AN ABSTRACT OF THE THESIS OF

Chun-Ho Kuo for the degree of Doctor of Philosophy in Industrial Engineering presented on May 7, 1998. Title: Distribution Center Performance Assessment.

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Abstract approved:

Kimberly Dunn and Sabah Randhawa

The objective of this research is to assess the performance measurement systems currently used in today's distribution centers. A comprehensive investigation of distribution centers' performance measurement system is completed. Three major research phases are included in this study. An overview of distribution centers, including background, components, functions, and material handling systems, is demonstrated in the first phase. In the second phase, a series of case studies is carried out for assessing measurement systems used in today's distribution centers. The findings of the case studies are summarized in terms of the distribution centers' characteristics and measurement systems used. In the last stage of this research, a comprehensive framework of normative attributes for measurement systems (adapted from Clark, 1995) is adopted to assess the performance measurement systems used in today's distribution centers.

The metrics used in distribution centers' performance measurement systems can be classified into six categories: Finance, Operations, Quality, Safety, Personnel, and Customer Satisfaction. In the five distribution centers, Safety is found to be the most significant measurement component. This is likely due to legal requirements. In contrast, very little emphasis is placed on Customer Satisfaction. This is not surprising as

current measurement systems in distribution centers have evolved from traditional systems where the primary emphasis was on organization-level financial and operational measures, with little attention on a formal process for assessing operator-and customer-level performance indices.

Based on the results of assessment of applying normative attributes to the measurement systems used in distribution centers, it is found that there is great opportunity for improvement. First, everyone in the distribution center should get involved with the development of the measurement system as much as possible. Only through wider input can a best-fit measurement system be designed. As a result, the traditional way of focusing on only organizational measurement is not appropriate any more. A focus should be placed on the individual level as well. Wider visibility of performance metrics across the organization would significantly help information to be understood more effectively and efficiently.

The results of this research also indicate that the primary focus in the measurement systems currently used in the distribution centers studied was on quantitative attributes. This type of thinking in the measurement philosophy must be expanded. Measurement and possible integration of both quantitative and qualitative measurements are important, and developing a formal structure to measure customer satisfaction could be a critical starting point.

Another significant improvement can be made is in the study-act part of Plan-Do-Study-Act (PDSA) area. The measurement systems studied only implemented part of the

process. Through a complete cycle of PDSA, the performance of the distribution centers can be improved significantly.

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DISTRIBUTION CENTER PERFORMANCE ASSESSMENT

by

Chun-Ho Kuo

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed 7 May, 1998
Commencement June 1998

Doctor of Philosophy thesis of Chun-Ho Kuo presented on 7 May, 1998

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ACKNOWLEDGMENT

I would like to express my sincerely thanks to both of my major professors: Dr. Kimberly Dunn and Dr. Sabah Randhawa, for their wisdom, patience, continuous support, and dedication in guiding me through this course of study. I will never forget the time they spent with me. Not only are they my mentors, advisors, and friends, but they also inspired me to a level of achievement I never would have dreamed possible. I am very fortunate to work with them.

To the other members of my committee, Dr. Dave Thomas, Dr. Eldon Olsen, and Dr. Shih-Lien Lu, I thank them for their valuable input and contribution of their experience to this dissertation.

I would also like to thank those members of distribution centers who had generously spent significant amount of their time with me and allowed me to come in to their facilities to conduct the research.

To my special family, who gave me insight, support, encouragement, and love, without whom I could not have persevered: Judith and Norman Berlowitz, and Jean Berlowitz, thanks for being with me through the hard time.

Finally, deep appreciation must go to my parents, for their unfailing continuous support and their faith in me.

CONTRIBUTION OF AUTHORS

Dr. Kimberly Dunn and Dr. Sabah Randhawa were involved in the design, analysis, and writing of each manuscript.

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DISTRIBUTION CENTER PERFORMANCE ASSESSMENT

CHAPTER 1

INTRODUCTION

Managing supply-chain operations is critical to any company's ability to compete effectively. Success of today's market depends on the ability to balance a stream of products and processes to stay competitive. One possible way to achieve this goal is through effective Logistics Management. In fact, direct expenditures for industrial logistics are more than 10 percent of the gross domestic product (Leake, 1995). As a result, more and more companies are becoming increasingly aware of the fact that the overall efficiency of operations is directly related to logistics management.

Through logistics management, companies try to achieve multiple goals: increase sales, reduce product costs, cut operating expenses, and improve return on assets. Unfortunately, these are not easy goals to achieve and there are not many operations, which would actually help to make concurrent progress toward more than one or two of the above goals. A function whose optimal execution impacts every business goal is the "distribution" function. Distribution supports sales and marketing through product and service combinations that differentiate a business from its competitors. It can also encompass the management of its materials from source to shelf, which reduces

manufactured and product costs. Thus, distribution center plays an important role in the logistics system.

The focus of this research is on measurement systems within distribution centers. With good performance measurement systems, companies are able to evaluate the business strategies as well as to motivate behavior leading to continuous improvement. With the changing industrial environment, companies need to find ways to compete and grow. An investigation of how to change the performance measurement system to help companies compete more effectively would be extremely and truly valuable. Thus, the objective of this research is to assess the performance measurement systems currently used in today's distribution centers.

A complete investigation of distribution centers' performance measurement systems is completed in this study. This research has three major research phases. The first phase begins with a comprehensive review of the background of distribution centers. The components and functions of distribution centers, along with the material handling system used, are discussed.

A series of case studies are carried out in the second phase. Five distribution centers in the Northwest are selected as the case study subjects. In this section, the research methodology used to conduct the study, including the design of the research and data analysis technique, is described. The findings of the case studies are summarized in terms of the distribution centers' characteristics and measurement systems used. Finally, a cross-case analysis is provided.

In the last stage of this research, a comprehensive framework of normative attributes for measurement systems (adapted from Clark, 1995) is adopted to assess the

performance measurement systems used in today's distribution centers. A comprehensive review of general theory of measurement systems is provided. An assessment of the performance measurement systems based on the results of cross-case analysis follows. The resulting strengths and opportunities for improvement of the performance measurement systems are discussed.

To complete this research, a summary of this document consolidates the overall findings from previous chapters and makes recommendation for improving measurement systems in distribution centers. The appendix provides a copy of the interview guide used for this case study analysis.

CHAPTER 2

DISTRIBUTION CENTERS: THE KEY TO SUCCESSFUL SUPPLY-CHAIN MANAGEMENT

ABSTRACT

This paper focuses on the contribution of distribution centers to the supply-chain. An overview of distribution center and supply-chain management is provided including a distribution center classification system, the components and functions of distribution centers, and an insight into how distribution makes significant contributions to achieving supply-chain managerial goals. The requirements and application of performance measurement systems to distribution centers are also discussed.

INTRODUCTION

In the past, manufacturers were the drivers of the supply-chain cycle -- managing the pace at which products were manufactured and distributed. Today, customers are calling the shots, and manufacturers are scrambling to meet customer demands for options, styles, features, quick order fulfillment, and fast delivery. Managing supply-chain operations is critical to any company's ability to compete effectively, and depends on the ability to balance a stream of product and process changes while meeting customer demands for delivery and flexibility. Data from Pittiglio, Rabin, Todd, & McGrath's (PRTM's) most recent integrated supply-chain benchmarking study shows that the performance gap between best-in-class and average companies is widening and that companies unable to effectively leverage their supply-chain are falling behind (Cohen, 1996).

Stevens (1989) defines the supply-chain as:

> *A system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feedforward flow of materials and the feedback flow of information.*

Defined more broadly, the supply-chain is the flow from the initial raw materials to the ultimate consumption of the finished product linked across supplier-user companies. A simplified supply chain structure is shown in Figure 2.1.

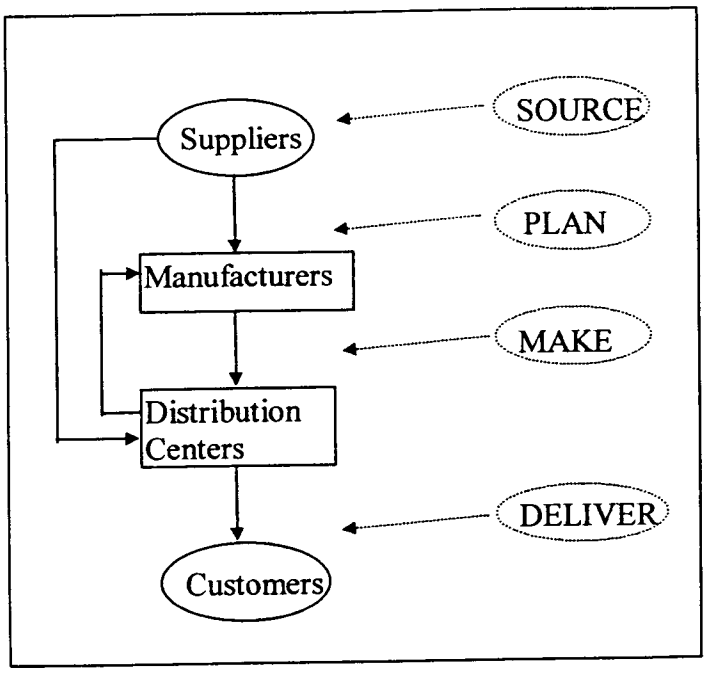

Figure 2.1 A Simplified Supply Chain Structure

Basically, there are four principal components in the system: Suppliers, Manufacturers, Distribution Centers, and Customers. Four basic processes: Source, Plan, Make, and Deliver, define the transformation efforts, including managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to customers.

If supply-chain is considered in a broader context, the concept is similar to logistics management discussed in industrial engineering literature. The Council of Logistics Management (CLM), 1985, defines logistics as follows:

> *The process of planning, implementing, and controlling the efficient cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information for the purpose of conforming to customer requirements.*

Thus, the prime objective of logistics is to ensure that materials and products are available at the right place, at the right time, and in the right quantities to satisfy demand or customers and to give a competitive advantage to the company. This is also the spirit of the supply-chain management. Logistics activities are performed to support production and marketing, and therefore logistics management is closely linked with marketing and production strategies. In other words, logistics management affects all major activities within the firm beginning with raw material deliveries and ending with deliveries of finished goods. Thus, logistics systems are critical for the success of a function or department and for the success of the entire company. As a result, if a single component of the supply-chain can be improved, significant success for the whole supply-chain enterprise would be achieved.

Today, more and more companies are becoming increasingly aware of the fact that the overall efficiency of operations is directly related to logistics management. Companies generally try to achieve multiple goals: increase sales, reduce product costs, cut operating expenses, and improve return on assets. These are not easy goals to achieve and there are not many operations which, when executed to perfection, actually help to make concurrent progress towards such multiple goals. For example, perfect production planning or efficient manufacturing will reduce operating expenses but may have virtually no impact on sales. However, a function whose optimal execution impacts every business goal is distribution. Distribution is far more than just warehousing and shipping. Distribution supports sales and marketing through product and service combinations that differentiate a business from its competitors. It can also encompass the management of its materials from source to shelf, which reduces manufacturing and

product costs. Finally, leading edge distribution practices can reduce fixed and working assets by cutting capital and operating costs without compromising customer service (Biciocchi, 1992). As a result, distribution is a value-added process. Through the value-added distribution process, companies are able to focus on true core competencies and avoid the building of any non-core, overhead infrastructure which would in turn reduce the supply-chain performance (Burton, 1996). Also as mentioned in Schary (1984), the distribution center is the most important facility in the logistics system and among logistics costs, the costs of storage are second only to transportation costs.

DISTRIBUTION CENTERS: AN OVERVIEW

Distribution is the activity associated with the movement of material, usually finished products or service parts, from the manufacturer to the customer. These activities encompass the functions of transportation, warehousing, inventory control, material handling, order administration, site and location analysis, industrial packaging, data processing, and the communications network necessary for effective management. It includes all activities related to physical distribution, as well as the return of goods to the manufacturer (Cox, Blackstone, and Spencer, 1995). Distribution of goods is a process of interpretation of an order to affect the movement of industrial or consumer goods from the point of manufacture or storage to the customer in accordance with company policy (Aylott, 1970).

A Distribution Center is a warehouse with finished goods and/or service items. It performs a function within a system of commerce, facilitating the movement of goods

from producer to consumer. It receives products and materials from factories and suppliers and passes them on for further production or distribution to users. It may hold inventory to service customer orders and may also perform receiving and shipping functions (Schary, 1984).

Classifications of Distribution Centers

Distribution centers can be classified into several categories based on a company's characteristics and functions, the extent of user control, or the nature of commodities (Table 2.1).

Table 2.1 Classification of Distribution Centers

Original Characteristics of Companies*	Extent of User Control**	Nature of Commodities***
Manufacturing	Private	Commodity
Wholesaler	Public	Bulk Storage
Retail	Contract	Cold Storage
Transportation	Contract	Household Goods

** Department of Economics, R.O.C., 1993*
***Ackerman, Gardener, and Thomas, 1972*
****Jenkins, 1968*

"Manufacturing" distribution centers are generally part of manufacturing organizations whose main function is manufacturing products and operating a distribution center to integrate the channel down into the retail stores. "Wholesale" distribution centers represent companies that wholesale products and also manage distribution in order to enhance their capability for selling products. "Retail" distribution centers focus

on regional sales and operate distribution centers in order to control the channel for purchasing the required products. "Transportation" distribution centers are associated with companies whose primary job is transportation of goods; the original function of distribution is modified so that these companies can incorporate distribution as one of their functions.

Based on the extent of user control, distribution centers can be classified into three categories (Ackerman, Gardener, and Thomas, 1972). A "Private" warehouse is one in which the warehouse user controls the building, the equipment, and the labor. A "Public" warehouse is managed by an independent contractor, who controls the building, its labor, and the materials handling equipment. A "Contract" warehouse is a combination of a private and public facility. Either the warehouse customer or the warehouse operator may control the warehouse space under a formal agreement.

Another way to classify warehouses is by the nature of commodities (Jenkins, 1968). "Commodity" warehouses limit their services to storing and handling certain commodities, such as lumber, cotton, tobacco, and other products that spoil easily. "Bulk" storage warehouses offer storage and handling of products in bulk, such as liquid chemicals, oil, and highway salts. They also mix products and break-bulk as part of their service. "Cold storage" warehouses are controlled, low-temperature warehouses. "Household goods" warehouses store and handle household items and furniture. Though furniture manufacturers may use these warehouses, the major users are household moving companies.

Input-Process-Output Model

At a macro level, the function of a distribution center can be described by the Input-Process-Output Model shown in Figure 2.2. There are two types of entities within a distribution center. The product flow represents the physical movement through the front of unloading docks to customers. The control information flow is defined by the customer order information to process the order to the point of purchasing replenishment product. For example, the input information can be the customer orders released by the retail stores and the shipping list along with purchasing order prepared by the vendors/manufacturers. The output would be the shipping orders along with products and purchase orders to the vendors.

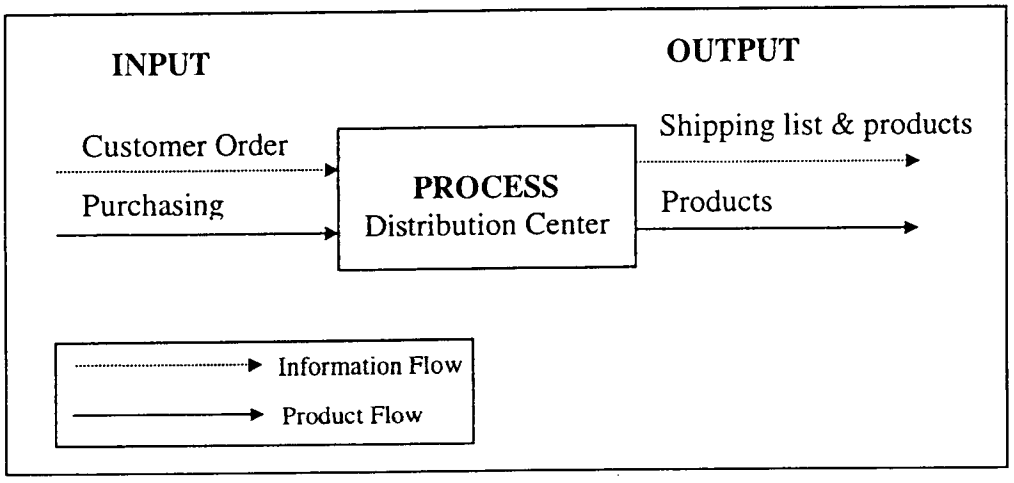

Figure 2.2 Input-Process-Output Model of Distribution Centers

DISTRIBUTION CENTERS: COMPONENTS AND FUNCTIONS

Components of Distribution Centers

In terms of organization structure, a distribution center consists of five departments:

1. The **purchasing department** handles purchasing related activities, including the receiving activity. Other activities include releasing the requisition order to the vendor and completing the contract conforming procedure, and monitoring of shipping status.
2. The **customer order department** handles the process for conforming, contracting, shipping, and expediting customers' requirements.
3. The **inventory department** is responsible for any inventory-related planning and controlling, including material handling and storage management. For the material handling system, the purpose is to move products or material from one location to another, including moving, storage, and control activities. The handling of materials must be performed safely, efficiently (at low cost), on a timely basis, accurately (right materials in the right quantities to the right location), and without damage to the materials (Lindkvist, 1985). As a result, the material handling system is an integration of material moving equipment and storage components accomplished through information control. Several commonly used material handling systems are discussed in a later section.

4. The **shipping department** is responsible for shipping-related activities, including repacking, loading/unloading, inspection (i.e. checking the labor), and distributing.
5. The **information department** controls the information flow within the distribution center, including integration of internal and external documents.

Figure 2.3 shows the interactions between the different departments. The cycle begins with the customer. Customers place orders with the customer order department, which sends appropriate information to the information control department. The purchasing department then places orders to manufacturers based on the information provided. Manufacturers deliver ordered goods to the receiving docks where the quantity and quality of goods is checked. The goods may be ready for immediate shipping in which case a cross-dock action occurs, meaning that goods are directly sent to the shipping area. Alternatively, the goods are moved to storage. When a customer places an order for an item in stock, then through the order-selection process, the requested goods are retrieved from storage. This picked-order is either sent to the shipping area or to the repacking area, if needed. Finally, the goods are distributed to customers from the shipping area.

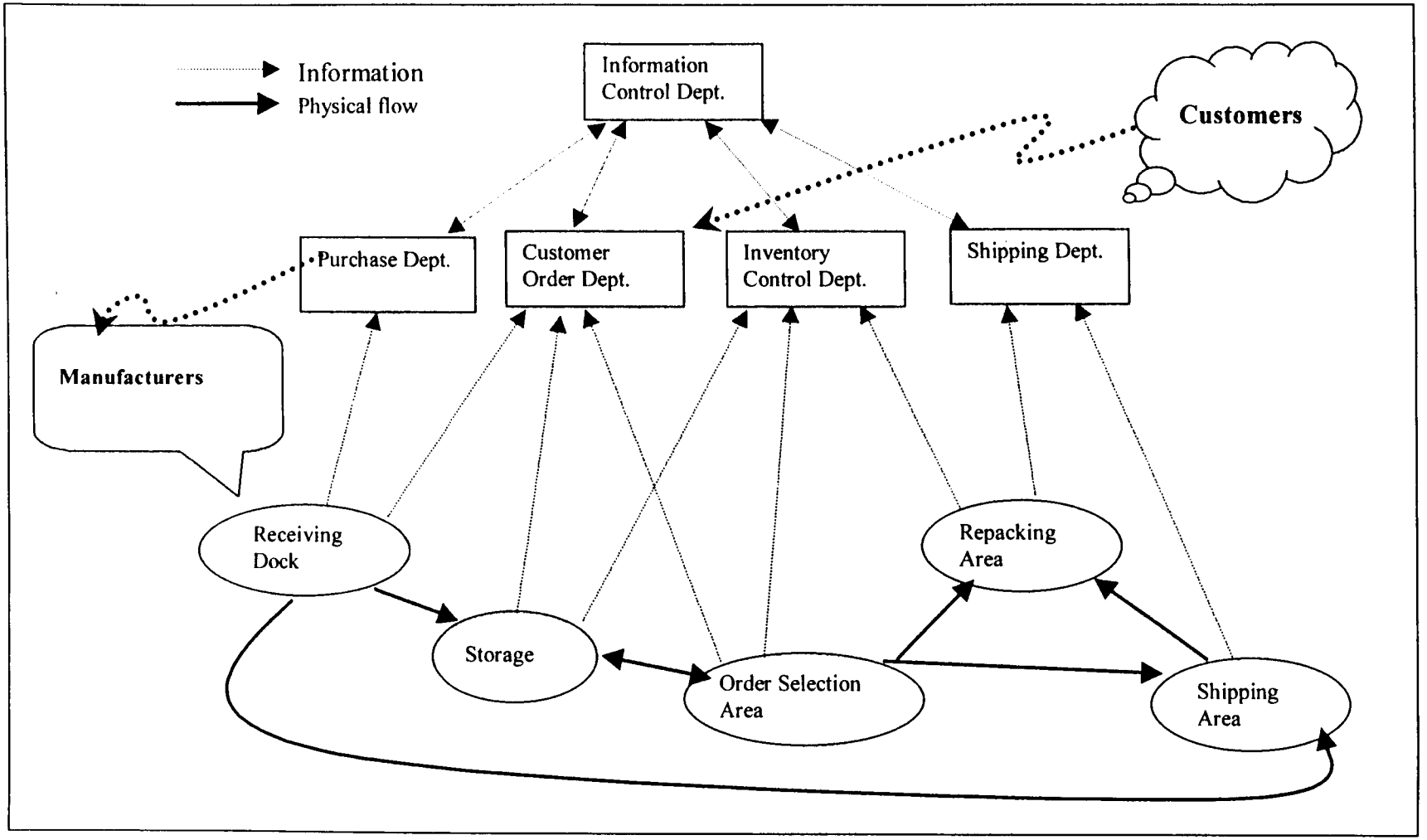

Figure 2.3 Interaction Flow Diagram for Distribution Center

Functions of Distribution Centers

The primary functions of a distribution center are:

1. **Distribution** includes the activities associated with the movement of material, usually finished products or service parts, from the manufacturer to the customer. It includes all activities related to physical distribution, as well as the return of goods to the manufacturer. In many cases, this movement is made through one or more levels of the field warehouse.

2. **Inspection** includes measuring, examining, testing, or gauging one or more characteristics of a product or service and comparing the results with specified requirements to determine whether conformity is achieved for each characteristic.

3. **Loading** includes handling the prepared shipping product and placing it into the assigned truck or equipment.

4. **Order Picking** includes selecting or "picking" the required quantity of specific products for movement to a packaging area (usually in response to one or more shipping orders) and documenting that the material was moved from the prior location to shipping.

5. **Packing** includes packing the product for safe shipping, unitizing one or more items of an order, and/or placing into an appropriate container.

6. **Put Away** includes removing the material from the dock (or other location of receipt), transporting the material to a storage area, placing that material in a staging area and then moving it to a specific location, and recording the movement and identification of the location where the material has been placed.

7. **Receiving** encompasses the physical receipt of material, the inspection of the shipment for conformance with the purchase order (quantity and damage), the identification and delivery to destination, and the preparation of receiving reports.

8. **Shipping** is the function that provides facilities for the outgoing shipment of parts, products, and components. It includes packing, marking, weighing, and loading for shipment.

9. **Sorting** is the function of physically separating a homogeneous subgroup from a heterogeneous population of items.

10. **Storing** is the retention of parts or products for future use or shipment.

To provide a better and integrated understanding of the operations of the distribution center, the major functions of a distribution center are summarized in Table 2.2.

Table 2.2 Summary of a Distribution center's Functions

Distribution Center Operations	Parallel Information Flow	Description
1. Receiving	▪ Bill of lading ▪ Package invoice ▪ Purchased order	▪ Check, inspect, and sign for all merchandise received ▪ Unload the merchandise
2. Movement to storage	▪ Movement ticket	▪ Move merchandise to storage area
3. Reserve storage	▪ Storage location records	▪ Put Away
4. Order selection	▪ Movement ticket ▪ Order picking ticket ▪ Order selection location record updated	▪ Move to the designed area for order picking ▪ Order picking
5. Repack	▪ Unit identification ▪ Packing	▪ Pack the merchandise according to the order
6. Preparing for Shipping	▪ Sales order ▪ Packing invoice ▪ Stock record updated	▪ Check the shipping information ▪ Mark any necessary contained, box, or pallet
7. Loading	▪ Bill of lading (or a manifest) ▪ List of shipments carried by each vehicle	▪ Load the merchandise to the vehicle

MATERIAL HANDLING SYSTEM USED IN DISTRIBUTION CENTERS

A variety of material handling systems are integral components of a distribution center. Figure 2.4 summarizes the material handling systems used in distribution centers, some of these systems are briefly discussed below.

- An **Automated Storage/Retrieval (AS/R) System** is defined by the Materials Handling Institute as:

  A combination of equipment and controls, which handles, stores, and retrieves materials with precision, accuracy, and speed under a defined degree of automation.

  AS/R systems are custom-planned for each individual application. They range in complexity from relatively small mechanized systems that are controlled manually to very large computer-controlled systems that are fully integrated with factory and warehouse operations. The system is comprised of four basic elements: the stacker/retriever crane, storage racks, load/unload stations, and the control station. The stacker crane lifts a unit load from a conveyor or transfer vehicle at the load station on command from a computer. It then places the load in a pre-assigned address. On command, the crane can also retrieve loads from specific locations in the rack and deliver them to the transfer station for movement to order assembly. The computer that controls the stacker crane is coordinated with inventory control, so that records are automatically created for stock locations and inventory levels whenever commands for movement are issued. The computer commands can also be linked to order processing so that as soon as the order is processed, the actual items of the order can be retrieved and sent to the order assembly area.

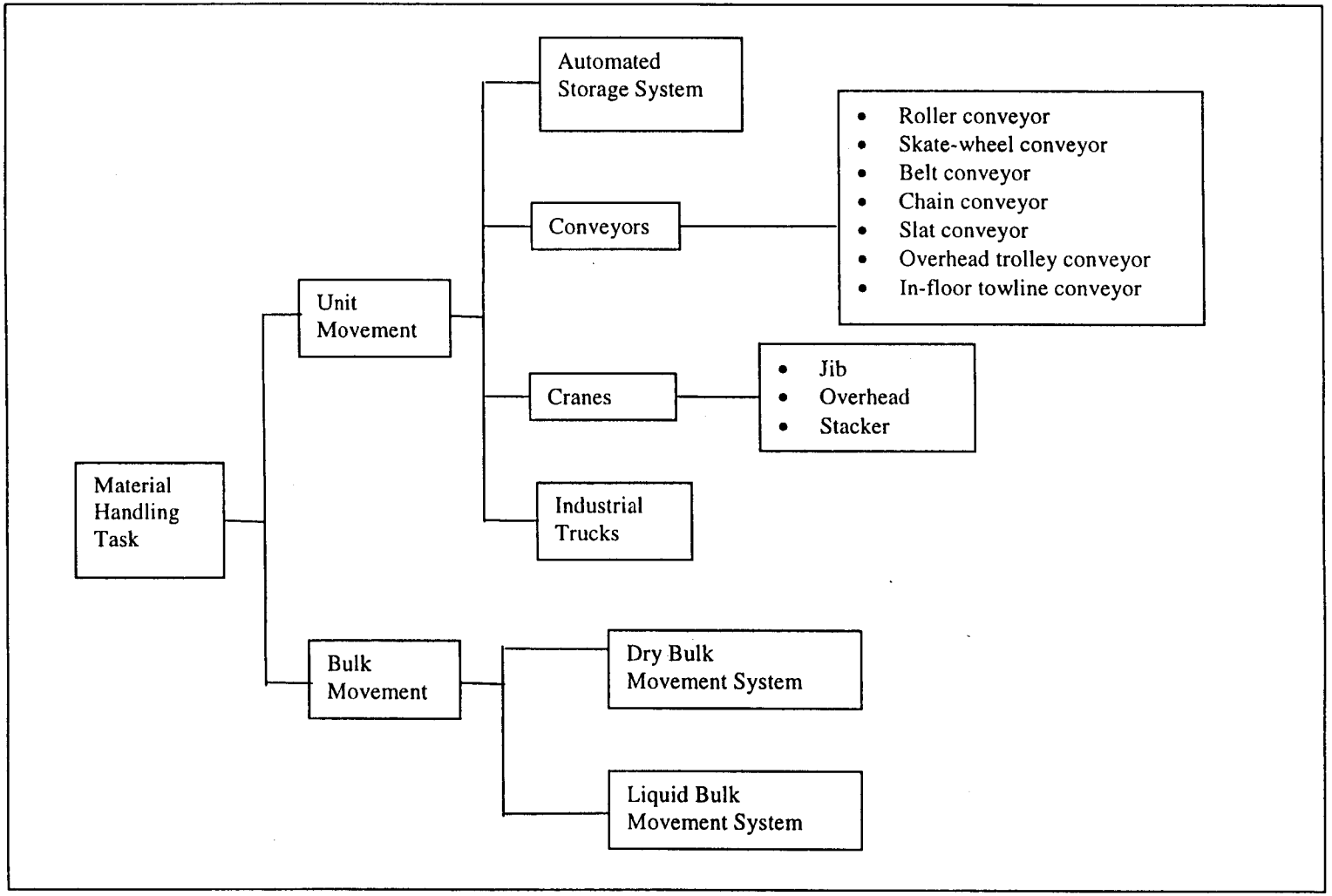

Figure 2.4 Material Handling Movement Equipment (Schary, 1983)

- A **Carousel Storage System** is a series of bins or baskets fastened to carriers that are connected together and revolve around a long, oval track system. The track system is similar to a trolley conveyor system. Its purpose is to position bins at a load/unload station at the end of the oval. The operation is similar to the powered overhead rack system used by dry cleaners to deliver finished garments to the front of the store. The load/unload station is manned by a human worker who activates the powered carousel to deliver a desired bin to the station. One or more parts are removed from the bin, and the cycle is repeated.

- A **Conveyor System** is used when materials must be moved in relatively large quantities between specific locations over a fixed path. Most conveyor systems are powered to move the loads along the pathways. Other conveyors use gravity to cause the load to travel from one elevation in the system to another. Major conveyor types include:

  - *Roller conveyors* are a very common form of conveyor system. The pathway consists of a series of tubes (rollers) that are perpendicular to the direction of travel. The rollers are contained in a fixed frame, which elevates the pathway above the floor level from several inches to several feet. Flat pallets or tote pans carrying unit loads are moved forward as the rollers rotate.

  - *Skate-wheel conveyors* place materials on a belt surface to travel along the moving pathway. The belt is made into a continuous loop so that half of its length can be used for delivering materials, and the other half is the

return run (usually empty). A frame that has rollers supports the belt or other supports spaced every few feet. At each end of the conveyor (where the belt loops back) are driver rolls (pulleys) that power the belt.

- *Chain conveyors* are made of loops of endless chain in an over-and-under configuration around powered sprockets at the ends of the pathway. There may be one or more chains operating in parallel to form the conveyor. The chains travel along channels that provide support for the flexible chain sections. Either the chains slide along the channel or they use rollers to ride in the channel. The loads generally ride along the top of the chain.

- *Slat conveyors* use individual platforms, called slats, which are connected to a continuously moving chain. Loads are placed on the flat surface of the slats and are transported along with them. Straight-line flows are common in slat conveyor systems.

- *Overhead trolley conveyors* use wheeled carriages running on an overhead rail from which loads can be suspended. A trolley conveyor consists of multiple trolleys, usually equally spaced along the rail system by means of an endless chain or cable. The chain or cable is attached to a drive wheel that supplies power to the system. The path is determined by the configuration of the rail system; it has turns and changes in elevation to form an endless loop. Suspended from the trolleys are hooks, baskets, or other receptacles to carry the loads.

- *In-floor towline conveyors* make use of wheeled carts powered by means of moving chains or cables located in trenches in the floor. The chain or cable is called the towline-hence the name of the conveyor system. The pathways of the conveyor system are defined by the trench and cable system; switches between powered pathways are possible in the towline system to achieve some flexibility in the handling routes.

- **Crane systems** can be divided into jib, overhead, and gantry types. The first two are designed for heavy loads such as steel and machinery. A jib has a horizontal beam, which assists in providing lift capacity. Jibs and gantry cranes are normally installed for localized movement. Overhead cranes are used over large areas.
- **Industrial trucks** include both lifting machines, such as forklifts, and transporting units, such as tow carts. Forklift trucks are widely used by distribution centers in conjunction with wood pallets and other unit load devices.

Compared to unit movement, equipment used in bulk movement includes both liquid and dry movement systems. Liquid systems use pipelines, and are associated with oil products and solids carried in slurry form. The product is converted into a liquid emulsion, carried through the pipeline and then reconverted into a dry form. Dry material can be moved in bulk as truck, rail, or barge loads, or in unit package or bags. Bulk movement is favored for large volume, low dollar-density products in order to reduce transportation and handling cost.

PERFORMANCE ASSESSMENT

It is surprising that even though distribution centers have been a topic of discussion for several decades, not much attention has been focused on performance assessment of distribution centers. A starting point to study the performance of distribution center is to examine available performance measurement systems and evaluate the potential of their use in distribution centers. Distribution centers can use performance measurement systems to evaluate their business strategies and to motivate behavior leading to continuous improvement.

The fundamental requirements of a performance measurement system, as described by Khadem & Lorber (1986), can be applied to the operation of distribution centers. If any one of the elements listed below is missing from a distribution center's measurement system, then the system should be revised for "optimum" results. These requirements are as follows.

1. Accountability: Everyone has to be clear on what they are being asked to do.
2. Data System: Performance information must be gathered to determine how well people are doing.
3. Feedback System: Once the performance information has been gathered, feedback must be given to people so they can continue to perform well or redirect their efforts to get performance back on line.
4. Recognition System: Good performance must make a difference. So a recognition system based on performance is a must in high-performance organizations.
5. Training System: If people do not have the skills to perform well, they must be trained. High expectations without skills will only lead to frustration and poor performance.

For accountability, everyone should know what they are expected to accomplish and how the outcomes are going to be measured. Clear vision and mission statements from management would help everybody in the organization understand what they are expected to achieve.

The data system is the heart of a measurement system. Accurate and timing data helps managers and employees make good decisions. The more one understands how the process performs, the better one can identify mechanisms to make improvements. If the data system is the heart of the distribution center, then the feedback and recognition systems must be the circulatory and nervous systems. Organizational improvement requires ongoing feedback with respect to current status and achievement of goals. With a good feedback system, employees can not only understand the measures, but also how the performance represented by those measures affects the competitive health of the company. A recognition system based on performance enhances the strength of the measurement system. With recognition as one component of the measurement system, there is a direct line of sight between employee behavior and the corresponding acknowledgement of their contribution. This encourages everyone to do his or her very best. However, many systems focus primarily on negative measurement categories, such as error rates, failure rates, and customer complaints. While these measures are important, a good measurement system should also include categories that can demonstrate success, such as efficiency improvement, number of orders delivered on time, or increase in yields.

The last requirement of an effective measurement system is training. People want to do a good job, but they must have the knowledge and skills necessary to accomplish

the task. If people do not have the skills necessary, they must be trained. High expectations without skills and knowledge will only lead to frustration and poor performance.

In order to provide readers with a general idea of how performance assessment is applied to a distribution center, Table 2.3 illustrates the applications of the five fundamental requirements of performance assessment to the order picking function of a distribution center. This table illustrates the usefulness of the five fundamental requirements in managing the order picking function.

Table 2.3 Application of Fundamental Requirements to Order Picking Function

	Function of Distribution Center	
	Purpose	**Order Picking Function (Example)**
1. Accountability	• Employees know what they need to do to contribute to company goals.	• Expected Performance
2. Data System	• Contributes to insuring that resources are available to be picked. • Allows productivity data to be gathered and analyzed.	• Warehouse Management System • Productivity Performance System
3. Feedback System	• Helps employees interpret results from the data system and align their future performance with company needs.	• Communication with the supervisor
4. Recognition System	• Reinforces desired behaviors through incentives such as team celebrations, bonuses, tokens of appreciation, or praising performance in public.	• Bonus, reserved parking space
5. Training System	• Ensures employees have the skills and knowledge necessary to perform their jobs.	• Through the data system, computer entry of filled orders was identified as an opportunity for improvement. A training class was designed to address this problem.

SUMMARY

This paper discussed the contribution of distribution centers to supply-chain management. The classifications, components, functions, and material handling system of modern distribution centers are discussed. Elements of a successful performance measurement system were identified and an example of how these elements apply to a specific distribution function was provided.

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CHAPTER 3

A CASE STUDY ASSESSMENT OF PERFORMANCE MEASUREMENT IN DISTRIBUTION CENTERS

ABSTRACT

Managing supply-chain operations is critical to any company's ability to compete effectively. Success of today's market depends on the ability to balance a stream of products and processes to stay competitive. Companies are constantly evaluating every area of operations to insure that productivity and cost objectives are realistic and attainable. Research has been carried out to investigate the measurement systems used in today's distribution centers. Five distribution centers in the Pacific Northwest were selected for this study. The characteristics of these five distribution centers and their measurement systems are discussed in this paper. A cross-case analysis is provided, which gives a view of a typical measurement system used in today's distribution centers.

INTRODUCTION

Managing supply-chain and logistics activities is critical for a company to stay competitive. The prime objective of logistics is to ensure that materials and products are available at the right place, at the right time, and in the right quantities to satisfy customer demands and to give a competitive advantage to the company. A good performance measurement system is a necessity for a company to grow and remain an industry leader. The objective of this research is to understand and assess the measurement systems used in today's distribution facilities. Questions of interest include: (1) How is the overall performance measured in distribution centers? (2) How is the productivity measured? and (3) What is a company's philosophy towards today's changing environment? In order to answer these questions and others, a case study approach was used to study five distribution centers. A complete description of research methodology, from research issues to data collection is given below. A discussion of results based on the findings of the case studies is also included.

RESEARCH METHODOLOGY

A research methodology is an overall plan for accomplishing research objectives. It maps out the research activities and describes what is involved in each activity. The research methodology used in this research has the following characteristics:

1. Applied research with focus on exploratory and descriptive analysis to develop recommendations for improvement.

2. The unit of analysis is the distribution center measurement system.
3. It uses naturalistic inquiry and an inductive paradigm with both quantitative and qualitative data.
4. It uses a case study research approach.
5. Sources of data include documentation, archival records, interviews, and direct observations.
6. Validation of confidence of findings is addressed using triangulation, multiple data sources, multiple methods, and multiple perspectives.

Each of these characteristics is discussed using Table 3.1, adapted from Patton (1990), that summarizes the research design issues:

1. Research Type

Research is "the manner in which we attempt to solve problems in a systematic effort to push back the frontiers of human ignorance or to confirm the validity of the solutions to problems other have presumably resolved" (Leddy, 1985). The primary purpose of basic research is to gain knowledge and understanding of a particular phenomenon, and not for a practical application with specific commercial objectives (National Science Board, 1982; Patton, 1990). Applied research contributes knowledge and understanding of a phenomenon so that a specific and recognized need may be met through the generation of potential solutions (National Science Board, 1982; Patton, 1990). Summative Evaluation, Formative Evaluation, and Action Research are

developmental kinds of research, which focus on intervention, improvement, or solving problems.

Table 3.1 Design Issues and Options (adapted from Patton, 1990)

Issues	*Sample Options and Considerations*	*Choice for this Research*
1. What type of research was this?		
1.a. What was the primary purpose of the study?	Basic research, applied research, summative evaluation, formative evaluation, action research	Applied Research and Formative Evaluation
1.b. What was the focus (nature) of the study?	Exploratory, descriptive, explanatory, predictive	Exploratory and Descriptive
1.c. Did the research build or confirm theory?	Theory-building, confirming theory	Recommendations for improvement
2. What were the units of analysis?	Individuals, groups, program components, whole programs, organizations, communities, critical incidents, time periods, etc.	Distribution Center Measurement System
3. What type of inquiry paradigm was used?		
3.a. What controls were exercised?	Naturalistic inquiry, experimental design, quasi-experimental options	Naturalistic inquiry
3.b. What analytical approach was used?	Inductive, deductive	Inductive
3.c. What types of data were collected?	Qualitative, quantitative or both	Both Qualitative and Quantitative
4. What research method was used?	Case study method, experimental method, historical method, etc.	Case study method
5. What was the source of data?	Documentation, archival records, interviews, direct observations, participant-observation, and physical artifacts (Yin, 1989)	Documentation, interviews, physical artifacts, and direct observations
6. How were validity of and confidence in the findings addressed?	Construct validity, internal validity, external validity, and reliability (Triangulation options, multiple data sources, multiple methods, multiple perspectives, and multiple investigators)	Triangulation, multiple data sources, multiple methods, and multiple perspectives

The second element is defining the nature of a research study. Basically, there are four categories: exploratory (focus on exploring a phenomenon to try to identify important issues, constructs, or develop hypotheses), descriptive (aims to simply describe by documenting a phenomenon in detail), explanatory (where the nature of the research is to explain relationships), and predictive (where research is conducted to predict outcomes) (Marshall and Rossman, 1989; Yin, 1989). These four categories are not necessarily mutually exclusive; research can have more than one focus. The last dimension of research is whether it attempts to build or test theory. Research can be used to generate a new theory resulting in concepts, constructs, hypotheses, theoretical propositions, and/or framework. On the other hand, a research can be conducted to evaluate or confirm existing knowledge.

This study was characterized as applied research and formative evaluation: to better understand the measurement system used in today's distribution centers, evaluate the strengths and weaknesses of these systems, and develop recommendations for improving measurement systems in distribution centers.

2. Unit of Analysis

The unit of analysis is the element used to conduct the investigation. It could be the individuals in the organization, groups, program components, measurement systems, or time periods. There are two units of analysis used in this research. One is the entire distribution center and the other is the measurement system.

3. Type of Inquiry Paradigm

This research followed the holistic-inductive paradigm, emphasizing three qualitative themes: naturalistic inquiry, inductive analysis, and qualitative data (Patton, 1990). Naturalistic inquiry consists of "studying real-world situations as they unfold naturally [in a] non-manipulative, unobtrusive, and non-controlling [manner]" with "openness to whatever emerges" and a "lack of predetermined constraints on outcomes" (Patton, 1990). Data gathered in this study is analyzed and interpreted inductively, which is "immersion in the details and specifics of the data to discover important categories, dimensions, and interrelationships; exploring genuinely open questions rather than testing theoretically derived (deductive) hypotheses" (Patton, 1990). Qualitative data is "detailed, thick description, inquiry in depth direct quotations capturing people's personal perspectives and experiences" (Patton, 1990). In addition to the qualitative data, quantitative data is also collected to describe various organizations.

4. Research Method

The research method used for this research is the case study method. The case study method allows the researcher to investigate a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used (Yin, 1989). Case studies provide a special way of collecting, organizing, and analyzing data to gather comprehensive, systematic, and in-depth information about each case of interest. The

case study method allows people being interviewed to describe experiences in their own language, rather than the researchers. The case study method is the most appropriate method for the conditions of this research because it is capable of handling both qualitative and quantitative data (Eisenhardt, 1989; Marshall and Rossman, 1989; Yin, 1989). A characteristic of case studies is the combination of data collection methods, such as interviews, questionnaires, and observations, discussed in the next section.

5. Source of Data

There are three ways to collect data from a system: ask, observe, and use system documentation. Evidence for case studies may come from various sources including documents, archival records, interviews, direct observation, participant-observation, and physical artifacts (Yin, 1989). In this study, all these data collection methods were used, except for participant-observation.

6. Validity of Findings

There are four tests relevant in evaluating the quality of any research study: construct validity, internal validity, external validity, and reliability (Yin, 1989). Internal validity is relevant only for explanatory or causal studies, not for descriptive of exploratory studies, and hence is not relevant for this research. The remaining three are relevant to this study, and various case study tactics associated to address the validity are summarized in Table 3.2.

To address construct validity, triangulation, a technique of combining different sources of evidence in a single study (Rossman & Wilson, 1985), was used. This combination of different sources is one of the major strengths of the case study approach (Yin, 1989). Other sources used in this study include interviews, documents, observations, and artifacts. The second tactic to address construct validity is to establish and maintain a chain of evidence, which allows an external observer to follow the derivation of evidence from initial research questions to ultimate case study conclusions. Furthermore, the accuracy of a case study and hence its construct validity can be increased by having key case informants review drafts of the case study description.

Table 3.2 Case Study Tactics for Validity Tests

Tests	Definition	Case study tactic	Phase of research in which tactic occurs
Construct validity	Establishing correct operational measures for the concepts being studied	• Use multiple sources of evidence	Data collection
		• Establish chain of evidence	Data collection
		• Have key informants review draft case study report	Composition
External validity	Establishing the domain to which a study's findings can be generalized	• Use replication logic in multiple-case studies	Research design
Reliability	Demonstrating that the operations of a study, such as the data collection procedures, can be repeated with the same results	• Use case study protocol	Data collection

Using replication logic in selecting case studies addresses external validity. Case study relies on analytical generalization (Eisenhardt, 1989; Yin, 1989), not statistical generalization as with experimental hypothesis-testing research. Once the replication is made, the results may be accepted even though further replications have not been performed (Yin, 1989).

To address the reliability, the case study protocol was used to guide the research process. The protocol is a major tactic in increasing the reliability of case study research and is intended to guide the investigator in carrying out the case study (Yin, 1989). This includes instrument (i.e. the interview questions), as well as procedures and general rules that should be followed. The case study protocol used will be discussed in the following section.

Case Study Design

Two aspects of case study design are case study protocol and data collection process. The protocol contains the instrument and the procedures and general rules that should be followed in using the instrument. In addition to increasing the reliability, the case study protocol reminds the investigator what the case study is about and helps the investigator to carry out the case study.

There are three major components included in the case study protocol: purpose, key features of the case study method, and the organization of the protocol (Figure 3.1). As mentioned before, the purpose of this study is to understand the measurement system in today's distribution centers. The questions of interest include: What performance

CASE STUDY PROTOCOL

I. **Purpose:** to study the performance measurement system in Distribution Centers.

- What performance measures are currently used in the system?
- How performance measures are measured?
  - How often?
  - By whom?
- Why are these performance measures tracked?

II. **Key Features of the Case Study Method:**

- Multiple Case studies: to draw cross-cases conclusions
- Multiple data sources: to increase the reliability of case studies
- Multiple level/unit analysis: to answer questions of interest

III. **Organization of this Protocol**

A. ***Procedure***

1. **First Contact**

(1) Send or Fax the following documents to the Distribution Centers:

- Objective Statement: *Performance Measurement in Distribution Centers*
- Data Collection Plan
- Interview Questions Outline

2. **Initial Schedule of Field Visit**

(1) Review of Preliminary Information:
- Verify the primary contact's information: name, title, phone number, and e-mail address.
- On first call ask for general information about the company
- Ask to get a copy of available information/documents by mail before the first visit, if possible.

(2) Verification of Access Procedures:
- How to get to the organization
- When to make the first visit: date and time.
- Individuals to see: name, title, phone number, and e-mail address.
- How much time allocated for each site.

(3) Special Documents

(4) Request a plant tour

Figure 3.1 Case Study Protocol

CASE STUDY PROTOCOL (Continued)

3. **Determination of People to Be Interviewed and other Sources of Information**

   (1) Operational measurements:

   - Receiving Functions
   - Storage Functions
   - Order Selection Functions
   - Repackaging Functions
   - Shipping Functions
   - Material Handling System
   - Others

   (2) Quality/Safety measurements

   (3) Employee measurements

   (4) Customer satisfaction measurements

   (5) For each person to be interviewed, ask for name, title, phone number, and e-mail Address.

B. ***Case Study Questions***

1. **Header:** Company information, interview's date, interviewee's name and title, and interview's name.
2. **Opening Statement**
3. **Interview guides/questions**

C. ***Analysis Plan and Case Study Reports***

1. **Individual Case Studies**
   (1) Descriptive Information
   (2) Explanatory Information
   (3) Outline of Individual Case Study Reports
2. **Cross-Case Analysis**
   (1) Descriptive Information
   (2) Explanatory Information
   (3) Cross-Case Report
   (4) References for Case Study Protocol

Figure 3.1 Case Study Protocol (Continued)

measures are used? Why are they used? How are they measured? The organization of the protocol outlines the procedure of how to carry out the field visit, designing the case study questions, and the analysis plan.

The primary activities in the data collection stage were conducting the site visits for the case studies and collecting data as needed before and after a visit. Five distribution centers in northwest Oregon were selected as case study sites. At the companys' requests, their names and locations of the distribution centers have been removed from this discussion. During site visits, data was collected through interviews, direct observations, and documentation provided by management. Use of a tape recorder in the interviews assisted with data collection and accuracy. Filed notes written during and after the site visits captured observations of any relevant events and descriptions. Follow-up was performed after each site visit. A "thank you letter" and typed interviewed notes were sent to the interviewees, along with any follow-up questions.

Data Analysis

The purpose of qualitative inquiry is to produce findings through analysis, interpretation and presentation of findings. The challenge in data analysis is to "make sense of massive amounts of data, reduce the volume of information, identify significant patterns, and construct a framework for communicating the essence of what the data reveals"(Patton, 1990). Unfortunately, data analysis is the least structured phase of qualitative research (Eisenhardt 1987; Miles & Huberman, 1984). Because statistical tests are not appropriate to be used to identify the significant patterns in qualitative data,

researchers can only rely on their own judgement, experience, and insight. In other words, there are no absolute rules or guidelines on how to analyze qualitative data.

There are two major steps included in data analysis: within case analysis and cross case analysis. Within case analysis entails becoming intimately familiar with each case individually and documenting it thoroughly. In cross case analysis, similarities and differences across cases are explored.

Within case analysis involves organizing the data by specific cases for in-depth study and is necessary to reduce the staggering volume of data (Esenhardt, 1989). Three major steps, adapted from Patton (1990) were used in this study:

1. Assemble the raw case data including interview transcripts, typed notes from observations, organization documentation, and other published articles about the case. All case data was summarized and organized into files for each distribution center.
2. Edit data, summarize the case information, eliminate redundant data, and organize topically for ready access.
3. Build data displays for each site data. Two displays were constructed for each case, one for the characteristics of distribution centers, and one for the measurement system used in the distribution centers.

Once the data collection and display for each case were completed, the search for cross-case patterns could begin. In reality, cross-case analysis and within-case analysis overlap. Searching for patterns across cases forces researchers to go beyond initial impressions and look at the data in divergent ways (Eisenhardt, 1090). Studying the data in different ways helps to decrease the potential for errors and bias in information processing. Patterns in qualitative data can be represented as dimensions, categories, classification schemes, and themes (Patton, 1990). Research questions were used as

categories to look for within-case similarities and between-case differences. More specifically, the following categories were used to perform cross-cases analysis: the measurement used in the distribution centers, how it is used, how often, and by whom. As in within-case analysis, data displays were useful in cross-case analysis to facilitate the search for patterns across cases. The primary purpose of displays is to describe the data based on analysis of the patterns. An unordered Meta-Matrix, which is a master chart assembling descriptive data from each of several sites in a standard format (Miles and Huberman, 1984), was used in cross-analysis. The unordered Meta-Matrices contained data on the types of measurement used in the five distribution centers in one display.

RESULTS

Case Study Characteristics

Table 3.3 summarizes general information about each of the five case study sites. DC-A is a retail distribution center, which belongs to a chain department store. Six distribution centers are owned by this department store chain. Common goods processed in this DC include garments, shoes, cosmetics, gifts, and jewelry. DC-A has operated for 18 years and services 22 stores in Oregon, Washington, and Alaska. There are about 300 employees working in this distribution center, including two shifts and over 16 operating hours per day.

Table 3.3 Characteristics of Distribution Centers

Distribution Center	A	B	C	D	E
1. Type of industry	Retail	Retail	Wholesale	Retail	Retail
2. Average Number of Goods Distributed	4,000 – 6,000 cartons/day	50,000 cartons/day	50,000-60,000 units/day	90,000 cases/day	800,000 units/day
3. Number of Shifts (on floor)	2	2	2	3	3
4. Union/Non-Union	Non-Union	Non-Union	Non-Union	Union	Union
5. % Cross Docking	≤ 1%	≤ 5%	None	≤ 2%	≤ 5%
6. Labeling / Repack	Yes	Yes	Yes	Small Repack No Labeling	Yes
7. Number of Employees	296	400	230	230	800* *Including drivers and temporary employees
8. Stores Serviced	22	40	Over 1,000	25	115
9. States Serviced	Oregon, Alaska, Washington	Oregon, Washington, Idaho, Montana	All States and International orders	Oregon, Washington, Idaho, Montana, California	Oregon, Washington, Idaho, Montana, Alaska, New Mexico, Nevada, Utah, Arizona
10. Years of Operation	18	1 ½	4	Site 1: 28 years Site 2: 1 year	21
11. Building Size	320,000 ft^2 (2 levels)	616,140 ft^2	265,000 ft^2 (3 levels)	Site-1: 250,000 ft^2 Site-2: 267,000 ft^2 (Perishable only) (Potential: 800,000 ft^2)	1,000,000 ft^2 (only for general merchandise DCs)
Truck Doors				Site-1 Site-2	
12. Shipping(Actual used)	30 (26)	75 (39)	16 (10)	26 (26) 52(for both)	52 (52)
13. Receiving(Actual used)	23 (20)	44 (20-25)	14 (6)	14 (14) 52 (for both)	37 (37)
14. Pallet Locations:	N/A	38,269	10,700	40,000	73,316
Types of Material Handling Devices Used					
15. Conveyor	Yes	Yes (2.97 miles)	Yes	No	Yes
16. Fork Truck	Yes	Yes	Yes	Yes	Yes
17. ASRS	No	No	No	No	No (but has High-Rise System)

DC-B is a retail distribution center belonging to a supermarket chain. This supermarket chain owns 10 distribution centers in the United States. DC-B is a new facility which had its grand opening one and a half years ago. The main commodities processed in this distribution center are grocery items, apparel, office supplies, electronics, and toys. No perishable items are distributed by DC-B. There are about 400 employees working in this facility, with distribution capacity of 50,000 cartons per day, servicing 40 chain stores in Oregon, Washington, Idaho, and Montana. This facility operates 19 hours per day.

DC-C is a whole sale apparel distribution center. This distribution center is four years old and is undergoing a major expansion at present. The capacity of DC-C is 50,000 – 60,000 units per day, with two shifts and over 22 hours of operations. DC-C is the major distribution center for the company processing domestic and international orders. There are over 1,000 customers serviced by this distribution center.

DC-D is another a food /grocery retail distribution center. This distribution center is 28 years old and is in the process of moving to a new facility. At the time of interviewing, the company had already completed moving their perishable/frozen sections into the new facility. The capacity of the current facility is 90,000 cases per day. It serves 25 stores in Oregon, Washington, Idaho, Montana, and California.

Finally, DC-E is the largest distribution center among the cases. This distribution center is 21 years old and services 115 stores in Oregon, Washington, Idaho, Montana, Alaska, New Mexico, Nevada, Utah, and Arizona. There are two major facilities included in this distribution center: General Merchandise and Perishable/Frozen Food. Only the General Merchandise distribution center is discussed in this study.

Measurement System

Table 3.4 represents the results of cross-case analysis, which takes data across all sites and draws conclusions. This cross-case analysis provides a view of a typical measurement system used in today's distribution centers. In general, measurement systems in distribution centers are characterized by six categories: Finance, Operations, Quality, Safety, Personnel, and Customer Satisfactions. In the following sections, the findings for each of these categories are detailed.

- **FINANCE**

The first category is Finance, which is a traditional performance measure emphasized over the years. It is clear that Cost per Unit is the most common measurement used in all distribution centers in this study. However, there is some variation associated with this measurement. In DC-A, Cost per Unit is only considered in terms of labor and this information is gathered on the daily basis. DC-C also monitors Cost per Unit on the daily basis by considering a variety of costs (e.g. labor cost, maintenance cost, and distribution cost). For DC-B, Cost per Unit is considered weekly, while DC-D and DC-E consider this measure over 4-weeks periods.

In addition, both DC-A and DC-D use Cost as % of Sale (or Percent to Sale) as a measurement to indicate how well or how many additional sales are needed to make a profit. The other measure used in DC-E is the ratio of expense to the amount of inventory withdrawn and returned for both budget and actual. This measurement gives

Table 3.4 CROSS-CASE ANALYSIS

Distribution Center	DC-A	DC-B	DC-C	DC-D	DC-E
FINANCE	▪ Labor Cost per Piece (Daily) $\frac{\text{Total salary dollars}}{\text{Total pieces processed}}$ ▪ % to Sale (Monthly) $\frac{\text{(Total expense - sales)}}{\text{Sales}}$ or $\frac{\text{Total expenses}}{\text{Sales}}$	▪ Cost per Unit (Weekly) $\frac{\text{Total cost}}{\text{Total units}}$	▪ Total Cost per Piece (Daily) $\frac{\text{Total expenses}}{\text{Total units processed}}$	▪ Cost as % of Sales (4 week & Quarterly) $\frac{\text{Total cost}}{\text{Total sales}}$ ▪ Cost per Piece Shipped (4 week & Quarterly) $\frac{\text{Total cost}}{\text{Total pieces shipped}}$ ▪ Cost per Ton Handled (4 week & Quarterly) $\frac{\text{Total cost}}{\text{Total tons handled}}$ ▪ Average Loaded Wage (4 week & Quarterly) $\frac{\text{Total labors cost *}}{\text{Total hours worked}}$ * Include supervisory and support personnel	▪ Cost per Unit (4 week) $\frac{\text{Total cost}}{\text{Total units}}$ ▪ Ratio of expenses to $ of inventory withdrawn and returned (for both budget and actual) (4 week) $\frac{\text{Actual expenses}}{\text{\$ of inventory withdrawn \& returned}}$ and $\frac{\text{Budgeted expenses}}{\text{\$ of inventory withdrawn \& returned}}$
OPERATIONS					
1. RECEIVING	▪ Productivity Index (Daily) $\frac{\text{Total standard hours}}{\text{Total available hours}}$ ▪ Quality Index (Daily) $1 - \frac{\text{\# of pieces found in error}}{\text{Total \# of pieces sampled}}$	▪ Productivity (Weekly) $\frac{\text{Volume processed}}{\text{Total hours}}$ ▪ Safety (ORI Frequency) (Weekly) $\frac{\text{\# of OSHA recordable incidents}}{\text{Total hours worked}}$ ▪ Quality (Weekly) Risk Analysis Rating	▪ Units (cartons) per Month (Monthly) ▪ Efficiency (Daily) $\frac{\text{Actual time}}{\text{Standard time}}$ ▪ Average $ per unit (Monthly)	▪ Efficiency (Tons per Hour) (Daily & Weekly) $\frac{\text{Total tons received}}{\text{Total man hours}}$	▪ Efficiency (Daily & Weekly) $\frac{\text{Total cases received}}{\text{Total hours}}$ ▪ # of Trailers Unloaded per Day (Daily & Weekly) $\frac{\text{Total \# of trailers unloaded}}{\text{Total \# of days}}$

Table 3.4 CROSS-CASE ANALYSIS (Continued)

Distribution Center	DC-A	DC-B	DC-C	DC-D	DC-E
2. STORAGE	▪ N/A	▪ N/A	▪ Accuracy (Semi-Yearly) ▪ Utilization of Pallet Rack (Monthly) ▪ Utilization of Case Rack (Monthly)	▪ Cube Utilization (% Filled) (Daily & Weekly) $\frac{\text{Total cubic feet occupied}}{\text{Total cubic feet}}$	▪ Reserve Utilization (% of Empty Reserved Space) (Weekly & Daily in busy season) $\frac{\text{\# of pallets positions empty}}{\text{\# of total positions}}$ ▪ Put-Away Performance $\frac{\text{Actual minutes}}{\text{Standard minutes}}$
3. ORDER-PICKING	▪ N/A	▪ Productivity (Weekly) $\frac{\text{Volume processed}}{\text{Total hours}}$ ▪ Safety (Weekly) ▪ Quality (Weekly)	▪ % of orders completed (Daily) ▪ Efficiency (Daily) $\frac{\text{Actual time}}{\text{Standard time}}$	▪ Efficiency (SE Performance) (Weekly & 6-Weeks) $\frac{\text{Total hours worked}}{\text{Scheduled expected hours}}$	▪ Performance Productivity (Daily) $\frac{\text{Actual hours}}{\text{Planned work hours}}$
4. REPACK	▪ Productivity Index (Daily) ▪ Quality Index (Daily)	▪ Department Productivity: SSP (Store Shipped Pack) per Hour (Weekly) $\frac{\text{Actual SSP packed}}{\text{Planned SSP packed}}$ ▪ Team Productivity (Weekly) $\frac{\text{Total SSP packed}}{\text{Hours worked by team}}$ ▪ Safety (Weekly) ▪ Quality (Weekly)	▪ Units (Cartons) per Week (Weekly) ▪ Efficiency (Daily) $\frac{\text{Actual time}}{\text{Standard time}}$	▪ Efficiency (SE Performance) (Weekly & 6-Weeks) $\frac{\text{Total hours worked}}{\text{Scheduled expected hours}}$	▪ Performance Productivity (Daily) $\frac{\text{Actual hours}}{\text{Planned work hours}}$
5. SHIPPING	▪ Productivity Index (Daily) ▪ Quality Index (Daily) ▪ Cost per Piece (Daily) ▪ % to Sales (Monthly)	▪ Productivity (Weekly) = Cartons per Hour or Trailer Filled (Avg. # of Cartons) ▪ Safety (Weekly) • Quality (Weekly)	▪ Total Volume Shipped (Daily) ▪ Quality of Shipping (Daily): The amount of returns, or carrier mis-shipments problems	▪ Efficiency (Daily &Weekly) $\frac{\text{Total tons shipped}}{\text{Total man hours}}$ ▪ Delivery Time (Daily)	▪ Efficiency (Pallet/hour) (Daily) $\frac{\text{Actual pallets shipped}}{\text{Planned pallets}}$

Table 3.4 CROSS-CASE ANALYSIS (Continued)

Distribution Center	DC-A	DC-B	DC-C	DC-D	DC-E
6. MHS	▪ Completion Ratio (Weekly) $\frac{\text{Actual \# of jobs finished}}{\text{Total \# of jobs}}$	▪ Conveyor Uptime (Weekly): Total production time – down time ▪ Sorter Uptime: Production time – down time ▪ Safety Check (Weekly) ▪ % of Orders Completed (Weekly)	▪ System Uptime (Daily): Operation time – down time ▪ % of returns on sorter (Every 6 months) $\frac{\text{\# of packages returned}}{\text{\# of packages processed}}$ ▪ # of garments placed on the tray correctly per person (Every 6 months)	▪ Total Maintenance Cost (4 weeks & Quarterly) ▪ Life Cycle Expectation = Life (years) of equipment	▪ # of Cases per Hour (Sorter) (Continuously, not used) $\frac{\text{Total \# of cases passed}}{\text{Total hours operated}}$ ▪ % of Mis-Sorts (Sorter) (Continuously) $\frac{\text{Total \# of cases mis - sorted}}{\text{Total \# of cases sorted}}$ ▪ Conveyor Down Time: Total minutes down per shift
QUALITY	▪ Quality Index (Daily) $1 - \frac{\text{\# of pieces found in error}}{\text{Total \# of pieces sampled}}$ ▪ % of Sampling (Daily) $\frac{\text{\# of pieces checked}}{\text{Total \# of pieces processed}}$	▪ Risk Analysis Rating (Weekly): (% of the pyramid value as compared to other DCs)	▪ % Defective (Monthly) $\frac{\text{\# of defects}}{\text{Total \# checked}}$ ▪ Vendor Charge Backs (Monthly) ▪ Shortage (Monthly) ▪ Damaged Cartons Shipped (Monthly) ▪ % of Mis-labeled Cartons (Monthly)	▪ # of Mis-Picks per Order per Selector (Daily) ▪ # of Errors per Hour (or per Piece) (Daily) $\frac{\text{Total \# of errors}}{\text{Total picking hours}}$ or $\frac{\text{Total \# of errors}}{\text{Total pieces picked}}$	▪ % Mis-Picked (Daily, Weekly & 4-weeks) $\frac{\text{Total \# of units mis - picked}}{\text{Total \# of units sampled}}$ ▪ # of Cases Damaged per Period: (# of cases thrown away or donated)

Table 3.4 CROSS-CASE ANALYSIS (Continued)

Distribution Center	DC-A	DC-B	DC-C	DC-D	DC-E
SAFETY	▪ # of Accidents (Monthly) ▪ $ Spent on Claims (Monthly)	▪ # of ORI Cases (OSHA recordable incidents) (Weekly) ▪ Operational Behavior's Sampling(%) (Weekly): The week's average of daily safety sampling results for certain behaviors	▪ # of Incidents and Severity (Monthly) ▪ Safety Violation (Monthly) ▪ Loss or Damage to the Equipment (Monthly)	▪ # of Accidents (Yearly) ▪ # of Write-Ups (Internal report of incidents) (Yearly) ▪ $ Spent on Injury Claims (Quarterly)	▪ "% Out of Budget" (Yearly) $\frac{\text{Actual \$ of Workers Comp. Claims}}{\text{Budgeted of \$ for Workers Comp. Claims}}$ ▪ Total # of Accidents (Yearly) ▪ # of Accidents per Injury Type (Yearly)
PERSONNEL	▪ Productivity Index (Daily) ▪ Safety (Monthly) ▪ Attendance (Daily)	▪ Productivity (Weekly) $\frac{\text{Volume Processed}}{\text{Total Hours}}$ ▪ Attendance (Weekly)	▪ Efficiency (Supervisor's opinion) $\frac{\text{\# of pieces processed}}{\text{Total time}}$ ▪ Attendance (Monthly)	▪ Efficiency (for all activity areas) (Weekly) ▪ Attendance (Weekly)	▪ Performance Productivity (Weekly) $\frac{\text{Actual hours}}{\text{Planned work hours}}$ ▪ Attendance (Weekly)
CUSTOMER SATISFACTIONS	▪ Feedback	▪ Feedback	▪ Feedback	▪ Feedback from Stores	▪ Feedback

management the insight concerning how well their budget is controlled. In all five distribution centers, all of the financial measurements are used by management.

▪ OPERATIONS

In Operations category, there are six functional measurement areas included: Receiving, Storage, Order-Picking, Repack, Shipping, and Material Handling System (MHS). Each area is reviewed in detail below:

- Receiving: In Receiving, either productivity or efficiency measures are used by all of the distribution centers to evaluate their receiving performance. Theoretically, productivity is defined as "the ratio of output to input" (Sink, 1985; Riggs and West, 1986). Actually, for DC-B, DC-D, and DC-E, the measurements used to describe the performance of receiving are partial productivity measures. Partial productivity measures are productivity measures which only consider one form of input. However, while using partial productivity measures to describe their receiving performance, DC-D and DC-E labeled the measurements as efficiency instead of productivity. On the other hand, DC-A uses efficiency to monitor receiving performance but uses the term "productivity index" to describe this measure. Efficiency is the degree to which the system utilizes the "right" things and is traditional defined as the ratio of resources expected to be consumed to resources actually consumed (Sink, 1985). Interestingly, DC-C actually uses the reciprocal of

efficiency to measure the performance of receiving but labels this metric as efficiency.

- Storage: For Storage, DC-A and DC-B do not have specific measures to evaluate this function. DC-C uses the "Accuracy", which is defined as the variance between actual and theoretical inventory level, to measure the Storage function. In addition, utilization of pallet rack and case rack is also used to monitor the efficiency of storage space in DC-C. DC-D uses a similar measure: "cube utilization" to evaluate their space utilization. In addition to the utilization of storage space, "Put-Away" performance, which is a kind of efficiency measure, is also applied to the storage function in DC-E.

- Order-Picking / Repack / Shipping: For Order-Picking, Repack, and Shipping functions, both productivity and efficiency measures are the common criteria to measure the performance. For Order-Picking and Repack, all productivity measures are actually reciprocals of the traditional efficiency definition. For Shipping, as previously discussed in the receiving function, DC-D and DC-E are actually measuring partial productivity measures for their receiving function but they are labeling these as efficiency measures. In addition, DC-C uses the percentage of order completed to monitor the performance of Order-Picking. All these measurements are used by either supervisors or management personnel to monitor the process and give an indication of how much more effort is needed to catch up their yield numbers. At the same time, to some degree, this information is shared with the operators to motivate morale to improve the productivity of the facility.

- Material Handling System (MHS): For the Material Handling Systems, the common measure used is machine uptime or downtime. The job completion ratio and the total maintenance cost are also used as an indication of performance of the MHS. This information is shared with maintenance department and integrated into the Prevent Maintenance (PM) program.

▪ QUALITY

Common measures used to track quality come in the form of the percentage of "errors", such as the occurrence of mis-picked, mislabeled, or number of defects found. In addition, DC-C uses "shortages" of counted goods as a quality indicator. DC-A uses sampling to develop a Quality Index. The Quality Index is defined as one minus the percentage of the sample found to be in error. The most unique quality measure is found in DC-B. DC-B uses a Risk Analysis Rating as a tool to measure quality. In the beginning of the fiscal year, the corporation will establish the Risk Analysis Rating goal of the year. Based on the best practices of all distribution centers owned by this company, a benchmarking algorithm is set this goal. For each area (i.e., function or department), the performance of each distribution center will be compared with the benchmark distribution center in the form of a percentage. Thus, the best performing distribution center among all of their distribution centers will be rated as 100%. The other distribution centers' performance will be scaled relative to this best practice. The overall performance for the entire corporation is determined by considering the average of the individual distribution center's score for a particular function. This corporate

average is known as the pyramid value and is shared with each distribution center. The results of these benchmarking are shared with the distribution centers utilizing the concept of a traffic light. If a measure is shaded red, this implies there is an alert in the performance level and special attention is critical. Yellow means that special attention is needed to address the issue. Green means everything is great and under control. The pyramid values give the indication of overall performance. This system is the most systematic approach to measuring quality among all of the distribution centers in this study. However, this system would not be appropriate for every distribution center. The comparison is only meaningful if they can be compared on a common basis. All distribution centers owned by DC-B's corporation are standardized with the same facility layout, the same processing procedures, and the same organizational structure. This standardization provides the basis for the pyramid values.

- **SAFETY**

There is a high degree of consistency across the cases for safety measurement. The number of accidents is used as a key measure for all of the distribution centers. Some distribution centers, like DC-B, also uses sampling to check for certain operations related behaviors every week to monitor safety. Similarly, in DC-C and DC-D, safety violations or incidents are tracked every month to monitor the safety of facility. DC-E also characterizes the accidents into different injury types to help reduce the operation-related injuries. All the safety-related information is shared with all management and all employees. Management uses this information to address safety issues such as the layout

of workstations, and work instructions. They seek better solutions to prevent work-related injuries.

- **PERSONNEL**

The criteria to evaluate employee performance across all five distribution centers are identical: Productivity (or Efficiency) and Attendance. Except for these two measurements, DC-A points out that Safety and Teamwork Flexibility are also qualities to look for when evaluating the performance of employees. These measurements provide the basis for the management to review employees. Some information, such as productivity, is shared with the employees individually.

- **CUSTOMER SATISFACTION**

Unfortunately, measures of customer satisfaction were limited for both external and internal customers. The only information reveled in this study is the feedback from customers on a case by case basis. No specific statistics were tracked to indicate the level of customer satisfaction.

SUMMARY

Based on the results from this study, the measurement systems found were very consistent across all five cases. Some general findings include:

1. Most distribution center in most categories measured productivity or efficiency. However, the terms productivity and efficiency were often not used to represent the traditional definitions of these terms (Sink, 1985; Riggs and West, 1986).
2. The greatest opportunity for improvement appears to be in the area of customer satisfaction measures.
3. Safety was the most consistently measured category. However, this is likely due to legal requirements.
4. DC-B was the only distribution center that uses three measures (productivity, quality, and safety) across all the functions.

When the results were compared based on the characteristics provided by Table 3.3, it was also found that there was no significant difference in the measurement systems among the distribution centers. In other words, distribution center characteristics, such as the type of industry, capacity of the center, union/non-union environment, or the years of operation, do not have significant impact on the measurement systems.

As a result, a good performance measurement system supports sound management decisions. A performance measurement system is effective if it provides high quality, reliable, and timely information to influence management decisions and employee behavior. While the measurement systems found in these cases were for the most part traditional, they do provide some information to support decision making.

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CHAPTER 4

EVALUATION OF PERFORMANCE MEASUREMENT ATTRIBUTES IN DISTRIBUTION CENTERS

ABSTRACT

The objective of this paper is to share the results of a cross-case analysis focused on performance measurement in distribution centers. This paper will review a comprehensive framework for performance measurement system as defined by Clark (1995). Clark's framework integrated current thinking on measurement systems from a variety of sources. This framework is used to assess the performance measurement systems of five distribution centers in the Northwest and to compare these with state-of-the-art theory on performance measurement.

INTRODUCTION

In today's changing environment, measurement systems play an important role in achieving organizational objectives and consequently, in accomplishing transformations to world class organizations. Organizational performance measurement is an issue requiring attention in any large-scale organizational effort (Akao, 1991; Deming, 1993; Hackman, 1990; Harris, 1994; Sink, 1982; Sink and Tuttle, 1985). The objective of this research is to link the performance measurement systems used in today's distribution centers with a comprehensive list of normative attributes for measurement systems (Clark, 1995). The strengths and opportunities for improvement of current measurement systems used in distribution centers are identified and discussed.

MEASUREMENT SYSTEMS

Clark's (1995) research on organizational performance measurement began with identifying normative measurement system attributes. Normative is an adjective describing "characteristics that constitute an authoritative standard; an ideal or preferred condition" (American Heritage, 1993). Collectively, these attributes represent a normative view of the characteristics a measurement system should possess from a variety of sources. These attributes can be further classified into seven categories: Measurement System Design Process, System Linkages, Feedback, Portrayal, Information Attributes, Balanced Scorecard, and the Study-Act part of the Plan-Do-Study-Act Cycle. Table 4.1 shows the seven categories along with a brief explanation of

Table 4.1 Explanation of Normative Measurement System Attributes

Category	Explanations
Measurement System Design Process	
1. Participative	▪ The measurement system is developed participatively with wide input (Mali, 1978; Meyer, 1994; Morris, 1975; Morris, 1979; Thor, 1993). ▪ If measurement is pervasive in organizations and represents a significant goal, it also must be the primary goal of the individual managers or supervisors (Mali, 1978).
2. Dynamic / Flexible	▪ The measurement system is flexible and dynamic and responsive to changes in the environment or user needs over time; people should feel they could influence what is measured (Bain, 1982; Dixon, Nanni, & Vollmann, 1993; Grief, 1989; Lynch & Cross, 1991; Kaplan, 1986; Kurstedt, 1992; Sink & Tuttle, 1989; Sink & Smith, 1992; Thor, 1993).
System Linkages	
3. Individual Measures	▪ Measures include individual, group and organizational level Key Performance Indexs (Cameron & Whetton, 1981; Cummings, 1980; Dansereau, Alutto, & Yammarino, 1984; Deming, 1986; Pennings & Goodman, 1977; Price, 1968; Scherkenbach, 1991; Sink & Smith, 1992; Thor, 1993; Van de Ven & Ferry, 1980).
4. Group Measures	▪ Measures include individual, group and organizational level Key Performance Indexs (Cameron & Whetton, 1981; Cummings, 1980; Dansereau, Alutto, & Yammarino, 1984; Deming, 1986; Pennings & Goodman, 1977; Price, 1968; Scherkenbach, 1991; Sink & Smith, 1992; Thor, 1993; Van de Ven & Ferry, 1980).
5. Organization Level Measures	▪ A measurement system should foster system cooperation, rather than internal competition and sub-optimization (Deming, 1986; Scherkenbach, 1991) ▪ The system of performance measures should reflect the different needs and perspectives of managers and leaders at various levels of the organization (Sink & Smith, 1992).
6. Upline System Level	▪ Measures should include upline or larger system measures so people in the organizational subsystem can see how their measures link to the measures at the next higher level (Deming, 1986; Sink, 1985; Sink & Tuttle, 1989).
7. Appropriate Aggregation Among Levels	▪ Measures are mathematically aggregated to higher levels of analysis using common denominators where appropriate (Adam, Herschauer, & Ruch, 1986; Dansereau, Alutto, & Yammarino, 1984; James, 1982; James & Jones, 1974; Kaplan, 1986; Morris, 1975).
8. Complete Functional Coverage	▪ The measurement system provides a set of measures for every organizational component; all areas have measures (Dixon, Nanni, & Bollmann, 1990).

Table 4.1 Explanation of Normative Measurement System Attributes (Continued)

Feedback	
9. Knowledge of Results	▪ The measurement system indicates both the progresses of planned organizational changes and changing results over time (Cosgrove, 1986-7; Sink & Tuttle, 1989).
10. Knowledge of Progress	▪ The measurement system provides feedback to individuals and groups (Blumberg & Pringle, 1982; Hackman & Oldham, 1980; Khadem & Lorber, 1986; Smith, 1978; Waldman & Spangler, 1989).
Portrayal	
11. Visibility	▪ The measurement system should be highly visible to users (Grief, 1989; Provost & Leddick, 1993).
12. Longitudinal Data	▪ The measurement system should portray data longitudinally, to allow for analysis of time series, business, cycles, and other patterns in the data (Deming, 1986; Deming, 1993; Joiner, 1992; Provost & Leddick, 1993; Shewhart, 1980; Wheeler, 1993).
13. Graphical Portrayal	▪ The measurement system should portray data graphically, pictorially, rather than portraying only tables of numbers; a picture of the data is worth 10,000 tables (Deming, 1986; Deming, 1993; Joiner, 1992; Provost & Leddick, 1993; Shewhart, 1980; Wheeler, 1993).
14. Statistical Analysis and Understanding Variation	▪ The measurement system should portray data Statistically and permit statistical analysis to distinguish signal from noise (Deming, 1986; Deming, 1993; Joiner, 1992; Provost & Leddick, 1993; Shewhart, 1980; Wheeler, 1993; Wickens, 1987). ▪ Only statistical analysis can separate potential signals from ever-present noise.
15. Clearly Operational Definition	▪ The measurement system should clearly define performance and other key measurement terms in ways that all users can develop common understanding of the measures (Sink, 1985; Sink & Tuttle, 1989; Deming, 1986; Sink & Smith, 1993; Whyte, 1990). ▪ Poor definitions generate misleading measurements, which, added together, yield misleading conclusions (Whyte, 1990).
16. Appropriately Simple	▪ The measurement system should be appropriately simple (Adam, Herschauer, & Ruch, 1986; Bain, 1982; Dixon, Nanni, & Vollmann, 1990; Grief, 1989; Meyer, 1994). ▪ Performance measurement systems should convey information through as few and as simple a set of measures as possible (Dixon, Nanni, &Vollmann, 1990). ▪ A measurement system should be simple enough for the users to be able to use it as an effective management tool. Interpretation of results must be easy for everyone; simplify computations and portrayals wherever possible (Grief, 1989).

Table 4.1 Explanation of Normative Measurement System Attributes (Continued)

Information Attributes	
17. Timely	▪ A measurement system should be timely (regular and frequent); measures should include shiftly, daily, weekly, monthly frequency as appropriate (Provost & Leddick, 1993). ▪ A measurement system should adequately address the issues of accuracy, timeliness, relevance, and completeness for the data and information provided (Burch & Grudnitski, 1986; Hill, 1989). ▪ Timelines ensures that data is provided soon enough for action to be taken when problems arise (Bain, 1982).
18. Relevant	▪ A measurement system should adequately address the issues of accuracy, timeliness, relevance, and completeness for the data and information provided (Burch & Grudnitski, 1986; Hill, 1989). ▪ A measurement system should allow all members of the organization to understand how their decisions and activities affect the entire business (Dixon, Nanni, & Vollmann, 1990).
19. Accurate	▪ A measurement system should adequately address the issues of accuracy, timeliness, relevance, and completeness for the data and information provided (Burch & Grudnitski, 1986; Hill, 1989). ▪ Accuracy refers to information's freedom from error (Hicks, 1984).
20. Completeness	▪ There is normally an inability to capture all information inputs, but there is a need for completeness in the measurements. The solution to this dilemma lies in recognizing what must be included, not for a perfect or totally complete measure, but to provide a meaningful measure in which we can be reasonable confident (Bain, 1982).
Balanced Scorecard	
21. Balanced Criteria	▪ Measures reflect balance across dimensions of performance or performance criteria (Grief, 1989; Kaplan, 1983; Kaplan & Norton, 1992; Lynch & Cross, 1991; Sink, 1982, 1985; Thor, 1993). ▪ Accounting information alone is not sufficient to measure the performance of an organization (Cosgrove, 1986-87).
22. Systems View	▪ Measures reflect balance across a system view of the organization (Deming, 1986; Grief, 1989; Imai, 1986; Kaplan & Norton, 1992, Lynch & Cross, 1991; Meyer, 1994; Provost & Leddick, 1993; Sink & Smith, 1992; Sink & Tuttle, 1989).
23. Customer	▪ Measures emphasize the customer (Dixon, Nanni, & Vollmann, 1990; Lynch & Cross, 1991; Thor, 1993). ▪ Performance measurements systems should reveal how effectively customers' needs and expectations are satisfied by focusing on measures that customers can see (Dixon, Nanni, & Vollmann, 1990).
24. Qualitative	▪ The measurement system should balance quantitative and qualitative approaches (Dalton, Todor, Spendolini, Fielding, & Porter, 1980; Deming, 1986; Sink & Tuttle, 1989).

Table 4.1 Explanation of Normative Measurement System Attributes (Continued)

25. Quantitative	▪ The measurement system should balance quantitative and qualitative approaches (Dalton, Todor, Spendolini, Fielding, & Porter, 1980; Deming, 1986; Sink & Tuttle, 1989).
Study-Act Part of PDSA	
26. Integrated SAM (Strategies, Actions, and Measures)	▪ The measurement system links strategies, actions and measures through a formal process (Akao, 1991; Bain, 1982; Dixon, Nanni, & Vollmann, 1990; Grief, 1989; Kaplan, 1986; Mali, 1978). ▪ The measurement system creates visibility for sub-system performance and visibility for linkages to overall system performance (Sink & Smith, 1993). ▪ The measurement system fosters system cooperation, rather than internal competition and sub optimization (Deming, 1986; Scherkenbach, 1991). ▪ The measurement system allows all members of the organization to understand how their decisions and activities affect the entire business (Dixon, Nanni, & Vollmann, 1990). ▪ An organization's system of performance and productivity measures should be designed to support and complement the organization's mission and its objectives (Sink & Smith, 1992). ▪ Improved alignment between an organization's strategies, actions, and measures appears to be a critical element of producing competitive results in the 1990's and beyond (Dixon, Nanni, and Vollmann, 1990).
27. Formal PDSA (Plan, Do, Study, and Action)	▪ The measurement system should promote the study-act part of the Plan-Do-Study-Act (PDSA) cycle at all system levels (Deming, 1986; Dixon, Nanni, & Vollmann, 1990; Dixon, Nanni, & Vollmann, 1993; Kaplan & Norton, 1992; Scherkenbach, 1991; Sink & Smith, 1992). ▪ The measurement system supports organizational learning and continuous improvement (Dixon, Nanni, & Vollmann, 1990; Dixon, Nanni, & Vollmann, 1993; Kaplan & Norton, 1992). ▪ The measurement system balances reporting, control, and improvement (Sink & Tuttle, 1989; Thor, 1993). ▪ The measurement system is a catalyst for performance improvement (Dixon, Nanni, & Vollmann, 1993).

the attributes in each category. While the information in Table 4.1 has its origin in Clark's (1995) work, this information has been restructured to more closely link the categories with Normative Attributes.

Measurement System Design Process

Measurement can not solely be the responsibility of top management in an organization. A good measurement system should be developed participatively with wide input (Mali, 1978; Meyer, 1994; Morris, 1975; Morris, 1979; Thor, 1993). The flow of accountability for performance measurement starts with top management, through to the line managers, and continues to the employees on the shop floor. Since everyone benefits from productivity, productivity improvement is everyone's responsibility, not solely management's. If measurement is pervasive in organizations and represents a significant goal, it also must be the primary goal of the individual managers or supervisors (Mali, 1978).

Meanwhile, the measurements of performance should be flexible and dynamic, responsive to the needs of the environment. A common complaint about measurement systems is that performance measures lag behind business changes. The old measures no longer reflect the varying diversity and complexity of the output. This tends to distort output and productivity measures. In other words, specific productivity or performance measures rarely remain useful with the passage of time due to changes within the organization and its operating environment (Sink & Smith, 1992), and thus need to be re-visited as the situation demands.

System Linkages

Attributes included in this category include individual, group, and organization level measures, as well as measures that define appropriate linkages and aggregation among measures at the sub-system level. The system of performance measures should reflect different needs and perspectives of managers and leaders at various levels of the organization (Sink and Smith, 1992). Thus a good measurement system should include individual, group, and organizational level key performance measures. These measures should also involve upline or larger system measures so people in the organizational subsystem can see how these measures link to the next higher levels of the organization.

A measurement system that is aligned with organizational goals should ideally include some measures that can be aggregated from the lowest to the highest levels of analysis. However, some measures normally exist at each level of the organization; it is seldom possible to aggregate these measures from one level to the next. In an ideal measurement scheme, at least some measures could be aggregated or disaggregated by organizational level (Adam, Herschaure, & Ruch, 1986).

A measurement system should provide a set of measures that cover all the functional areas in an organization. As a result, the measurement system would provide an integrated, comprehensive, and complete picture of an organization's performance.

Feedback

A good measurement system should provide feedback to individuals and groups so that they can continue to perform well or redirect their efforts to get performance back on track. Two attributes, results of knowledge and knowledge of progress, are included for this purpose. The importance of knowledge about results is well established in the literature (Clark, 1995). The employees should also be regularly told of their improvements (i.e. knowledge of progress) by management.

Portrayal

The attributes for a measurement system included in this category are visibility, longitudinal data, graphical portrayal, statistical analysis, clear operational definitions, and simplicity. Being able to visually see the requirements and expectations of daily work would encourage the employees to develop motivation and versatility. Sharing information at all organization levels would improve the system's performance dramatically (Grief, 1989).

A measurement system should portray data longitudinally to allow the analysis of time series, cycles, and other patterns in the data (Deming, 1986; Deming, 1993; Joiner, 1992; Provost & Leddick, 1993; Shewhart, 1980; Wheeler, 1993). Data should be also presented graphically and pictorially to help the user to adapt the information for their use more effectively and efficiently (Tufte, 1983). In general, a graph is considered superior to numbers, tables, or scales if the shape of the depicted function is important for

decision-making or when interpolation is necessary (VanCott & Kinkade, 1972). Also, to distinguish the assignable causes from the random noise, portraying the data statistically and understanding the variations are important.

A clearly defined operation, performance, and other key measurements could help the users to have a better understanding of the measures and their impact on the system's performance. As measurement is driven by definitions, poor definitions usually generate misleading measurements, which consequently lead to misleading conclusions (Whyte, 1990). The operational definitions should be specific enough so that actual data source and computational methods are identified. The measurement system should also be simple enough for the designed users to use, understand, and make good decisions.

Information Attributes

Information-based attributes include timeliness, relevancy, accuracy, and completeness. Timeliness ensures that data is provided soon enough for action to be taken when problems arise. Whereas continuous, or real time, productivity measurement may not be practical, the system would preferably be designed to recognize and communicate, to those directly responsible, significant exceptions at least on a daily basis (Bain, 1982). A measurement should adequately address the issues of relevancy and accuracy, to allow all members of the organization to understand how their decisions and activities affect the entire business. While it is normally impossible to capture all information inputs, there is a need for completeness in the measurements. One possible solution to this dilemma is to recognize that the information included is a meaningful

measure in which the managers are reasonably confident compared to a perfect or totally complete measure (Bain, 1992).

Balanced Scorecard

This category focuses on the completeness and trades off among the attributes in a measurement system. As mentioned by Kaplan and Norton (1992), "What you measure is what you get". Managers understand that traditional financial accounting measures, like return-on-investment and earnings-per-share, can give misleading signals for continuous improvement and innovation activities that today's competitive environment demands. The traditional financial performance measures worked well for the industrial era, but they are out of step with the skills and competencies companies are trying to focus on today. As managers and academic researchers have tried to remedy the inadequacies of current performance measurement systems, some have focused on making financial measures more relevant. However, managers should not have to choose between financial and operational measures. It is realized that no single measure can provide a clear performance target to focus attention on the critical areas of a business. Neither can a common set of measures be used to assess and compare performance and productivity at all levels of an organization (Sink and Smith, 1992). Managers want a balanced presentation of both financial and operational measures to accurately represent today's business and technical environment. A good measurement system should also focus on every system aspect to achieve the balance across the organization from a system's viewpoint. In addition to the system aspects, a good measurement system

should focus on customer needs. Furthermore, a number of measures are hard to quantify. Such qualitative measures should be adequately addressed and interpreted in a measurement system.

Study-Act Part of Plan-Do-Study-Action (PDSA)

A performance measurement system should be aligned with and serve organizational goals or purposes. The organization's goals must be fully understood and internalized by the members of the organization. Only then will the measurements can be designed and implemented with regard to the organization's goals (Bain, 1982). A measurement breakdown structure indicates relationships and linkages among measures at various levels of analysis. The highest level of the breakdown structure may be taken as performance criteria (e.g. effectiveness, efficiency, or productivity), other measurement perspectives (e.g. customer, environment, or internal), or even functional domains (e.g. warehouse, transportation, or shipping). These measurement breakdown structures were emphasized to encourage people to adopt a system view of their entire set of key performance indicators. It is believed that portraying a vector of measures and their relationships is necessary to inhibit sub-optimization of some measures at the expense of others (Dixon, Nanni, and Vollumann, 1991; Morris, 1975; Sink and Smith, 1993; Thor, 1985). As a result, a good performance measurement system should link strategies, actions, and measures through a formal process (Grief, 1989; Bain, 1982; Dixon, Nanni, and Vollmann, 1990; Mali, 1978; Kaplan, 1986).

It has also been pointed out that at any given sub-system level, and at all levels collectively, organizations were not very good at the study-act part of Deming/Shewhart Plan-Do-Study-Act (PDSA) cycle (Sink and Smith, 1992). This results in the lack of supporting organizational learning and continuous improvement. The PDSA is a generic model of how to improve quality by involving problem solving and learning. In the plan phase, a plan is developed to determine what changes and resources are needed to solve the problem. In the do phase, the plan is carried out. Then the results are studied in the study phase. Finally the action is taken based on what was learned from the study. A new cycle of learning is again started. Any problem-solving effort involves multiple cycles of PDSA. Each cycle leads to new knowledge. Therefore, a good measurement system should promote the study-act part of the PDSA cycle at all system levels (Deming, 1986, 1993; Scherkenbach, 1991).

Historical Development of Measurement Systems

Based on the normative attributes in Table 4.1, Table 4.2 summarizes the measurement system attributes as developed and used by various researchers. Obviously, different research and theories favor different attributes, and there is no single measurement system that satisfies all attributes. From 1970 to 1980, measurement systems mainly focused on the process design phase and linkages of measurement systems. Only Smith (1978), and Hackman and Oldham (1980) emphasized the feedback aspect of a measurement system. Shewhart (1980) advocated the importance of portrayal characteristics in measurement systems. In the early eighties, the focus of

Table 4.2 Reference for Normative Measurement System Attributes (Adapted from Clark, 1995)

		Participative	Dynamic	Individual	Group	Organization	Upline	Aggregation	Coverage	Results Knowledge	Progress Knowledge	Visibility	Longitudinal	Graphical	Statistical	Clearly defined	Simple	Timely	Relevant	Accurate	Complete	Balanced criteria	Systems view	Customer	Qualitative	Quantitative	Integrated SAM	Formal PDSA
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
Price	1968			√	√	√																						
James & Jones	1974							√																				
Morris	1975	√						√																				
Pennings & Goodman	1977			√	√	√																						
Mali	1978	√																									√	
Smith	1978									√	√																	
Morris	1979	√																										
Cumming	1980			√	√	√																						
Dalton, Todor, Spendolini, Fielding, & Porter	1980	√	√																									
Hackman & Oldham	1980									√	√																	
Shewhart	1980												√	√	√													
Van de Ven & Ferry	1980		√	√	√																							
Cameron & Whetton	1981			√	√	√																						
Bain	1982		√														√	√									√	
Blumberg & Pringle	1982									√	√																	
Deming	1982			√	√	√	√						√	√	√	√							√		√	√	√	√
James	1982							√														√						
Sink	1982																											
Dansereau, Alutto, & Yammarino	1984			√	√	√		√																				
Hicks	1984																	√	√	√	√							√
Sink	1985	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√					√	√	√	√	√		
Adams, Hershauer, & Ruch	1986							√									√											
Burch & Grudruitski	1986																	√	√	√	√							
Cosgrove	1986										√											√						
Imai	1986																						√					
Kaplan	1986		√					√														√					√	√
Khadem & Lorber	1986									√	√																	

Table 4.2 Reference for Normative Measurement System Attributes (Continued) (Adapted from Clark, 1995)

		Participative	Dynamic	Individual	Group	Organization	Upline	Aggregation	Coverage	Results Knowledge	Progress Knowledge	Visibility	Longitudinal	Graphical	Statistical	Clearly defined	Simple	Timely	Relevant	Accurate	Complete	Balanced criteria	Systems view	Customer	Qualitative	Quantitative	Integrated SAM	Formal PDSA
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
Helander	1987											√		√														
Senn	1987																	√	√	√	√							
Wickens	1987												√		√													
Grief	1989		√									√					√					√	√				√	
Hill	1989																	√	√	√	√							
Sink & Tuttle	1989	√	√	√	√	√	√			√	√					√						√	√		√	√		√
Waldman & Spangler	1989									√	√																	
Dixon, Nanni, & Vollumann	1990		√						√								√	√	√	√	√			√			√	√
Akao	1991																										√	
Lynch & Cross	1991		√																			√	√	√			√	
Scherkenbach	1991			√	√	√																					√	√
Joiner	1992												√	√	√													
Kaplan & Norton	1992																					√	√					√
Kurstedt	1992		√																			√						
Deming	1993			√	√	√	√						√	√	√	√							√		√	√	√	√
Dixon, Nanni, & Vollumann	1993		√						√															√			√	√
Provost & Leddick	1993											√	√	√	√			√				√	√					
Sink & Smith	1993		√	√	√	√										√						√	√				√	√
Thor	1993	√	√	√	√	√																√		√				
Wheeler	1993												√	√	√													
Harris	1994																					√	√					
Meyer	1994	√															√						√					

measurement systems seemed to move from the measurement system design process and system linkages to feedback and portrayal. According to Deming (1982), a good measurement system should integrate the portrayal characteristics, measurement system design process, and system linkage, and have a blend of both qualitative and quantitative information. Later in 1985, Sink espoused the idea that the best measurement systems have a blend of the objective with the subjective, quantitative with qualitative, intuitive with explicit, hard with soft, and judgement with decision rules or even artificial intelligence. From the late eighties to early nineties, an increased focus has been placed on having multiple dimensions of measurement systems. Numerous researchers advocate the importance of balancing the criteria throughout the organization and placing the customers as the first priority.

CASE STUDY APPLICATION

A series of case studies were conducted to study the measurement systems used in today's distribution centers. Five distribution centers in the Pacific Northwest were selected for this study. In order to provide a better understanding, Table 4.3 summarizes general information about each of the five distribution centers.

DC-A is a retail distribution center, which belongs to a chain department store. Common goods processed in this DC include garments, shoes, cosmetics, gifts, and jewelry. DC-A has operated for 18 years and services 22 stores in Oregon, Washington, and Alaska.

Table 4.3 Summary of Characteristics of Distribution Centers

Distribution Center	A	B	C	D	E
1. Type of industry	Retail	Retail	Wholesale	Retail	Retail
2. Average Number of Goods Distributed	4,000 – 6,000 cartons/day	50,000 cartons/day	50,000-60,000 units/day	90,000 cases/day	800,000 units/day
3. Number of Shifts (on floor)	2	2	2	3	3
4. Union/Non-Union	Non-Union	Non-Union	Non-Union	Union	Union
5. Labeling / Repack	Yes	Yes	Yes	Small Repack No Labeling	Yes
6. Number of Employees	296	400	230	230	800* *Including drivers and temporary employees
7. Stores Serviced	22	40	Over 1,000	25	115
8. Years of Operation	18	1 ½	4	Site 1: 28 years Site 2: 1 year	21
9. Building Size	320,000 ft^2 (2 levels)	616,140 ft^2	265,000 ft^2 (3 levels)	Site-1: 250,000 ft^2 Site-2: 267,000 ft^2 (Perishable only)	1,000,000 ft^2 (only for general merchandise DCs)

DC-B is a retail distribution center belonging to a supermarket chain. This supermarket chain owns 10 distribution centers in the United States. DC-B is a new facility, which had its grand opening one and a half years ago. The main commodities processed in this distribution center are grocery items, apparel, office supplies, electronics, and toys. No perishable items are distributed by DC-B.

DC-C is a whole sale apparel distribution center. This distribution center is four years old and is undergoing a major expansion at present. The capacity of DC-C is 50,000 – 60,000 units per day, with two shifts and over 22 hours of operations. DC-C is the major distribution center for the company processing domestic and international orders. There are over 1,000 customers serviced by this distribution center.

DC-D is another a food /grocery retail distribution center. This distribution center is 28 years old and is in the process of moving to a new facility. At the time of interviewing, the company had already completed moving their perishable/frozen sections into the new facility. The capacity of the current facility is 90,000 cases per day. It serves 25 stores in Oregon, Washington, Idaho, Montana, and California.

Finally, DC-E is the largest distribution center among the cases. This distribution center is 21 years old and services 115 stores in Oregon, Washington, Idaho, Montana, Alaska, New Mexico, Nevada, Utah, and Arizona. There are two major facilities included in this distribution center: General Merchandise and Perishable/Frozen Food. Only General Merchandise distribution center is discussed in this study.

The measurements used in these five distribution centers are classified into six categories: Finance, Operations, Quality, Safety, Personnel, and Customer Satisfaction. In the following section, the assessment of measurement systems used in these five distribution centers is discussed.

ASSESSMENT OF MEASUREMENT SYSTEM IN DISTRIBUTION CENTERS

The results of comparing the normative attributes to the measurement systems used in the five distribution centers are summarized in Table 4.4. The rows of Table 4.4 consist of seven categories with 27 normative attributes as shown in Table 4.2. The columns are measurement components used in distribution centers, including finance, operations, quality, safety, personnel, and customer satisfaction.

It is clear that the safety is the most significant measurement component in all the distribution centers. There is a high degree of consistency across the cases for safety measurement. The number of accidents is used as a key measure in all the distribution centers. Almost every distribution center's safety measurement systems match the normative attributes except for the study-act part of PDSA. Only DC-A and DC-B use a formal PDSA cycle to track the performance of safety. Whenever there is an accident occurrence, in addition to filing necessary reports and action required by the government, DC-A also studies and documents the potential causes of the accidents. Then a seminar or other short communication speech takes place to discuss the results with the employees. In DC-B, two safety behaviors are picked every month. Each behavior is

Table 4.4 Comparison between Normative Attributes and the Measurement Systems of Distribution Center Components

Category	Attributes	Distribution Centers Measurement System					
	A: DC-A B: DC-B C: DC-C D: DC-D E: DC-E	Finance	Operations	Quality	Safety	Personnel	Customer Satisfaction
Measurement System Design Process	1. Participative		B	A,B	A,B	A,B,E	
	2. Dynamic / Flexible				A,B,C, D, E		
System Linkages	3. Individual		A, D		A,B,C, D, E	A,B,C, D, E	
	4. Group		B	A, B	A,B,C, D, E	B	
	5. Organization	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E		
	6. Upline		A,B	A, B	A,B,C, D, E		
	7. Aggregation	A,B,C, D,E		B	A,B	B	
	8. Coverage	A,B,C, D,E	C,D,E	A,B	A,B,C, D,E	A,B,C, D,E	
Feedback	9. Results Knowledge	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	
	10. Progress Knowledge		A,B,C, D, E	A,B,C	A,B,C, D, E	A,B,C, D, E	
Portrayal	11. Visibility		B	B	B	A	
	12. Longitudinal	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	
	13. Graphical		B	B	B		
	14. Statistical		A,B,C, D, E	A,B,C	A,B,C, D, E		
	15. Clearly defined	A,B,C, D, E	A,B,C, D, E	A,B	A,B,C, D, E	A, C,D, E	
	16. Simple		A,B,C, D, E	B	A,B,C, D, E		
Information Attributes	17. Timely	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	
	18. Relevant	A,B,C, D,E	A,B,C, D,E	A,B,C, D, E	A,B,C, D,E	A,B,C, D,E	
	19. Accurate	A,B,C, D,E	A,B,C, D,E	A,B,C, D, E	A,B,C, D,E	A,B,C, D,E	
	20. Complete	A,B,C, D,E	A,B,C, D,E	A,B,C, D, E	A,B,C, D,E	A,B,C, D, E	
Balanced Score Card	21. Balanced criteria						
	22. Systems view	B	B	B	B		
	23. Customer						
	24. Qualitative						
	25. Quantitative	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	A,B,C, D, E	
Study-Act Part of PDSA	26. Integrated SAM		B	B	B		
	27. Formal PDSA					A,B	

observed and investigated. The results are shared with all team members to improve safety.

It is no surprise that the main focus of financial measurement is at the aggregate or organizational level. A high degree of consistency on the financial measurement is found across the five distribution centers. All the distribution centers use cost per unit as a major indicator of financial performance; this provides full coverage of information attributes (i.e. timeliness, relevancy, accuracy, and completeness).

Similarity is also found in the measures used in the Operations category. Productivity and efficiency measures are used in all five distribution centers across all functions of operations. These two measures give management the capability to track the performance of operations in a timely and relevant manner. Thus, the information attributes are fully satisfied. Feedback information is also supported in operation measurements through continuously interactive communication between employees and management.

An emphasis is placed on some of the system linkage attributes, information, and feedback for the quality dimension for the five distribution centers. However, only DC-B encourages all employees to be involved with the quality measurement, focuses on team (or group) quality, and applies the visibility attribute to quality measurement. For example, DC-B has the graph posted to show the current level of quality, milestones, and comparison with other distribution centers within the same corporation.

As to the personnel component, all five distribution centers consider the attributes of feedback (i.e. results of knowledge and progress knowledge) and information (i.e. timeliness, relevancy, accuracy, and completeness) to be important. Emphasis exists on coverage, longitudinal portrayal, and quantitative attributes. All distribution centers investigated in this study record the attendance and efficiency of employees.

Measurement systems in the distribution centers studied did not emphasize customer satisfaction using a formal process. This does not imply that customer satisfaction is not important. For example, whenever there is an issue, customers call and the problem is fixed. In other words, customer complaints are handled on a one-to-one basis and there is no formal mechanism to handle such complaints.

If examining the measurement systems used in these distribution centers in terms of normative attributes (i.e. from a row perspective of Table 4.4), it is obvious that all information attributes are satisfied across all components, except for customer satisfaction. Measurements used in finance, operations, quality, safety, and personnel generally provide with timely, relevant, accurate, and complete information. For example, the finance reports are generated on the regular basis (i.e. monthly or quarterly) providing timely information to the management. Personnel measurements, such as productivity, efficiency, and attendance, are used in all five distribution center to provide appropriate and timely information to help management supervise performance of employees.

Since all the measurement data are collected in a continuous basis, this allows for time series analysis and identification of business cycles and other patterns in the data. It

is thus clear that the longitudinal attribute is well served. As the measurement systems in these distribution centers have evolved, there has been a greater focus on organizational level measurement and tracking of finance, operations, quality, and safety, compared with individuals or group level emphasis in all cases on quantitative or measurable attributes. It is no surprise that measurement systems are slow to formalize customer satisfaction, a relatively qualitative attribute.

SUMMARY

Based on the results of measurement system assessment discussed above, the strength of measurement systems currently used in the five distribution centers was in safety and aspects of finance, operations, quality, and personnel. The most thoroughly covered attributes were feedback, portrayal, and information-based with focus on quantitative measures.

From the column perspective (i.e. measurement components), all distribution centers in this study showed significant effort placed on safety issues. Safety is enforced at both individual and organizational levels and is a continuous on-going on event throughout the whole organization. In fact, based on the golden triangle model, safety is a key component of achieving ultimate success of business as well as productivity and quality (Knight, 1998).

From the viewpoint of attributes (i.e. row perspective), most measurement components, including finance, operations, quality, safety, and personnel, recognize the importance of feedback. Measurements used in these components are found to be

capable of indicating both the progress of planned organizational changes and changing results over time.

Since measurement information is collected on a continuous basis, the attribute of longitudinal is naturally satisfied. By having all the measurement data portrayed along with the time frame, the analysis of time series can be performed to study the process cycle, changes of business, or to identify particular patterns that happen in the organization.

Since the measurement data is collected on the daily basis in these five distribution centers, there is no doubt that the system is capable of providing the management with the timely information. By using these measurements, which are closely linked to the functional areas, such as cost per unit in finance, and productivity and efficiency in operations, the relevance attribute is observed. Based on the data collected and feedback from the employees and managers, accuracy and completeness seem to be satisfied.

As mentioned previously, the measurement systems used in these distribution centers has been found very traditional. There is a great opportunity for the improvement. First, everyone in the distribution center should get involved with the development of the measurement system as much as possible. Responding to measurement is not only the responsibility of managers; it is everyone's responsibility to improve the process. In other words, the traditional way of only focusing on the organizational performance should be changed. Measurement should focus on the individual level as well. In addition, only through wider input can a best-fit measurement

system possibly be designed. Flexibility and dynamic attributes should also be incorporated into these measurement systems, since performance measures lagging behind business changes are useless.

The visibility attribute has been found to be a powerful characteristic for improving performance. Making measurement visible would help everyone to be aware of any changes in the distribution center. Combined with graphic displays, this will help information to be understood more effectively and efficiently.

Today, managers understand that no single measure can provide a clear performance target. Managers need to have a set of measures that provide a balance among different measurement components to stay competitive and to grow. The idea of a balanced scorecard can motivate breakthrough improvements in such critical areas as product, process, customer, and finance. With balance among all of the measurement components (i.e. finance, operations, safety, quality, personnel, and customer satisfaction), and balance across the organization from a system's viewpoint, the distribution centers can change the structure of current measurement systems from the traditional approach to a state-of-the-art measurement class. In addition, measurement should be designed to measure customer satisfaction. Appropriate qualitative data should be collected and integrated with some of the quantitative measurements.

Finally, significant improvement can be made in the study-act part of Plan-Do-Study-Act (PDSA) area. PDSA is a powerful quality improvement tool. PDSA process involves both problems solving and learning. The measurement systems currently used in the five distribution centers are only part of the process. Only plan, do, and perhaps

part of study have been implemented. To illustrate, the number of defects is used to measure the quality performance (i.e. plan phase). Then the measurement data is collected (i.e. do phase). Next, the report based on the data collected is generated (i.e. study phase), but the "action" part seems to be lacking. If the data collected can not be transformed into useful information to make the process better, this data is useless and all the effort is wasted. What is needed here is to complete the cycle or close the loop. Only with a complete PDSA process can new knowledge be learned and applied to make improvements.

BEST PRACTICES

The best practices for measurement systems in distribution centers are identified in Figure 4.1. For finance, the current measurements used, including Labor Cost per Piece, Total Cost per Piece, and Percent to Sale, are adequate to reflect pertinent financial measures.

For operations, using productivity and efficiency across all functional areas provides a good basis for monitoring operational performance. For quality, percent defective is a standard measure. In addition, quality index and risk analysis rating are identified as important measures. Quality index is actually defined as the same as percent defective but in a different form. It is identified as one of the best practices because it looks at the quality from a positive perspective rather than a "negative" perspective. Risk analysis rating provides a mean of comparison among departments, functions, or distribution centers.

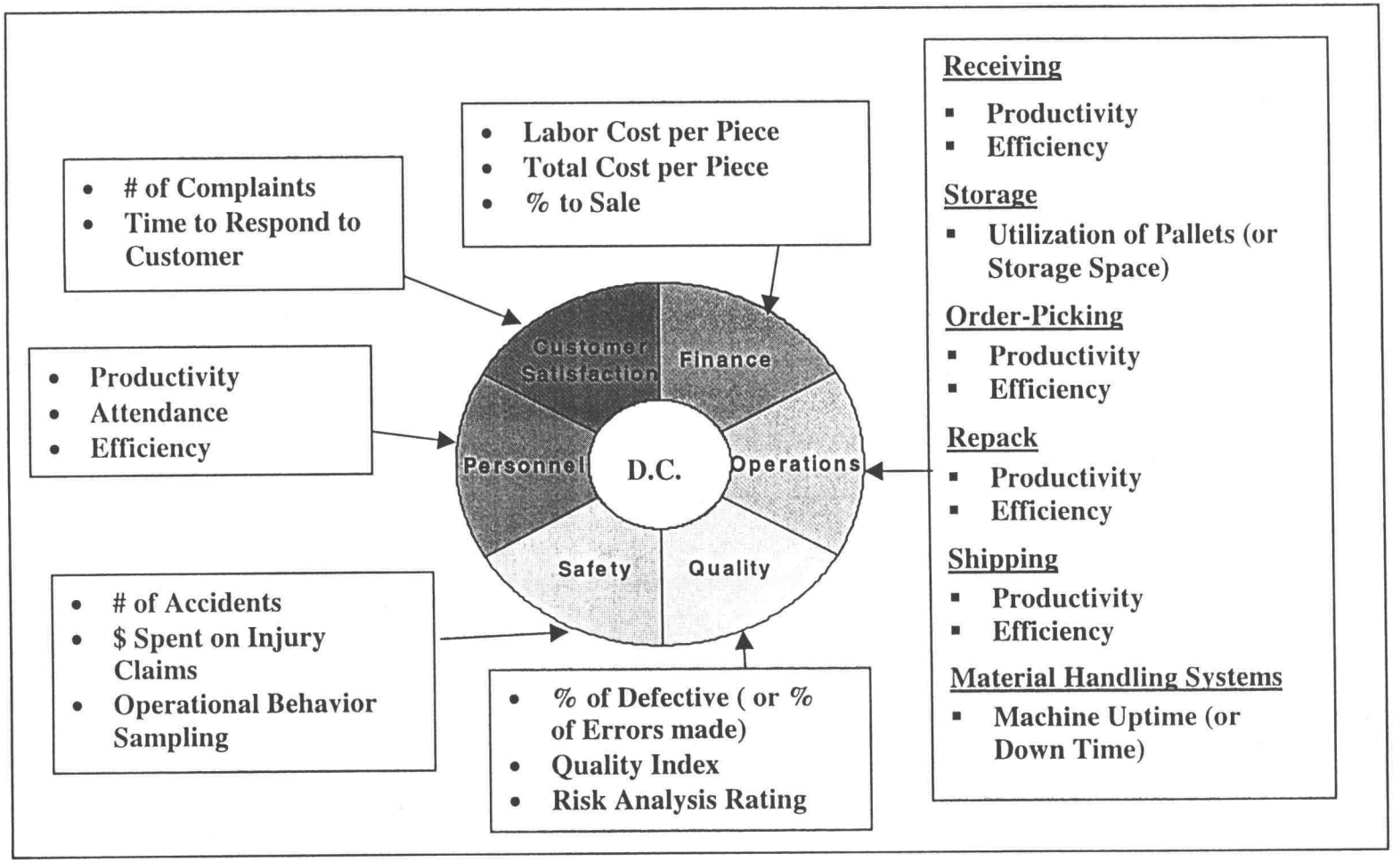

Figure 4.1 Best Practices for Measurement Systems in Distribution Centers

As mentioned before, safety is well-addressed issue in distribution centers. In addition to the required safety measures of number of accident and resources spent on injury claims, "operational behavior sampling" is included as one of the metrics. The operation behavior sampling is defined as the average of daily safety sampling results for certain behaviors. Measured on a continuous basis would make workers more aware of safety. Productivity, attendance, and efficiency are considered sufficient to measure the personnel's performance.

Among all the distribution centers studied, no formal measure is used to assess customer satisfaction. It is suggested that metrics, such as the number of customer complaints and time to respond to customers be used to formally and regularly monitor customer satisfaction.

In the final analysis, the choice of an appropriate set of metrics is a tradeoff between the outcomes desired by an organization and the resources available to collect and analyze data and to institute appropriate feedback and corrective mechanisms. It is suggested that each distribution center develop its unique set of objectives, be it financial-, quality-, or customer-based, and then select performance metrics that would help the distribution center in achieving these objectives.

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CHAPTER 5

CONCLUSION

This research focused on assessing current measurement systems used by distribution centers. Three phases have been carried out to complete the research. The first phase began with a comprehensive review of the background of distribution centers. In this phase, the importance of the distribution centers in supply-chain management was recognized. The classifications, components, functions, and material handling system of modern distribution centers were discussed. Elements of a successful performance measurement system were identified and an example of how these elements apply to a specific distribution function was provided.

The second phase of the research was a study of the measurement systems currently used in today's distribution centers. Five distribution centers in the Northwest were selected as case study subjects. The results showed that there is a high degree of consistency in the nature of the measurement systems used across these five distribution centers. Some key findings include:

1. The most common measures used in these distribution centers, across operational functions, were productivity and efficiency. However, the term productivity and efficiency used in the distribution centers were not used consistently as defined in the literature (Sink, 1985; Riggs and West, 1986).
2. The greatest opportunity for improvement identified in this phase was in the area of customer satisfaction measures.

3. Safety was the most consistently measured category. However, this is likely due to legal requirements.
4. Only one distribution center included in this research used a systematic approach to measuring performance across the whole organization. In this distribution center, productivity, quality, and safety are consistently measured in the whole plant.

Based on the results of cross-case analysis from phase 2, an evaluation of these performance measurement systems was completed by examining the normative attributes expected in a state of the art measurement system. The results showed that a key strength of measurement systems currently used by these five distribution centers was found in the area of safety, which is consistent with the finding from phase 2.

As the measurement systems used in these distribution centers have been found to be very traditional, there is a significant opportunity for improvement. First, everyone in the distribution center should get involved with the development of the measurement system as much as possible. Only through wider input can a best-fit measurement system be designed. As a result, the traditional way of focusing on only organizational measurement is not appropriate any more. A focus should be placed on the individual level as well. As the visibility attribute has been found to be a very powerful characteristic for improving performance, making measurement data visible would help everyone to be aware of any changes in the distribution center. Combined with graphic displays, this will help information to be understood more effectively and efficiently.

Today, managers understand that no single measure can provide a clear performance target. A set of measures that can provide a balance among different measurements and help the company to stay competitive is necessary. The results of this

research indicate that there was a discrepancy identified in the measurement systems currently used in these distribution centers. One possible remedy is to reconsider the way of the distribution center's measurement philosophy. Both quantitative and qualitative measurements are important, and developing a formal structure to measure customer satisfaction could be a critical starting point.

Another significant improvement can be made is in the study-act part of Plan-Do-Study-Act (PDSA) area. As mentioned previously, PDSA is a powerful quality tool, which can generate new knowledge to improve the system. Thus, through a complete cycle of PDSA, the performance of the distribution centers can be improved significantly. However, the measurement systems used in these distribution centers only implemented part of the process. In most cases, the "action" part is missing from the process. This results in a "black hole" in the process. If the data collected from the process can not be transformed into useful information to help make better decisions, this data is useless and effort is wasted. What is needed here is to complete the cycle, a closed loop. Collecting and studying the measurement data is not enough, "action" must be taken to improve the process.

As stated earlier, a good performance measurement system supports sound management decisions. A performance measurement system is effective if it provides high quality, reliable, and timely information to influence management decisions and employee behavior. While the measurement systems found in these distribution centers are traditional and somewhat outdated from the current viewpoint of state-of-the-art

measurement system, they did provide some information to support decision making and, as always, there is great opportunity for improvements.

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APPENDIX

INTERVIEW GUIDE

OUTLINE

I. General Questions

(1) Background

(2) Structure

(3) Capacity

(4) Overall Performance / Measurement System

II. Specific Performance Measures

(1) Operational and Financial Measurements

- Finance (if applicable)
- Receiving
- Storage
- Order-selection
- Repackaging
- Shipping
- Material Handling System

(2) Quality Measurements

(3) Safety Measurements

(4) Customer Satisfaction Measurements

Internal Customers

External Customers

1. What measurements are used?

   For each measurement:

   - How is it measured?
   - How often is it measured?
   - Who measures it? Which department?
   - Who uses this measure? What is it used for?

2. Are these useful measurements?

3. Suggestions?

(5) Employee Measurements →

- Which measures are tracked at the individual employee level? At the team level? Department level?
- How is this information shared?
- Are these measures displayed publicly?

(6) Others: Is there anything else that you would like to share?

INTERVIEW GUIDE

A- Distribution Center

- **INTERVIEW DATE:** _____
- **INTERVIEWEE'S NAME:** _____
- **INTERVIEWEE'S TITLE:** _____
- **INTERVIEWER'S NAME:** Chun-Ho Kuo

OPENING STATEMENT:

As you probably know, my name is Chun-Ho Kuo and I am working on my Ph.D. in Industrial and Manufacturing Engineering Department at Oregon State University. My dissertation will study Performance Measurement Systems in distribution centers. The purpose of today's interview is to collect the data about the performance measurement system in your distribution center. What I'd like to do is to go down through the questions and record your responses. The interview usually takes between 30-45 minutes. I need to warn you that I don't write as fast as I'd like to so you will have to bear with me and I may ask you to slow down at times. To help with this problem, I can use a tape recorder to help me to capture your responses. Would you prefer for me to use a recorder? After I go back to school, I will type these notes up and mail them or fax them to you. What I'd like you to do is to read through them and edit them. You can delete, modify, or insert things, and then mail it back to me in the stamped envelope I provide. You can also fax them to me if you prefer. This will insure the accuracy of our communication. Our conversation today is confidential. No one else will have access to your interview and I will not use your name with any quote I may use from our interview, unless I have your permission to do so. Do you have any questions for me before we get started?

INTERVIEW QUESTIONS:

I. General Questions

(1) Background

1. What was the opening date / how many years of operation?

2. What type of industry? Retail? Wholesale?

3. What is the location of the distribution center?

4. What is the site size (e.g. how many acres)? What is the building size (e.g. distribution center)? Is it multi-level?

5. How many employees at the distribution center?

6. Is it union or non-union?

7. Is the distribution center 24 hours operation? What are the operating hours? How many shifts do you have per day?

8. What is the geographic area you provide service to? (e.g. what states are serviced?)

9. How many stores are serviced?

10. How many distribution centers does this company have in the United States?

11. Does your distribution center provide Kitting, Labeling, or Repack services?

12. Does your distribution center support cross docking? If so, what is proportion of cross docking compared to the overall operation?

(2) Structure

13. Can you describe the formal organization structure in your distribution center?

14. What is your distribution center Mission? Goals?

(3) Capacity

15. What is the total pallet capacity?

16. How many doors (or gates) are there for shipping? Are they expandable?

    - On average, how many doors are used per day?

17. How many doors (or gates) are there for receiving? Are they expandable?

    - On average, how many doors are used per day?

18. What is the average number of goods (in dollars, weight, or units) distributed per day?

    - Is current loading below, above, or about the distribution center's capacity?

19. What is the average number of goods (in dollars, weight, or units) received per day?

    - Is current loading below, above, or about the distribution center's capacity?

(4) Overall Performance / Measurement System

20. Describe the measurement system used in your distribution center.

21. What is the basis of comparison for overall distribution center's performance over time?

22. Do you compare your distribution center's performance with other distribution centers?

23. Do all employees understand this measurement system?

    - If not, which levels of the organization is the system designed for?

    - If yes, how are new employees educated about the measurement system?

24. What are the advantages of this system?

25. What can be improved?

26. What measurements are used to measure the quality?

    - Measure 1:

        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

27. Do you think these are useful quality measurements? Are they too complicated or too simple?

28. Do you have any suggestions to improve these quality measurements?

29. What measurements are used to measure the safety?

    - Measure 1:
        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

30. Do you think these are useful safety measurements? Are they too complicated or too simple?

31. Do you have any suggestions to improve these quality measurements?

32. Is there anything else you would like to share?

II. Specific Performance Measures (Operational and Financial)

Financial Measurements (if applicable)

(1) Operational and Financial Measurements: *Financial Measurements*

1. What measurements are used to measure the financial performance of the distribution center?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

2. Do you think these are useful financial measurements? Are they too complicated or too simple?

3. Do you have any suggestions to improve these financial measurements?

4. Is there anything else that you would like share?

Receiving

(1) Operational Measurements: *Receiving*

1. What measurements are used to measure the performance of the receiving?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

2. (For *Receiving*) Do you think these are useful measurements? Are they too complicated or too simple?

3. (For *Receiving*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) Quality Measurements: *Receiving*

4. (For *Receiving*) What measurements are used to measure the quality performance of the distribution center?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

5. (For *Receiving*) Are there any other measures used to measure quality in the distribution center?

6. (For *Receiving*) Do you think these are useful quality measurements? Are they too complicated or too simple?

7. (For *Receiving*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Receiving*

8. (For *Receiving*) What measurements are used to measure the safety?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

9. (For *Receiving*) Are there any other measures used to measure quality in the distribution center?

10. (For *Receiving*) Do you think these are useful safety measurements? Are they too complicated or too simple?

11. (For *Receiving*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Receiving

Internal Customer Satisfaction

12. (For *Receiving*) What measurements are used to measure the *Internal Customer Satisfaction*?

    - Measure 1:

- How is it measured?
- How often is it measured?
- Who measures it? Which department?
- Who uses this measure? What is it used for?

13. (For *Receiving*) Are there any other measures used to measure quality in the distribution center?

14. (For *Receiving*) Do you think these are useful measurements? Are they too complicated or too simple?

15. (For *Receiving*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

16. (For *Receiving*) What measurements are used to measure the *External Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

17. (For *Receiving*) Are there any other measures used to measure quality in the distribution center?

18. (For *Receiving*) Do you think these are useful measurements? Are they too complicated or too simple?

19. (For *Receiving*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: *Receiving*

20. Which measures are tracked at the individual employee level? At the team level? Department level?

21. How is this information shared?

22. Are these measures displayed publicly?

(6) Others: *Receiving*

23. Is there anything else that you would like to share?

Storage

(1) Operational Measurements: *Storage*

1. What measurements are used to measure the performance of the storage?

    - Measure 1:

        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

2. (For *Storage*) Do you think these are useful measurements? Are they too complicated or too simple?

3. (For *Storage*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) Quality Measurements: *Storage*

4. (For *Storage*) What measurements are used to measure the quality performance of the distribution center?

    - Measure 1:

        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

5. (For *Storage*) Are there any other measures used to measure quality in the distribution center?

6. (For *Storage*) Do you think these are useful quality measurements? Are they too complicated or too simple?

7. (For *Storage*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Storage*

8. (For *Storage*) What measurements are used to measure the safety?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

9. (For *Storage*) Are there any other measures used to measure quality in the distribution center?

10. (For *Storage*) Do you think these are useful safety measurements? Are they too complicated or too simple?

11. (For *Storage*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Storage

Internal Customer Satisfaction

12. (For *Storage*) What measurements are used to measure the *Internal Customer Satisfaction*?

    - Measure 1:

- How is it measured?
- How often is it measured?
- Who measures it? Which department?
- Who uses this measure? What is it used for?

13. (For *Storage*) Are there any other measures used to measure quality in the distribution center?

14. (For *Storage*) Do you think these are useful measurements? Are they too complicated or too simple?

15. (For *Storage*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

16. (For *Storage*) What measurements are used to measure the *External Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

17. (For *Storage*) Are there any other measures used to measure quality in the distribution center?

18. (For *Storage*) Do you think these are useful measurements? Are they too complicated or too simple?

19. (For *Storage*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: *Storage*

20. Which measures are tracked at the individual employee level? At the team level? Department level?

21. How is this information shared?

22. Are these measures displayed publicly?

(6) Others: *Storage*

23. Is there anything else that you would like to share?

Order-selection

(1) Operational Measurements: *Order-selection*

1. What measurements are used to measure the performance of the order-selection?

   - Measure 1:

     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

2. (For *Order-selection*) Do you think these are useful measurements? Are they too complicated or too simple?

3. (For *Order-selection*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) Quality Measurements: *Order-selection*

4. (For *Order-selection*) What measurements are used to measure the quality performance of the distribution center?

   - Measure 1:

     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?

- Who uses this measure? What is it used for?

5. (For *Order-selection*) Are there any other measures used to measure quality in the distribution center?

6. (For *Order-selection*) Do you think these are useful quality measurements? Are they too complicated or too simple?

7. (For *Order-selection*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Order-selection*

8. (For *Order-selection*) What measurements are used to measure the safety?

   - Measure 1:
   - How is it measured?
   - How often is it measured?
   - Who measures it? Which department?
   - Who uses this measure? What is it used for?

9. (For *Order-selection*) Are there any other measures used to measure quality in the distribution center?

10. (For *Order-selection*) Do you think these are useful safety measurements? Are they too complicated or too simple?

11. (For *Order-selection*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Order-selection

Internal Customer Satisfaction

12. (For *Order-selection*) What measurements are used to measure the *Internal Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

13. (For *Order-selection*) Are there any other measures used to measure quality in the distribution center?

14. (For *Order-selection*) Do you think these are useful measurements? Are they too complicated or too simple?

15. (For *Order-selection*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

16. (For *Order-selection*) What measurements are used to measure the ***External Customer Satisfaction***?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

17. (For *Order-selection*) Are there any other measures used to measure quality in the distribution center?

18. (For *Order-selection*) Do you think these are useful measurements? Are they too complicated or too simple?

19. (For *Order-selection*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: ***Order-selection***

20. Which measures are tracked at the individual employee level? At the team level? Department level?

21. How is this information shared?

22. Are these measures displayed publicly?

(6) Others: ***Order-selection***

23. Is there anything else that you would like to share?

Repackaging

(1) Operational Measurements: *Repackaging*

1. What methods are used in repackaging?

2. What is the capacity of repackaging? How many people?

3. What measurements are used to measure the performance of the repackaging?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

4. (For *Repackaging*) Do you think these are useful measurements? Are they too complicated or too simple?

5. (For *Repackaging*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) Quality Measurements: *Repackaging*

6. (For *Repackaging*) What measurements are used to measure the quality performance of the distribution center?

   - Measure 1:

- How is it measured?
- How often is it measured?
- Who measures it? Which department?
- Who uses this measure? What is it used for?

7. (For *Repackaging*) Are there any other measures used to measure quality in the distribution center?

8. (For *Repackaging*) Do you think these are useful quality measurements? Are they too complicated or too simple?

9. (For *Repackaging*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Repackaging*

10. (For *Repackaging*) What measurements are used to measure the safety?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

11. (For *Repackaging*) Are there any other measures used to measure quality in the distribution center?

12. (For *Repackaging*) Do you think these are useful safety measurements? Are they too complicated or too simple?

13. (For *Repackaging*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Repackaging

Internal Customer Satisfaction

14. (For *Repackaging*) What measurements are used to measure the *Internal Customer Satisfaction*?

    - Measure 1:
        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

15. (For *Repackaging*) Are there any other measures used to measure quality in the distribution center?

16. (For *Repackaging*) Do you think these are useful measurements? Are they too complicated or too simple?

17. (For *Repackaging*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

18. (For *Repackaging*) What measurements are used to measure the *External Customer Satisfaction*?

    - Measure 1:
        - How is it measured?
        - How often is it measured?
        - Who measures it? Which department?
        - Who uses this measure? What is it used for?

19. (For *Repackaging*) Are there any other measures used to measure quality in the distribution center?

20. (For *Repackaging*) Do you think these are useful measurements? Are they too complicated or too simple?

21. (For *Repackaging*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: *Repackaging*

22. Which measures are tracked at the individual employee level? At the team level? Department level?

23. How is this information shared?

24. Are these measures displayed publicly?

(6) Others: *Repackaging*

25. Is there anything else that you would like to share?

Shipping

(1) Operational Measurements: *Shipping*

1. What measurements are used to measure the performance of the shipping?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

2. (For *Shipping*) Do you think these are useful measurements? Are they too complicated or too simple?

3. (For *Shipping*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) Quality Measurements: *Shipping*

4. (For *Shipping*) What measurements are used to measure the quality performance of the distribution center?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

5. (For *Shipping*) Are there any other measures used to measure quality in the distribution center?

6. (For *Shipping*) Do you think these are useful quality measurements? Are they too complicated or too simple?

7. (For *Shipping*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Shipping*

8. (For *Shipping*) What measurements are used to measure the safety?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

9. (For *Shipping*) Are there any other measures used to measure quality in the distribution center?

10. (For *Shipping*) Do you think these are useful safety measurements? Are they too complicated or too simple?

11. (For *Shipping*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Shipping

Internal Customer Satisfaction

12. (For *Shipping*) What measurements are used to measure the *Internal Customer Satisfaction*?

    - Measure 1:

- How is it measured?
- How often is it measured?
- Who measures it? Which department?
- Who uses this measure? What is it used for?

13. (For *Shipping*) Are there any other measures used to measure quality in the distribution center?

14. (For *Shipping*) Do you think these are useful measurements? Are they too complicated or too simple?

15. (For *Shipping*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

16. (For *Shipping*) What measurements are used to measure the *External Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

17. (For *Shipping*) Are there any other measures used to measure quality in the distribution center?

18. (For *Shipping*) Do you think these are useful measurements? Are they too complicated or too simple?

19. (For *Shipping*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: *Shipping*

20. Which measures are tracked at the individual employee level? At the team level? Department level?

21. How is this information shared?

22. Are these measures displayed publicly?

(6) Others: *Shipping*

23. Is there anything else that you would like to share?

Material handling system

(1) Operational Measurements: *Material handling system*

1. What types of material handling devices are used in your organization (e.g. distribution center)?

   - Fork truck? Total number?
   - Conveyor? How long is it? What is its capacity?
   - ASRS?
   - Others?

2. What measurements are used to measure the performance of the material handling system?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

3. Does your distribution center have a sortation system? If yes, go to question 4. If no, go to question 6.

4. What is the capacity of the sortation system?

5. What are the measurements used to measure the performance of the sortation system?

   - Measure 1:
     - How is it measured?
     - How often is it measured?

- Who measures it? Which department?
- Who uses this measure? What is it used for?

6. If no sortation system, how do you sort your order?

7. What measurements are used to measure the performance of sorting (no sortation system)?

   - Measure 1:
     - How is it measured?
     - How often is it measured?
     - Who measures it? Which department?
     - Who uses this measure? What is it used for?

8. (For *Material handling system*) Do you think these are useful measurements? Are they too complicated or too simple?

9. (For *Material handling system*) Do you have any suggestions to improve these measurements?

The following questions relate to quality, safety, and customer satisfaction. If you already mentioned a measure that describes that type of performance, just let me know so that I will make note of it and we will not repeat the specific questions for that measure.

(2) **Quality Measurements:** ***Material handling system***

10. (For *Material handling system*) What measurements are used to measure the quality performance of the distribution center?

    - Measure 1:
      - How is it measured?
      - How often is it measured?
      - Who measures it? Which department?

- Who uses this measure? What is it used for?

11. (For *Material handling system*) Are there any other measures used to measure quality in the distribution center?

12. (For *Material handling system*) Do you think these are useful quality measurements? Are they too complicated or too simple?

13. (For *Material handling system*) Do you have any suggestions to improve these quality measurements?

(3) Safety Measurements: *Material handling system*

14. (For *Material handling system*) What measurements are used to measure the safety?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

15. (For *Material handling system*) Are there any other measures used to measure quality in the distribution center?

16. (For *Material handling system*) Do you think these are useful safety measurements? Are they too complicated or too simple?

17. (For *Material handling system*) Do you have any suggestions to improve these safety measurements?

(4)* Customer Satisfaction Measurements: *Material handling system

Internal Customer Satisfaction

18. (For *Material handling system*) What measurements are used to measure the *Internal Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

19. (For *Material handling system*) Are there any other measures used to measure quality in the distribution center?

20. (For *Material handling system*) Do you think these are useful measurements? Are they too complicated or too simple?

21. (For *Material handling system*) Do you have any suggestions to improve these measurements?

External Customer Satisfaction

22. (For *Material handling system*) What measurements are used to measure the *External Customer Satisfaction*?

- Measure 1:
  - How is it measured?
  - How often is it measured?
  - Who measures it? Which department?
  - Who uses this measure? What is it used for?

23. (For *Material handling system*) Are there any other measures used to measure quality in the distribution center?

24. (For *Material handling system*) Do you think these are useful measurements? Are they too complicated or too simple?

25. (For *Material handling system*) Do you have any suggestions to improve these measurements?

(5) Employee Measurements: ***Material handling system***

26. Which measures are tracked at the individual employee level? At the team level? Department level?

27. How is this information shared?

28. Are these measures displayed publicly?

(6) Others: ***Material handling system***

29. Is there anything else that you would like to share?