resource Consumption

This measure is a collection of various resource one-time consumption and consumption rates. Examples of one-time consumption are land cost and equipment investment cost. Examples of consumption rates are labor and utilities.

Flexibility and Robustness

The flexibility of warehouse is the ability of the warehouse to adapt to changing conditions in products, product mix, order size, … There does not appear to exist a consistent and widely accepted measure of flexibility or units of flexibility.

The robustness of the warehouse indicates the relative operating efficiency of the warehouse under varying conditions compared to the best operating efficiency for each particular condition. Typical relative robustness is expressed as a ratio of cost performances and hence is dimensionless.

Kouvelis and Yu (1997) give the following definition of relative robustness

$$\max_{s \in S} \left\{ \frac{z_s(x_R) - z_s^*(x_s^*)}{z_s^*(x_s^*)} \right\} \tag{21.1}$$

where $z_s(x_R)$ is the cost performance of the implemented warehouse configuration x_R for a particular condition or scenario s, and $z_s^*(x_s^*)$ is the optimal cost performance of the optimal warehouse configuration x_s^* for a particular condition or scenario s.

Main Functional Areas in a Warehouse

1. Receiving
2. Storage - Holding
3. Order Picking - Retrieval
4. Consolidation - Sorting
5. Shipping

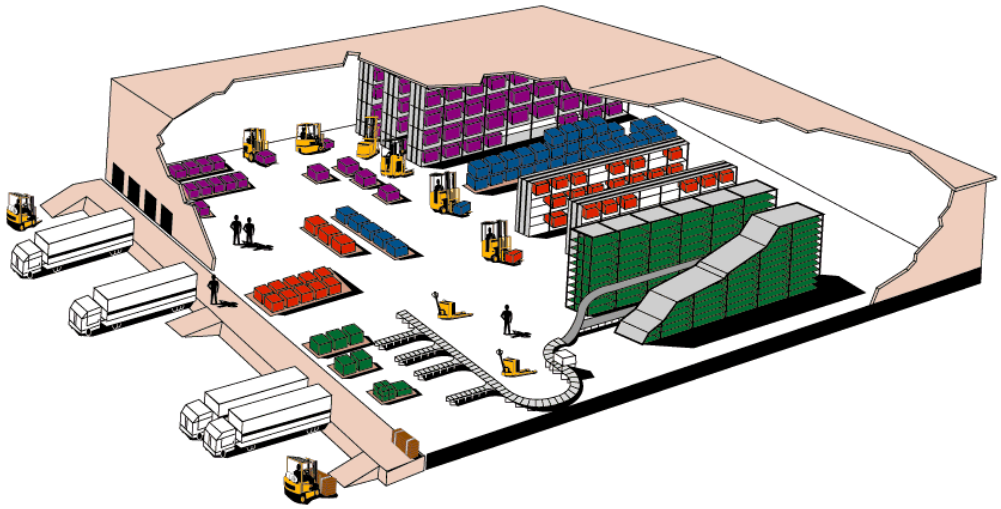

Figure 21.8. Warehouse Illustration

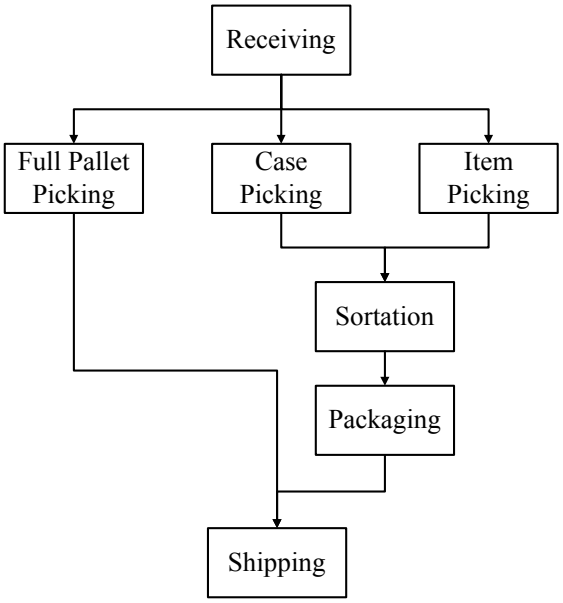

Figure 21.9. Warehousing Functional Process Diagram

The functional areas or departments of a warehouse are shown in Figure 21.9. Similar warehouse process diagrams are given in Yoon and Sharp (1996) and Sharp (2000). Not all warehouses will contain all departments and department flows. The major areas are

1. receiving
2. pallet storage area
3. pallet pick area
4. carton pick area
5. item pick area
6. sorting area
7. consolidation area
8. staging and shipping area

Different line items of a customer order and even different quantities of the same line item in a customer order may follow different flow path through the warehouse. For example, a customer may order 2.5 cartons or case of a particular SKU in a single order. The two whole cartons may have been stored on pallets in the pallet storage area, then transported to the carton pick area, picked there, sorted, and then consolidate with the rest of the order. The half carton may be picked as items. The item may have been stored on a pallet in the pallet storage area, then transported to the item pick area, picked there, and then

consolidated with the rest of the order. The functional areas and material flows are mapped to physical departments in the warehouse layout as illustrated in Figure 21.10.

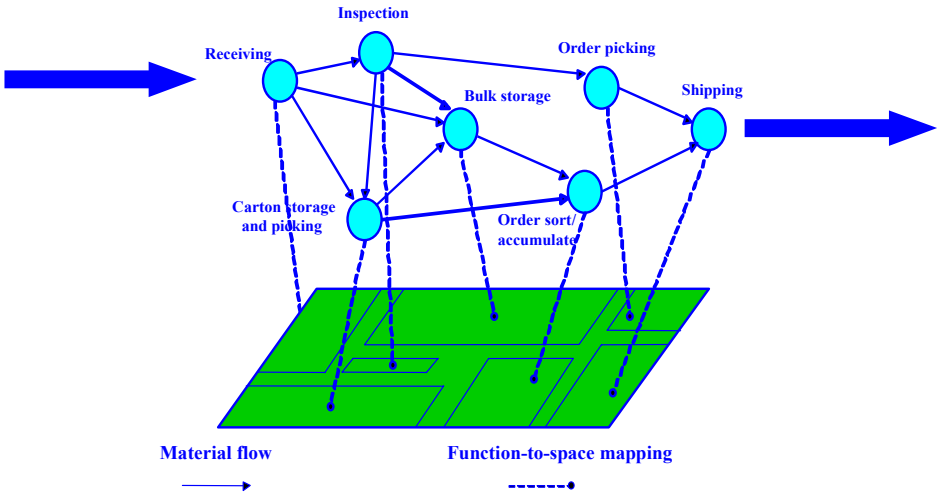

Figure 21.10. Functional Flow Network in Warehouse

Order picking is a prime component of labor and its associated costs in the warehouse. Two main layouts for warehouses are common. The first layout executes the order picking operations directly from the storage locations for a product. When the number of picks for that product become larger, this mode of operations becomes increasingly more expensive because the large storage area causes large travel distances for the order picker. A second layout executes the order-picking operations mostly from a concentrated forward picking area, while keeping the bulk of the inventory for a product in a larger reserve storage area. When the inventory is low in the forward picking area, it is replenished from the reserve storage area. The costs associated with this extra material handling move must be traded off with the savings of picking the products from the smaller forward picking area.

21.2. Systematic Warehouse Design

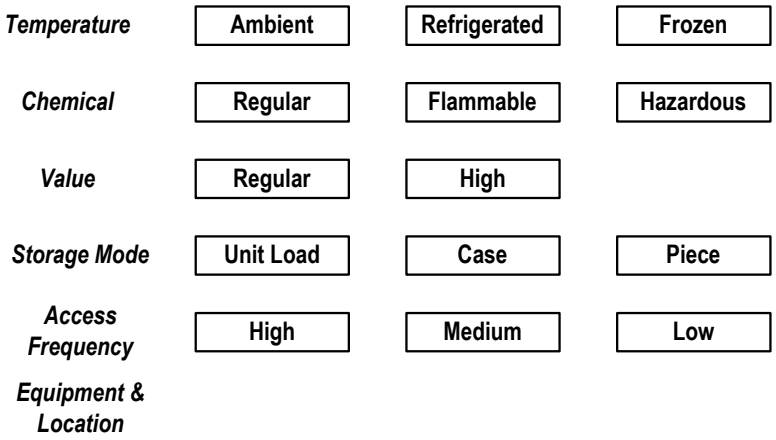

Figure 21.11. Systematic Product and Warehousing Segmentation

References

1. Ackerman, K. B., (1999). "Designing Tomorrow's Warehouse: A Little Ahead of the Times." ***Journal of Business Logistics***, Vol. 20, No. 1, pp. 1-4.

2. Ashayeri, J. and Gelders, L. F., (1985), "Warehouse Design Optimization," ***European Journal of Operational Research***, Vol. 21, pp. 285-294.

3. Cormier, G. and Gunn, E. (1992), "A Review of Warehouse Models**,"** ***European Journal of Operational Research***," Vol.58, pp. 1-13.

4. Cormier, G. and Gunn, E. (1996), "Simple Models and Insights for Warehouse Sizing," ***Journal of the Operational Research Society***, Vol. 47, pp. 690-696.

5. Frazelle, E., (1997). **World Class Warehousing**, Course Notes, December 1-3, Atlanta, Georgia. The Logistics Institute, Georgia Institute of Technology, Atlanta, Georgia.

6. Graves, R., (1998). "A Review of Material Handling Research Publications." *Proceedings of the 5th International Colloquium on Material Handling Research*. June 20-23, 1998, Phoenix, Arizona, Material Handling Institute, Charlotte, NC.

7. Gray, A. E., Karkamar, U. S., and Seidmann, A., (1992), "Design and Operation of an Order-Consolidation Warehouse: Models and Application," ***European Journal of Operational Research***, Vol. 58, No. 10, pp. 14-36.

8. Kouvelis, P., and G. Yu, (1997), **Robust Discrete Optimization and Its Applications**, Kluwer Academic Publishers, London

9. Mantel, R. J., and Rouwenhorst, B., (1998). "A Warehouse Design Model." *Proceedings of 1998 Progress in Material Handling Research Conference*, Phoenix, Arizona, 1998. Material Handling Institute, Charlotte, NC.

10. Tompkins, J. and Harmelink, D., (1994), **The Distribution Management Handbook**, McGraw-Hill, New York, New York.

11. van den Berg, J. and W. Zijm, (1999), "Models for warehouse management: classification and examples," ***International Journal of Production Economics***, Vol. 59, pp. 519-528.

12. White, J. A., and Kinney, H. D., (1982), "Storage and Warehousing," in **Handbook of Industrial Engineering**, G. Salvendy (ed.), John Wiley & Sons, New York, New York.

13. Yoon, C. S. and G. P. Sharp, (1996), "A structured procedure for analysis and design of order pick systems," ***IIE Transactions***, Vol. 28, pp. 379-389.