REGIONAL UTILIZATION OF REUSABLE PALLETS BY THE GROCERY AND RELATED PRODUCTS INDUSTRY

by

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CHAPTER I

INTRODUCTION

The U.S. pallet industry depends greatly on the future availability of timber resources, since over 90 percent of its products are made from wood. Since 1960, annual pallet production has quadrupled, and the industry's use of hardwood lumber has increased from 14 percent to more than 50 percent of total hardwood lumber production. By 1976, 3.2 billion board feet of hardwood lumber were consumed by the pallet industry out of a total production of 6.5 billion board feet (USDA Forest Service 1982). The increased demand for pallets increases the volume of wood consumed by the industry. Between 1960 and 1979, wood use by the pallet industry has increased an average of 7 percent per year. Present hardwood consumption for pallet products includes raw material inputs such as cants, short bolts, and tree-length logs as well as hardwood lumber. Thus, the total hardwood input to pallet production is greater than just 50 percent of hardwood lumber production.

Growth in pallet usage is derived from two sources: increases in industrial production and increases in movement of domestic products on pallets. Increases in movement on pallets results from manufacturers and distributors converting to pallet handling systems from other material handling systems. Increases in industrial production results in an increase in pallets needed for systems already using pallets.

From 1950 to 1960, average growth in pallet production per year was 42.1 million units, of which 3.8 million was due to growth in industrial production and 38.3 million was due to palletization (Wallin and Luppold 1983). For the period 1961 to 1983, average growth in annual production attributed to industrial growth was 7.6 million while that attributed to palletization was 152 million out of a total of 160 million.

The grocery and related products industry is a potential major growth area for pallet usage over the next decade. This industry is already the largest market for industrial packaging, which includes pallets, boxes, and containers, accounting for almost 37 percent of total packaging in 1980. Its projected growth in manufacturers' output is expected to exceed 2.8 percent per year between 1980 and 1995 (Walsh 1981).

The grocery and related products industry is unique in two ways. First, a majority of the products handled by the industry's distribution system are already handled on pallets; and second, these pallets are generally a standardized 48"x40" size. In a 1977 survey of pallet manufacturers, the 48x40 pallet constituted 27.5 percent of the total number of pallets produced. McCurdy and Ewers (1985) estimated that in 1982, 20 percent of the pallets manufactured were 48"x40" in size, while the next seven most frequently manufactured sizes together accounted for only 28 percent of the total.

THE PROBLEM

Future timber demands by the pallet industry are not well understood. Information required to make decisions based on the regional levels of these demands is lacking. This has an impact on the accuracy of timber demand and supply modeling as well as on the ability of pallet producers to make decisions regarding future availability of raw material resources for pallet production. There is a need to determine what levels of pallet demand can be expected within specific regions and to assess the potential effects of the demand for pallets on the timber resource within the regions.

If present pallet use and construction methods continue, the resulting demand for pallets will have an uneven effect on the availability and price of the hardwood resource in the various regions of the country. Some regions of the country have large quantities of underutilized hardwood resources, and these regions, theoretically, can meet the needs of increased demand without significant raw material cost increases. Other regions are utilizing a much larger portion of the existing hardwood resource and a large increase in demand could cause increases in raw material costs (Anderson 1986, 1987). Because raw material costs represent a substantial portion of the production cost of pallets, those regions that can provide lower cost raw material could have an advantage over resource-deficient regions.

In order to assess the pallet industry's impact on the hardwood resources, better information is needed on future usage of reusable

pallets by the grocery and related products industry. This industry is the biggest user of reusable pallets and is expected to continue this trend as a major user in the future. Knowing current pallet use by this industry will enable us to make estimates of future use under different food flow and pallet durability assumptions.

Pallets have a relatively low value-to-weight ratio, so their initial use usually occurs within the same region in which they are produced. In a recent survey of pallet manufacturers, McCurdy and Ewers (1986) found that firms sold most of their pallets within a 100 mile radius of the plant. The median distance was only 50 miles, with 61 percent of the firms selling pallets only within their home state. An analysis of the regional use of reusable pallets, therefore, would be more useful than a national study. Previous studies (Anderson 1986,1987) have shown that sufficient wood resources should be available in the future at the national level for pallet production, but individual regions may experience demands that exceed their regional resource availability.

Information is needed on how new and used pallets are distributed within and between regions and what effects the interregional movements of grocery and related products have on pallet requirements within regions. The absence of this information will result in market uncertainty, misallocation of resources among regions, reduced quantities traded, and increased equilibrium prices within regions.

The beneficiaries of this research include resource policymakers who must anticipate future timber demands by the pallet industry in order to develop long-term forest policy which will facilitate more efficient forest management practices. This research will also benefit pallet producers by providing information that will allow them to better understand the long-term potential and long-term trends in the grocery pallet segment of their markets. The ultimate beneficiary is the consumer, who will benefit from better forest planning and better allocation of forest resources in the overall pallet industry.

Although the pallet industry is the largest single user of hardwood raw material, it is made up of many small, independent firms. No individual firm within the pallet industry has the resources to do market research which can provide the detailed information required to make informed decisions. The National Wooden Pallet and Container Association, with which many of the firms have contact, also has a limited budget and staff and cannot provide this type of research. The present study will provide a basis for further assessments of regional pallet usage within other markets. With more complete knowledge of the grocery pallet market and the influence that important factors have on this market, pallet producers will be better able to anticipate future changes in regional market behavior. This information will therefore facilitate better management decisions on the part of pallet producers that could not be made in the absence of such information.

OBJECTIVES

The ultimate objective of this research is to provide information that can be used to understand the long-term potential and long-term trends in the grocery pallet market as they relate to future regional timber demands by the pallet industry. Specific objectives within this overall objective include:

1. Provide information on current use of grocery pallets in the grocery distribution industry through the identification and quantification of grocery pallet use within the retailing and wholesaling sectors of the grocery and related products industry.

2. Provide a theoretical framework for future analysis of the regional demand for grocery pallets resulting from the use of grocery pallets in satisfying grocery distribution between regions and between market areas within the same region, and determine the relationship between grocery pallet use and regional grocery pallet demand under specific food flow and pallet durability assumptions.

3. Provide information on the demand for regional timber resources resulting from grocery pallet production within specified regions.

ORGANIZATION OF DISSERTATION

The pallet market is described in Chapter II. The grocery and related products market is described in Chapter III, addressing the requirements of the first objective. The information presented in Chapter II and Chapter III, along with a review of literature presented in Chapter IV, is incorporated into the model development presented in Chapter V. The estimated demand for pallets by the grocery and related products industry demand, the second objective, will be presented in Chapter VI. The relationship between pallet demand and the regional timber resource, the third objective, is presented in Chapter VII. Chapter VIII is a presentation of the summary, and conclusions of the study.

CHAPTER II

THE PALLET INDUSTRY

This chapter describes the major characteristics of the pallet industry, beginning with a summary of the development of the pallet and its use in modern materials handling systems. Emphasis is placed on the market for hardwood pallets, since hardwood pallets are preferred for the distribution of grocery and related products. The degree of standardization within this market and possibilities for substitution will be discussed.

INDUSTRY DEVELOPMENT

A pallet has been described as "...a low, sturdy platform on which materials in process of manufacture, or finished goods, may be stacked in order to expedite their handling, movement, and storage with the use of mechanical fork-lifts, and/or hand trucks" (Panshin, et al. 1962).

The wood pallet industry is composed of about 2500 firms producing a wide variety of wood pallets, skids, bases, containers, and dunnage items. The 1977 Census of Manufacturers shows less than 27 percent of the firms with more than 20 employees (U.S. Department of Commerce 1981). In a study of the Eastern hardwood pallet industry, Sendak reported nearly 50 percent of the firms employed fewer than 10 persons (Sendak 1971).

The wood pallet industry started as a part of the wooden box industry in the early 1920's. The development of materials handling systems using mechanical lifts required a base or platform on which the goods could be stacked. Military use of pallets prior to and during World War II provided the motivation for industries to develop palletization programs involving the mechanical handling of goods on pallets (Panshin et al. 1962).

Pallets were initially produced using a table to assemble the individual pieces and a hammer to nail the pieces together. This hand-nailing method of assembly was used by almost all pallet manufacturers through the mid-1950's (Eichler 1976). As Eichler points out, "... in those days the quantities of pallets ordered by customers were smaller and, therefore, change-over time from one size to another was a consideration. Labor rates were much lower and fringe benefits were nonexistent; therefore, production output per man was not of too much concern."

As production needs increased, the technology of assembling pallets improved. Pneumatic gun nailers and stapling machines replaced the hammer. Using these devices and an assembly table enabled production workers to more than triple production rates that could be expected from the hand nailing method of assembly.

Further increases in the demand for pallets resulted in the development of pallet-nailing machines or pallet assembly lines. These machines provide semi- or fully-automatic assembly of pallets at twice

the rates obtained with the pneumatic gun nailers and stapling machines. Built-in assembly tables on these machines automatically position the pallet parts for nailing or stapling. By combining the pallet-nailing or stapling machine with conveyors, automatic stringer and deckboard in-feed hoppers, and automatic pallet stackers, a completely automated assembly line is capable of producing 4,000 pallets per day using two production workers.

PRODUCT STANDARDIZATION

The pallet industry is characterized by great diversity in the design, styling, and construction of pallets produced. In a 1977 survey, 77 different designs of pallets were reported (NWPCA 1980). In a study of the materials handling environments of 88 warehouses throughout the United States in 1980, over 100 different designs of pallets were found (Goehring and Wallin 1980).

Pallet life is described by such terms as durable, permanent, warehouse, expendable, shipping, one-way, and reusable; but, in fact, pallet life is a continuum varying from single-use, one-way pallets to long-life pallets that may be used for several years. Between these extremes, the life expected depends on the pallet user's specification.

Pallets are needed to handle materials or products through a series of shipping and/or storage operations. Pallets were initially used for moving and storing goods within a single plant or site. Over

the past 3 decades, however, shipping between plants or sites has become a more important function of pallets (Strobel and Wallin 1969).

The Census of Transportation provides data on product movement in the United States by type of carrier, type of product, and geographic region. Nearly 1.5 billion tons of product were shipped inter-city in 1972 (U.S. Department of Commerce 1976). About 20 percent, or 300 million tons, could be shipped by pallet, which is the equivalent of approximately 600 million pallet loads (Wallin 1977). This tonnage represents the potential level of shipments by pallets in 1972. Actual pallet production in 1972 was reported as almost 155 million units (NWPCA 1983). With an unspecified number of pallets already in the system in addition to those produced in a given year, it is apparent that an individual pallet is used to make more than one trip per year. It has been estimated that, on the average, a pallet transports six loads per year (Wallin 1977).

Continued pressure to reduce materials handling costs will result in increased palletization in those industries that can, but may not presently, move goods by pallet unit-loads. McKeever and Dickerhoof(1980) point out that, "Rising labor costs, coupled with improved materials-handling systems in warehouses and transportation systems, will directly influence a trend toward increased palletization."

The pallet industry produces a differentiated product for many different buyers. Wallin (1977) points out that a pallet seller may

produce the same product for different buyers, different products for the same buyer, or different products for different buyers. In each case, the seller is selling one product--pallets. The buyer differentiates the product based on the buyer's needs. Thus, the buyer can substitute pallets from different sellers only if the pallets have the same design, style, and construction specifications.

GROCERY PALLET CONSUMPTION

The grocery and related products industry offers more possibilities for substitution of pallets from different sellers because of the much greater degree of standardization of pallet specifications within this industry. This means that the same pallet design will be used to carry an almost endless variety of products. For example, the typical food distribution center may contain more than 13,000 different food and related products, all of which can be placed on the standard 48x40 pallet.

One problem in estimating grocery pallet consumption is identifying how much of a given product is actually palletized (Table 1), and more specifically, how much of a given product (identified by weight, volume, or number of items) is carried on an individual pallet. In a study which detailed information on 2706 shipments by 422 manufacturers to 10 major food distribution centers, Strobel and Wallin (1969) classified products on the basis of physical handling

Table 1.-- Percent of tons of product movement palletizable, by shipper group and class, for all geographic regions.

Code No.	Shipper Group and Class Description	Percent
012	Meat products	100.0
013	Dairy products	100.0
021	Canned fruits and vegetables	100.0
022	Canned specialities, seafood, frozen food	100.0
023	Grain mill products, cane and beet sugar	8.6
024	Miscellaneous and kindred food products	100.0
031	Candy and confectionery	100.0
032	Alcoholic beverages	87.0
033	Canned & bottled soft drinks and flavorings	100.0
034	Tobacco products	88.0
06-	Paper and allied products	37.9
071	Inorganic chemicals, gases, dyes, and pigments	8.6
072	Miscellaneous industrial chemicals	8.4
073	Plastics, synthetic resins, rubber, fibers	49.2
082	Soap, detergents, perfume, cosmetics, etc.	100.0
083	Pain and allied products	13.0
084	Wood, agricultural, miscellaneous chemicals	8.6
104	Miscellaneous plastics products	50.0
13-	Stone, clay, glass (less containers) products	51.6
132	Glass containers and other products	100.0
171	Metal cans	100.0
172	Bolts, nuts, screws, rivets, washers	100.0
21-	Electrical products and supplies	21.3
	Total, all products	19.9

Source: Wallin, W. B. 1977. Characteristics of the U.S. Pallet Industry. Unpubl. Rep., Forestry Sciences Lab., Princeton, W. Va.

characteristics. Their classification resulted in the following 5 product groups:

Group I--paper products	Bags, meat trays, toilet tissue,facial tissue, towels, napkins.
Group II--low-density items	Baking soda, cereals, charcoal, crackers, cookies, dried fruit, pet food in bags, toys, games.
Group III--canned goods	Evaporated milk, fish, fruits juices, pet food, pork & beans, soups, spaghetti, vegetables.
Group IV--products in glass	Baby food, catsup, jams, jellies, spreads, salad dressings, shortenings, oils, syrups.
Group V--heavy package goods	Baking mixes, flour, powdered milk, rice, salt, sugar, soaps and detergents.

One factor that influences grocery pallet consumption is change in the consumer's utility functions. Changing economic status (e.g., multiple wage-earner households) and changes in family eating habits have increased the demand for more pre-processed and convenience foods (Conner, et al. 1985). For example, the demand for instant potatoes and hamburger helper has increased faster than the demand for raw potatoes and meat products which require more processing in the home prior to consumption. Because of the additional processing, which is accomplished at the food manufacturing facility as opposed to in the home, the grocery product is more frequently packaged in a manner which lends itself to palletized handling of the product.

Changes in the processing levels of meat products at the primary processor is another example of a grocery product which has been altered to lend itself more to palletized handling. Ten years ago, much of the

meat handled at grocery distribution centers was in the form of hanging carcasses, which were processed into individual cuts of meat at the retail stores. Presently, the carcasses are broken down at packing houses, boxed by grouping major cuts of meat, and shipped on pallets to the distribution centers. The palletized boxes are distributed to retail stores where the individual cuts of meat are finally packaged for sale to consumers.

CHAPTER III

THE GROCERY INDUSTRY

This chapter outlines the major characteristics of the grocery and related products industry. These characteristics include the structure of the industry, standardization of pallets within the industry, and current industry practices with regard to pallet use. Particular emphasis is given to the distribution system between the wholesale and the retail segments of the industry. Pallets are used within the distribution system from grocery manufacturers to retail stores. Demand for grocery pallets is derived solely from the need for movement and storage of grocery and related products within the industry. The above characteristics of the industry must be considered as possible influences on the long-term potential for grocery pallet demand.

In order to provide resource policymakers and pallet producers with information on the current use of grocery pallets in grocery distribution, a survey of the distribution system was conducted. Information was obtained through personal interviews with distribution center managers, both on-site and by telephone contact, and through on-site inspection of distribution center warehouse operations. The format of questions asked during each interview was informal rather than in the form of a formal, or structured, questionnaire.

Two reasons existed for using an informal format for questioning distribution center managers as opposed to using a structured

questionnaire. First, because the US Forest Service provided the funds for the on-site visits to distribution centers, government regulations restricted the conduct of interviews based on a written questionnaire. Prior approval for written questionnaires was required. Since the approval process for questionnaires normally exceeded 12 months with no guarantee that all pertinent questions would appear on the approved questionnaire, an informal format was considered to be the best choice. Second, from earlier contacts with industry members, it was clear that a mailed questionnaire to distribution management would seldom reach the individual with the most detailed knowledge of pallet use. In fact, in all nine on-site personal interviews at least two individuals, and in one case three individuals, were interviewed before the informal series of questions could be completely answered.

Although the questions asked in each interview were informal, the same areas of interest were covered in each interview. Following each interview, notes on the responses of distribution center personnel were collected and follow-up telephone calls were made to clarify any information that was left out during the initial interview.

In presenting the results of these interviews in this and subsequent chapters, I have attempted to show the consensus response from all the distribution center personnel that were interviewed. This information is indicated as coming from industry sources and should not be considered as an average of all the responses received. Rather, the

information presented reflects the respondents best estimates of industry operation levels at the current time.

The following chain and independent grocers' distribution centers were visited:

Food Lion Stores, Salisbury, N.C.

Giant Food, Inc., Landover, Md.

The Kroger Co., Salem, Va.

The Kroger Co., Charleston, W. Va.

The Kroger Co., Cincinnati, Ohio

Richfood, Inc., Mechanicsville, Va.

Safeway Stores, Inc., Landover, Md.

Virginia Foods of Bluefield, Bluefield, Va.

Winn-Dixie Stores, Inc., Charlotte, N.C.

The following companies were contacted by telephone:

Acme Markets, Inc., Philadelphia, Pa.

Albertson's, Inc., Boise, Idaho

American Stores Co., Salt Lake City, Utah

Atlantic & Pacific Tea Co., Montvale, N.J.

Giant Eagle, Inc., Pittsburgh, Pa.

Lucky Stores, Inc., Dublin, Calif.

Publix Super Markets, Inc., Lakeland, Fla.

Supermarkets General Corp., Woodbridge, N.J.

These contacts provided the information used in the analysis of the use of pallets in the food distribution system. Distribution

centers visited include a representative sample of the top 20 food chains, as ranked by sales, several independent food retailers, a cooperative, and an independent food wholesaler. As a group, the food retailing chains and independents included in this survey combine to account for over 50 percent of all retail food sales in the United States.

STRUCTURE OF THE INDUSTRY

The present study is directed at an analysis of the distribution segment rather than the manufacturing segment of the grocery and related products industry. Handy and Padberg (1971) point out that distribution is typically handled by the manufacturer of products and that no models existed prior to their analysis concerning behavior within an industry dominated by a distributor. They further point out that large distributors occurred only infrequently outside the food industries until recently and that the economic characteristics of the large distributor have not been extensively studied.

Handy and Padberg's model of competitive behavior in the food industries provides a basic description of the structure of the industry. It includes a model of bilateral interaction (large manufacturer vs. a large distributor) with functional specialization among manufacturing and retailing sectors. Their model is specified schematically rather than quantitatively. The analysis includes the identification of manufacturing, distribution, and retailing sectors

within the food industry. Behavior patterns are found to result primarily from the tendency toward specialization by the various sectors.

The structural elements of Handy and Padberg's model include a food manufacturing oligopoly core; a large fringe of small- and medium-size food manufacturing firms; a food distribution oligopoly core (large food chains); and, a large fringe of small- and medium-size food retailing firms. These structural elements are defined as follows:

> Core manufacturers-these food manufacturers are large firms, usually diversified into many products. A major part of their competitive strategy revolves around improving brand meaning and impact.
>
> Core distributors-the primary competitive advantage of core distributors is their preretailing operations. All core distributors have warehouses, manufacturing plants, quality control labs, and computer-controlled logistic systems. The preretailing advantages pertain to matters of cost and efficiency, not product quality.
>
> Fringe manufacturers-these many small- and medium-size food processors have little or no marketing capability. Private-label programs enable them to specialize in the physical functions of food processing - their primary competitive advantage.
>
> Fringe distributors- these do not have preretailing capabilities of the big chains. Their advantages involve greater merchandising flexibility. Smaller retailers use this flexibility to adapt their stores to the particular needs of communities they serve. The wider variety of more progressive products from core manufacturers fulfills their product and service needs. In competing with the standard offerings of large chains, fringe distributors have become more innovative in store design as well as merchandise variety. In this way, their competitive advantage is compatible with the competitive emphasis of core manufacturers (Handy and Padberg 1971).

Core distributors tend to emphasize private label programs; hence, they are best served by the fringe manufacturers. This combination is a separate channel organized to emphasize physical efficiency and price competition. The drive for physical efficiency directs innovative activity within this channel toward process development as opposed to product development. Products within this channel tend to be differentiated on a price basis.

Core distributors have a comparative advantage in pre-retail operations which are subject to significant economies of scale. Most warehouse economies are realized by operations of $100 million or more annual retail sales. However, to obtain economies of manufacturing and private-label operations, annual retail sales of over one-half billion dollars may be necessary.

Fringe distributors tend to work most directly with core manufacturers. This combination of large, diversified-product manufacturers and smaller, more specialized distributors constitutes a channel that emphasizes innovation and progress in defining the character of the product and services. It is on this basis that products within this channel are differentiated.

Fringe distributors are able to overcome much of the core distributors' pre-retail cost advantage by more effective performance at the retail level. Progressive fringe distributors rely on unique store decor, highly motivated personnel, and innovative merchandising programs.

While distribution oligopolies have achieved their most advanced development in food industries, they now extend far beyond this sector, particularly into the general merchandising discounting field. Distribution oligopolies are probably a structural characteristic of the more mature industry sectors (Handy and Padberg 1971).

A firm may be said to possess market power if a price, production, marketing, or purchasing decision it might practically make can directly and materially affect the incomes of other firms or persons or can appreciably change the average price, total quantity, or marketing or purchasing practices in a market in which it participates (Brandow 1969). Under oligopoly, rivalry is personal, firms have character, power is part of the industry environment; under pure competition, everything focuses impersonally on price, and producers may not even regard each other as rivals.

Because food manufacturing and distribution is considered to be dominated by a few large firms, the long-term potential for pallet demand depends more on the continued growth in retail sales than on changes in industry operation techniques. In a mature industry with substantial capital investment in materials handling equipment dependent on the use of pallets, substitution of alternative materials handling techniques that would completely replace the use of pallets would involve large expenditures of new capital.

RELATIONSHIP BETWEEN RETAIL STORES AND DISTRIBUTION CENTERS

Any retail store selling a line of dry grocery, canned goods, or non-food items plus some perishable items is defined as a grocery store. The number of grocery stores has varied over the years. According to statistics published by Progressive Grocer Information Sales, in 1985 there were approximately 154,000 grocery stores in the United States, broken down as follows:

All grocery stores	154,000
Supermarkets (over $2 million)	30,505
Independent Supermarkets	13,285
Chain Supermarkets	17,220
Convenience Stores	45,400
Other (small) stores (under $2 million)	78,095

Over the last 40 years, there has been a decrease in the number of retail grocery stores in the United States from over 340,000 to less than 155,000. Most of this decrease was in stores operated by single-unit firms. The number of stores operated by multi-unit firms has increased substantially, particularly for firms operating more than 11 units, which is defined as a chain. Also, the growth in convenience stores has been dramatic. Convenience store sales in 1980 were $24.5 billion and $47.5 billion in 1984, nearly doubling.

The primary function of a grocery distribution center is to act as a central point from which a retail store can receive products to replenish the products sold. It would be prohibitively expensive for

individual retail stores to purchase products directly from a manufacturer in the small quantities which a retail store deals with on a daily or weekly basis, primarily because of the shipping costs involved. Also, the size of most retail stores prohibits the stockpiling of large quantities of goods to meet consumer needs for an extended period of time.

The distribution center therefore provides an intermediate buffer between the manufacturer and the consumer, allowing purchases of large quantities of goods at substantial volume discounts and the storage of those goods until they are needed by the retail store. Also, the distribution center allows the development of a more efficient distribution system which involves the use of pallets for moving the products to the retail store than would be possible if all retail stores had to receive products directly from manufacturers. Instead of many trucks making deliveries of small quantities of products, one truck can make deliveries of a multitude of products to the same retail store.

Four categories of grocery distribution centers may be identified: chain-store distribution centers; voluntary-group distribution centers; cooperative distribution centers; and non-sponsoring wholesale distribution centers. The distribution centers in each category operate independently. That is, there is no trading of pallets between centers in different categories. The chain-store distribution centers generally serve a national or regional chain of retail stores. The voluntary-group distribution centers act as

wholesale sponsors for a voluntary merchandising group of independent retail stores who operate under a common company name. The cooperative distribution centers serve generally independent retail stores who are stock holding members of a cooperative wholesale buying group. The non-sponsoring wholesale distribution centers serve retail grocers who are unaffiliated with any of the other distribution centers.

One feature which distinguishes the above categories of distribution centers is in the corporate relationship between the centers and the retail stores they serve. The chain-store distribution center is generally a separate profit center within a larger corporation. The other three types of distribution centers are corporate entities in themselves, although in the case of the cooperative distribution center, the retail stores do own stock in the corporation. Another feature is the size differences between distribution centers in each category. This relates to the market share held by each category. Generally, the chain-store distribution centers are the largest in terms of physical volume of products moved through them on an annual basis, while the non-sponsoring wholesale distribution centers are the smallest. The other two catagories fall in between these two extremes. The larger distribution centers are more likely to depend on automated handling equipment within the center to handle to the volume of product moving through the center, while the smallest centers are more likely to use a greater amount of manual labor to move products through the center.

Production and distribution economies of scale are substantial in the food industry. As noted earlier in the section on the structure of the industry, Handy and Padberg (1971) estimate that to obtain economies of manufacturing, distribution, and retailing, annual retail sales of over one-half billion dollars may be necessary. With regard to just grocery distribution, they estimate that most economies of scale are achieved when annual retail sales handled by distribution centers equals or exceeds $100 million. This is true whether the grocery distribution center is a part of a larger corporation or an individual wholesaler. The optimal size for a distribution center is determined by the size of the market served, which relates to the number of retail stores served and their level of retail sales, and the distances involved between the retail stores and the distribution center. Current structural changes in the grocery distribution industry, such as increasing access to scanning data, introduction of high-rise storage facilities, and the development of better pallet handling equipment, will further increase the economies of scale in grocery distribution. As grocery distribution centers achieve these economies of scale, their pallet procurement power should increase more rapidly relative to grocery manufacturing.

PALLET STANDARDIZATION IN GROCERY DISTRIBUTION

Grocery distribution centers handle a wide variety of products. These products include dry grocery products, canned goods, produce, frozen food, meats, and dairy products, as well as many types of

non-food items. Because of federal and state health and sanitation regulations, all products stored in a distribution center warehouse must be stored on some type of platform or, at least, not directly on the floor.

Based on the survey of distribution centers, it is concluded that nearly all merchandise in the grocery distribution warehouses are on pallets. Most frequently, pallets are used to store merchandise in pallet racks. Nothing is stored directly on the floor, although floor stacks of goods on pallets are not uncommon. When floor stacks of goods on pallets are found, the maximum height of the stacks seldom exceeds 4 pallets in height. Floor stacking is used exclusively in few warehouses. It is used primarily for holding inventory of large volume, low unit-weight items, although a few warehouses do pick orders for shipping from floor stacked pallets.

Materials are handled on pallets in warehouses with few exceptions. When goods arrive at the warehouse on slipsheets or deadpiled on the floor of a truck or railcar, they are placed on pallets at the receiving dock before they are moved to storage in the warehouse. Goods arriving on nonstandard pallets are restacked on warehouse pallets prior to entry into the warehouse. Gravity-fed hoppers may be found in smaller warehouses where low-volume items (less than case lots) are available to pickers, one unit at a time.

The standard grocery pallet size used in warehouses is 48 by 40 inches. Although different pallet sizes may be found, the use of

pallets other than the standard 48 by 40 pallet is limited to special applications. These include dairy operations, health and beauty aids sections, slow moving items sections, automated meat lines, and automated frozen food sections. Typically, these special pallet sizes are found in captive pallet systems, that is, in systems where the pallet never leaves the warehouse or where control of the pallet is maintained by the distribution center.

No distribution center could function without the aid of a computer. Items are received, stored, picked, and shipped as a result of a computer generated order. Use of computerized coded bins to store goods within the warehouse means that the space in the warehouse is divided up into a number of cubes, each one of which is identified by the computer, so that any individual cubic space in the warehouse is identified by an appropriate code and any good stored in that space can also be identified by an appropriate code.

Maintaining the quality of pallets in the system is a major problem for distribution center managers when pallets are exchanged with suppliers and are used in the distribution to retail stores. In a direct exchange of pallets between distribution centers and suppliers of grocery products, the pallet received under product and the empty pallet returned to the supplier must be equal in quality. This requirement is not always satisfied. No distribution center reports receiving the same quality pallet in the direct exchange, although managers maintain that the distribution centers return only good or satisfactory pallets.

Pallet standards do not appear to be substantially different in any of the distribution centers visited. Causes of damage to pallets have been explored elsewhere in the literature, but this still remains as a source of concern throughout the food distribution system.

PALLET USE IN GROCERY DISTRIBUTION

The life of a pallet in the food distribution system is limited. At some point, pallets must be replaced so that a minimum level of pallet quantity is maintained. Pallets may enter a distribution center in a number of ways:

1. Direct purchase from a pallet manufacturer.
2. Direct purchase from a pallet distributor.
3. Indirect purchase from a pallet manufacturer.
4. Indirect purchase from a pallet distributor.
5. Exchange with grocery vendor.
6. Exchange with other distribution centers.
7. Exchange with retail stores served by the distribution center.

Considerable variation exists among distribution centers methods for maintaining a minimum level of pallet quantity in the system. However, price and availability appear to be the governing factors in the decision regarding how the level of pallet quantity is to be maintained.

The quantity of pallets purchased directly from either a pallet manufacturer or pallet distributor varies considerably from one

distribution center to another. Few distribution centers purchase all of their pallet needs directly. In these cases, local pallet manufacturers or pallet distributors are contacted and asked to submit bids for the delivery of pallets meeting the distribution center's specifications. Some distribution centers purchase only new pallets while others purchase only reconditioned or used pallets. Price and availability of used pallets are critical in the case of used pallet purchases.

Most distribution centers obtain pallets through indirect purchase from pallet manufacturers or pallet distributors. That is, they negotiate with the manufacturers of grocery products, hereafter noted as vendors, to deliver their grocery products on pallets which meet the specifications required by the distribution center. These may be new pallets which the vendor purchases from a pallet manufacturer or they may be reconditioned or used pallets purchased from a pallet distributor. The vendor ships the product to the distribution center on pallets and bills the distribution center for the cost of the product as well as the cost of the pallet. These pallets then enter the distribution system and are added to the stock of pallets in the system. This is the predominate way in which new pallets enter the system.

Most vendors who deliver their product to a distribution center on pallets do not have agreements which include the purchase of the pallet as well as the product by the distribution center. In a majority of

cases, the vendors shipping on pallets have a direct exchange agreement with the distribution center. The vendors will deliver goods on pallets to the receiving dock of the distribution center and pick up the same number of pallets to take back to the vendor. While the number of pallets at the distribution center has not changed as a result of this direct exchange, the composition of pallets has changed. That is, the distribution center may no longer have exactly the same pallets, in terms of quality, that it had prior to the exchange. When multiplied by the total number of similar shipments received, the number of pallets exchanged can exceed the number of pallets in the distribution center in a relatively short time period, or in most cases, in less than one month. This means that the quality composition of pallets in the distribution center is very dependent on vendors shipping goods on pallets that meet the standards set by the distribution center, regardless of whether the pallets are to be purchased by the distribution center or are to be exchanged for a like number of pallets.

Some products are delivered to the distribution centers either on slip sheets or on the floor of the truck. The quantities of product received at individual distribution centers in this fashion varies considerably. Some distribution centers receive as much as 40 percent of their products in this way; but, the industry average must be closer to 35 percent. Depending on the arrangement with the individual carrier, the truck driver may be responsible for unloading the truck and placing the product on pallets at the receiving dock. Regardless of the

arrangement, all products received on slip sheets or on the floor of the truck are placed on pallets prior to being placed in storage.

Although pallets and slip sheets require alternate handling equipment, they may be used together in a distribution system. That is, products carried on slip sheets may be either placed directly on the slip sheets, or placed on pallets after being placed on slip sheets. The latter procedure occurs frequently in the handling of grocery products where the products are shipped from the manufacturers on slip sheets and are placed on pallets upon arrival at a distribution center for subsequent handling in the center. In this case, slip sheets are complements used with pallets not substitutes for pallets.

The possibilities for replacing pallets with slip sheets in materials handling of grocery and related products are limited by the overall handling environment for grocery and related products. Grocery distribution centers have substantial capital investments in handling equipment which is designed to accomodate pallets. In order for pallets to be replaced by slip sheets, distribution centers would be required to make major outlays of capital for new equipment. Thus, the price cross-elasticity for substitution of slip sheets for pallets must be very low. Conversely, the price cross-elasticity for substitution of pallets for slip sheets may not be so low because of the greater flexibility of handling equipment in the area of distribution where slip sheets are presently in use.

Exchange of pallets between distribution centers within the same corporation does occur, particularly when one center has an excess number of pallets in relation to its needs and another has a shortage of pallets. This does not occur frequently, primarily because the individual distribution centers associated with a single corporation are usually spread out over the country to provide regionalized service and are not within close enough proximity to each other to be able to afford shipping of pallets between them. A more typical response by a distribution center to an excess of pallets in the system would be to return the excess pallets to the captive supplier, that is, a vendor who ships products on pallets which are kept by the center. In this case, the distribution center essentially sells the pallets back to the captive supplier who may then turn around and ship more product back to the distribution center on those pallets and again bill the distribution center for both the product and the pallet.

Since most distribution centers ship products to retail stores on pallets, another way pallets enter the distribution center is through an exchange of pallets with the retail store. In almost all cases, the retail store submits a request for certain products to the distribution center. This request is translated into a picking order which designates the location of the items in the warehouse, the order in which the items are to be picked, and the quantities of each item that are to be loaded onto each pallet. As the order is picked, the cartons of product are stacked on a pallet in such a manner that the stack has

square sides - or the pallet is said to be cubed. The top layers of product stacked on the pallet are tied together in various ways - with strapping tape, string, or stretch wrap applied by hand or by machine.

Pallets with completed orders on them are taken to the shipping docks where they are loaded onto trailers for delivery to the retail stores. Some distribution centers deliver products to the retail stores in trailer lots, that is, all of the products on a trailer go to one store. Other centers will have mixed loads with a trailer dropping off part of each load at several stores. The latter case occurs most frequently for centers serving smaller retail stores which do not have the volume of product moving through the store that the large super stores have.

The pallets are unloaded at the retail stores, with the products still on them. Stores load empty pallets, paper bales, bread trays, milk trays and so on into the trailer which returns to a receiving dock at the distribution center where the pallets are sorted out and returned to the system.

Although a majority of distribution centers deliver products to retail stores on pallets, there are alternative methods such as dead-piling products on the floor of the trucks and shipping products on metal carts rather than pallets. In both of these cases, the pallets used in the distribution center for storage of products never leave the distribution center unless the center has an exchange agreement with a vendor who ships product to the distribution center on pallets.

Backhaul operations are an important part of the distribution system for grocery and related products. It is more efficient as well as profitable to have a truck on the road carrying a load rather than empty, so distribution centers schedule the pickup of product for return to the center whenever possible. A typical case would be as follows: a truck delivers a trailer load of palletized product to a retail store, drops the trailer off, and picks up an empty trailer that was left at the store on the previous delivery. The trailer is taken to a vendor in close proximity to the retail store and a palletized load of product is picked up for delivery to the distribution center. Alternatively, the trailer may unload at the retail store and proceed to the vendor on the same day. In these cases, the pallets which are picked up at the retail store may be traded or exchanged with the vendor when the trailer picks up the backhaul load. This differs from the earlier case were the pallets were returned directly from the retail store to the distribution center. The use of backhaul arrangements occurs throughout the country although those distribution centers located in the western part of the United States appear to receive a larger portion of the products at the distribution centers as a result of backhauls than those in the eastern half of the United States. This is a result of the greater distances involved between distribution centers in the west and their retail stores served.

Keeping track of the pallets in a system requires a substantial amount of paperwork on the part of the distribution center management.

The problems are compounded when pallets are exchanged that are not of the same quality or standard required by the distribution center. Those systems which have captive pallets appear to have less problems with maintaining standards than those systems which involve many direct exchanges of pallets.

Pallet repair may be contracted with an outside agency or it may be done inside the distribution center. It appears that the decision regarding whether to repair pallets internally or to contract out is made on the basis of least cost rather than convenience. Pallet repair operations vary in levels of complexity from one-man, hand-nailing operations to sophisticated pallet un-nailing machines with several employees working multiple shifts replacing up to four deck-boards and one stringer per pallet.

CHAPTER IV

DISTRIBUTION MODELS

The initial section of this chapter is a review of the use of mathematical models to analyze market behavior. This section is followed by a literature review of previous economic studies of a variety of markets, including the forest products markets. The techniques used in these studies may have application to modeling of the grocery distribution system. These techniques include plant location models, spatial equilibrium models, econometric models, and simulation models. The concluding section of this chapter will discuss the applicability of existing models to analysis of the grocery distribution system.

REVIEW OF LITERATURE

The use of mathematical programming to analyze market behavior has been explored extensively in a number of studies since Samuelson (1952) pointed out that an objective function can be written by restating the firm's revenue and cost functions in the form of a profit function where profit equals revenue minus cost. Samuelson showed that maximization of the objective function guarantees fulfillment of the conditions of a competitive market. While some of the studies have been purely theoretical, his basic idea also has proven useful in the realm of empirical economics, particularly in the context of agricultural

planning models which may contain rather detailed supply side specifications. Fromm (1973) illustrates a number of different approaches to the use of theory in the specification and estimation of models and provides a discussion on movement from empirical models to modifications or improvements of theory.

Duloy and Norton (1975) develop a procedure for representing competitive and noncompetitive structures in linear programming models. Arbitrarily close approximations to nonlinear forms - in both the objective function and constraint set - can be made without much loss of the computational efficiency of the simplex algorithm. Product substitution effects in demand can be approximated by a linear program. The demand structure can be transformed to take account of any shift in demand which can be represented by a rotation of the demand function. The objective function in these cases again maximizes profit, which is expressed as the difference between the revenue obtained from selling activities and the costs incurred in production activities.

Hazell (1979) provides a method for formulating linear programming models in which one or more factors have upward sloping supply schedules, and the prices of these factors are to be endogenously determined at either their competitive market equilibrium values or at the levels set by a monopsonist. The method for achieving these results utilizes the sum, over the relevant factor markets, of the producers' and consumers' surplus, and is an extension of existing methods for solving price endogenous models of product markets. This procedure

extends the Duloy-Norton method to obtain the solution to endogenous factor markets in aggregate agricultural production models. In this case, it is the factor supply function that is given exogenously, and the factor demand function which is implicitly contained in the production decision model. The method is first developed using a continuous increasing cost function, and then the special complexities inherent with the use of step functions are considered.

PLANT LOCATION MODELS

Plant location models have been used to analyze the relative efficiency of various plant sites and to select the least cost locations for production and inter-regional transportation. For example, Fedeler and Heady (1976) have developed ten specifications of a linear programming model to jointly select the least cost locations of grain production and interregional grain transportation in the US. Their results suggest that choice of transportation mode and grain flows are sensitive to transportation cost changes and the distribution of exports among ports but the location of grain production is not. Transportation costs in their model are designed to represent transportation operators' costs, not the market price of transportation services, plus grain elevator loading and unloading costs. Although the flow of grain through an elevator may be stable, the location of those who buy from or sell to the elevator may be sensitive to transportation and export changes.

Kloth and Blakely (1971) develop a production-distribution model utilizing separable programming to determine the optimum number, size, and location of processing plants that will minimize assembly, processing, and distribution costs of the U. S. dairy industry. Significant economies are possible under optimum organizations of the dairy industry, but they note that models which minimize industry costs with a single firm in each market overestimate the potential savings from reorganization of the industry. A substantial portion of such savings might be attributed to the economies associated with the establishment of a single firm in the local markets.

Another algorithm has been suggested that operationalizes the Stollsteimer (1963) model for plant location problems where a large number of plants may enter the optimum solution (Warrack and Fletcher 1970). Also stated as a product distribution model, given m geographically dispersed market demand (Qj) to be supplied from any one or more of N possible plant locations, their model solves for the number of plant locations, $n<N$, that should be used, the locational configuration for the n plant locations, and the size of plant at each location chosen.

Focusing on rail shipments, Ladd and Lifferth (1975) developed a transshipment plant location model which was used to determine the number, size, and location of new subterminals, expansions in storage capacity of existing country elevators, the rail network, and the monthly flows of grain from origins to elevators to destinations to

maximize joint net revenue of grain producers within a 6 1/2-county region. Their method of solution extends the Stollsteimer model.

An activity analysis model was developed to determine the optimum period of production at a chain of sugarcane processing plants and the optimal regional transport network flows of cane and raw sugar (Ryland and Guise 1975). Explicit treatment is given to discrete variations in input quality which affect revenue at each plant location in each time period. Optimal solutions to three market configurations open to a multifacility monopolist - spatiotemporal quality competition, spatial quality competition, and pure competition - are obtained.

A variety of interregional linear programming models have been used to study the optimal location of the cattle feeding industry. Byrkett, Miller, and Taiganides (1976) performed an analysis to determine which factors are most influential in determining feedlot location and thus need to be included in these models. In addition to traditional factors, consideration is given to the effects of region definition and regional land use practices. Their results indicate the importance of feeders, grain, and land use patterns.

Combination of a single-equation location model and interregional trade analysis into one model has provided an effective tool to simultaneously determine regionally optimal numbers and sizes of processing plants and optimal interregional trading and pricing. The results of an earlier empirical application of a model on the prospective soybean industry in India were reviewed after four years of

actual development (von Oppen and Scott 1976). The model was constructed in two parts: the plant location was determined with the help of a single equation optimization model and the interregional trade of inputs and products was analyzed by means of a quadratic programming model. Included with the model was a flow chart of a spatial equilibrium model for plant location and interregional trade.

SPATIAL EQUILIBRIUM MODELS

Spatial equilibrium models which analyze price, production, and consumption patterns over time have been constructed for a number of industries. Those models included in this review, by no means an exhaustive list, analyze such industries as the Northeast milk market (King and Ho 1972), the international paper and paperboard market (Hassan and Wisdom 1982), the lumber and plywood markets of the United States (Adams and Haynes 1980), the North American paper industry (Buongiorno and Gilless 1981 and 1983), the international trade of forest products (Buongiorno and Gilless 1983), the New England dairy industry (Kottke 1970), the U.S. apple industry (Fuchs, Farrish, and Bohall 1974), the North American pork sector (Martin and Zwart 1975), the world sugar economy (Gemmill 1977), the national coal economy (Libbin and Boehlji 1977), and the world rapeseed industry (Furtan, Nagy, and Storey 1979).

King and Ho (1972) used reactive programming developed by Tramel (1965) to solve a spatial equilibrium problem concerning projected milk

prices, consumption and production during the period 1965-1975. Equilibrium prices and trade flows were calculated based on given demand functions for each consuming area, supply functions for each producing area, and transfer costs from each producing area to each consuming area.

Hassan and Wisdom (1982) developed single market analyses of international trade for three paper products: newsprint, printing paper, and paperboard. Demand equations were estimated for all three commodities within regions. Likewise, regional supply equations based on product and input prices were estimated. Cost of shipping products along major trade routes were estimated, although the same regions were not used in the analysis of each product market.

The Timber Assessment Market Model (TAMM) developed by Adams and Haynes (1980) analyzed a spatial model of North American softwood lumber, plywood, and stumpage markets. Six product demand regions and nine supply regions (including Canada) were included in the model. The model was designed to provide long-range projections of price, consumption, and production trends. Regional processing response functions, which corresponded to Hassan and Wisdom's supply equations, were developed. Regional stumpage supplies, which depended on price and local forest inventories, were also developed. The assumption was made that regional stumpage demand was limited to the local processing sector.

In an economic model of the North American paper industry, Buongiorno and Gilless (1983) used spatial equilibrium methodology to calculate production, transport and consumption of raw materials, intermediate products, and final goods traded in the industry. The model was designed to predict long-term developments of the industry under various economic and demographic scenarios. The model focused on seven supply and five demand regions in the United States. The forecasts for the paper sector resulting from the model were considered to be compatible with those of the solid wood sector based on the TAMM methodology.

An adaptation of the previous model to consider international trade in wood products was presented by Buongiorno and Gilless (1983) for the trade of newsprint between major importers and exporters in a relatively aggregated set of world regions. The model featured the introduction of potential barriers to trade such as tariffs and quotas and the inertia of trade adjustments. The model determined equilibrium imports and exports and corresponding prices by maximizing the surplus value of trade for all countries simultaneously.

A set of recursive relations incorporating linear and quadratic programming formulations were used to handle the temporal and product-use dimensions in addition to the spatial dimension. An application of such a model to the New England dairy industry traced price, production, and consumption patterns over time (Kottke 1970).

The concept of recursiveness in multistages may have general applicability in the design of similar models for other industries.

Fuchs, Farrish, and Bohall (1974) found that analysis of the U. S. apple industry and its problems requires simultaneous consideration of its multiple dimensions of space, time, resources, commodities, production activities, and marketing levels. They constructed an empirical quadratic programming model incorporating these dimensions and demonstrated its use for policy analysis by measuring the impact of alternative size reductions in regional apple marketings on f.o.b. level industry and regional net returns. The model could also be used in determining the ramifications of changes in consumer demand, transportation costs, and marketing margins on such factors as production, prices, and interregional flows.

A quarterly recursive quadratic programming model of the North American pork sector was constructed to explain spatial and temporal variations in the sector and to evaluate the repercussions of policy changes (Martin and Zwart 1975). An adjustment in the Takayama-Judge specification of the quadratic programming model was necessary for the inclusion of storage demand relationships. Storage considerations should be included in spatial analyses when storage is an important factor in the market.

U. S. sugar policy was examined in an international context by means of a spatial equilibrium model of the world sugar economy in which various trade barriers were imposed (Gemmill 1977). The solution gave

quantities produced and consumed in each region as well as intersectoral trade and the domestic price in each region. Five policy experiments of particular interest to the United States were conducted.

A multiperiod spatial equilibrium model of the national coal economy was developed to evaluate future interregional shifts in coal production and the investment requirements and sequencing for exploitation of a nonrenewable, variable quality resource (Libbin and Boehlje 1977). The objective function of the model was designed to minimize the total discounted cost of mining, washing, and transporting coal, reclaiming strip-mined land, and constructing new mines, subject to constraints on mining equipment availability, known coal reserves, current mining standards, and the projected demand for coal. Cost minimization was justified on the basis of firm size, the competitive structure of the industry, and the behavior of utilities to obtain competitive bids. Eighteen demand and twenty-one supply regions were specified with unique points of origin and destination.

A four-region, three-commodity, spatial equilibrium, quadratic programming model of the world rapeseed industry was constructed to measure the impact of the various policy changes (Furtan, Nagy, and Storey 1979). Excess demand and supply in primary and intermediate markets was illustrated for equilibrium market conditions in a single commodity, multiregion case. The equilibrium price in each market was determined by the difference in transport and tariff charges. The quantities traded, produced, and consumed in each market related to the

price through the specified demand and supply curves. In the general case of joint production, prices of the commodities were linked through a marketing margin equation. The objective function was then to maximize the net social payoff as calculated in all commodity markets. If a margin equation was employed, then this equation formed a derived demand in the primary commodity market. Once the supply of the primary product was known, then the supply of final products could be determined in each market. The objective function then allocated the final product between the regions given the respective demand curves.

ECONOMETRIC MODELS

Econometric models are composed of a number of components which reflect various aspects of demand, supply, and price determination. In order to isolate price-quantity relationships by statistical means, variables that cause these relationships to shift must be included in the analysis. One critical aspect of price determination in many of these models is the linkage between inventory levels and price adjustments. Even where sufficient data exists for model building, it may be impossible to identify the particular price needed for market clearing and adjustment.

The market model, which focuses on the price mechanism that serves to clear the market, is the most basic type of econometric model. Process models, on the other hand, deal with supply and demand within an industry rather than across a market. That is, they focus on the

transformation of commodity inputs into finished products. While market models balance supply and demand to produce an equilibrium price, prices in a process model are normally a function of production and material costs. Thus, process models concentrate on the industrial production process, requirements for raw materials, and labor and plant capacity (Labys and Pollak 1984).

Simultaneous equation models are one of the most frequently developed types of econometric models. For example, the major cyclical characteristics of the coffee economy have been explained by this type of model, which considers the lagged response of supply to price (Edwards and Parikh 1976). Coffee prices and production are characterized by strong long-term cycles, around which are found smaller short-run fluctuations. These may be explained to a large extent by a simultaneous equations model, taking account of the lags in the responses of demand and supply to prices. Such a model was established to simulate the impact of alternative stabilization policies, the objectives of which were to improve the average level of earnings, to break the long-term cycle, and to reduce the amplitude of short-term fluctuations.

McKillop (1967) developed an econometric model consisting of a system of linear supply and demand relationships for a variety of wood products and primary products in the United States. The major aims of this study were to estimate the structural parameters of the relationships and to provide point estimates of the demand and supply

elasticities. Coefficients of wood product supply and demand relationships were estimated using a 2-stage least squares procedure. Additionally, forecasts of future consumption and price levels were made for the period ending in 1975.

In contrast to the previous simultaneous equation model of McKillop, which estimated supply and demand functions for a broad range of forest products, Adams and Blackwell (1973) developed a model of the forest products industry at the various stages of production which appears to be more recursive in nature. They noted that the model combined features of the process model with elements of a market model. This model was used to forecast lumber demand, supply, and prices to 1975 and to examine various policies for limiting future price increases.

Manning (1975) developed an econometric model of the Canadian softwood lumber industry that explicitly investigated the relationships among Canadian softwood forest industry sectors, prices, and substitute goods. While similar to the two previous models, the model was different in that it included a major export market, the United States, as a sector in the model. Canadian requirements for softwood lumber were hypothesized as a residual of United States' demand for Canadian softwood lumber, where that demand was determined by the price and level of construction activity in the United States.

Adams (1974) focused on the response of prices and output to alternative National Forest timber supply policies in an econometric

model of the Douglas-fir Region forest products markets. Using a set of simultaneous linear equations, the structural relationships between the major sectors and subsectors of the regional forest economy were identified. The major sectors included in the model were the stumpage sector, log sector, and secondary products sector. The latter sector was similar to that developed by McKillop for the lumber and plywood subsectors. The third component of the secondary products sector, pulp products, was treated as exogenous.

The relationships between changes in food sector input costs and retail food prices have been examined using an analysis based on a twenty equation econometric model of the food-price determination process, specified following Popkin's "stage of processing" approach (Lamm and Westcott 1981). Their results indicate that increases in factor prices pass quickly to consumers, within two quarters for most foods.

A logit model was used to estimate the elasticities and cross elasticities for freight transport services. The model was applied to a sample of cherry and apple shipments. The performance of the model in explaining choice of transportation method was found to be highly satisfactory (Miklius, Casavant, and Garrod 1976). Inventory considerations as well as the decision where to buy were closely interrelated with the choice of the transport mode. The logit model has been modified to handle choices among unranked alternatives. The decisions to purchase from different production areas, therefore, could

be analyzed concurrently with the choice of transport mode. The authors limited their analysis to the choices of transport mode.

Another econometric model by Arzac and Wilkinson (1979) was designed to provide quarterly forecasts for such variables as livestock and grain production and prices, the retail-producer price spreads for meat products, and consumer demand for meat. The forecasts were conditional upon assumed values of such exogenous variables as disposable personal income, government policy with respect to the livestock and feed grain markets, and certain other developments in the economy.

Three independent methodological approaches and data sets were used to estimate the consumer loss due to monopoly in the US food manufacturing industries for 1975. They include estimates:- built up from previously estimated components of consumer loss; - derived from a regression analysis of the relationship of market structure to industry price-cost margins; and, - derived from regression analysis of the market structure determinants of national brand-private label price differences. All three estimates converge to the $12 to 14 billion range. Virtually all of the consumer loss is attributed to income transfers; 3% to 6% is due to allocative inefficiency (Parker and Conner 1979).

Heien (1980) presented a dynamic model of farm and retail prices and quantities. The system derived its dynamics from the assumption that supply and demand were not in balance and that this imbalance was

the determining factor in causing price changes in auction-type markets. Central to this theory was the notion that changes in retail food prices were caused by changes in prices at lower levels in the marketing chain. These cost changes were transmitted via markup type pricing rules which were shown to be consistent with firm optimization behavior under the assumption of constant returns to scale and time-fixity of production coefficients.

A dynamic model of the consumer demand for durable goods developed by Houthakker and Taylor (1966 and 1970) uses the concept that current purchases of a consumer durable depend on current income and prices as well as the level of inventory on hand for a particular consumer durable good. In this model, noted as a stock adjustment model, current purchases are viewed as an attempt to maintain inventories at some desired or equilibrium level and are influenced by past behavior. The effect of past behavior is assumed to be reflected in the current quantities of certain "state variables", which are changed by current decisions but these decisions depend on all past purchases with more emphasis on recent purchases and corresponding less emphasis on purchases made long in the past.

Other studies by Huang (1964), Duncan (1980), Berkovec (1985), and Chow (1957 and 1960), apply the stock adjustment model to the demand for durable goods in the automobile industry. In these studies, the desired stock of automobiles is considered to be a function of the relative price of automobiles and consumer income. Purchases of automobiles are

affected by differences between desired and existing stocks of automobiles.

Pearce and Wisley (1983) use the stock adjustment model to develop a model of retail inventories that measures changes in retail inventory investment. Inventory investment is shown to be a function of differences between the desired stock of inventories and the actual stock held at the beginning of some time period as well as unexpected sales in the period. The desired stock of inventories is hypothesized to depend on expected sales and on the expected real rate of interest. Their findings indicate that retailers make adjustments quite rapidly when differences exist between actual and desired inventory stocks.

Kmenta (1971) and Gordon (1978) present models of stock adjustment for intermediate goods, which use the concept that firms will maintain some functional relationship between the quantity of the durable good and the firms' expected sales. Gordon's accelerator hypothesis of net investment uses the concept that firms will maintain a fixed relation between their stock of capital and expected sales. Similarly, Kmenta suggests that the volume of stock of a commodity that a firm seeks to maintain can be expressed as a function of sales. In both cases, the desired level of stock at the end of period t, or Q^*_t, and the sales during period t, or X_t, are related as follows:

$$Q^*_t = f\{X_t\}$$

The adjustment made by the firm to the desired level of stock in any one period may be expressed as follows:

$$Q_t - Q_{t-1} = g^*(Q^*_t - Q_{t-1})$$

where Q_t equals the actual level of stock at the end of period t. The multiplier, g^*, represents the percentage adjustment made between the actual and desired levels of stock in any one period.

Griliches (1960) uses the stock adjustment model in developing a demand model for a durable input, farm tractors, to the production of agricultural products. Two features distinguish this model from other models which examine the demand for a consumer durable good. First, the model does not include a "scale" variable like consumer income. Griliches notes that in the conventional theory of the firm, the firm has no "budget restraint". The firm's only constraint is its production function. Second, in estimating the annual purchase of tractors, replacement demand is assumed to be proportional to existing stock. Thus, annual purchases equal the sum of changes in actual stock, resulting from differences between actual and desired levels of stock, and replacement demand.

SIMULATION MODELS

Simulation provides a fourth approach to analyzing the use of pallets in the food distribution system. In general, simulation is an approach which uses a model of a situation or a system and manipulates it with the help of a computer in order to imitate the system's behavior over time for the purpose of evaluating alternative operating decision rules. A major advantage of using simulation techniques is the

flexibility that is possible in the formulation of assumptions about the system. Relationships in the system do not need to take the linear or other forms required for analytical solutions.

A simulation model for hog production has been developed as part of an information system which may assist hog farm managers both in choosing between competing management strategies and also in implementing any chosen plan (Blackie and Dent 1976). The process involved in selecting the most suitable management strategy is illustrated using data from several hog units. The incorporation of the model into an information system ensures that the model is accessible to farm managers and their advisers. For a model to be used effectively, it needs not only to mimic accurately the real system but also to be accessible to managers. Effective communication between the model and its intended users is most readily obtained by incorporating the model into an information system which includes a comprehensive data collection and transmission service.

A six-plant, three-firm system simulation model of the processing sector of the domestic vegetable oil industry was constructed by specifying the technical parameters of representative stage, plant, and firm production functions item by item (Lamm 1976). Five measures or conceptual approaches were applied to market performance analysis when price and cost data were not available. These were productivity measures, marketing bill measures, flow analysis, market structure measures, and the application of welfare economics. Using the

simulation approach allowed for the segregation of individual product markets from aggregates and for the use of explicit measures of market performance, measures that were more precise than the vague and sometimes misleading market structure measures frequently used.

A stochastic simulation model was specified by Bigman and Reutlinger (1979) to assess the impact of trade and buffer stock policies on the stability of consumption and prices and the expected values and standard deviations of costs and gains to consumers, producers, and the government, and the balance of payments. Trade policies were shown to have a greater impact on the stability of a country's food grain supply than any reasonable size buffer stock.

APPLICABILITY OF EXISTING MODELS

The usefulness of plant location models as predictive devices for determining the flow of pallets in the grocery distribution system appears to be limited by the focus of these models on costs, particularly the cost of transfer from supply point to demand point. These models assume that firms will make their location and output decisions in such a way as to minimize industry costs, based on known levels of demand for the product. Bobst and Waananen (1968) maintain that firms are much more likely to base these decisions on profit maximizing criteria than on cost minimizing ones. Only in the case of a perfectly competitive industry will the profit maximizing criteria and cost minimizing criteria result in an identical location or output

decision. As these criteria deviate from one another, actual spatial organizations will differ from those predicted by the models, and the models will underestimate realized industry costs.

Therefore, I reject the plant location modeling approach in modeling the demand for grocery pallets by the grocery distribution industry on the basis that the grocery distribution industry is not a perfectly competitive industry, and furthermore that regional quantity of grocery pallets demanded is unknown.

Most spatial models, linear or nonlinear, and most supply-response models analyze specific economic activities, such as the production or the distribution of a commodity. Spatial models use a region as the basic producing unit; supply-response models use an individual (representative or typical) firm. Supply-response models try to predict market supply under a given set of market conditions - ignoring, for the most part, interactions between firms in different regions or, for that matter, between firms in the same region. Spatial models try to take account of interregional competitive forces by explicitly including demand restraints and permitting interregional commodity shipments. Insofar as they are inconsistent with regional effects, individual-firm effects are largely ignored (Heady and Hall 1968).

Both the linear and nonlinear models postulate a linearly homogeneous production function. To the extent that such a production function is a distortion of reality, it is an inherent weakness of these models. Heady and Hall (1968) note that supply-response models make the

same assumption. Spatial models also assume complete resource mobility among firms in a given region. This assumption is obviously inconsistent with short-run equilibrium. As more regions are incorporated, the distortion is reduced. A distinct advantage of supply-response models is that, by their very nature, they include resource immobilities between firms.

The pattern of spatial prices is explained largely by transfer costs such as transport, marketing margins, and governmental trade barriers. Spatial equilibrium models have attempted to explain these price differentials by assuming that the products being traded are perceived by demanders as being homogeneous. These models, however, do not allow consumer prices of a commodity in a particular import market to vary by supplier at a given point in time. In addition, they predict a unidirectional trade flow pattern, so that either cross-hauling of commodities between two trading regions is prohibited or the trade pattern predicted is a net trade pattern. Commodities supplied by different regions may be differentiated in the eyes of importers.

If the pallet is considered to be a differentiated product, models based on product differentiation may be justified in at least two ways. First, the demand theory of Lancaster (1966) states that consumers ultimately desire product characteristics, and products can combine these characteristics in varying proportions. Johnson, Grennes, and Thursby (1979) outline an alternative approach which stresses differences among suppliers rather than product characteristics. Some

suppliers may be more reliable than others and buyers may want to diversify to protect against the possibility of supply interruption. If suppliers offer different contracts in terms of delivery dates, credit, or other services, prices of identical products in a market may vary by supplier. If particular suppliers are more reliable than others, then a contract delivered from a reliable supplier is of a different quality than a contract made with less reliable suppliers.

Commodities are differentiated frequently by quality or place of origin. Monke and Petzel (1984) propose two complimentary tests - bivariate price regressions and hedonic index estimation - as methods to identify whether differentiated products are amenable to treatment as a homogenous commodity. These price linkage tests represent necessary, rather than sufficient, conditions for aggregation and must be supplemented by information on market structure. The distinction between homogenous and differentiated products has obvious importance for the formulation of empirical models of regional trade. A homogenous commodity obeys the law of one price, in which prices across regions can differ by no more than the cost of commodity arbitrage. Analyses of regional trade have often assumed differentiated products to imply distinct markets without systematically testing for linkages. The source of differentiation usually has involved the place of origin or destination or quality variation.

Although prices of different products may differ, this phenomenon does not preclude an aggregate treatment of these products. If

differentiated products demonstrate a high degree of substitutability in production or consumption, the shocks from changes in the supply and demand of one product are transmitted to other products in the commodity group. In the case of pallets, the wood raw material input to the production of grocery pallets can alternatively be used to produce non-grocery pallets. The products are differentiated by end-use; but, the raw material input has a high degree of substitutability. This mechanism leads to price linkages across the differentiated products that can be identified statistically. Integrated markets are defined as markets in which prices of differentiated products do not behave independently. Markets which are independent must be modeled in a disaggregate manner, while markets which are integrated may be amenable to aggregate analysis.

As noted earlier, spatial equilibrium models depend on the identification of transfer costs for products being traded between regions. Identification of regional transfer costs for grocery and related products is complicated by the fact that reform or elimination of most state and federal economic regulations of motor carriers (Beilock and Freeman 1984) has coincided with the elimination of most data collection by those agencies with regard to motor freight rates. Thus, identification of regional transfer costs would require separate surveys of private motor carriers, rail car shippers, and grocery distribution captive fleet operations. Although such surveys are considered to be outside the scope of this study, they could be

conducted to provide a point estimate of current transfer costs between regions.

In addition, spatial equilibrium models are designed to predict a unidirectional trade flow where cross-hauling of commodities between two trading regions is not considered. If the objective of this study was limited to modeling only the demand and supply of grocery products on a regional basis, a spatial equilibrium model for the unidirectional flow of grocery products from manufacturer to retail store would be appropriate. However, the objective particularly involves modeling the demand and supply of grocery pallets in the grocery distribution industry. In modeling the demand and supply of grocery pallets, I must consider that the movement or use of pallets in grocery distribution is not unidirectional. That is, pallets continuously circulate through the system until they are no longer serviceable. This continuous circulation of pallets presents a complication which spatial equilibrium models are not equipped to handle. For this reason, I also reject the spatial equilibrium modeling approach in modeling the demand for grocery pallets by the grocery distribution industry.

Econometric models which identify price-quantity relationships using a system of demand and supply equations are limited in their application to the analysis of the grocery distribution system for several reasons. First, these models depend on the availability of time series data which identifies the historical relationship between quantities demanded or supplied and price. Sufficient historical data

do not exist for the building of statistical models which would permit such an analysis. Second, the demand for pallets in the grocery distribution system is complicated by the existence of inventory levels of pallets already in the system. The linkage between inventory levels and the price of pallets demanded from outside sources has been identified as a critical aspect of price determination. Again, the lack of price data for grocery pallets prevents any statistical estimation of the effects of this linkage. Finally, the supply of pallets to the grocery distribution system cannot be simply estimated as a function which relates the production and material costs to the quantity of new pallets supplied. Used pallets, repaired pallets, and exchanged pallets also enter the distribution system in addition to the new pallets supplied. The problem here is not with the used pallets or the repaired pallets which have prices associated with the quantities supplied to the system, but rather with the exchanged pallets that have no price associated with them. These exchanged pallets can affect the life expectency of pallets in the system which in turn effects the rate of replacement and ultimately effects the quantities supplied. However, there is no price linkage which can be estimated between total quantities supplied and the quantities of pallets exchanged.

One aspect of the econometric modeling approach included in this study is the identification, in descriptive rather than statistical terms, of the components which make up the various elements of demand, supply, and price determination in the associated market levels of the

distribution system. The variables which affect the demand for grocery products are linked with those which affect the demand for movement of grocery products and these, in turn, are linked with the variables which effect the demand for pallets in the system. The price mechanism exists which serves to clear the market, but it can only be described schematically rather than in statistical terms.

The existence of inventory quantities of grocery pallets in the grocery distribution industry requires a different econometric approach to demand modeling for grocery pallets. The stock adjustment modeling approach permits identification of the quantity of grocery pallets demanded by expressing the quantity demanded as a function of expected sales of grocery and related products. I will use this approach to develop a model that first identifies the inventory quantity of pallets in the system and subsequently relates inventory quantity to the quantity of pallets demanded. This model can be used in assessing the long-term potential and long-term trends in the grocery pallet market in terms of the level of retail sales in the grocery and related products industry.

Simulation modeling is the final approach considered for analysis of pallet use by the grocery and related products industry. One advantage of using a simulation approach is that it allows for the segregation of individual pallet markets rather than having to aggregate production or consumption over the entire country. Another advantage is

that the lack of price and cost data does not present a restriction on model development as it would with other model forms.

Simulation techniques are designed to imitate a system's behavior over time. Therefore, an analysis of the flows of grocery products on pallets between market areas to achieve a known level of retail sales in a given year is possible. However, the objective of this research is to develop a model for analysis of future demand and supply of grocery pallets. Application of the simulation modeling approach would require that future levels of retail grocery sales be estimated or predicted, which is outside the capability of the simulation modeling approach. Even if retail grocery sales were predicted using an alternate econometric approach, application of simulation techniques to analyze the future flows of grocery products on pallets would lack any measure of the error associated with the predicted flows of pallets. For these reasons, I also reject the simulation modeling approach in modeling the demand for grocery pallets by the grocery distribution industry.

CHAPTER V

GROCERY DISTRIBUTION MODEL

The initial section of this chapter describes the spatial relationship between various market levels of the grocery distribution system. In the next section, I describe the movement of pallets between grocery demand and supply points in order to identify the relationship between movement of grocery products and the demand for pallets at each point of shipment origin. Demand and supply relationships in the grocery distribution system are presented in the following sections of the chapter. Finally, a stock adjustment model for grocery distribution is presented.

SPATIAL ASPECTS OF GROCERY PRODUCTION AND DISTRIBUTION

Grocery production and distribution is not randomly distributed among the various regions of the country. Rather the location of these economic activities is determined by a number of factors, such as regional endowment of resources, production costs for intermediate and final products, transfer cost functions, and demand functions for the final products. The relative level of these factors determines the comparative advantage of one area to another. This, in turn, influences both the direction and extent of growth and development of the above activities in the region (Nichols 1969). Two examples are used to

illustrate this point. First, the 1982 Census of Manufactures (U.S. Dept. of Commerce 1985) reports a total of 16,813 companies manufacturing food and kindred products (SIC Code 20). However, only 32 companies are reported manufacturing cereal breakfast foods (SIC Code 2043). The eight largest of the 32 companies account for over 90 percent of the value of shipments, which are reported to exceed 4.1 billion dollars in 1982. More importantly, the cereal breakfast food companies located in the North Central Region account for over 70 percent of the value of shipments. The firms located in the North Central Region have a comparative advantage over firms located in other regions, in terms of resource availability, lower cost for raw material inputs, and lower production costs resulting from economies of scale. The comparative advantage for cereal breakfast food manufacturers in the North Central Region results in a concentration of firms in the region.

As another example, frozen orange juice processing firms are concentrated in Florida and California. The 1982 Census of Manufactures reports value of shipments of frozen juice products exceeding 1.8 billion dollars in 1982, with approximately 79 percent of the value of shipments coming from Florida and California. Kilmer, et al (1983) notes that orange juice processing plants are typically located in close proximity to the orange groves. These firms minimize the cost of getting the raw material to the processing plant. Also, by shipping frozen juice rather than unprocessed juice oranges, the value of each pallet load of product shipped is increased. From our survey of

distribution centers, it is estimated that the average pallet load of frozen food products is valued at $800 while produce, like juice oranges, is valued at less than $400. Thus, the comparative advantage over other regions in manufacturing and shipping frozen orange juice results in these production activities being concentrated in the two states.

Grocery production and distribution activities can be centered in regions spatially separate from the location of demand for grocery products (Figure 1). Because of the tendency for food production, distribution, and consumption to be spatially separated activities in the food production chain, each stage in processing generates a demand for the movement of products. This demand is satisfied, particularly in the latter stages, by materials handling services that include the use of pallets.

Grocery Manufacturers

The raw materials for grocery and related products are moved from a farm or other intermediate manufacturing site to the final product manufacturing plant, symbolized in Figure 1 as an arrow between Raw Material Producer and Grocery Manufacturer. An example of raw material movement is the shipment, by railcar, of grain products from grain elevators in the North Central Region to Kellog Co., in Battle Creek, Mich., and Ralston Purina Co., in Cincinnati, Ohio, both manufacturers of cereal breakfast foods located in the North Central Region that

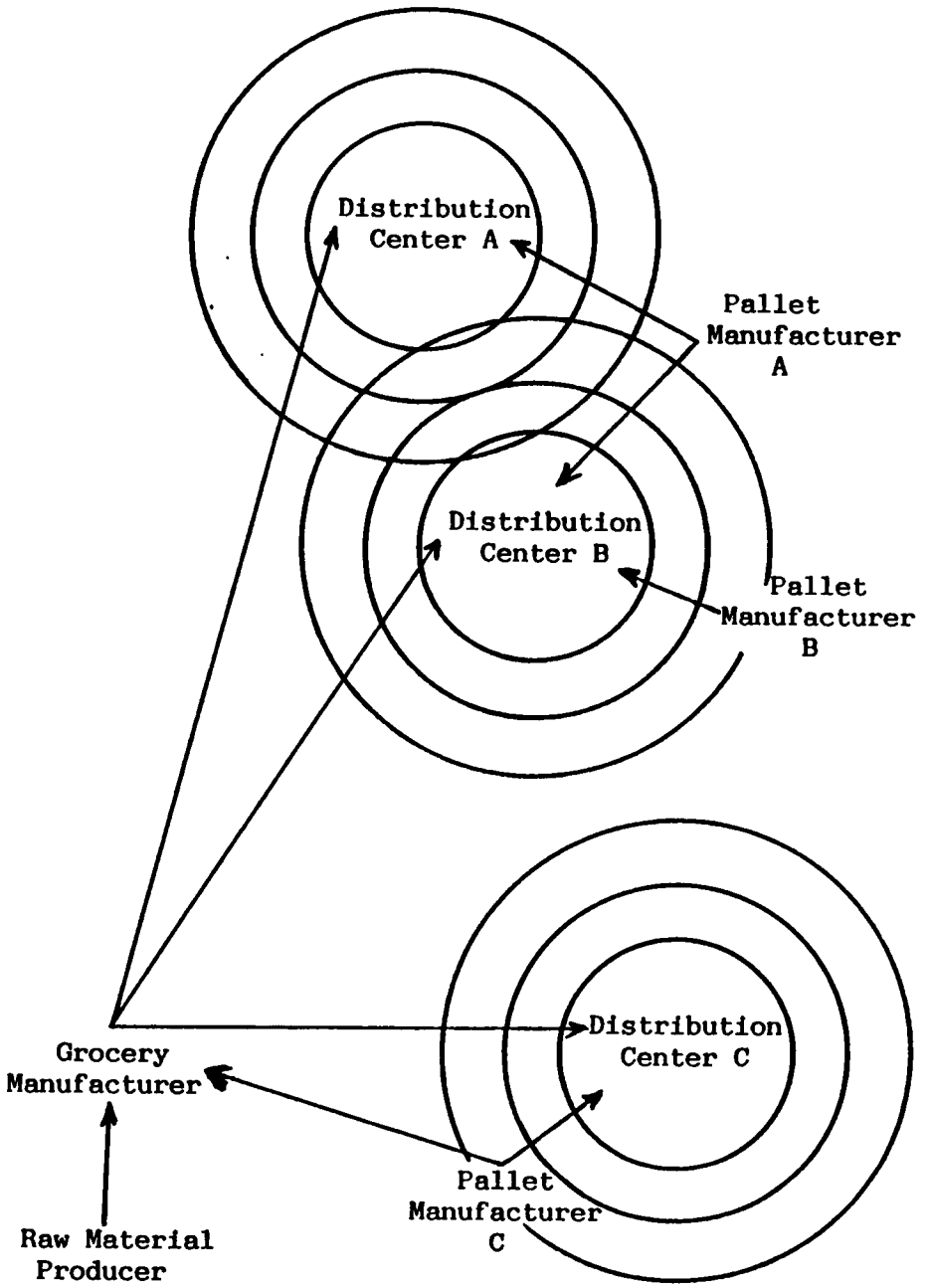

Figure 1. Spatial Aspects of Grocery Distribution.

distribute their products nationally. From the Grocery Manufacturer, final products are moved to grocery distribution centers, symbolized in Figure 1 as arrows between Grocery Manufacturer and Distribution Centers A, B, and C. An example of this movement of final products is the shipment of cereal products from Kellog Co. and Ralston Purina Co. to Kroger distribution centers in Cincinnati, Ohio, and Roanoke, Va., and to a cooperative distribution center, Richfood, Inc., located in Richmond, Va.

Some grocery and related products manufacturers maintain regional warehouses, spatially separated from their manufacturing facility, from which products are supplied to grocery distribution centers. Examples of these include General Foods, Morton-Norwich, and Quaker Oats Company. Thus, the shipment of palletized product from grocery manufacturer to grocery distribution center may involve a trans-shipment through a grocery manufacturer's regional warehouse. But, the shipment is originally palletized at the grocery manufacturing facility (the pallet demand point) and palletized product moves through the manufacturer's regional warehouse without being unloaded from the pallet. Therefore, the function describing the grocery manufacturer's supply of grocery and related products to grocery distribution centers requires the same number of pallets even though the palletized product may not proceed directly from the manufacturer to the grocery distribution center.

Grocery Distribution Centers

The preceeding example considers distribution centers operating in two separate geographic areas, designated as the Cincinnati market area and the Charleston - Roanoke market area. The 1987 Progressive Grocer's Marketing Guidebook reports that 18 distribution centers serve 3,445 retail grocery stores in the Charleston - Roanoke market area, and 17 distribution centers serve 4,923 retail grocery stores in the Cincinnati market area. These 35 distribution centers receive cereal breakfast food shipments from both of the above manufacturers, one of which, Kellog Co., is located outside the market area served by all 35 distribution centers, and the other, Ralston Purina Co., is outside the market area served by the 18 distribution centers in the Charleston - Roanoke market area.

Both demand and transfer cost functions for grocery products are critical in determining the location of grocery distribution centers in relation to the retail stores. The demand for grocery products must be sufficient to justify the investment needed to operate a distribution center. From values reported by Kaylin (1968), adjusted to reflect current prices, it is estimated that a distribution center can be operated profitably with the value of products shipped by the center as low as 20 to 26 million dollars annually. Thus, the retail stores served by the distribution center must be expected to generate sales equal to or exceeding this range to justify establishing a distribution center in a particular location. However, the transfer cost function

places a limit on the area which can be profitably served by a distribution center. Using Figure 1 as an example, the maximum distance that a retail store can be located from a distribution center and still be profitably served is indicated by the outer circle around each distribution center. This distance varies as the transfer cost function for each distribution center varies; however, Kaylin (1968) notes that 150 miles is the average limit on distance between distribution center and retail store for maintenance of acceptable ratios of expense to total volume of products transported. Industry sources indicate that this distance is still valid in transportation of grocery products to retail stores in the current market, particularly in the Eastern half on the United States.

Shippers of grocery products must consider the full transport cost and not just the freight rate. The full transport cost is the freight rate plus any nonprice costs associated with the service quality offered by the mode of transportation. These characteristics include speed, reliability, flexibility regarding scheduling, routing, shipment size, load handling and monitoring characteristics, and claims handling procedures (Beilock and Casavant 1984). The magnitude of the full transport cost is determined by the cost and availability of a dependable and flexible transportation system, the cost of labor and other materials handling techniques, and the distances between shippers and receivers. In order to minimize transport cost and maintain the flexibility required in grocery distribution to retail stores, most

distribution centers maintain their own fleet of trucks, hereafter referred to as a captive fleet, which are used to deliver grocery products to retail stores. However, products may be shipped to the distribution center using common carrier trucks, captive fleet trucks, or rail cars, depending on the cost efficiencies of the alternate carriers.

Retail Stores

The locations of retail stores served by each distribution center are indicated in Figure 1 as a series of circles around each distribution center. In reality, the distance of retail stores from the distribution center is not uniform as indicated by the circles; however, the circles serve to indicate the geographic area within which a distribution center operates. Distribution Centers A and B serve some retail stores located in the same geographic area, symbolized by the overlapping circles. The Kroger distribution center in Roanoke, Va., and the Richfood distribution center in Richmond, Va., are examples of this. A total of 79 supermarkets (retail grocery stores with annual sales of over 2 million dollars) are served by Kroger and 25 supermarkets are served by Richfood in the Charleston - Roanoke market area. The Kroger distribution center serves a total of 107 supermarkets, with 28 located outside the geographic area designated as the Charleston - Roanoke market area. The Richfood distribution center serves a total of 241 supermarkets, with 216 located outside the

Charleston - Roanoke market area. This example further illustrates the fact that few distribution centers serve retail stores in exactly the same geographic area even though their service areas frequently overlap. It is important to note that retail stores are typically served by a single distribution center. Thus, even though retail stores are located in the same geographic area, they may or may not be served by the same distribution center. Whether they are or are not served depends primarily on the corporate affiliation between the retail store and the distribution center.

The Kroger distribution center in Cincinnati, Ohio, is an example of a distribution center (C in Figure 1), which serves retail stores in an entirely separate geographic region. Although it is part of the same corporate chain as the Roanoke, Va., Kroger distribution center, the Cincinnati, Ohio, Kroger distribution center serves 86 Kroger supermarkets solely in the Cincinnati market area and is not involved in distribution to stores in the Charleston - Roanoke market area.

Pallet Manufacturers

A pallet manufacturer supplies pallets to distribution centers and grocery manufacturers in response to their demand for materials handling services. In Figure 1, only Pallet Manufacturer A supplies pallets to more than one distribution center. Pallet Manufacturer C, on the other hand, is able to profitably supply pallets to both Distribution Center C and the Grocery Manufacturer. In general, pallet manufacturers are

found to be located in close proximity to the purchaser of their pallets, primarily because of the limits that the cost of transportation place on the distribution of pallets. As mentioned earlier, the average limit on the distance between pallet manufacturer and purchaser is 50 miles. The average distance between distribution centers within the same corporate organization is approximately 300 miles however, based on the fact that distribution centers may serve retail stores located 150 miles away. Therefore, it is likely that a pallet manufacturer serving one distribution center in a corporate chain like Kroger would not serve another distribution center in the same chain. If one considers that the 1987 Progressive Grocer's Marketing Guidebook identifies 409 distribution centers located throughout 55 geographic areas of the country and that Emanuel (1985) identifies 2,470 pallet manufacturers, also located throughout the various regions of the country, then the probability of finding a pallet manufacturer within 50 miles of either a distribution center or grocery manufacturer is very high. In fact, Emanuel's tabulation of pallet manufacturers indicates that 17 pallet manufacturers are within 50 miles of the Kroger distribution center and Ralston Purina food manufacturer in Cincinnati, Ohio. His survey also indicates that 11 pallet manufacturers are within 50 miles of the Kroger distribution center in Roanoke, Va. and another 16 are located within 50 miles of the Richfood distribution center in Richmond, Va.

One must keep distinct the movement of pallets between pallet demand and supply points, from the movement of pallets between grocery

demand and supply points. As identified above, there are potentially 2,470 pallet supply points located throughout the United States. The 1982 Census of Manufactures reports 22,130 establishments, including multi-establishment companies, engaged in manufacturing food and kindred products which may be combined with the 409 distribution centers identified above to yield potentially over 22,500 pallet demand points in the grocery distribution industry.

With regard to the movement of pallets between grocery demand and supply points, 108,600 retail grocery stores are reported in the 1987 Progressive Grocer's Marketing Guidebook, excluding convenience stores which operate outside the relevant grocery distribution system and account for only 7 percent of total retail sales. If one counts the 409 distribution centers as both grocery demand and supply points in terms of the movement of pallets between these points, then there are over 109,000 potential grocery demand points and over 22,500 grocery supply points where the movement of pallets occurs.

The movement of pallets between grocery demand and supply points does not represent trade in pallets but, rather, the utilization of pallets. The trade is in grocery items. As a result of grocery trade, pallets move from place to place, thereby influencing the net demand for pallets at a given point. It is the geographic movement of pallets in the course of their use that makes the estimate of regional pallet demand unique from, say, the demand for construction lumber where the demand for lumber at one point cannot be satisfied by the supply of

lumber to another point. The movement of food from place to place influences the demand for pallets at each point of shipment origin, which may be either a grocery manufacturer or a grocery distribution center. If at each point of shipment origin the supply of pallets from incoming cargo, including pallets involved in backhaul shipments, is inadequate to handle outgoing cargo, the deficit must be met by new or reconditioned pallets. In order to understand how pallets are supplied at each point of shipment origin and thereby determine the demand for new or reconditioned pallets, one must consider how pallets move through the grocery distribution system.

PALLET FLOWS IN THE MODEL

Grocery pallets are durable goods in the sense that they provide a flow of services, i.e., carrying grocery and related products, over a period of time. Thus, a new pallet does not have to be purchased every time a palletized load of grocery and related products is moved from a manufacturer to a distribution center or from a distribution center to a retail store. Generally the movement of grocery products is unidirectional - from the manufacturer of the grocery product to a distribution center and from there to a retail store, as illustrated in our previous example. The movement or use of pallets in the grocery distribution system is not unidirectional but is instead circular in nature - from the distribution center to the retail store and back to the distribution center, for example. The demand for new pallets at the

distribution center to satisfy this circular flow is zero only if the number of pallets returned from the retail stores in usable condition are equal to or greater than the number of pallets needed to move grocery and related products from the distribution center to the retail stores. The demand for new pallets at the distribution center is also zero in the case of movement of palletized product from a manufacturer to the distribution center that is coupled with the direct exchange of pallets at the distribution center.

Grocery Distribution Center

This analysis concentrates on the grocery distribution center as the focal point of activity with regard to the movement of grocery and related products and resulting flow of pallets (Figure 2). It is important to note that some pallet flows, indicated as dotted lines in Figure 2, occur outside the distribution system surrounding an individual distribution center. These flows are important because they clearly indicate that the distribution center system is not a closed system. Pallets flow from pallet manufacturers and from grocery and related products manufacturers within the system diagramed to systems surrounding other distribution centers. In addition, other pallet manufacturers and other grocery products manufacturers, that are not involved in the flow of pallets within the system diagramed, also move pallets to other distribution centers outside the system diagramed. Thus, the distribution center system is a component of a larger, closed

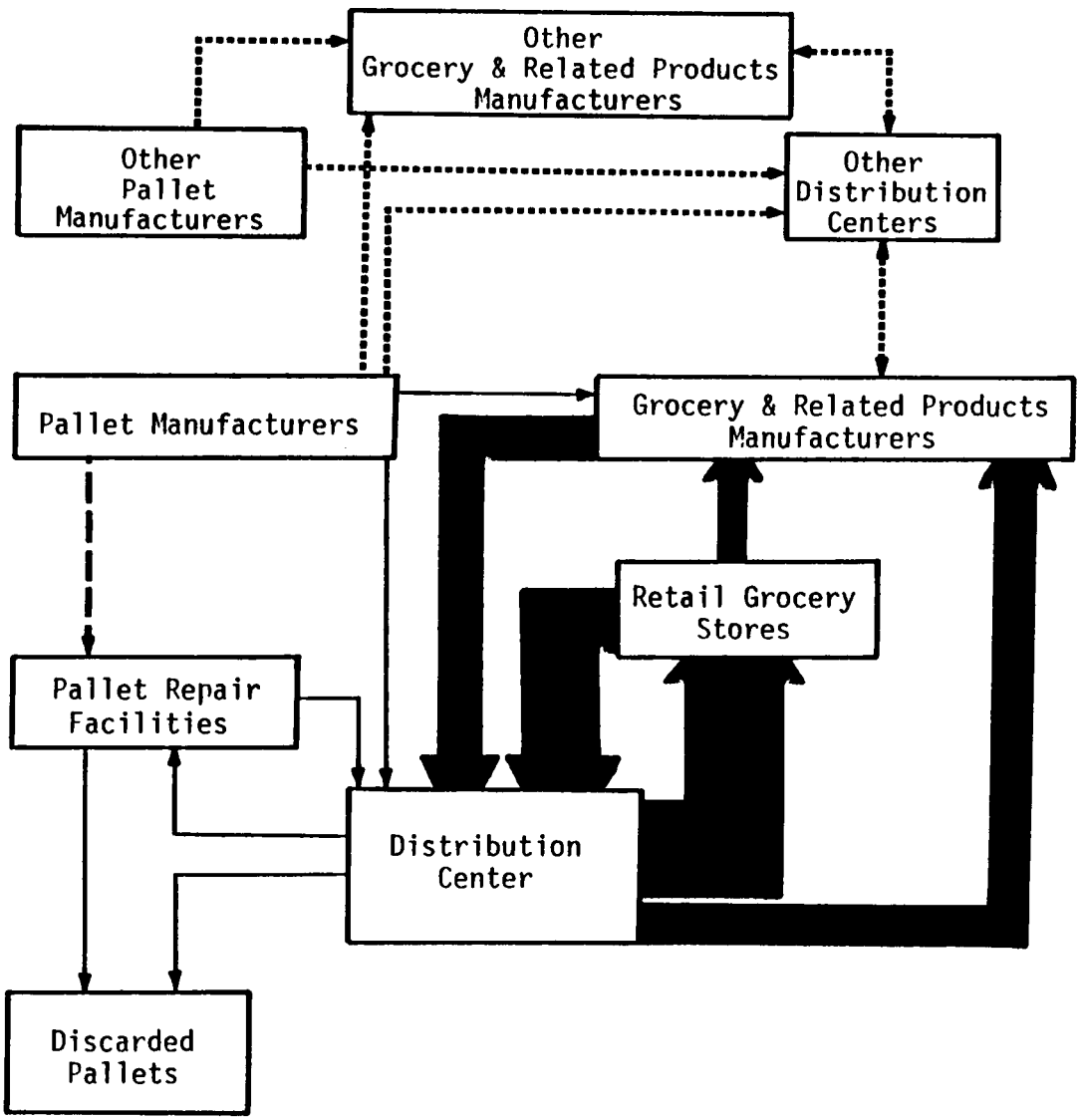

Figure 2. Flow of Pallets in a Grocery Distribution System.

system that includes all distribution centers, pallet manufacturers, and grocery and related product manufacturers.

A model of the grocery distribution system centered around the distribution center is important because it shows the relationship between quantity of new pallets entering the system and quantity of grocery and related products moving through the system. Because pallets are used to warehouse grocery and related products in the distribution center, the model must also include those pallets in order to accurately reflect the quantity of new pallets needed in the system. The total quantity of pallets in use at a distribution center is equal to pallets in the distribution center's warehouse area minus pallets leaving the distribution center plus pallets coming into the distribution center. These three pallet uses will be noted as "warehouse", "outflow", and "inflow".

Warehouse

The quantity of pallets in the distribution center warehouse is not static, but is constantly changing as the quantity of grocery products stored in the warehouse changes. Warehouse pallets may be divided into stock and float pallets. Stock pallets carry or support products in storage. Industry sources indicate that a large distribution center warehouse with over one million square feet of floor space typically has over 100,000 pallets in use as stock pallets. An average sized distribution center warehouse with approximately 500,000

square feet of floor space typically has over 40,000 pallets in use as stock pallets. As grocery products are removed from storage daily for shipment to retail stores, a portion of the stock pallets used to carry those products in storage become available for other uses and become additions to the quantity of float pallets. Float pallets are defined as pallets that are not carrying or supporting products in storage at a given point in time. That is, the float pallets are available for storage of products not on pallets when they arrive at the center, for exchange with pallets arriving from a grocery manufacturer, or for movement of grocery products from the distribution center to the retail stores. The quantity of float pallets in a typical distribution center varies with the daily movement of grocery products in and out of the distribution center but generally is less than one-tenth of the quantity of stock pallets in the warehouse.

Thus, at any given point in time, the total quantity of pallets at a distribution center (QDC) is composed of the quantity of stock pallets used for storage of grocery and related products and the quantity of float pallets used to absorb the fluctuations in the quantity of pallets moving in and out of the distribution center. This quantity may be represented as follows:

QDC = Stock + Float

While this equation includes all pallets in the distribution center, it does not include the flow of pallets moving through the distribution

system surrounding the center that result in pallets leaving the center (outflow) and pallets returning to the center (inflow).

Pallet Outflow

The quantity of pallets in the outflow from the distribution center includes pallets used to transport products to retail stores, pallets returned to grocery manufacturers, pallets sent to repair facilities, and discarded pallets (Figure 3). In the first two flows, the quantity of pallets leaving the distribution center depends on the demand for grocery product movement within the grocery distribution system. In the latter two flows, the quantity of pallets depends on the wear-out rate of pallets in the system and the frequency of damage to pallets in the system. In the following sections, we examine each of these flows in more detail.

Retail Store

Pallets carrying grocery products from distribution center to retail stores constitutes the single largest outflow of pallets from the distribution center. Using a large distribution center from the survey as an example, daily shipments to retail stores average over 4700 pallet loads of products each day. This is based on a reported average of 1500 trailer shipments per week and 22 pallet loads of product in each trailer. An important point to note here is that these pallets reduce the quantity of float pallets available at the distribution center.

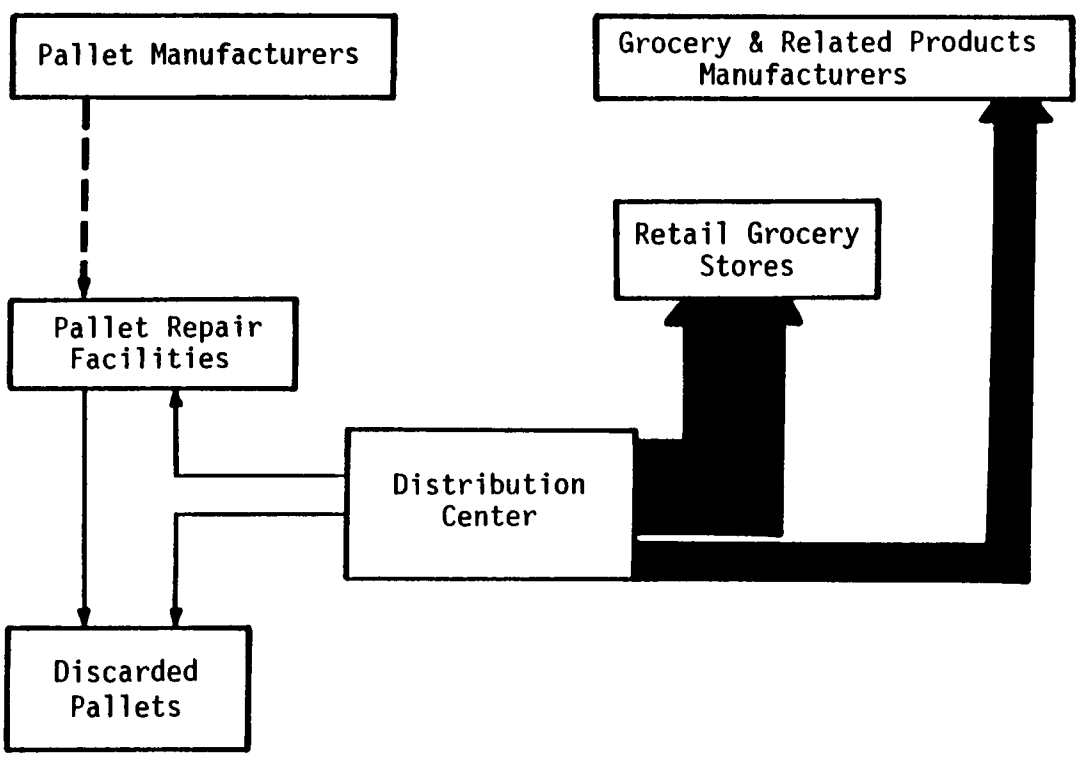

Figure 3. Pallet Outflow from a Distribution Center.

Grocery Manufacturer

Pallets are returned to grocery manufacturers as a result of prior agreements with selected grocery manufacturers. Industry sources note that approximately 50 percent of the grocery and related products arriving each day come from manufacturers who have prior agreements with the distribution center management that involves a one-for-one exchange of equivalent pallets. That is, if the manufacturer ships a trailer load containing 22 pallet loads of product to the distribution center, the manufacturer expects the trailer to return to the manufacturing facility with a similar number of unloaded pallets of quality equal to the delivered pallets. Because the distribution center places the 22 pallet loads of products directly into storage, the pallets returned to the manufacturer must come from the quantity of float pallets available at the distribution center. For a large distribution center, this direct exchange would amount to an outflow of about 2000 pallets per day.

Pallet Repair

The quantity of pallets in the distribution center is also reduced when pallets are taken out of service for repair. The decision made by the distribution center manager to repair rather than replace damaged pallets with newly purchased pallets is based primarily on the difference between the cost of repair and replacement cost. The surveyed distribution center managers indicate that the cost of in-house

repair is limited to 25 to 30 percent of the cost of a new pallet. This limitation results from space, time, and equipment constraints at in-house repair facilities rather than a constraint on the cost of repair. Storage space for pallets awaiting repair in-house is usually limited because warehouse space is more profitably used in the storage of grocery and related products. The limited storage space means that pallets must be repaired and returned to service as quickly as possible otherwise the pallets awaiting repair take up too much space. Finally, the equipment generally available for in-house pallet repair is not capable of the same level of dismantling and re-assembly of salvaged pallet parts associated with outside pallet repair facilities. This means that extreme rebuilding of a pallet is avoided and repairs generally involve quick replacement of one to three deckboards. However, there are substantial savings gained in repairing pallets in-house over purchasing new pallets.

Although distribution center managers indicate that they consider the expected life of repaired pallets to be equal to the expected life of a new pallet, this observation must be considered to be biased as a result of the managers' perception of the length of time that a pallet remains in service in the distribution center. This perception is related to the practice, described above, of direct exchange of pallets. When a pallet leaves the distribution center as a result of a direct exchange agreement, there is no guarantee that the same pallet will ever return to the distribution center. Thus, the expected life of

a repaired pallet is perceived by distribution center managers to be the length of time that a pallet remains in a distribution center until it is exchanged for another pallet. The exchange agreements only call for an equivalent quality pallet to be returned. Because of the uncertainty of getting back the same pallet in any exchange, distribution centers prefer to exchange a lower cost repaired pallet as opposed to a higher cost new pallet.

The outflow of pallets for repair constitutes a reduction in the quantity of float pallets primarily because the pallets are sorted at this stage in the warehouse operation. That is, empty pallets are evaluated prior to being loaded. Warehouse personnel are instructed to visually inspect each pallet before placing grocery products on it. If a pallet is found to be damaged or no longer serviceable it is taken out of the system for repair. With the exception of pallets which are so badly damaged that they are beyond repair, a distribution center usually sends damaged pallets to a repair facility, either in-house or an outside contractor, without assessing the extent of damage. At this point, outside pallet repair facilities dismantle and salvage pallets which cannot be repaired economically. In-house pallet repair facilities discard pallets which cannot be repaired economically in the sense that they relinquish ownership of these pallet to pallet salvage operators. The criteria for what constitutes a repairable pallet in-house are consistent across the surveyed distribution centers. The general rule-of-thumb used allows up to four deckboards and one

full-length stringer to be replaced in the repair of a damaged pallet. If the damage to a pallet requires more than four deckboards or more than one full-length stringer for repair, the pallet is sold to pallet salvage operators. The cost of repair varies depending on the amount of damage, but a typical cost of in-house deck damage repair ranges between $1.25 and $1.75 for the centers surveyed. For outside pallet repair operations, the average cost of repair is over $2.00 and the amount of damaged parts replaced may exceed four deckboards and one full-length stringer.

Another aspect of pallet repair concerns the quantity of pallet parts purchased from pallet manufacturers by the repair facility for use in the repair of pallets (dashed line in Figure 3). The total amount of wood raw material going into the repair of pallets is determined by the number of pallets repaired and the amount of wood used in each pallet for repair. The total amount of wood raw material needed for grocery and related products distribution therefore includes the amount needed for repair as well as that needed for the production of new pallets.

Pallet Discard

The total quantity of pallet material discarded includes that discarded at the distribution center as well as that discarded by the outside repair facility. In general, grocery pallets are not totally discarded. Only the broken or damaged parts are discarded during pallet repair or salvage. However, in this study, pallet discard from in-house

repair facilities is considered to be that quantity of pallets which cannot be repaired economically in-house. Because ownership of these pallets is transferred to pallet salvage operators, these pallets are considered to have permanently left the distribution system and thus need to be replaced. The quantity of pallets sold for salvage varies greatly from one distribution center to another; but, based on the information provided by distribution center managers, this quantity averages 30 percent of pallets damaged. This means that 70 percent of damaged pallets are recovered through repair operations as described in the preceeding section. For a large distribution center, the quantity of pallets sold for salvage may exceed 35,000 pallets over a period of one year.

Later in this study, the simplifying assumption is made that the total quantity of pallets discarded or sold for salvage is a constant proportion of the existing quantity of pallets in the system. However, this quantity may also be expressed as a function of the expected service life of a grocery pallet, and the average age of pallets in the system. As the average age of pallets in the system increases, or as it approaches the expected service life, the portion of pallets discarded will increase in a given time period. As new pallets are added to the system, the average age of pallets in the system decreases and the portion of pallets discarded also decreases. Implicitly contained in the above assumption is a second assumption regarding the expected service life of pallets. That is, the specifications for new pallet

construction which influence expected service life are also assumed to be constant.

Pallet Inflow

The quantity of pallets entering the distribution center includes pallets returned from retail stores, pallets loaded with grocery products shipped from a grocery manufacturer, pallets returned from repair, and pallets received from pallet manufacturers (Figure 4). In the following sections, these flows are examined in more detail.

Retail Store

The quantity of pallets returned from retail stores constitutes the largest daily flow of pallets into the distribution center. For a large distribution center, this quantity incoming daily would amount to 3600 pallets. The pallets returned from retail stores are considered as additions to float pallets because they are returned empty from the retail stores and are available for storage or further movement of grocery products. The quantity of pallets returned from retail stores depends on two factors: the demand for movement of grocery products to the retail stores and the quantity of grocery products backhauled from grocery manufacturers in captive fleet trucks to the distribution center. In the example above, over 4700 pallets were used to satisfy the daily demand for movement of grocery products to retail stores. If all pallets used to satisfy this demand were returned directly to the

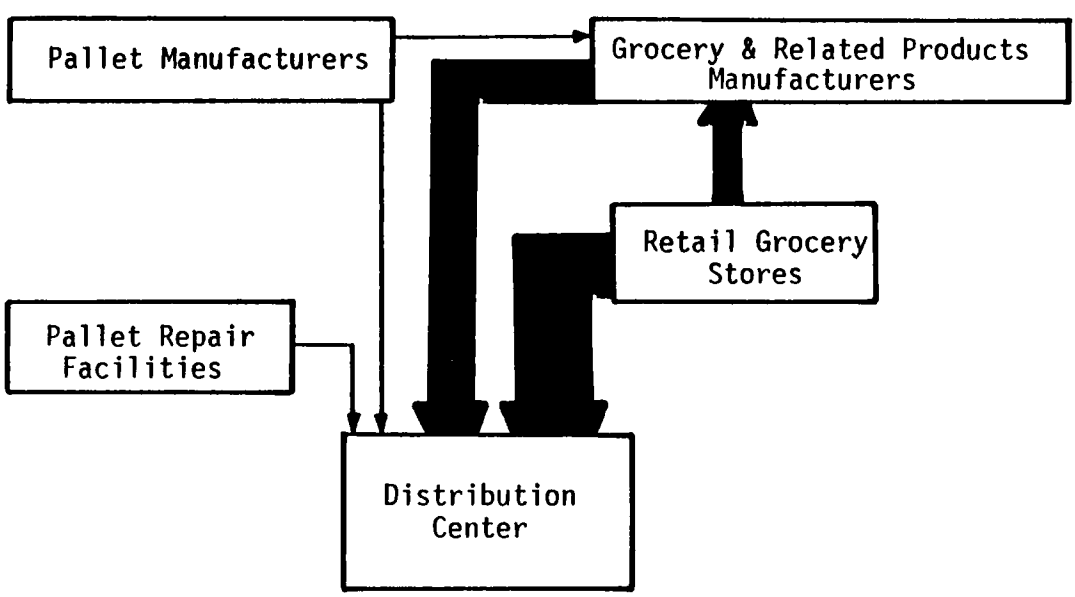

Figure 4. Pallet Inflows to a Grocery Distribution Center.

distribution center, then on the average, there would be 4700 pallets returned daily from retail stores. The difference between the 4700 pallets sent to retail stores and 3600 pallets returned from retail stores results from the use of 1100 pallets for grocery product backhauls. These backhauls are made using captive fleet trucks which make delivery of grocery products to retail stores and proceed to grocery manufacturers with empty pallets picked up at retail stores (shown in Figure 4 as an arrow between retail stores and grocery manufacturers). The empty pallets are exchanged at the manufacturer for pallets loaded with grocery products which are delivered to the distribution center. Industry sources state that between 35 and 40 percent of grocery products nationally are backhauled from grocery manufacturers in captive fleet trucks to the distribution center.

The net effect of backhauls in captive fleet trucks is a temporary reduction in the quantity of float pallets at the distribution center. Where backhaul arrangements exist, grocery products are moved to distribution centers on the pallets that were exchanged at the grocery and related products manufacturers for pallets which would normally return empty from retail stores. However, because these backhaul pallets arrive at the distribution center carrying products, they are added to the quantity of stock pallets in the warehouse rather than the quantity of float pallets as in the case of pallets returned to the distribution center directly from retail stores.

Grocery Manufacturer

The quantity of pallets received daily from grocery manufacturers, including backhauls, is the second largest flow of pallets into the distribution center. For a large distribution center, this quantity would amount to 3100 pallets, incoming daily. The pallets received from grocery manufacturers are considered as additions to stock pallets since they are used in the warehouse to store the products shipped from the manufacturers. This includes pallets arriving on captive fleet trucks carrying backhauls as well as on common carriers and on trucks owned by grocery manufacturers.

Pallet Repair

Another inflow of pallets into the distribution system occurs when pallets are returned to service after repair. Repaired pallets are considered as additions to float pallets because they are available for storage or movement of products in the warehouse. The quantity of pallets involved in this inflow depends on the rate of repair as well as on the total number of pallets sent to repair. As noted above, about 70 percent of damaged pallets are recovered through repair operations. In an average size distribution center, the quantity of pallets returned to the system after repair averages about 100 pallets per day. On the other hand, in a large distribution center this quantity may exceed 750 pallets per day. For example, one industry source reported a total of 45,000 pallets repaired over a three month period. If this rate of

repair was maintained throughout the year, the quantity of pallets repaired would exceed the total quantity of pallets in the warehouse. One reason explaining the magnitude of the above numbers is that the pallets continually flow through the system rather than remaining stationary in the warehouse. It is in the handling of grocery products on pallets that the damage to the pallet occurs which requires repair.

Pallet Manufacturer

While the repair of pallets is generally a continuous activity, occurring on a daily basis, the purchase of new pallets occurs at less frequent intervals. The decision to purchase new pallets is made by the managers at the distribution centers. Although these managers may have different titles, such as Traffic Manager, Warehouse Manager, Director of Distribution, Service Superintendent, etc., they all have the responsibility for purchase of new pallets to maintain the quantity of pallets available in the distribution system at some desired or optimum level.

The quantity of new pallets purchased by a distribution center is a function of two factors: the quantity of used pallets available in the system that includes the quantity of repaired pallets returned to the system and excludes the quantity of pallets discarded, and the volume of grocery and related products to be moved. Purchases are made by managers based on their knowledge of the quantity of pallets available in the system and their estimate of the quantity of pallets required to

handle the expected growth in volume of grocery and related products. Industry sources report that pallet purchases for a large distribution center can exceed 110,000 pallets per year. About one-third of the new pallets purchased are replacement for pallets which are discarded or sold for salvage because they are worn-out, damaged beyond repair, or they do not meet the construction specifications required by the user. The other two-thirds of the new pallets purchased are required to handle growth in the movement of grocery and related products.

In order to balance the flow of pallets in a distribution system between distribution center, retail stores, and grocery manufacturers, new pallets must also be shown to enter the system through grocery manufacturers (shown in Figure 4 as an arrow between pallet manufacturer and grocery manufacturer). These new pallets may be purchased by a grocery manufacturer or by a distribution center for delivery to the grocery manufacturer as a result of an exchange agreement. For example, Del Monte Corp., a grocery manufacturer in Swedesboro, N.J., has a direct exchange agreement with a distribution center in Richmond, Va. The distribution center receives products on pallets from Del Monte but does not exchange pallets directly upon receipt of the product. The distribution center purchases new pallets from a pallet manufacturer in Philadelphia, Pa., in close proximity to the Del Monte plant. These pallets are delivered to Del Monte in exchange for the pallets delivered with product. Although it is noted above that distribution centers prefer to exchange used or repaired pallets rather than new pallets, in

this particular case the savings in transportation costs gained by shipping the pallets directly to the manufacturer outweigh the cost of new pallets delivered to the distribution center. Thus, total quantity of new pallets entering a distribution system is the sum of new pallets received by distribution centers and by grocery manufacturers.

DEMAND AND SUPPLY ASPECTS OF THE MODEL

In the following section, the demand and supply conditions are described at two market levels, that is, the final product and pallet market levels. In the ideal case where data limitations did not exist, I would follow this description with statistical estimation, based on times series data, of the relationships between quantity of grocery and related products demanded and supplied and the quantity of pallets demanded and supplied. In this case, however, I am limited to a discussion of the theoretical relationships that exist in the final product and pallet market levels because of the absence of times series data on the factors involved.

As an intermediate product, pallets are not directly demanded by the final consumer in the sense that grocery and related products are demanded by the final consumer. However, the quantity of grocery and related products supplied is shown to directly affect the quantity of pallets demanded by the grocery distribution system. It is necessary to model both market levels because of the linkage that exists between the final consumer demand for grocery and related products and the derived

demand for pallets as a means of moving the grocery and related products to the point where the final consumer demand can be satisfied. A diagram which illustrates the market levels also shows the relationship between product supply and input demand at each market level (Figure 5). As the equilibrium price is reached in the market for grocery and related products, the demand for grocery and related products equals the supply of those products. The price of grocery and related products is a factor in the demand function for grocery pallets. Likewise, as the equilibrium price is reached in the market for grocery pallets, the demand for grocery pallets in the distribution and storage of grocery and related products equals the supply of grocery pallets. Because grocery pallets are inputs to the production function for distribution and storage of grocery and related products, the price of grocery pallets is a factor in the supply function for grocery and related products.

Final Product Market Level

The final product market level for grocery and related products is defined as the market for grocery and related products at retail grocery stores. At this level, the demand for grocery and related products is a final consumer demand determined by the weighted price of a market basket of grocery and related products measured in dollars per ton of product, the price of other goods and services, and consumer average

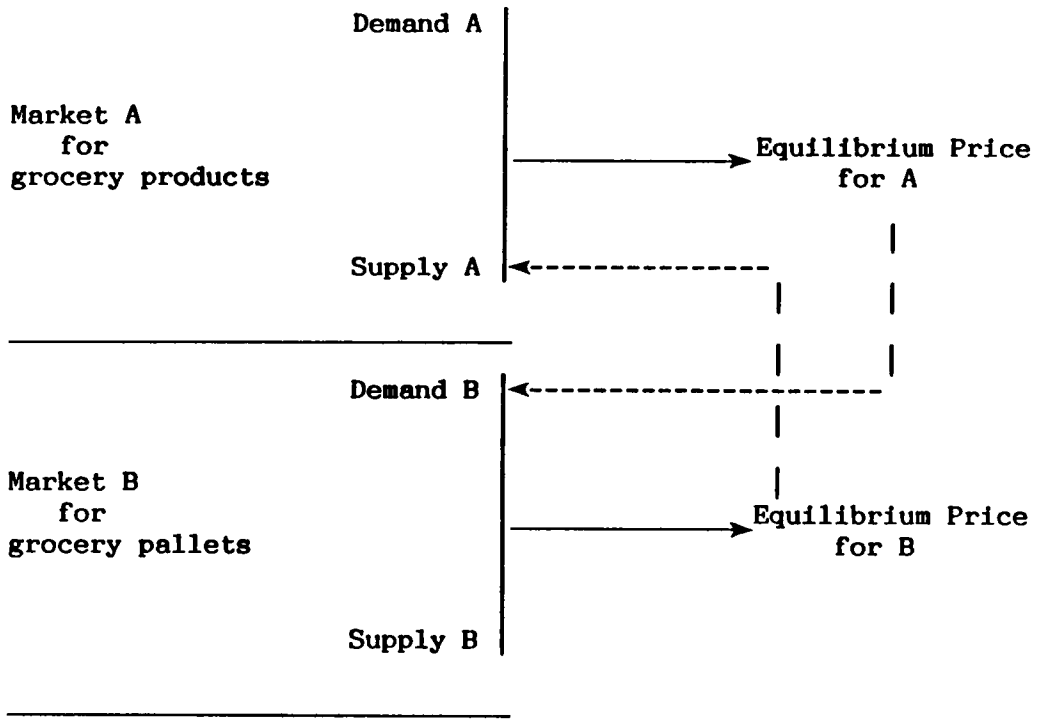

Figure 5. Demand and Supply Linkage Between Market Levels.

income. The quantity of grocery and related products demanded at retail stores may be represented as follows:

$$Q^{D}_{GP} = f \{ P_{GPS}, P_S, P_C, P_0, I_C \}$$

where Q^{D}_{GP} is the total quantity of grocery and related products demanded by consumers measured in tons or cubic foot volume, P_{GPS} is the price per ton or per cubic foot volume of grocery and related products at the retail stores, P_S is the price of substitutes, P_C is the price of complements, P_0 is the price of all other goods and services, and I_C is average consumer income. The above functional relationship should be considered as a stylized or classic representation of the demand function for grocery and related products. This relationship can be constructed to reflect the demand for grocery and related products on a per-capita basis. In empirical specification and estimation of the grocery demand function, other variables may need to be considered. These variables could include population demographics like age structure which may vary from one region to another and measures of the consumer price index in relation to the price of grocery and related products in different regions.

Substitutes for the quantity of grocery and related products demanded at retail stores could include other food sources such as convenience stores, farmers markets, and home gardens. Convenience stores are included as possible substitutes for demand at retail stores because the distribution system for convenience stores is considered to be separate from the distribution system for retail stores. That is,

the distribution system for convenience stores does not employ grocery pallets in moving grocery products to the convenience stores. Complements for quantity of grocery and related products demanded at retail stores could include such factors as the price of cooking utensils, opportunity costs associated with home food preparation, and transportation costs incurred by consumers in obtaining grocery and related products.

Given the above aggregate demand function faced by grocery manufacturers, the supply function for grocery and related products manufacturers includes the cost of raw material inputs as well as other inputs to the production and distribution of grocery products. The supply function faced by the grocery and related products manufacturer may therefore be expressed as follows:

$$Q^S_{GP} = f \{ P_{GPP}, P_{MH}, P_{RM}, P_O \}$$

where Q^S_{GP} is the total quantity of grocery and related products supplied, P_{GPP} is the price received by the manufacturer or producer of grocery and related products, P_{MH} is the price of materials handling services, P_{RM} is the price of raw material inputs used in the production of grocery and related products, and P_O is the price of other inputs to the grocery production activities.

Two points must be noted concerning the above demand and supply functions. First, the price of grocery and related products at retail stores, P_{GPS}, includes the manufacturers or wholesale price, P_{GPP}, so that changes in the latter price are reflected in the former. The

reason for making a distinction between the retail and wholesale price in grocery distribution is that the supply of grocery products goes through multi-echelon inventory supply points with inventories maintained at both the wholesale and retail levels. Because of this, the grocery distribution center is both a demand and supply point for grocery and related products. Thus, both the wholesale price and the retail price are factors in the demand and supply functions for a distribution center, as will be shown in the following section.

The second point concerns the price of materials handling services, P_{MH}. This is not a single value but rather is a weighted value of all materials handling services incurred in moving grocery and related products to the final consumer. Specifying a realistic weighted value that could be used to estimate the above supply function requires that the individual elements making up that value be identified.

Materials Handling Elements of Final Product Supply

Because of the spatial separation between producing and consuming points, as documented earlier in this chapter, materials handling services are needed to transport grocery and related products from their point of production to consuming centers. As noted above, the cost of materials handling services is included as a part of the production cost for the grocery products. This appears reasonable if the process of transporting a grocery product from producer to consumer is considered

to be a part of the process of preparing the grocery product for final consumption.

Materials handling services for grocery and related products are made up of several parts, including the transportation of grocery products from manufacturers to distribution centers, the handling of products within distribution centers, and the transportation of products from the distribution centers to the retail stores. It should be noted that an open market exists for the transportation of grocery products from manufacturer to distribution centers. Alternate forms of transportation in this market include captive fleet trucks owned by manufacturers or distribution centers, common carrier trucks, and rail cars. The choice of transportation mode must be made based on the least cost incurred in moving the grocery products from manufacturer to distribution center.

Materials handling services therefore include a number of elements which can be considered separately but are not necessarily independent. The use of railcars and trucks to move products are examples. Railcars may be used in conjunction with trucks to move grocery products to distribution centers. However, almost all shipments to retail stores are accomplished by truck and, at this stage in the distribution system, truck and railcar shipping are not substitutable. Materials handling also includes automated conveyor systems, pallet handling equipment, pallets, and finally, labor.

Grocery Manufacturers

Having noted that the movement of products frequently occurs between manufacturers in one region of the country and distribution centers in a spatially separate region, I must consider that transportation services needed for shipment of grocery and related products are one of the inputs to grocery manufacturers production functions. The cost of transportation therefore is a factor in determining price and quantity of grocery and related products supplied and changes in the cost of transportation will result in changes in the price of grocery and related products. The functional relationship for quantity of grocery and related products supplied by grocery manufacturers in response to the demand for those products in different regions therefore includes the cost of transport and may be expressed as follows:

$$Q^{S}_{GP,MFG} = f \{ P_{GPP}, P_{RM}, P_{MH}, P_{P}, P_{O} \}$$

where $Q^{S}_{GP,MFG}$ is total quantity of grocery and related products supplied by a grocery manufacturer for which materials handling services are required, P_{GPP} is the price of grocery and related products that reflects the manufacturers production and distribution costs, P_{RM} is the price of raw material inputs used in the production of grocery and related products, P_{MH} is now the unit cost of transport measured in dollars per ton-mile or dollars per cubic foot volume-mile, P_{P} is the weighted price of grocery pallets used in distribution, and P_{O} is the weighted price of other factor inputs to the production function. This

is the same functional relationship expressed for the supply of grocery and related products by grocery manufacturers in the preceeding section. However, in this function the value of P_{MH} reflects only the unit cost of transport. Also, the function shows the price of pallets separately from the weighted price of other factor inputs to indicate that pallets are a necessary input to the grocery manufacturers production and distribution function.

Grocery Distribution Centers

Materials handling services are required at grocery distribution centers for handling of grocery and related products in storage and for transport of products to retail stores. These are the other two parts of the materials handling services for grocery and related products listed earlier. The first of these parts is specified as an inventory problem where it is necessary to stock grocery and related products for the purpose of satisfying the demand for those products at retail stores over a specified time period. The economic parameters which determine the quantity of grocery and related products handled in storage at the distribution center may be expressed as follows:

$$Q^{D}_{GP,DC} = f \{ S_C, P_{GPP}, P_{GPS}, H_C, P_P \}$$

where $Q^{D}_{GP,DC}$ is the quantity of grocery and related products handled in storage at the distribution center, S_C is a setup cost which is associated with the placement of an order to the manufacturer, P_{GPP} is the purchase price or production and transportation cost for

the manufacturer of the grocery products, P_{GPS} is the price charged at retail stores for the product, H_C is a holding cost or the cost of carrying the product in inventory, and P_P is the price of grocery pallets required to hold the products in storage. This function has added importance in that $Q^D_{GP,DC}$, the quantity of grocery and related products handled in storage, is also the quantity of grocery and related products demanded by the distribution center from grocery manufacturers. This demand is derived from the distribution centers production function which seeks to satisfy the demand for grocery and related products at retail stores.

The second part is specified as a transportation distribution problem which involves the determination of a minimum cost shipping schedule to satisfy the demand for grocery products at retail stores at several destinations with available supply. In this problem, the quantity of grocery and related products supplied by a distribution center equals the quantity delivered to retail stores. However, grocery distribution centers typically minimize the cost of transporting these products by applying linear programming techniques which consider the quantity of grocery and related products to be transported, and P_{MH}, the unit cost of transport. Pallet use in transport of grocery products to retail stores is independent of distance traveled. Pallet use is a function of volume of products moved and demand for pallets is exogenous to the determination of minimum cost shipping schedules.

The functional relationship which identifies the volume or quantity of grocery and related products supplied by distribution centers in response to the demand for those products at retail stores may be expressed as follows:

$$Q^{S}_{GP,DC} = f \{ P_{GPP}, P_{GPS}, P_{P}, P_{O} \}$$

where $Q^{S}_{GP,DC}$ is total quantity of grocery and related products supplied to retail stores by distribution centers, P_{GPP} is the purchase price of grocery and related products, P_{GPS} is the price of grocery and related products at retail stores, P_{P} is the weighted price of grocery pallets used in distribution, and P_{O} is the weighted price of other factor inputs to the production function. A weighted price for other factor inputs is included because the production function for a distribution center is satisfied from the use of other materials handling factors as conveyors, pallet handling equipment, and labor.

Demand for Materials Handling Services

The demand for materials handling services employing pallets is the last materials handling element of final product supply that is considered; but, it is the most important in terms of defining grocery pallet consumption. The demand for materials handling services employing pallets in the grocery distribution system is derived from the movement and storage of grocery and related products by grocery manufacturers and grocery distribution centers as outlined in the

preceeding two sections. This demand is considered to be a function of the price of capital or the interest rate, the price of materials handling equipment, the price of labor, and the price of alternate systems. More importantly, this demand is a result of a past decision by grocery distribution industry management to invest capital in a system using pallets. Once this system was put into operation, the quantity of pallets needed to operate the system is directly proportional to the quantity of grocery and related products moved and stored in the system. Pallets are input in terms of a fixed proportion production function for materials handling services at both the grocery manufacturers and the grocery distribution centers. That is, each ton or cubic foot volume of grocery and related products supplied by manufacturers or moved and stored by grocery distribution centers requires a fixed quantity of pallets to satisfy the demand for materials handling services.

Because the materials handling services production function is of fixed proportions with regard to pallet input, the consumption function for grocery pallets can be expressed in terms of the quantity of grocery and related products moved and stored. In this functional relationship, the aggregate quantity of pallets consumed is not expressed in terms of the price of pallets, price of grocery and related products, and price of other factor inputs to the production function for distribution of grocery and related products. Instead, these prices are embodied in the functional relationships expressed for the quantities of grocery and

related products included in the consumption relationship. Thus, changes in these prices can be expected to affect the aggregate quantity of pallets consumed, although they do not appear directly in the consumption function. The aggregate consumption of pallets in grocery distribution is therefore represented as follows:

$$Q^{C}_{P} = a_1 Q^{S}_{GP,MFG} + a_2 Q^{D}_{GP,DC} + a_3 Q^{S}_{GP,DC}$$

where Q^{C}_{P} is total quantity of grocery pallets consumed in the materials handling of grocery and related products, $Q^{S}_{GP,MFG}$ is the total quantity of grocery and related products transported from grocery manufacturers to grocery distribution centers, $Q^{D}_{GP,DC}$ is the total quantity of grocery and related products handled in storage at grocery distribution centers, $Q^{S}_{GP,DC}$ is the total quantity of grocery and related products transported from distribution centers to retail stores, and a_1, a_2, and a_3 are constants from the fixed proportion production function for materials handling services which define the quantity of pallets required to move or store a unit of grocery and related products.

It is important to note that the constants a_1, a_2, and a_3, are not necessarily equal. Shipments of grocery products from manufacturers to distribution centers, related to the a_1 constant, are exclusively unit-loads. That is, a given quantity of a single product is loaded on a pallet for delivery to the distribution center. On the other hand, shipments of grocery products from distribution center to retail stores, related to the a_3 constant, are normally mixed-loads,

with a variety of products in less-than unit-load quantity loaded on each pallet. While the grocery and related products are stored on pallets in the distribution center warehouse in unit-load quantities, the constant a_2 must also consider the storage of products which do not arrive at the distribution center on pallets.

The aggregate grocery pallet consumption relationship including the constants a_1, a_2, and a_3, is a short-term relationship. When the demand for materials handling services employing pallets changes as a result of changes in the previously defined factors affecting that demand function, the constants a_1, a_2, and a_3 will also be changed. Thus, in the long term, these constants can be altered by changes in the price of capital, price of labor, price of materials handling equipment, and price of alternate systems which may not use pallets in the same proportion. As alternate systems are employed in moving grocery and related products, the ratio of quantity of pallets used to quantity of grocery products moved can change over time. It is important to note that, in the short term, the constants that define the quantity of grocery product which may be moved or stored on a pallet are independent of the price of the pallet. That is, regardless of the price of the pallet, the quantity carried on the pallet is limited and defined by the constant.

Pallet Market Level

Demand for pallets in grocery distribution is derived from the transportation and storage of grocery and related products by grocery manufacturers and grocery distribution centers. In the preceeding sections, the production functions and corresponding demand and supply functions for grocery manufacturers and grocery distribution centers have been identified. The demand for pallets in grocery distribution is derived from these productions functions and is expressed in terms of the price of pallets, the wholesale and retail prices of grocery and related products, and price of other factor inputs to the production functions for grocery manufacturers and grocery distribution centers. The aggregate demand for pallets in grocery distribution is therefore represented as follows:

$$Q^D_P = f \{ P_P, P_{GPP}, P_{GPS}, P_O \}$$

where Q^D_P is total quantity of grocery pallets demanded for materials handling of grocery and related products, P_P is the weighted price of grocery pallets used in the distribution of grocery and related products, P_{GPP} is the grocery manufacturers delivered price of grocery and related products, P_{GPS} is the price of grocery and related products charged to retail stores, and P_O is the price of other factor inputs to the production and distribution of grocery and related products. These other factor inputs include complements of pallet demand such as automated conveyor systems and pallet handling equipment, and substitutes for pallet demand such as manual labor and metal carts.

The quantity of pallets estimated by the aggregate pallet demand relationship is the total quantity of pallets used in the movement and storage of grocery and related products in a specified time period. The total pallet demand relationship reflects changes in the volume of grocery and related products moved or stored through changes in the wholesale and retail prices of the grocery and related products.

The total quantity of pallets supplied in grocery distribution is expressed as a function of the price of factor inputs to the production function for grocery pallets. That is,

$$Q^S_P = f \{ P_P, P_{CAP}, P_{LAB}, P_O \}$$

where Q^S_P is total quantity of grocery pallets supplied for materials handling of grocery and related products, P_P is the weighted price of grocery pallets used in materials handling of grocery and related products, P_{CAP} is the price of capital or the interest rate, P_{LAB} is the price of labor, and P_O is the price of other factor inputs to the production function for grocery pallets.

When the system is in equilibrium, the quantity of grocery pallets demanded and the quantity supplied are equal as shown by the following identity:

$$Q^D_P \equiv Q^S_P$$

where Q^D_P is total quantity of grocery pallets demanded for materials handling of grocery and related products and Q^S_P is total quantity of grocery pallets supplied for materials handling of grocery and related products.

Because grocery pallets remain in the system from one time period to another, the total quantity of grocery pallets supplied for the materials handling of grocery and related products includes new grocery pallets and grocery pallets already available in the system. That is,

$$Q^{S}_{P} = Q_{NP} + Q_{INV}$$

where Q^{S}_{P} is the total quantity of grocery pallets supplied for the distribution of grocery and related products, Q_{NP} is the quantity of new grocery pallets, and Q_{INV} is the inventory quantity of grocery pallets available at all supply points in the system. From this expression, we can identify the quantity of new grocery pallets demanded.

As noted earlier, the demand for new grocery pallets depends on two factors: quantity of grocery pallets available in the system and changes in the volume of grocery and related products moved. Q_{INV} identifies the quantity of pallets available in the system, and Q^{S}_{P} identifies the quantity of pallets supplied to move a given volume of grocery and related products in a specified time period. Therefore, the demand for new pallets is the total quantity of pallets supplied less the available inventory of pallets in the system. That is, new pallet demand is an "excess demand" function, which may be expressed as follows:

$$Q^{D}_{NP} = Q^{S}_{P} - Q_{INV}$$

where Q^{D}_{NP} is the quantity of new pallets demanded, Q^{S}_{P} is the total quantity of pallets supplied, and Q_{INV} is the inventory quantity

of pallets available at all supply points in the system. Thus the demand for new grocery pallets is a residual, or the difference between total grocery pallet supply and the quantity of grocery pallets available in inventory within the system.

The total quantity of new grocery pallets supplied for the materials handling of grocery and related products may be expressed as follows:

$$Q^{S}_{NP} = f \{ P_{NP}, P_{RM}, P_{O} \}$$

where Q^{S}_{NP} is the quantity of new pallets supplied for materials handling of grocery and related products, P_{NP} is the price of new grocery pallets, P_{RM} is the price of raw material inputs used in the production of new grocery pallets, and P_{O} is the price of other factor inputs to the pallet production function. The quantity Q^{S}_{NP} is the total quantity of pallets produced by pallet manufacturers for all grocery products manufacturers and distribution centers in the grocery distribution system. The above new grocery pallet supply function is the market supply function which, in equilibrium with the demand function for new grocery pallets, determines the price and quantity of new grocery pallets supplied to the grocery distribution system.

Other factors can also affect the price and quantity of new grocery pallets supplied. In the short term, an increase in the demand for non-grocery pallets could result in a price increase for grocery pallets. That is, pallet manufacturers would experience increasing marginal costs of production in producing an increased quantity of

non-grocery pallets. This would put upward pressure on the price of pallets supplied, including grocery pallets. For those pallet manufacturers operating at or close to maximum capacity, the gain from producing an additional, higher-value, non-grocery pallet would be greater than that for producing an additional grocery pallet; so, fewer grocery pallets would be supplied. This again would put upward pressure on the price of grocery pallets and as this price increased, both the demand for pallet repair and the extent of damage which would be repaired would tend to increase.

The quantity of pallets available in inventory includes those available at grocery manufacturers as well as at the distribution center. This quantity has an associated decay function which expresses the quantity available in the system as a function of the quantity available in the preceeding time period less the quantity expected to be discarded. The quantity of pallets in inventory may be expressed as follows:

$$Q_{INV} = Q_{t-1} - w^{*}Q_{t-1}$$

where Q_{INV} is the total quantity of pallets available in inventory for materials handling of grocery and related products in a given time period, Q_{t-1} is the quantity of pallets in the preceeding time period, and $w^{*}Q_{t-1}$ is the quantity of pallets discarded in the preceeding time period. This decay function considers the stock of pallets available at all supply points in the system and adjusts the

quantity available to reflect only those pallets available for the movement of grocery and related products.

STOCK ADJUSTMENT MODEL FOR GROCERY DISTRIBUTION

The total quantity of pallets in use throughout the distribution system constitutes the inventory of pallets in the system. Estimation of the quantity of pallets in inventory is necessary for solution of the pallet demand and supply relationships outlined in the preceeding section. Recalling that pallets are a durable good, an application of a stock adjustment model permits identification of the quantities of pallets in inventory in the grocery distribution system. The stock adjustment model also provides another approach to demand specification for new pallets which emphasizes the importance of inventory levels to the overall demand for new pallets.

Grocery distribution centers and grocery products manufacturers purchase new pallets in order to maintain a sufficient quantity of pallets for the materials handling of grocery and related products. These purchases are based on the expected volume of grocery and related products passing through the distribution system. That is, purchases of new pallets are made in order to maintain a "desired" quantity of pallets in inventory and this quantity is based on the expectations of grocery distribution managers regarding volume of grocery and related products that will require pallets for movement and storage. The "actual" quantity of pallets available in the system, which involves a

physical count of all pallets in use throughout the system, constitutes the inventory of pallets in the system. Considering that all of the used and repaired pallets in the system were, at one time in the past, purchased as new pallets, then this inventory quantity can be expressed as a function of all past purchases of new pallets, or

$$Q_t = f \{Q_{NP,t}, Q_{NP,t-1}, Q_{NP,t-2}, \cdots Q_{NP,t-n}\}$$

where Q_t is the actual quantity of pallets available in the system in time period t, and $Q_{NP,t}$ is the quantity of new pallets demanded in time period t.

The inventory quantity of pallets maintained in a distribution system can also be expressed as a function of the dollar volume of grocery and related products sales. In a stock adjustment model, the desired quantity of pallets at the end of period t, or Q^*_t, and the dollar volume of grocery and related products sales during period t, or X_t, are related as follows:

$$Q^*_t = f \{ X_t \}$$

Although the quantity of pallets is changed by current decisions about the desired quantity of pallets, these decisions depend on all past quantities of pallets available with more emphasis on recent available quantities and corresponding less emphasis on quantities available long in the past. The adjustment made by the distribution system to the desired quantity of pallets in any one period may be expressed as follows:

$$Q_t - Q_{t-1} = g^* (Q^*_t - Q_{t-1})$$

where Q_t equals the actual quantity of pallets in the system at the end of period t. The multiplier, g^*, represents the percentage adjustment made between the actual and desired quantity of pallets in any one period. In this study, the assumption is made that the time period between the observations (1 year) is long enough so that the actual quantity of pallets in the system is equal to the desired quantity in any one period. Therefore, in this study the multiplier equals one. Thus, for pallets in grocery distribution,

$$Q_t = Q^*_t = f \{ X_t \}$$

where Q_t is the actual quantity of pallets in the system in time period t, Q^*_t is the desired quantity of pallets in time period t, and X_t is the dollar volume of grocery and related products sales in time period t.

In the stock adjustment model, the net change in quantity of pallets from one time period to another, N_t, is expressed as a function of the changing dollar volume of grocery and related products sales from one time period to another, or

$$N_t = Q_t - Q_{t-1} = f \{ X_t - X_{t-1} \}$$

If the new pallets purchased each year remained in the system indefinitely, then the net change in inventory quantity would represent the total demand for new pallets in the grocery distribution system, or

$$Q_{NP,t} = N_t = f \{ X_t - X_{t-1} \}$$

In this case, if the dollar volume of grocery and related products sales decreased from one year to the next, there would be a negative demand

for new pallets. However, as noted earlier, the life of a pallet in a grocery distribution system is finite. Therefore, one must also account for replacement of discarded pallets which are lost because of excessive damage and for the repair of damaged pallets which can be returned to service after repair. Considering the replacement aspect first, the assumption is made that the quantity of discarded pallets can be expressed as a constant proportion of the quantity of pallets in the system in the preceeding time period, or

$$W_t = w^*(Q_{t-1})$$

where W_t is the quantity of discarded pallets which must be replaced in time period t, w^* is the percentage of pallets previously purchased that is affected, and Q_{t-1} is the quantity of pallets in the system in the preceeding time period. A further assumption is made that a pallet can incur damage which results in the pallet being discarded at any time after the pallet enters the distribution system. In this assumption, the quantity of pallets being discarded is considered to be a constant function of the quantity of pallets exposed to potential damage. This assumption may be restated as one which assumes that replacement demand for discarded pallets is proportional to existing inventory. This is the same as an assumption of a declining balance depreciation formula used in other studies of stock adjustment, particularly Griliches (1960).

The quantity of discarded pallets impacts on the relationship for net change in the quantities of pallets in the system as follows:

$$N_t = Q_t - Q_{t-1} + W_t$$

In this relationship, the quantity of pallets discarded further increases the net change in the inventory quantity of pallets in the system and thereby increases demand for new pallets in time period t. However, the introduction of the term W_t means that we cannot express the net change solely as a function of dollar volume of sales without some additional manipulation of the equation elements.

Substituting for W_t,

$$N_t = Q_t - Q_{t-1} + w^*(Q_{t-1})$$

Combining terms yields,

$$N_t = Q_t - (1 - w^*)Q_{t-1}$$

This relationship may finally be expressed as a function of changes in the dollar volume of retail sales for grocery and related products, or

$$N_t = f \{ X_t - (1 - w^*)X_{t-1} \}$$

In the case of repaired pallets, consideration must be given to whether the repair is accomplished within the same time period that the damage occurs. If the quantity of pallets in a given time period equals Q_t and R_t pallets are removed from service for repair, the quantity of pallets in the system has decreased by the amount R_t. However, if the assumption is made that R_t pallets are repaired and returned to the system in the same time period, then the net change in the quantity of pallets is zero and the quantity of pallets in the system remains the same as before, or,

$$Q_t - R_t + R_t = Q_t$$

Recalling that the repair of pallets occurs on a more or less continuous (daily) basis and further that this study depends on yearly observations of levels of retail sales, I conclude that the time period between observations is sufficient to make this assumption viable.

One apparent limitation of this model is that it does not explicitly consider the cost of repair in comparison to the price of new pallets. The stock adjustment model deals only with the inventory quantity of pallets in the system as a function of the dollar volume of grocery and related products sales in the estimation of demand for new pallets. However, I have noted that only the quantity of pallets available in the system, along with the volume of products moved, influences the demand for new pallets. Then, as long as the repaired pallets are available, the cost of repair does not directly influence the quantity of new pallets demanded.

If a pallet is removed from the system for in-house repair and is found to have damage that exceeds the criteria previously enumerated for economic repair, that pallet is discarded, or as defined earlier, sold for salvage. The net effect is a reduction in the inventory quantity of pallets in the system. However, having made the assumption that the quantity of pallets sold for salvage is a constant proportion of the existing inventory, I can say that this quantity of pallets is already included as discarded pallets. Therefore, the constant, w^*, in the net change equation, also accounts for those pallets which are removed

from the system for in-house repair but are lost permanently when it is discovered that they cannot be economically repaired.

Thus, the net change in the quantity of pallets in the system, after adjusting for the effect of pallets that have been discarded, does constitute the quantity of new pallets demanded in the grocery distribution system in a given time period. This quantity, noted earlier in this section as $Q_{NP,t}$, is expressed as a function of changes in the dollar volume of retail sales for grocery and related products:

(1) $Q_{NP,t} = f \{ X_t - (1 - w^*)X_{t-1} \}$

or, in terms of the quantity of pallets in the system:

(2) $Q_{NP,t} = Q_t - (1 - w^*)Q_{t-1}$

At the beginning of this section, a functional relationship between the total quantity of pallets in use and past purchases of new pallets is given. Using formula (2) above, a mathematical expression (developed in Appendix B.) is presented for the total inventory quantity of pallets in the system in terms of all past purchases of new pallets, or

$$Q_{INV} = Q_{NP,t} + (1 - w^*)Q_{NP,t-1} + (1 - w^*)^2 Q_{NP,t-2} + \cdots + (1 - w^*)^n Q_{NP,t-n}$$

Although this expression considers all past purchases of new pallets, in practical terms one does not need to go any further back in time than the expected service life of an average pallet. For most grocery pallets, this time period will vary depending on the number of trips

that the pallet makes. For example, if the assumption is made that the average life of a pallet in the grocery distribution system is two years, in effect the assumption is that the annual replacement rate, w^*, must be greater than or equal to 50 percent. At least half of the pallets in the system are assumed to be replaced each year so that over a two year period 100 percent of the pallets can be expected to be replaced in the system.

Using the relationship in formula (1) above, the total inventory quantity of pallets is finally expressed as a function of changes in the dollar volume of retail sales of grocery and related products:

$$Q_{INV} = f \{ X_t - (1 - w^*)X_{t-1} \}$$

Estimation of this functional relationship provides the second element in the "excess demand" function noted in the preceeding section on the pallet market level.

THE COMPLETE MODEL

The following demand and supply functions from the final product market for grocery and related products and the market for pallets illustrate the linkages between each demand and supply point in the grocery distribution system and the price linkage between the quantity of grocery and related products requiring materials handling services and the resulting aggregate demand for pallets in the grocery distribution system. It is important to note that the functions representing the grocery pallet market could be estimated separately from the functions representing the grocery and related products market. That is, in future empirical estimation, the portion of the model representing the grocery pallet market could stand alone and be estimated separately from the demand and supply functions for grocery and related products.

Definitions of variables included in the functional relationships are summarized as follows:

Q^{D}_{GP} = total quantity of grocery and related products demanded by consumers measured in tons or cubic foot volume.

P_{GPS} = retail price of grocery and related products at retail stores.

P_S = price of substitutes.

P_C = price of complements.

P_O = price of all other goods and services.

I_C = average consumer income.

$Q^S_{GP,DC}$ = total quantity of grocery and related products supplied to retail stores by distribution centers.

P_{GPP} = wholesale price of grocery and related products.

P_{GPS} = retail price of grocery and related products.

P_P = weighted price of grocery pallets used in distribution.

P_O = weighted price of other factor inputs to production function.

$Q^D_{GP,DC}$ = quantity of grocery and related products handled in storage at the distribution center.

S_C = setup cost associated with placement of order to manufacturer.

P_{GPP} = wholesale price of grocery and related products.

P_{GPS} = retail price of grocery and related products.

H_C = holding cost or cost of carrying product in inventory.

P_P = weighted price of grocery pallets.

$Q^S_{GP,MFG}$ = total quantity of grocery and related products supplied by a grocery manufacturer.

P_{GPP} = wholesale price of grocery and related products.

P_{RM} = price of raw material inputs used in the production of grocery and related products.

P_{MH} = unit cost of transport measured in dollars per ton-mile or dollars per cubic foot volume-mile.

P_P = weighted price of grocery pallets.

P_O = weighted price of other factor inputs to the production function.

Q^D_P = total quantity of grocery pallets demanded for materials handling of grocery and related products.

P_P = weighted price of grocery pallets.

P_{GPP} = wholesale price of grocery and related products.

P_{GPS} = retail price of grocery and related products.

P_O = price of other factor inputs to production and distribution of grocery and related products.

Q^S_P = total quantity of grocery pallets supplied for materials handling of grocery and related products.

P_P = weighted price of grocery pallets.

P_{CAP} = price of capital or the interest rate.

P_{LAB} = price of labor.

P_O = price of other factor inputs to production function for grocery pallets.

Q^D_{NP} = quantity of new pallets demanded for materials handling of grocery and related products.

Q^S_P = total quantity of pallets supplied.

Q_{INV} = inventory quantity of pallets available in the system.

Q^S_{NP} = quantity of new pallets supplied for materials handling of grocery and related products.

P_{NP} = price of new grocery pallets.

P_{RM} = price of raw material inputs used in production of new grocery pallets.

P_O = price of other factor inputs to the pallet production function.

Q_{INV} = inventory quantity of pallets available in the system.

X_t = dollar volume of grocery and related products sales in period t.

Using the variables defined above, the demand and supply functions are summarized as follows:

Grocery and related products:

Retail Stores:

Demand: $Q^D_{GP} = f \{ P_{GPS}, P_S, P_C, P_O, I_C \}$

Grocery Distribution Centers:

Supply: $Q^S_{GP,DC} = f \{ P_{GPP}, P_{GPS}, P_P, P_O \}$

Demand: $Q^D_{GP,DC} = f \{ S_C, P_{GPP}, P_{GPS}, H_C, P_P \}$

Grocery Manufacturers:

Supply: $Q^S_{GP,MFG} = f \{ P_{GPP}, P_{RM}, P_{MH}, P_P, P_O \}$

Pallets:

Demand(total): $Q^D_P = f \{ P_P, P_{GPP}, P_{GPS}, P_O \}$

Supply(total): $Q^S_P = f \{ P_P, P_{CAP}, P_{LAB}, P_O \}$

Demand(new): $Q^D_{NP} = Q^S_P - Q_{INV}$ (Excess Demand)

Supply(new): $Q^S_{NP} = f \{ P_{NP}, P_{RM}, P_O \}$

Inventory: $Q_{INV} = f \{X_t - (1 - w^*)X_{t-1}\}$ (Stock Adjustment)

Market Clearing

Identities: $Q^D_P \equiv Q^S_P$ and $Q^D_{NP} \equiv Q^S_{NP}$

CHAPTER VI

PALLET CONSUMPTION BY THE GROCERY INDUSTRY

The initial section of this chapter describes the available data base and includes an analysis of the flows of grocery and related products in terms of dollar volume of retail sales between market areas within a region as well as market areas in different regions. The purpose of this analysis is to provide a base of information from which regional pallet consumption may be estimated under specific food flow and pallet durability assumptions. Available price and quantity data for grocery pallets is inadequate for statistical estimation of the demand and supply models presented in the preceeding chapter. Therefore, estimation of grocery pallet consumption, which does not consider pallet price in estimating quantity of pallets consumed, is presented in place of grocery pallet demand and supply estimation.

DATA BASE

The 1977 Census of Transportation contains the latest available data from the Bureau of the Census (U.S. Department of Commerce 1981) that identify the movement of goods between regions in terms of tons and ton-miles of shipments for three-digit SIC categories of food and kindred products. However, more recent and sufficiently detailed information published in the Progressive Grocer's 1987 Marketing Guidebook (Progressive Grocers Information Sales 1987) will be used to

establish the levels of shipments within and between market areas. The nine major regions identified by the Bureau of the Census in the United States can be compared to the seven regions specified by Progressive Grocer's Marketing Guidebook (Figure 6).

Although there are similarities between the regions identified by the Bureau of the Census and the Marketing Guidebook, some major differences exist. These differences are largely explained by the fact that in the definition of regions, the Bureau of the Census uses state boundaries to outline its regions while the Marketing Guidebook crosses state boundaries to include adjoining counties in defining market areas. First, the Bureau of the Census East South Central region and portions of the South Atlantic regions are combined into the South East region in the Marketing Guidebook. Second, the Bureau of the Census Mountain region is partitioned between the West Central, South West, and Pacific regions in the Marketing Guidebook. Third, the East Central and Mid Atlantic regions in the Marketing Guidebook cover portions of the Bureau of the Census South Atlantic region. Finally, the East Central region includes the Pittsburgh market area which is included in the Bureau of the Census Mid Atlantic region.

Within each region of the country specified in the Marketing Guidebook, major market areas are identified (Table 2). As an example, the East Central region is divided into eight market areas as follows: Charleston/Roanoke, Cincinnati, Cleveland, Detroit, Grand Rapids, Indianapolis, Louisville, and Pittsburgh.

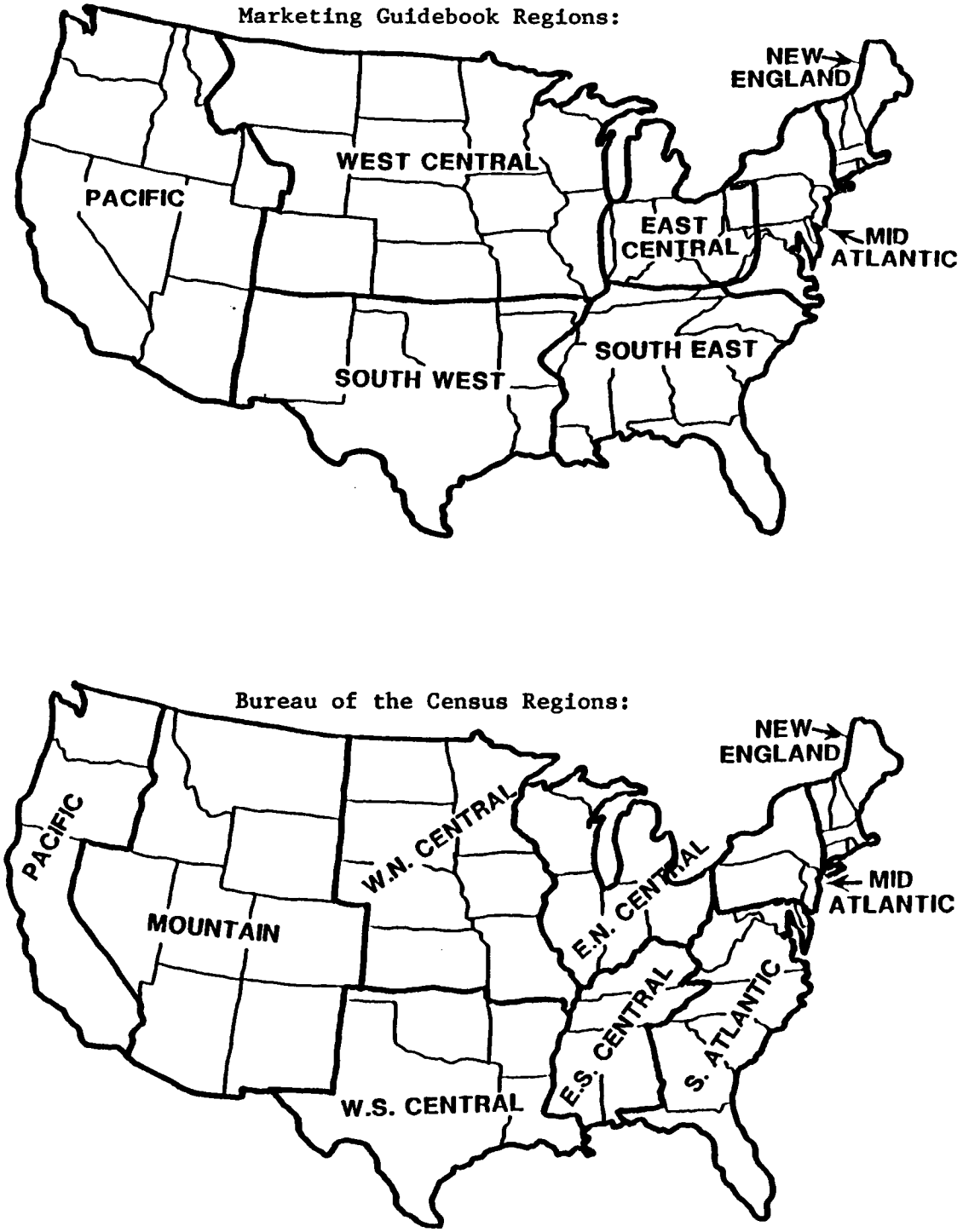

Figure 6. Comparison of Bureau of the Census and Marketing Guidebook Regions.

Table 2. Regions defined in the 1987 Marketing Guidebook.

Region:	Market Areas:
New England	Boston; Hartford
Mid-Atlantic	Albany; Baltimore/Washington; Buffalo; New York; Philadelphia; Richmond
Southeast	Atlanta; Birmingham; Charlotte; Columbia, SC; Jacksonville; Knoxville; Memphis; Miami; Nashville; New Orleans; Raleigh; Tampa
East Central	Charleston/Roanoke; Cincinnati; Cleveland; Detroit; Grand Rapids; Indianapolis; Louisville; Pittsburgh
Southwest	Albuquerque; Dallas; Houston; Oklahoma City; San Antonio; Springfield
West Central	Billings; Chicago; Denver; Des Moines; Fargo Kansas City; Milwaukee; Minneapolis; Omaha; St. Louis; Wichita
Pacific	Alaska; Hawaii; Los Angeles; Phoenix; Portland; Sacramento/Fresno; Salt Lake City; San Francisco; Seattle; Spokane

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

These market areas generally cover the standard metropolitan statistical areas and surrounding counties. Using the Charleston/Roanoke market area as an example, the market area is comprised of 4 Kentucky counties, 3 Ohio counties, 30 West Virginia counties, and 30 Virginia counties, surrounding the metropolitan areas of Charleston, W. Va., and Roanoke, Va. Market information for each of the counties includes statistics such as population, number of households, dollar volume of food store sales, and number of food stores, convenience stores, and supermarkets.

The 1986 dollar volume of food store sales for each market area and the market area's percent share of the region's dollar volume of food store sales are reported in the Marketing Guidebook (Table 3). The individual market areas of New York and Los Angeles are the two largest in terms of dollar volume of food store sales with $20.79 and $20.75 billion worth of sales, respectively. The dollar volume of food store sales in each of these market areas exceeds that for the combined two market areas making up the New England region, which has the smallest level of sales at 15.49 billion dollars. The South East region, with 12 market areas, has the largest number of market areas of any region and the largest total dollar volume of food store sales at 63.79 billion dollars. Both the South East and the East Central regions are comprised of market areas with fairly uniform levels of sales, ranging generally between 3 and 8 billion dollars. The other five regions have at least one market area with sales exceeding 10 billion dollars and show

Table 3. Food Store Sales in 1986, by Region & Market Area.

REGION	MARKET AREA	PERCENT OF REGION	SALES ($000)
New England			
	Boston	76.0	$11,788,944
	Hartford	24.0	3,698,962
	TOTAL	100.0	$15,487,906
Mid-Atlantic			
	Albany	10.0	$5,607,955
	Baltimore/Washington	20.0	11,170,217
	Buffalo	7.4	4,101,796
	New York	37.2	20,789,047
	Philadelphia	17.0	9,468,848
	Richmond	8.4	4,685,126
	TOTAL	100.0	$55,822,989
South East			
	Atlanta	9.7	$6,184,960
	Birmingham	8.4	5,358,737
	Charlotte	5.4	3,460,527
	Columbia, S.C.	10.2	6,499,413
	Jacksonville	5.4	3,435,189
	Knoxville	4.6	2,955,056
	Memphis	11.5	7,308,076
	Miami	8.8	5,636,713
	Nashville	4.8	3,095,671
	New Orleans	10.2	6,480,781
	Raleigh	8.1	5,181,349
	Tampa	12.9	8,197,408
	TOTAL	100.0	$63,793,880
East Central			
	Charleston/Roanoke	9.5	$4,002,146
	Cincinnati	16.7	7,046,424
	Cleveland	15.1	6,328,266
	Detroit	18.4	7,726,058
	Grand Rapids	7.9	3,310,179
	Indianapolis	10.7	4,512,758
	Louisville	8.2	3,458,105
	Pittsburgh	13.5	5,676,087
	TOTAL	100.0	$42,060,023

Table 3. continued.

REGION	MARKET AREA		PERCENT OF REGION	SALES ($000)
West Central				
	Billings		2.7	$1,414,341
	Chicago		21.6	11,282,468
	Denver		12.2	6,401,808
	Des Moines		6.0	3,120,443
	Fargo		3.0	1,592,231
	Kansas City		7.9	4,108,853
	Milwaukee		12.0	6,299,715
	Minneapolis		9.7	5,042,066
	Omaha		6.7	3,518,947
	St. Louis		14.9	7,767,359
	Wichita		3.3	1,710,722
		TOTAL	100.0	$52,258,953
South West				
	Albuquerque		14.0	$4,887,604
	Dallas		29.6	10,343,536
	Houston		21.0	7,318,515
	Oklahoma City		13.4	4,683,653
	San Antonio		15.9	5,549,917
	Springfield		6.1	2,132,660
		TOTAL	100.0	$34,915,885
Pacific				
	Alaska		1.4	$793,658
	Hawaii		2.2	1,215,175
	Los Angeles		36.8	20,750,916
	Phoenix		8.1	4,558,119
	Portland		7.5	4,204,871
	Sacramento/Fresno		10.8	6,087,548
	Salt Lake City		7.3	4,123,041
	San Francisco		14.5	8,199,194
	Seattle		7.1	4,013,756
	Spokane		4.3	2,405,440
		TOTAL	100.0	$56,351,718
		GRAND TOTAL		$320,691,354

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

considerably more disparity between market areas with the largest and smallest dollar volumes of sales.

Based on information published in the Marketing Guidebook, the retail market shares for distribution centers serving a specific market area can be identified. This information includes whether the distribution center is located within the market area or is located outside the market area. It also indicates the number of supermarkets served in the area and in other market areas. For example, the Charleston/Roanoke market area is served by a total of eighteen distribution centers, of which eight are located within the market area and ten are located outside the market area (Table 4). These distribution centers serve a total of 191 chain supermarkets and 267 independent supermarkets with a total retail share of over 93 percent of the total market, divided into 62.7 percent from in-market distribution centers and 31.1 percent from out-of-market distribution centers.

The out-of-market distribution centers serving a particular market area are not necessarily located in the same region as the market area they serve. In the case of the Charleston/Roanoke market area, the ten out-of-market distribution centers are divided as follows: two are located in the same region (East Central) as the Charleston/Roanoke market area with a combined retail market share of 3.91 percent; three are located in the Mid Atlantic region with a combined retail market share of 6.67 percent; and, the remaining five are located in the South East region with a combined retail market share of 20.56 percent.

Table 4. Market Area: Charleston/Roanoke

In-Market Distribution Centers:

Distribution centers located within area	Supermarkets in area	Retail Share	Supermarkets Served
Acme Markets	8	2.12%	9
Associated Grocers, Inc.	23	4.17	23
Fleming Foods of VA	34	5.82	52
The Kroger Co.	79	24.73	107
Mid-Mountain Foods	19	6.11	43
United Grocers, Inc.	29	5.12	29
Virginia Foods of Bluefield	19	2.82	19
Wetterau, Inc.	72	11.78	107

Out-of-Market Distribution Centers:

Distribution centers located outside area	Supermarkets in area	Retail Share
Atlantic & Pacific Tea Co.	6	1.02%
Big Bear Stores	7	2.78
Fleming Foods of TN	28	4.02
Food Lion Stores	28	7.65
Harris-Teeter Spr. Mkts.	13	3.11
Merchants Distributors	11	2.38
Richfood, Inc.	25	4.65
Safeway Stores	4	1.00
Super Valu Stores	9	1.13
Winn-Dixie Stores, Inc.	14	3.40

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

The retail sales in 1986 attributed to distribution centers serving each market area may be expressed as a percent of total food store sales in the market area (Table 5) or as an actual dollar volume of sales in the market area (Table 6). In Table 5 and Table 6, the percent or dollar volume of total food store sales attributed to distribution centers is separated into two catagories. These catagories identify the location of distribution centers serving a particular market area. The distribution centers serving a market area are either located within the market area (IN-MARKET) or are located outside the market area (OUT-OF-MARKET). The sum of these two catagories yields the total retail sales, expressed either as a percent or as a dollar volume, attributed to all distribution centers serving a particular market area. For example, Table 5 shows that in the Boston market area, 88.3 percent of retail sales in 1986 can be attributed to distribution centers located within the Boston market area. Another 8.2 percent of retail sales can be attributed to distribution centers located outside the Boston market area. The percent of total retail sales attributed to distribution centers serving the Boston market area is the sum of the in-market and out-of market percents, or 96.5 percent.

The combined retail market share for both in-market and out-of-market distribution centers serving a particular market area does not necessarily equal total food store sales in that market area. In addition to those distribution centers serving the retail food stores in an area, there are usually a number of in-market buying offices, food

Table 5. Retail Sales (%) Attributed to Distribution Centers, 1986.

REGION	MARKET AREA	TOTAL	DISTRIBUTION CENTER LOCATION	
			IN-MARKET	OUT-OF-MARKET
		(%)	(%)	(%)
New England				
	Boston	96.50	88.30	8.20
	Hartford	95.58	61.23	34.35
Mid-Atlantic				
	Albany	86.21	69.75	16.46
	Baltimore/Washington	92.97	82.12	10.85
	Buffalo	95.32	88.61	6.71
	New York	95.48	92.88	2.60
	Philadelphia	99.55	61.46	38.09
	Richmond	95.19	79.01	16.18
South East				
	Atlanta	93.15	46.26	46.89
	Birmingham	96.54	76.40	20.14
	Charlotte	97.15	81.84	15.31
	Columbia, S.C.	98.79	74.47	24.32
	Jacksonville	92.75	67.17	25.58
	Knoxville	91.06	49.71	41.35
	Memphis	91.13	79.84	11.29
	Miami	96.54	83.13	13.41
	Nashville	91.96	76.62	15.34
	New Orleans	96.76	69.55	27.21
	Raleigh	96.80	44.80	52.00
	Tampa	93.65	77.08	16.57
East Central				
	Charleston/Roanoke	93.81	62.67	31.14
	Cincinnati	93.41	81.06	12.35
	Cleveland	95.77	85.77	10.00
	Detroit	90.79	60.25	30.54
	Grand Rapids	93.87	72.90	20.97
	Indianapolis	95.96	69.83	26.13
	Louisville	87.27	65.65	21.62
	Pittsburgh	90.93	74.51	16.42

Table 5. continued.

REGION	MARKET AREA	TOTAL	DISTRIBUTION CENTER LOCATION	
			IN-MARKET	OUT-OF-MARKET
		(%)	(%)	(%)
West Central				
	Billings	93.19	72.09	21.10
	Chicago	92.74	84.65	8.09
	Denver	97.22	94.86	2.36
	Des Moines	96.92	82.95	13.97
	Fargo	93.63	76.14	17.49
	Kansas City	96.36	80.76	15.60
	Milwaukee	94.65	87.70	6.95
	Minneapolis	96.62	88.74	7.88
	Omaha	95.79	57.22	38.57
	St. Louis	92.10	77.41	14.69
	Wichita	95.68	72.35	23.33
South West				
	Albuquerque	97.92	78.64	19.28
	Dallas	92.38	84.63	7.75
	Houston	89.75	83.82	5.93
	Oklahoma City	96.04	83.36	12.68
	San Antonio	59.19	33.71	25.48
	Springfield	94.71	76.64	18.07
Pacific				
	Alaska	93.65	35.86	57.79
	Hawaii	73.49	27.88	45.61
	Los Angeles	97.79	96.70	1.09
	Phoenix	98.04	98.04	0.00
	Portland	95.86	94.51	1.35
	Sacramento/Fresno	80.45	32.53	47.92
	Sale Lake City	97.05	91.03	6.02
	San Francisco	85.01	72.73	12.28
	Seattle	98.63	93.68	4.95
	Spokane	95.29	51.86	43.43

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

Table 6. Retail Sales ($000) Attributed to Distribution Centers, 1986.

REGION	MARKET AREA	TOTAL	DISTRIBUTION CENTER LOCATION	
			IN-MARKET	OUT-OF-MARKET
		($000)	($000)	($000)
New England				
	Boston	11,376,331	10,409,638	966,693
	Hartford	3,535,468	2,264,874	1,270,593
	SUB-TOTAL	14,911,799	12,674,512	2,237,287
Mid-Atlantic				
	Albany	4,834,618	3,911,549	923,069
	Baltimore/Washington	10,384,951	9,172,982	1,211,969
	Buffalo	3,909,832	3,634,601	275,231
	New York	19,849,382	19,308,867	540,515
	Philadelphia	9,426,238	5,819,554	3,606,684
	Richmond	4,459,771	3,701,718	758,053
	SUB-TOTAL	52,864,792	45,549,271	7,315,521
South East				
	Atlanta	5,761,290	2,861,162	2,900,128
	Birmingham	5,173,325	4,094,075	1,079,250
	Charlotte	3,361,902	2,832,095	529,807
	Columbia, S.C.	6,420,770	4,840,113	1,580,657
	Jacksonville	3,186,138	2,307,416	878,721
	Knoxville	2,690,874	1,468,958	1,221,916
	Memphis	6,659,850	5,834,768	825,082
	Miami	5,441,683	4,685,800	755,883
	Nashville	2,846,779	2,371,903	474,876
	New Orleans	6,270,804	4,507,383	1,763,421
	Raleigh	5,015,545	2,321,244	2,694,301
	Tampa	7,676,873	6,318,562	1,358,311
	SUB-TOTAL	60,505,833	44,443,481	16,062,352
East Central				
	Charleston/Roanoke	3,754,413	2,508,145	1,246,268
	Cincinnati	6,582,065	5,711,831	870,233
	Cleveland	6,060,580	5,427,754	632,827
	Detroit	7,014,488	4,654,950	2,359,538
	Grand Rapids	3,107,265	2,413,120	694,145
	Indianapolis	4,330,443	3,151,259	1,179,184
	Louisville	3,017,888	2,270,246	747,642
	Pittsburgh	5,161,266	4,229,252	932,013
	SUB-TOTAL	39,028,408	30,366,558	8,661,850

Table 6. continued.

REGION	MARKET AREA	TOTAL ($000)	DISTRIBUTION CENTER LOCATION: IN-MARKET ($000)	DISTRIBUTION CENTER LOCATION: OUT-OF-MARKET ($000)
West Central				
	Billings	1,318,024	1,019,598	298,426
	Chicago	10,463,361	9,550,609	912,752
	Denver	6,223,838	6,072,755	151,083
	Des Moines	3,024,333	2,588,407	435,926
	Fargo	1,490,806	1,212,325	278,481
	Kansas City	3,959,291	3,318,310	640,981
	Milwaukee	5,962,680	5,524,850	437,830
	Minneapolis	4,871,644	4,474,329	397,315
	Omaha	3,370,799	2,013,541	1,357,258
	St. Louis	7,153,738	6,012,713	1,141,025
	Wichita	1,636,819	1,237,707	399,111
	SUB-TOTAL	49,475,333	43,025,145	6,450,188
South West				
	Albuquerque	4,785,942	3,843,612	942,330
	Dallas	9,555,359	8,753,735	801,624
	Houston	6,568,367	6,134,379	433,988
	Oklahoma City	4,498,180	3,904,293	593,887
	San Antonio	3,284,996	1,870,877	1,414,119
	Springfield	2,019,842	1,634,471	385,372
	SUB-TOTAL	30,712,686	26,141,366	4,571,320
Pacific				
	Alaska	743,261	284,606	458,655
	Hawaii	893,032	338,791	554,241
	Los Angeles	20,292,321	20,066,136	226,185
	Phoenix	4,468,780	4,468,780	0
	Portland	4,030,789	3,974,024	56,766
	Sacramento/Fresno	4,897,432	1,980,279	2,917,153
	Salt Lake City	4,001,411	3,753,204	248,207
	San Francisco	6,970,135	5,963,274	1,006,861
	Seattle	3,958,768	3,760,087	198,681
	Spokane	2,292,144	1,247,461	1,044,683
	SUB-TOTAL	52,548,073	45,836,641	6,711,432
	GRAND TOTAL	300,046,924	248,036,974	52,009,950

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

brokers, non-food distributors, candy, tobacco and media distributors who provide the balance of products to the food stores. What is important is that the combined retail market share for the distribution centers averages over 93 percent of total retail food store sales for all market areas in the United States. This means that the vast majority of grocery and related products delivered to retail food stores are handled in a distribution system which has been shown to use pallets in accomplishing those deliveries.

Examination of retail sales expressed as a percent of total sales shows that the average share of retail sales over all market areas is 73.33 percent for the in-market distribution centers and is 19.85 percent for the out-of-market distribution centers. Sales volume attributed to the in-market distribution centers ranges from a low of 27.88 percent for the Hawaii market area to a high of 98.04 percent for the Phoenix market area. The sales volume attributed to out-of-market distribution centers ranges from a low of 0.0 percent for the Phoenix market area to a high of 57.79 percent for the Alaska market area.

The Alaska and Hawaii market areas are unique in that they are physically separated from the other market areas in the continental United States. Retail stores in both market areas receive more shipments from distribution centers located in market areas along the West Coast than they do from distribution centers located in their respective market areas. This may be explained by the economies of scale achieved by the distribution centers on the West Coast, serving

much larger markets in terms of sales volume than either the Alaska or Hawaii market area.

The Phoenix market area is something of an anomaly in that it is served by no out-of-market distribution centers. In this case, the market is large enough for in-market distribution centers to operate efficiently and is concentrated largely in the Phoenix/Tucson area, which means that there are no other distribution centers within cost effective shipping distance to this market.

Market concentration and economies of scale in distribution systems do have an effect on the amount of retail sales which can be attributed to out-of-market distribution centers. In the two largest markets, New York and Los Angeles, the percent of retail sales allocated to out-of-market distribution centers is 2.60 percent and 1.09 percent, respectively. In the other four market areas with retail sales over 10 billion dollars, the percent of retail sales allocated to out-of-market distribution centers ranges from 7.75 percent to 10.85 percent, which is well below the average for market areas over the entire United States.

ESTIMATION OF PALLET CONSUMPTION

Based on the stock adjustment model for grocery distribution, new pallet consumption is expressed in terms of the inventory quantity of pallets in the system, or

$$Q_{NP,t} = Q_{INV,t} - (1-w^{*})Q_{INV,t-1}$$

where $Q_{NP,t}$ is the quantity of new pallets consumed in materials handling of grocery and related products in period t, $Q_{INV,t}$ is the quantity of pallets in inventory in period t, and $(1-w^*)$ is the percent of pallets remaining in inventory from the preceeding period. Estimation of the quantity of new pallets consumed in period t therefore requires identification of the quantity of pallets in inventory in successive time periods. Total pallet production data and total retail grocery store sales are available over the past 13 years (Table 7). However, this information has certain limitations that preclude statistical estimation of the inventory quantity of pallets in the system. Total pallet production data include all types of pallets produced, that is, expendable as well as permanent pallets of varying size and construction specifications. Thus, total pallet production includes many factors, only one of which relates to the consumption of pallets by the grocery industry. For example, the increase in total pallet production from 228.3 million pallets in 1982 to 372.8 million pallets in 1986 represents an increase of over 63 percent in production over the four year period. This increase can be attributed largely to growth in the general economy. As industrial production has expanded during this period, the demand for pallets by all industries using pallets in materials handling has increased as well. Thus, the 27.3 percent increase in grocery store sales over the same period, measured in current dollars, can be expected to account for part of the increase in total pallet production; but, the exact amount of increased pallet

Table 7. Pallet Production and Grocery Store Sales.

Year	Pallet Production for all uses Total Units	Grocery Store Sales Total
	(million)	(current $ billion)
1974	205.1	130.5
1975	159.3	142.5
1976	195.7	152.0
1977	235.9	162.8
1978	270.3	179.6
1979	296.0	199.9
1980	258.4	220.8
1981	252.2	240.9
1982	228.3	252.0
1983	257.7	263.8
1984	304.4	279.4
1985	334.8	292.2
1986	372.8	320.7

Sources: National Wooden Pallet and Container Association. 1986. Production Report (New Pallets). Washington, D.C., and Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

production attributed to increased grocery store sales cannot be identified.

In estimating quantity of new pallets consumed in the grocery distribution system, the portion of total pallet production that is used to maintain the inventory quantity of pallets in the grocery and related products manufacturing and distribution industry must be identified. Point estimates of total 48x40 pallet production, which include grocery pallets but are not limited to grocery pallet production, are available from surveys taken in three specific years, 1979, 1982, and 1984. These estimates range from a low of 20 percent of total pallet production in 1982 (McKeever, et al. 1986) to a high of 31 percent in 1984 (NWPCA 1985) with an estimate of 27 percent in 1979 (NWPCA 1980). These estimates are incomplete measures of grocery pallet production because the 48x40 size pallet is used in materials handling of products other than grocery and related products. Although grocery pallet production estimates are contained in the point estimates, the actual quantity of grocery pallets produced is not reported.

Because neither the quantity of new grocery pallets nor the total inventory quantity of pallets used by the grocery distribution system can be identified directly from the available data, estimation of the inventory quantity of pallets in the system must be made indirectly through assumptions about the relation of retail sales to inventory quantity of pallets. Estimation is based on assumptions about the nature of pallet use in the system from a study by Wallin (1977) and

information obtained during interviews with grocery distribution center managers.

CONVERSION FACTORS

The quantity of grocery and related products demanded in a particular area is satisfied by shipments of products from distribution centers to retail stores. The number of shipments from distribution centers is therefore directly reflected in the dollar volume of retail sales in an area. This measure of shipments, that is, retail sales, can be converted into an estimate of the number of pallets required to sustain that level of shipments. Certain assumptions about pallet use in the grocery distribution system must be made to develop the conversion factors and make estimates of the number of pallets in the system. These assumptions include the following:

a. Average pallet life = 2.5 years.

b. Average trips per life of pallet = 20 trips.

c. Average number of pallets per shipment = 22 pallets.

d. Average retail dollar volume per shipment = $15,000.

e. Average turnover period for product in warehouse = 3 weeks.

The first two assumptions are based on data from an unpublished report by Wallin (1977). The last three assumptions are based on information obtained from the survey of grocery distribution center managers. The assumption about dollar volume per shipment to retail stores is critical

because it provides the link between known levels of retail sales and the number of pallets in use in the system.

From Table 7, one notes that 320.7 billion dollars in retail grocery sales were reported in the United States in 1986. But, only 93.6 percent of these sales were attributed to retail stores served by distribution centers, or just over 300 billion dollars based on information from the 1987 Marketing Guidebook. Assuming that these sales required the use of trucks to deliver the products from distribution centers to retail stores, then an estimated 20 million truck loads were required to deliver the grocery products to retail stores, at an average of $15,000 of product per truck load. With an average of 22 pallets per truck load, an estimated total of 440 million pallet loads were required to move the products. Based on the assumptions that a pallet remains in the system for 2.5 years, on the average, and that it makes an average of 20 trips in that time, it is assumed that the average pallet makes 20/2.5 or 8 trips per year. Therefore, the 440 million pallet loads required an estimated 55 million pallets, with each pallet making a minimum of 8 trips, to deliver grocery and related products to retail stores in 1986.

One may approach this estimate of 55 million pallets in another way. Industry sources indicate that in 1986 the dollar value per pallet load of product shipped from a distribution center varied from approximately $2000 per pallet for meat to $350 per pallet for produce, with an average value of products carried on each pallet equal to

approximately $700. Using the above assumptions, it is calculated that each pallet carries an average of $15,000/22 or $682 of grocery products on each trip, which is reasonably close to the average value per pallet load reported by industry sources. Again assuming that each pallet makes 8 trips per year, the total retail sales dollar volume for each pallet used in shipping grocery products to retail stores is 8 times $682, or $5456 per pallet. Thus, in satisfying 300 billion dollars in retail sales, distribution centers needed 300 billion/5456, or about 55 million pallets to move grocery and related products from the distribution centers to retail stores.

The above estimate omits two important aspects of grocery distribution. First, the pallets used in movement of products from the manufacturer to the distribution center must be included, and second, the number of pallets used in the warehouse for product storage must be estimated.

Further information is required to estimate the number of pallets used in movement of products from the manufacturer to the distribution center. For example, if it is assumed that the same number of pallets are required to deliver the products to the distribution centers as are required to deliver products to the retail stores, then another 55 million pallets could be added to the number of pallets required for the movement of grocery and related products. However, based on the survey of grocery distribution center managers, about 35 percent of the products coming in to the distribution center are not palletized. Thus,

in 1986 the number of pallets required for movement of grocery and related products from the manufacturers to the distribution center is estimated to be 65 percent of the number required for movement of products to the retail stores, or about 36 million pallets.

Estimation of the number of pallets used in the warehouse for product storage is based on the assumption of the frequency of product turnover in the warehouse and how it relates to the number of pallets used to distribute products to the retail stores. If it is assumed that the product turnover occurs every three weeks, or on an average of 17 times per year as reported by the surveyed distribution center managers, then the dollar volume of products stored in the warehouse is assumed to be 3/52 or about 6 percent of the total dollar volume of products moved from the distribution center to the retail stores in a period of one year. Six percent of the 55 million pallets used to move products to the retail stores yields an estimated 3 million pallets in the distribution system for the storage of products in the warehouse. This estimate is reinforced by the observed quantity of pallets in surveyed distribution centers. For example, one large distribution center shipped approximately 1.7 million pallet loads of products to retail stores in 1986. This distribution center maintained an average of 100,000 pallets in the warehouse for storage of grocery and related products, which is about 6 percent of the quantity of pallets the distribution center used to move products to retail stores.

The total inventory quantity of pallets in the grocery distribution system is attained by adding up the estimates made from the above assumptions. Again, using 1986 retail sales to base the assumptions on, the total number of pallets in the system is estimated to be 55 + 36 + 3 million pallets or 94 million pallets. This is the total inventory quantity of pallets in the grocery distribution system required for the movement and storage of grocery and related products in 1986, not the quantity of new pallets required in 1986.

In order to obtain an estimate of the quantity of new pallets required in 1986, one must first estimate the inventory quantity of pallets in the system in the preceeding year, 1985. With the same assumptions outlined above, the total inventory quantity of pallets required in 1985 to handle the volume of products generating 273 billion dollars in retail sales is calculated to be 85 million pallets. Thus, if all pallets in the system in 1985 remained in the system in 1986, then an additional 9 million new pallets were required to move the increased volume of grocery products. However, based on the assumption that a pallet stays in the system for 2.5 years, an estimated 40 percent of the pallets in the system were discarded in 1985. Therefore, an additional 34 million new pallets were required to replace pallets discarded in 1985. Using the equation specified earlier, I calculate

$$Q_{NP,1986} = 94 - (0.60)*85 = 43$$

Total new grocery pallets purchased or consumed in 1986 is therefore estimated to be 43 million pallets, or over 11 percent of total pallet production in 1986.

The only published reference points for validating this estimate of grocery pallet production are the point estimates for 48x40 pallet production reported above. Because these reported percentages include all uses of 48x40 pallets, the estimate of grocery pallet production was expected to be less than the reported percentages. Dr. Edward C. Brindley, Jr., President, Industrial Reporting, Inc., Richmond, Va., estimated that grocery pallet production in Virginia was less than 15 percent of total quantity of pallets produced in the state. Brindley also estimated that national levels of grocery pallet production are about half of the total market for the 48x40 pallet. Based on the reported surveys, this would indicate that grocery pallet production could range from 10 to 15 percent of total production. Thus, the estimate of 43 million grocery pallets purchased in 1986 appears reasonable in view of the existing information.

REGIONAL PALLET CONSUMPTION

The volume of retail sales of grocery and related products is the driving force in generating consumption of new pallets. Without retail sales there would be no incentive to move or store grocery and related products on pallets. For this reason, the estimate of consumption of new grocery pallets in 1986 is broken down between regions on the basis

of the volume of retail sales occurring in each region. From the previous section, I note that 38 percent of new pallet consumption occurs in the movement of grocery products to distribution centers, while 62 percent occurs in the storage and movement of grocery products through distribution centers. As a result, allocation of the quantity of new pallets consumed between regions depending on regional retail sales is biased in that not all new pallets are consumed at distribution centers in satisfying retail sales. In fact, 38 percent of new pallet consumption occurs at grocery and related products manufacturing facilities, not at distribution centers. Inasmuch as the grocery manufacturing facilities are not always located in the same region as the distribution centers they serve, the regional estimates of new pallet consumption are not exact. However, these estimates do reflect the concentration of distribution centers within market areas and for that reason, they are included in this analysis.

In order to allocate the estimate of 43 million grocery pallets between regions, or more specifically, between market areas as defined earlier, regional levels of retail sales attributed to distribution centers must first be expressed as a percent of total sales (Table 8). The percent of national retail sales attributed to distribution centers is separated into two catagories that identify the location of distribution centers serving a particular market area. For example, in the Boston market area, 3.47 percent of retail sales is attributed to

Table 8. Regional Sales, as a percent of Total Sales in 1986.

REGION	MARKET AREA	TOTAL	DISTRIBUTION CENTER LOCATION	
			IN-MARKET	OUT-OF-MARKET
		(percent)	(percent)	(percent)
New England				
	Boston	3.79	3.47	0.32
	Hartford	1.18	0.75	0.43
	SUB-TOTAL	4.97	4.22	0.75
Mid-Atlantic				
	Albany	1.61	1.30	0.31
	Baltimore/Washington	3.46	3.06	0.40
	Buffalo	1.30	1.21	0.09
	New York	6.62	6.44	0.18
	Philadelphia	3.14	1.94	1.20
	Richmond	1.49	1.23	0.26
	SUB-TOTAL	17.62	15.18	2.44
South East				
	Atlanta	1.92	0.95	0.97
	Birmingham	1.72	1.36	0.36
	Charlotte	1.12	0.94	0.18
	Columbia, S.C.	2.14	1.61	0.53
	Jacksonville	1.06	0.77	0.29
	Knoxville	0.90	0.49	0.41
	Memphis	2.21	1.94	0.27
	Miami	1.81	1.56	0.25
	Nashville	0.95	0.79	0.16
	New Orleans	2.09	1.50	0.59
	Raleigh	1.67	0.77	0.90
	Tampa	2.56	2.11	0.45
	SUB-TOTAL	20.15	14.79	5.36
East Central				
	Charleston/Roanoke	1.26	0.84	0.42
	Cincinnati	2.19	1.90	0.29
	Cleveland	2.02	1.81	0.21
	Detroit	2.34	1.55	0.79
	Grand Rapids	1.03	0.80	0.23
	Indianapolis	1.44	1.05	0.39
	Louisville	1.01	0.76	0.25
	Pittsburgh	1.72	1.41	0.31
	SUB-TOTAL	13.01	10.12	2.89

Table 8. continued.

REGION	MARKET AREA	TOTAL	DISTRIBUTION CENTER LOCATION	
			IN-MARKET	OUT-OF-MARKET
		(percent)	(percent)	(percent)
West Central				
	Billings	0.44	0.34	0.10
	Chicago	3.49	3.18	0.31
	Denver	2.07	2.02	0.05
	Des Moines	1.01	0.86	0.15
	Fargo	0.50	0.41	0.09
	Kansas City	1.32	1.11	0.21
	Milwaukee	1.99	1.84	0.15
	Minneapolis	1.62	1.49	0.13
	Omaha	1.12	0.67	0.45
	St. Louis	2.38	2.00	0.38
	Wichita	0.55	0.42	0.13
	SUB-TOTAL	16.49	14.34	2.15
South West				
	Albuquerque	1.60	1.28	0.32
	Dallas	3.19	2.92	0.27
	Houston	2.19	2.05	0.14
	Oklahoma City	1.50	1.30	0.20
	San Antonio	1.09	0.62	0.47
	Springfield	0.67	0.54	0.13
	SUB-TOTAL	10.24	8.71	1.53
Pacific				
	Alaska	0.24	0.09	0.15
	Hawaii	0.30	0.12	0.18
	Los Angeles	6.77	6.69	0.08
	Phoenix	1.49	1.49	0.00
	Portland	1.34	1.32	0.02
	Sacramento/Fresno	1.63	0.66	0.97
	Salt Lake City	1.33	1.25	0.08
	San Francisco	2.33	1.99	0.34
	Seattle	1.32	1.25	0.07
	Spokane	0.77	0.42	0.35
	SUB-TOTAL	17.52	15.28	2.24
	GRAND TOTAL	100.00	82.64	17.36

Source: Progressive Grocers Information Sales. 1987. 1987 Marketing Guidebook. Stamford, Conn.

distribution centers located within the market area. Another 0.32 percent of retail sales is attributed to distribution centers located outside the Boston market area. The total percent of national retail sales attributed to distribution centers serving the Boston market area is the sum of the above values, or 3.79 percent of all retail sales attributed to distribution centers throughout the United States in 1986. As shown in Table 8, nearly 83 percent of retail sales attributed to distribution centers throughout the United States comes from distribution centers located within the particular market area served.

Multiplying the percent of retail sales in each market area by the total quantity of new pallets consumed yields the estimated quantity of grocery pallets purchased in each market area in 1986 (Table 9). The estimated quantity of new grocery pallets consumed is also separated into two catagories that identify the location of distribution centers serving a particular market area. For example, in the Boston market area, an estimated 1.49 million grocery pallets were consumed in 1986 by distribution centers located within the Boston market area. Another 0.14 million grocery pallets were consumed by distribution centers serving the Boston market area from outside the market area. Thus, total grocery pallet consumption estimated for distribution centers serving the Boston market area in 1986 was 1.63 million pallets. As shown in Table 9, over 35 million grocery pallets were estimated to be consumed in 1986 by distribution centers located within the particular market area served.

Table 9. Estimated Regional Pallet Consumption in 1986.

REGION	MARKET AREA	TOTAL (million)	DISTRIBUTION CENTER LOCATION: IN-MARKET (million)	DISTRIBUTION CENTER LOCATION: OUT-OF-MARKET (million)
New England				
	Boston	1.63	1.49	0.14
	Hartford	0.51	0.33	0.18
	SUB-TOTAL	2.14	1.82	0.32
Mid-Atlantic				
	Albany	0.69	0.56	0.13
	Baltimore/Washington	1.49	1.32	0.17
	Buffalo	0.56	0.52	0.04
	New York	2.85	2.77	0.08
	Philadelphia	1.35	0.83	0.52
	Richmond	0.64	0.53	0.11
	SUB-TOTAL	7.58	6.53	1.05
South East				
	Atlanta	0.83	0.41	0.42
	Birmingham	0.74	0.59	0.15
	Charlotte	0.48	0.41	0.07
	Columbia, S.C.	0.92	0.69	0.23
	Jacksonville	0.46	0.33	0.13
	Knoxville	0.39	0.21	0.18
	Memphis	0.94	0.83	0.11
	Miami	0.78	0.67	0.11
	Nashville	0.41	0.34	0.07
	New Orleans	0.90	0.65	0.25
	Raleigh	0.72	0.33	0.39
	Tampa	1.10	0.91	0.19
	SUB-TOTAL	8.67	6.37	2.30
East Central				
	Charleston/Roanoke	0.54	0.36	0.18
	Cincinnati	0.94	0.82	0.12
	Cleveland	0.87	0.78	0.09
	Detroit	1.01	0.67	0.34
	Grand Rapids	0.44	0.34	0.10
	Indianapolis	0.62	0.45	0.17
	Louisville	0.43	0.32	0.11
	Pittsburgh	0.74	0.61	0.13
	SUB-TOTAL	5.59	4.35	1.24

Table 9. continued.

REGION	MARKET AREA	TOTAL (million)	DISTRIBUTION CENTER LOCATION: IN-MARKET (million)	DISTRIBUTION CENTER LOCATION: OUT-OF-MARKET (million)
West Central				
	Billings	0.19	0.15	0.04
	Chicago	1.50	1.37	0.13
	Denver	0.89	0.87	0.02
	Des Moines	0.43	0.37	0.06
	Fargo	0.21	0.17	0.04
	Kansas City	0.57	0.48	0.09
	Milwaukee	0.85	0.79	0.06
	Minneapolis	0.70	0.64	0.06
	Omaha	0.48	0.29	0.19
	St. Louis	1.03	0.86	0.17
	Wichita	0.24	0.18	0.06
	SUB-TOTAL	7.09	6.17	0.92
South West				
	Albuquerque	0.69	0.55	0.14
	Dallas	1.37	1.26	0.11
	Houston	0.94	0.88	0.06
	Oklahoma City	0.64	0.55	0.09
	San Antonio	0.47	0.27	0.20
	Springfield	0.29	0.23	0.06
	SUB-TOTAL	4.40	3.74	0.66
Pacific				
	Alaska	0.10	0.04	0.06
	Hawaii	0.13	0.05	0.08
	Los Angeles	2.91	2.88	0.03
	Phoenix	0.64	0.64	0.00
	Portland	0.58	0.57	0.01
	Sacramento/Fresno	0.70	0.28	0.42
	Salt Lake City	0.57	0.54	0.03
	San Francisco	1.00	0.85	0.15
	Seattle	0.57	0.54	0.03
	Spokane	0.33	0.18	0.15
	SUB-TOTAL	7.53	6.57	0.96
	GRAND TOTAL	43.00	35.55	7.45

CHAPTER VII

EFFECT OF GROCERY PALLET USE ON HARDWOOD RESOURCE

This chapter describes the major characteristics of wood raw material usage by the grocery distribution industry. The emphasis is on wood raw material consumption in the construction of new grocery pallets, although the quantity of wood raw material consumed in pallet repair is also considered. Since hardwood pallets are presently preferred for distribution of grocery and related products, the impact of increasing quantity of grocery pallets on the hardwood resource is discussed in a concluding section. Because of data limitations, particularly with respect to overall pallet production within regions, this section will be largely descriptive in nature.

In the grocery pallet supply model, the quantity of new pallets supplied is expressed as a function of the price of pallets, price of wood raw material input, and price of other factor inputs to the pallet production function. Estimation of this model would show that price of pallets and price of wood raw material directly effect the quantity of pallets supplied. However, in this study, estimation of quantity of new pallets supplied in grocery distribution is limited to a technical conversion for quantity of new pallets consumed. This does not mean that the interaction between prices of wood raw material and pallets and the quantity of pallets supplied is not functioning in the system; rather, the inadequacy of available data to estimate these interactions

necessitates a technical conversion approach to the estimation of wood raw material consumed.

WOOD RAW MATERIAL - NEW PALLETS

The volume of wood raw material consumed annually in the production of grocery pallets can be estimated through an analysis of national and regional levels of new pallet consumption in grocery distribution. In this analysis, the quantity of new pallets consumed is converted to an equivalent volume of wood raw material input to production of grocery pallets. In making the conversion, both the volume of wood contained in the average grocery pallet and the volume of wood consumed in the production of the pallet are evaluated. I consider the board foot volume in an average grocery pallet nationally to be in the same range as that reported for non-expendable pallets by McCurdy (1988), or 16.24 board foot per pallet. This value is the average volume of lumber contained in a non-expendable pallet, not the volume of wood raw material consumed in the production of the pallet.

Although McCurdy (1988) also reports that the average volume of lumber per pallet varies depending on the region where the pallet is produced, his study reflects all types of non-expendable pallets. Unlike this study, it is not restricted specifically to grocery pallets. I consider that the modified GMA grocery exchange pallet (described in Appendix C) constitutes the average pallet in the industry

and is used as a reference point by pallet manufacturers and purchasers of grocery pallets throughout all regions of the United States.

In estimating the volume of wood raw material consumed in the production of grocery pallets, I must consider the volume of wood lost during production as well as the volume of wood actually contained in the pallet. The wood volume lost during production includes sawdust, edgings, and end trims, which are not included in the volume of wood contained in the finished pallet. This wood volume lost during production is expressed as a percent of the volume of wood actually contained in the finished pallet. Pallet manufacturers contacted during this study and in my previous studies relating to the pallet industry indicate that the average waste factor for pallet production, or the wood volume lost during production, is about 20 percent of the wood volume actually going into pallets. This factor will vary from one pallet manufacturer to another depending on the conversion efficiency of each mill and the type of wood raw material used in the production process, ie., logs, lumber, cants, or pre-cut parts. But, an industry average of 20 percent waste in production appears realistic based on the information available. Thus, a pallet containing 16.24 board foot of wood requires an estimated 19.5 board foot of wood raw material in production of the pallet.

Although grocery pallets only constituted an estimated 11 percent of the total quantity of pallets produced in 1986, the volume of wood consumed in production of these pallets is shown to be a significantly

greater share of total volume of hardwood raw material consumed in pallet production. Based on the above estimate of wood consumed per pallet, the 43 million pallets required by the grocery distribution industry in 1986 consumed a total of 838.5 million board foot of wood raw material. This is 18 percent of an estimated 4.5 billion board foot of hardwood raw material consumed by the industry for all types of pallets in 1986 (McCurdy 1988).

Regional allocation of the volume of wood raw material consumed in the production of grocery pallets is based on the estimated regional consumption of new grocery pallets shown previously in Table 9. As noted earlier, these estimates cannot be considered exact because of the uncertainty associated with the location of grocery manufacturing facilities that use pallets in the movement of grocery products from the manufacturing facility to distribution centers. However, the majority of new pallets in grocery distribution are consumed at distribution centers. This consumption has been shown to be satisfied by the supply of pallets from pallet manufacturers in close proximity to the point of demand (McCurdy and Ewers 1986). Therefore, in the absence of better information, the estimated regional new grocery pallet consumption is used to provide a qualified estimate of the regional volume of wood raw material consumed in the production of grocery pallets in 1986 (Table 10). The estimated quantity of wood raw material consumed is separated into two catagories that identify the location of distribution centers serving a particular market area. For example, in the Boston market

Table 10. Estimated Wood Raw Material Consumption in Grocery Pallet Production, 1986.

REGION	MARKET AREA	TOTAL (MMBF)	DISTRIBUTION CENTER LOCATION	
			IN-MARKET (MMBF)	OUT-OF-MARKET (MMBF)
New England				
	Boston	31.79	29.09	2.70
	Hartford	9.88	6.33	3.55
	SUB-TOTAL	41.67	35.42	6.25
Mid-Atlantic				
	Albany	13.51	10.93	2.58
	Baltimore/Washington	29.02	25.63	3.39
	Buffalo	10.93	10.16	0.77
	New York	55.47	53.96	1.51
	Philadelphia	26.34	16.26	10.08
	Richmond	12.46	10.34	2.12
	SUB-TOTAL	147.73	127.29	20.44
South East				
	Atlanta	16.10	8.00	8.10
	Birmingham	14.46	11.44	3.02
	Charlotte	9.40	7.91	1.48
	Columbia, S.C.	17.94	13.53	4.42
	Jacksonville	8.90	6.45	2.46
	Knoxville	7.52	4.11	3.41
	Memphis	18.61	16.31	2.31
	Miami	15.21	13.09	2.11
	Nashville	7.96	6.63	1.33
	New Orleans	17.52	12.60	4.93
	Raleigh	14.02	6.49	7.53
	Tampa	21.45	17.66	3.80
	SUB-TOTAL	169.09	124.20	44.89
East Central				
	Charleston/Roanoke	10.49	7.01	3.48
	Cincinnati	18.39	15.96	2.43
	Cleveland	16.94	15.17	1.77
	Detroit	19.60	13.01	6.59
	Grand Rapids	8.68	6.74	1.94
	Indianapolis	12.10	8.81	3.30
	Louisville	8.43	6.34	2.09
	Pittsburgh	14.42	11.82	2.60
	SUB-TOTAL	109.07	84.86	24.21

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Table 10. continued.

REGION	MARKET AREA	TOTAL (MMBF)	DISTRIBUTION CENTER LOCATION	
			IN-MARKET (MMBF)	OUT-OF-MARKET (MMBF)
West Central				
	Billings	3.68	2.85	0.83
	Chicago	29.24	26.69	2.55
	Denver	17.39	16.97	0.42
	Des Moines	8.45	7.23	1.22
	Fargo	4.17	3.39	0.78
	Kansas City	11.06	9.27	1.79
	Milwaukee	16.66	15.44	1.22
	Minneapolis	13.61	12.50	1.11
	Omaha	9.42	5.63	3.79
	St. Louis	19.99	16.80	3.19
	Wichita	4.57	3.46	1.12
	SUB-TOTAL	138.26	120.24	18.03
South West				
	Albuquerque	13.37	10.74	2.63
	Dallas	26.70	24.46	2.24
	Houston	18.36	17.14	1.21
	Oklahoma City	12.57	10.91	1.66
	San Antonio	9.18	5.23	3.95
	Springfield	5.64	4.57	1.08
	SUB-TOTAL	85.83	73.05	12.77
Pacific				
	Alaska	2.08	0.80	1.28
	Hawaii	2.50	0.95	1.55
	Los Angeles	56.71	56.08	0.63
	Phoenix	12.49	12.49	0.00
	Portland	11.26	11.11	0.16
	Sacramento/Fresno	13.69	5.53	8.15
	Salt Lake City	11.18	10.49	0.69
	San Francisco	19.48	16.66	2.81
	Seattle	11.06	10.51	0.56
	Spokane	6.41	3.49	2.92
	SUB-TOTAL	146.85	128.09	18.76
	GRAND TOTAL	838.50	693.15	145.35

area, an estimated total of 31.79 million board foot of wood raw material was consumed in 1986 in grocery pallet production for distribution centers serving that market area. This total is further broken down into 29.09 million board foot of wood raw material consumed for distribution centers within the Boston market area and 2.70 million board foot of wood raw material consumed for distribution centers serving the Boston market area that are located outside the market area. As shown in Table 10, over 693 million board foot of wood raw material are estimated to be consumed in production of grocery pallets for distribution centers located within the market area served by those distribution centers.

WOOD RAW MATERIAL - PALLET REPAIR

The volume of wood raw material consumed annually in the repair of grocery pallets depends on two technical factors and one economic factor. The two technical factors include the quantity of pallets actually repaired and the severity of damage sustained by pallets requiring repair. The economic factor is simply the interaction between the cost of pallet repair and the purchase price of a new grocery pallet. As the cost of repair increases relative to the purchase price of a new pallet, the grocery distribution system can be expected to replace more damaged pallets with new pallets rather than repair. Conversely, as the purchase price of new grocery pallets increases relative to the cost of pallet repair, the grocery distribution system

can be expected to increase the extent of repair for pallets which would earlier have been replaced with new pallets. I note that one of the elements that is considered in both the cost of repair and the price of new pallets is the price of wood raw material used in repair of damaged pallets or in construction of new pallets. Thus, the price of wood raw material is implicitly contained in the interaction between the cost of pallet repair and the purchase price of new pallets.

Given a level of pallet consumption in grocery distribution as noted in Chapter 6, I can estimate the volume of wood raw material consumed based on an analysis of the above technical factors, i.e., the quantity of pallets repaired and the severity of damage that requires repair. As noted in Chapter 5, pallets are repaired on a more or less continuous basis each year in order to maintain the inventory quantity of pallets in the system. While precise figures are not available with regard to the number of pallets repaired each year, estimates can be made on the basis of information provided by distribution center managers and our previous estimates of the inventory quantity of pallets in the system. Information provided by distribution center managers indicates that a typical distribution center either repairs in-house or contracts for outside repair of an average of 100 pallets per day. Although large distribution centers (with over one million square feet of floor space) may repair 300 to 750 pallets daily, an average sized distribution center (with one-half million square feet of floor space) usually reported around 100 pallets repaired daily. Assuming that 100

pallets repaired daily represents an industry average, then approximately 26,000 pallets are repaired each year in an average distribution center. This calculation is based on the fact that a typical pallet repair operation is reported to operate on a 40-hour, 5-day work week, or about 260 days per year. With 409 distribution centers in the system, the total quantity of pallets repaired in distribution centers in 1986 is estimated to equal 10.6 million pallets.

However, pallets used for storage and movement of grocery products through distribution centers are estimated in an earlier chapter to constitute only 62 percent, or 58 million out of the total 94 million pallets estimated in the grocery distribution system pallet inventory in 1986. The above 10.6 million pallets reflects a repair rate in distribution centers of 18.28 percent of inventory quantity. This rate of repair is considered to be the same for grocery manufacturers in maintaining the balance of 36 million pallets in the grocery distribution inventory in 1986. Recalling that these pallets were involved in moving grocery and related products from manufacturers to distribution centers, an additional 6.6 million pallets are therefore estimated to require repair at grocery manufacturers, based on the 18.28 percent repair frequency. Thus, the total quantity of pallets requiring repair in 1986 over the entire grocery distribution system is estimated at 17.2 million pallets.

The volume of wood raw material consumed as a result of grocery pallet repair also varies depending on the severity of damage sustained

by the pallet. Based on information provided by industry sources, an upper limit can be placed on the volume of wood raw material used in the repair of a grocery pallet. As noted earlier, any pallet that requires more than the repair of four deck boards and one full-length stringer is discarded. The volume of wood contained in the four deck boards and one full-length stringer is about one-third of the total board foot volume in a typical grocery pallet, which is considered to have three stringers and 12 deck boards. Therefore, the upper limit on the volume of wood raw material consumed in the production of pallet parts, ie., stringers and deck boards used in the repair of a grocery pallet, is 6.5 board foot per pallet, or one-third of the 19.5 board foot estimated for production of parts used in construction of a new grocery pallet. The total volume of wood raw material required for repair of grocery pallets thus has an upper limit of nearly 112 million board foot of additional wood raw material required in 1986. In combining the wood raw material volume estimated in 1986 for new grocery pallet production with the estimate of wood raw material for pallet repair, the total volume has the potential to be 21 percent of total hardwood consumption for all types of pallets in 1986, or over 950 million board foot of hardwood raw material.

The lower limit on the volume of wood raw material used in the repair of grocery pallets considers repair of one deck board, comprising approximately 1.5 board foot of wood raw material, as the minimum amount of repair incurred. This lower limit equals about 26 million board foot

of wood raw material for repair of grocery pallets in 1986. The average volume of wood raw material consumed in the production of pallet parts for repair of grocery pallets must fall between 6.5 and 1.5 board foot of wood raw material per pallet, but a more precise estimate of this volume is not possible given the available information. For this reason, in distributing the volume of wood raw material required for repair of pallets on a regional basis, I present the volumes required as upper and lower estimates (Table 11).

Table 11. Estimated Wood Raw Material Consumption in Grocery Pallet Repair, 1986.

REGION	UPPER LIMIT	LOWER LIMIT
	(MMBF)	(MMBF)
New England	5.57	1.29
Mid-Atlantic	19.73	4.58
South East	22.57	5.24
East Central	14.57	3.38
West Central	18.47	4.29
South West	11.47	2.66
Pacific	19.62	4.56
TOTAL	112.00	26.00

INDUSTRY TRENDS IN WOOD USE

The grocery distribution industry has shown consistent growth, exceeding 5 percent annually, in the volume of products moved over the past 5 years (Progressive Grocers Information Sales 1987). This growth has been projected to continue over the next decade (Food Marketing Institute 1988). The impact of continued growth in the grocery distribution industry on the wood resource must be considered in relation to several trends in product movement and pallet use observed at distribution centers or identified by distribution center managers. These trends include the continued use of pallets in grocery distribution, continued preference for hardwood species in pallet construction, greater standardization in pallet size and construction characteristics, and potentially greater numbers of captive pallet operations with fewer exchanges of pallets between grocery manufacturers and distribution centers.

Continued Pallet Use

The demand for reusable pallets by the grocery and related products industries is expected to continue to be an important part in the overall demand for new pallets. None of the distribution center managers contacted in this study expect to replace the use of pallets in grocery distribution in the foreseeable future with alternative handling systems. The benefits derived from palletized handling of grocery and related products have been enumerated earlier. Managers expect these

benefits to continue through future use of pallets in handling grocery products. As the volume of grocery products increases each year, continued use of pallets in handling grocery products will increase the demand for grocery pallets.

Continued Preference for Hardwood Species

Even though grocery pallets produced in 1986 only constituted about 11 percent of the total number of new pallets produced, the volume of wood raw material consumed in production of these pallets exceeded 18 percent of the total volume of hardwood raw material attributed to pallet production. Based on information provided by distribution center managers, the preference for hardwood species as the source of raw material in construction of grocery pallets is consistent across all regions. This preference appears to be based on the distribution center managers' perceptions of a superiority of hardwood pallets over softwood pallets with regard to pallet durability, load-carrying capacity, and overall length of expected service. Additionally, grocery pallet users show a reluctance in specifying higher cost, alternate materials for construction of pallets, that is other than hardwood lumber, as long as they can continue to purchase low-cost hardwood lumber pallets in sufficient quantity to satisfy their needs. Thus, the cost of pallets made from hardwood raw material also plays a role in the continued preference for hardwood species in grocery pallet construction.

The effect on the hardwood resource in any particular region resulting from changes in demand for reusable pallets by the grocery and related products industries could be considerably different than the effect resulting from changes in overall pallet demand. Although pallets are produced in nearly every state, pallet manufacturers are concentrated in the East Central and South East regions. And, the pallet manufacturers in the East Central and South East regions are the largest users of hardwood materials. As noted earlier, pallet production tends to be located in areas where food processing or distribution facilities are located. In Table 10, the breakdown of regional demand for wood raw material in grocery pallet construction shows that 72 percent of the wood raw material consumed in grocery pallet production is used by producers in the combined Central and Eastern regions. Because these regions also contain the bulk of the nation's hardwood resources, the impact of increased growth in grocery pallet use on this resource is likely to be less critical than it would be in the Pacific or South West regions where hardwood resources are less plentiful.

Increasing Standardization of Pallets

The trend toward even greater standardization in pallet size and construction characteristics than already exists in the industry is documented in recently released guidelines by the Joint Grocery Industry Committee (Food Marketing Institute 1988). These guidelines are aimed

at reducing grocery product losses from shipping damage which are estimated to be $2.5 billion annually. One of the industry recommendations identified in these guidelines is the universal use of standard 48x40 pallets. This recommendation is based on industry estimates that 2 out of every 3 pallets currently in use do not conform to industry guidelines for the 48x40 pallet and that 20 percent of all product damage can be attributed to sub-standard or damaged pallets.

The Grocery Pallet Council, formed in 1972 to manage pallet pool operations in the food industry, developed a program for certifying that pallets in the pool met specified construction characteristics (Wallin 1984). This program was discontinued in 1974, but the GMA (Grocery Manufacturers of America) specifications for pallet construction which came out of this program have remained as unofficial guidelines for the construction of grocery pallets. The new guidelines by the Joint Grocery Industry Committee appear to be a step forward in the direction of a new industry standard. The problem in implementing any industry standard, as always, is the cost of a pallet which meets the standard as opposed to the cost of a pallet which almost meets the standard.

Any grocery manufacturer or distribution center that purchases standard pallets and exchanges them on a regular basis with other grocery pallet users must constantly be on guard to ensure that pallets conforming to the same standard are exchanged. If a sub-standard pallet can be purchased for a few cents less than the cost of a standard pallet and subsequently is exchanged for a standard pallet, the purchaser of

the sub-standard pallet has obtained a better quality pallet at a lower cost. Over the course of a year, the money saved through purchasing sub-standard pallets can amount to thousands of dollars for a typical distribution center. However, these savings are illusions when the sub-standard pallets are a direct contributor to grocery product damage and loss.

Efforts by industry groups to promote standardization must consider pallet construction characteristics in relation to overall cost. Historically, pallet construction characteristics have changed only in response to changes in the pallet users detailed specifications for their pallets (Wallin 1977). However, the Joint Grocery Industry Committee appears to be promoting more awareness of design procedures which incorporate strength properties of wood and properties of fasteners (Food Marketing Institute 1988). Thus, more efficient pallets with satisfactory performance characteristics can be produced at a cost that will reduce the incentive to purchase a pallet which does not conform to the standard. This means that long-term growth of the grocery pallet industry will not necessarily result in a proportional increase in wood raw material use. The new design procedures and better fastening devices may result in even less wood raw material used per pallet, which would result in a smaller proportional increase in wood raw material use than would be expected on the basis of increased growth in the volume of grocery products moved.

Captive Pallet Operations

Several distribution center managers contend that a major trend in future grocery pallet use is the possibility of more captive pallet operations. In these operations, the user maintains control of the pallet at all times and does not exchange the pallets with other users. This trend has the potential to reduce the rate of growth in the volume of wood raw material used in grocery pallet construction for two reasons: increased longevity of pallet life resulting from closer control of pallets in the system will reduce the frequency of new pallet purchase; and, reduced occurrence of pallets with sub-standard construction specifications will also reduce the frequency of pallet damage requiring repair. The trend will not eliminate the use of grocery pallets in grocery distribution. Thus, increases in the volume of grocery products moved and stored will still result in increases, at a reduced rate, in the volume of wood raw material used in grocery pallet construction.

Because pallet users have more control over the captive pallets in the system, they can expect that replacement or repair of sub-standard pallets will be reduced. One example of a captive pallet operation in a distribution center warehouse illustrates this point dramatically: a frozen food warehouse operated by Giant Food, Inc., in Jessup, Md., uses captive pallets in a completely automated, high-rise storage system. The distribution center purchased 6,300 pallets for use in the system when it was constructed in 1981. Virtually all of the original 6,300

pallets remain in the system today with little visible sign of wear on the pallets.

While the above example is exceptional in the longevity achieved in individual pallet use, the opportunity of extending pallet life and reducing the cost of repair or replacing pallets exists in other areas of grocery distribution as well. The interest in captive pallet operations is also linked with distribution center managers' observation of a trend over the past two years increasing the use of slip sheets in movement of products from manufacturers to distribution centers. At present, the industry average for shipping on slip sheets is less than 30 percent of total grocery products moved from manufacturers to distribution centers. The rate of increase in slip sheet use could not be identified from the response of distribution center managers; but, their responses clearly indicated that a continuation of the trend, if it actually existed, would permit closer control of pallets moving through the distribution center. While the distribution center would continue to handle the product on pallets from the receiving dock through final delivery to retail stores, the opportunity to eliminate the direct exchange of pallets with grocery manufacturers provides an opening for more captive pallet operations between distribution centers and retail stores. Again, only that portion of grocery pallet production currently going to grocery manufacturers would have an effect on the demand for wood raw material in grocery pallet production.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The purpose of this chapter is to summarize the findings of previous chapters and to discuss the implications of these findings. Future research needs in the area of pallet use by the grocery and related products industry are discussed in the concluding section.

SUMMARY

Since 1960, pallet production has quadrupled, increasing the pallet industry's use of hardwood lumber from 14 percent to almost 50 percent of total hardwood lumber production. Part of this growth can be attributed to the grocery and related products industry, which should continue as a potential major growth area for pallet usage over the next decade. Reported growth in retail sales dollar volume of grocery and related products, measured in real dollars, has averaged about 2.5 percent from 1980 to 1986. Projected growth in manufacturer's production in the grocery products industry, measured in real dollar volume of products shipped, is expected to average 2.8 percent per year between 1986 and 1995.

If present pallet use and construction methods are continued, the resulting demand for pallets by the grocery and related products industry could have an uneven effect on the availability and price of the hardwood resource in the various regions of the country. Some

regions of the country have large quantities of currently underutilized hardwood resources. These resources are available to meet the needs ofincreasing demand for pallet raw material. Because raw material costs are a substantial portion of the production cost of pallets, the regions which can provide the lower cost raw material have a decided advantage in future pallet production.

Information is needed for pallet producers to understand the long-term potential and long-term trends in the grocery pallet market. Also, in order to assess the regional impact that grocery pallet production will have on future hardwood resources, better information is needed on the current use of reusable pallets by the grocery and related products industry. The pallets used in the distribution of grocery and related products are believed to be unique in two ways: they are almost exclusively made up of 48x40 size pallets, and are used consistently within the industry to move and store products in preference to other handling devices.

The general objective of this study is to provide information that can be used to understand the long-term potential and long-term trends in the grocery pallet market as they relate to future regional timber demands by the pallet industry. The specific objectives were:

(A) Provide information on current use of grocery pallets in the grocery distribution industry through the identification and quantification of grocery pallet use within the retailing and wholesaling sectors of the grocery and related products industry.

(B) Provide a theoretical framework for future analysis of the regional demand for grocery pallets resulting from the use of grocery pallets in satisfying grocery distribution between regions and between market areas within the same region, and determine the relationship between grocery pallet use and regional grocery pallet demand under specific food flow and pallet durability assumptions.

(C) Provide information on the demand for regional timber resources resulting from grocery pallet production within specified regions.

Objective A was fulfilled by the specification and documentation of market models for the grocery and related products market and the grocery pallet market. These market models consisted of four functional relationships representing aggregate demand and supply in the grocery and related products market, and an additional four functional relationships representing the aggregate demand and supply in the grocery pallet market. In the grocery pallet market model, the demand for new grocery pallets was expressed as an 'excess demand' where the quantity of new grocery pallets demanded equaled the difference between the total quantity of pallets used in the movement or storage of grocery and related products in a given time period and the available inventory of grocery pallets in that time period. The available inventory of grocery pallets in the grocery distribution system was expressed as a function of the dollar volume of retail sales, based on an application of a stock adjustment model for a durable input.

Objective B was fulfilled by the specification of an equation representing the quantity of new grocery pallets consumed in the grocery distribution system in terms of the inventory quantity of grocery pallets in the system. The inventory quantity of pallets in the system was expressed in terms of the dollar volume of retail sales reported in each region. Regional pallet consumption estimates were made subject to the qualification that the regional allocation of pallet consumption by grocery manufacturers was not exact.

Based on the estimates of regional grocery pallet consumption, the volume of wood raw material consumed in production of new grocery pallets and repair of damaged grocery pallets was estimated for specified regions. Because grocery pallet consumption was estimated rather than grocery pallet demand, the price-quantity relationships that could be used to measure the effect of changes in grocery pallet demand on the timber resource were not determined. These price-quantity relationships could be determined in future estimation of the demand and supply model for grocery pallets, provided that additional grocery pallet price and quantity data became available. National trends affecting wood use in grocery distribution were considered. However, specific regional trends affecting wood raw material use were not identified.

In documenting the market models, the spatial aspects of the grocery distribution industry were discussed along with the perceived flow of pallets through the distribution system. Because of the

tendency for food production, distribution, and consumption to be spatially separated activities in the grocery and related products industry, each of these activities required movement of the grocery and related products. This movement was shown to be satisfied, in large part, by the use of pallets. The distinction made between pallet demand and supply points and the movement of pallets between grocery demand and supply points was a key element in the discussion of the spatial aspects of grocery distribution.

Pallet supply points were identified by the location of pallet manufacturers that produced grocery pallets. Although 2,470 pallet manufacturers were reported in the 1985 survey, the number of pallet manufacturers actually producing grocery pallets was not available but was considered to be less the the total number of pallet manufacturers in the industry. The market for grocery pallets was considered to be highly competitive primarily because pallet manufacturers have considerable ease of entry and exit in the market for grocery pallets.

Pallet demand points were identified by the location of grocery manufacturers and distribution centers that use grocery pallets in the movement and storage of grocery and related products. The 409 distribution centers identified in the study were all considered to be pallet demand points, in that they all used pallets at least for the storage and movement of grocery products within the distribution center warehouse. In addition, the location of these distribution centers was specified by region and by market area within a region. On the other

hand, the 22,130 grocery manufacturers were identified only as potential pallet demand points. The percent of grocery manufacturers actually using pallets was an unknown in this study. Also, the location of grocery manufacturers using grocery pallets was not identified as specifically as the location of the distribution centers. This factor created a major obstacle in subsequent identification of regional pallet demand.

The flow or movement of grocery pallets through the distribution system was shown to revolve around and through individual grocery distribution centers. However, this movement of pallets depended on the demand for grocery products at retail stores and at distribution centers as well as on the supply of grocery products from grocery manufacturers to distribution centers and from distribution centers to retail stores. The movement of grocery and related products from grocery supply points to grocery demand points generated the demand for grocery pallets at each point of shipment origin. Had this demand for grocery pallets been satisfied by supply of grocery pallets from pallet manufacturers each time the demand occurred, the market models would have been simplified. However, grocery pallets were shown to be a durable input to the production and distribution of grocery products. That is, an inventory quantity of pallets was shown to exist in the grocery distribution system. While an aggregate level of demand for grocery pallets resulted from the movement and storage of grocery products, the demand for new grocery pallets supplied by pallet manufacturers was shown to be a

function of the quantity of pallets available in the system and the overall level of aggregate pallet demand. The circular nature of pallet flows in the system was indicated simply because grocery pallets were recycled through the system as long as they remained in serviceable condition.

Pallet repair operations were included in the description of pallet flows in grocery distribution. However, pallet repair, whether handled in-house or contracted out, was considered as a maintenance operation and as such, entered into grocery manufacturers' and distribution centers' production functions as a fixed cost.

Neither the quantity of new grocery pallets nor the total inventory quantity of pallets in the grocery distribution system could be identified from published data. Therefore, estimation of the quantity of new pallets and the inventory quantity of pallets in the system was made based on assumptions about the relation of retail sales to quantity of pallets in inventory. The accuracy of these assumptions was dependent on the accuracy of the responses received in interviews with distribution center managers. In a number of these interviews, the responses were considered to be "best guess" estimates of existing industry conditions on the part of distribution center managers. For this reason, considerable variation was expected between the estimated quantity and actual quantity of pallets, either in inventory or as new pallets entering the system. The only reference points for validating the estimate of 43 million new grocery pallets purchased in 1986 were

three surveys conducted in 1979, 1982, and 1984. The estimate of new grocery pallets purchased in 1986 did fall within the range expected from the information provided in the three surveys.

The 1986 estimate of new grocery pallets purchased nationally was broken down into regional estimates of new pallet consumption. In making these regional estimates, it was noted that only 62 percent of the new pallet consumption could be expected to occur at distribution centers while the remaining 38 percent was more likely to be attributed to grocery and related products manufacturers. Since the grocery manufacturing facilities could not be shown to be located in the same regions as the distribution centers they served, the regional estimates of new pallet consumption were considered primarily to reflect the consumption or purchase of new pallets by distribution centers.

The volume of wood raw material used in 1986 for production of grocery pallets was estimated to exceed 838 million board foot of hardwood raw material, or potentially over 18 percent of the 4.5 billion board foot of hardwood raw material consumed in the production of all types of pallets. Regional allocation of this volume of hardwood raw material was also considered to reflect primarily the consumption of hardwood raw material for production of pallets by distribution centers.

The volume of wood raw material used in the repair of grocery pallets in 1986 was expressed in terms of an upper and lower limit to the volume of wood raw material used in repair operations. At least 26 million board foot and no more than 112 million board foot of wood raw

material was considered to be required for the repair of grocery pallets in 1986. If the volume of hardwood raw material actually used in repair of grocery pallets approached the upper limit of 112 board foot, the estimated total volume of hardwood raw material consumed in the production of pallet parts in 1986, estimated to exceed 950 million board foot, was shown to potentially exceed 20 percent of the total hardwood consumption for all types of pallets.

General industry trends in wood use were considered to include continued use of hardwood pallets in grocery distribution, marked preference for hardwood species over softwood species in pallet construction, more emphasis on standardization in terms of pallet quality and physical characteristics, and a potential for more captive pallet operations in the future.

CONCLUSIONS

The general objective of this study was to provide information about the economic structure of the grocery distribution industry. In accomplishing this objective, I have provided a framework, based on economic theory, that can be built on as additional data become available for empirical estimation of the functional relationships comprising the market models. Potential or future changes in the grocery pallet industry cannot be estimated empirically given the present availability of economic data. In order to estimate the econometric models specified in Chapter 5, grocery pallet price and

quantity data must be collected either for specified regions or individual market areas as outlined in Chapter 6.

A stock adjustment model was used to develop a functional relationship between grocery pallet inventory levels and the volume of retail sales. Application of the stock adjustment model in this study of a demand for a durable input was not unique. Other demands for durable inputs have been examined using this tool. However, in dealing with the problem of pallets remaining in the system from one time period to another, the stock adjustment model provided a logical and consistent technique for bridging the gap between the quantity of pallets considered in the grocery manufacturers and distribution centers production functions and the demand function for new purchases of pallets.

The consumption of grocery pallets by the grocery distribution industry was shown to be an important part in the overall new pallet production even though the pallet used, 48x40 inches, only constituted about 11 percent of the total number of new pallets produced in 1986. A disproportional effect on the hardwood resource was shown for grocery pallets in relation to the quantity of grocery pallets consumed. With over 20 percent of the total hardwood consumption for all types of pallets being attributed to the manufacture of grocery pallet parts, the effect on the hardwood resource in any particular region resulting from changes in the grocery pallet consumption can potentially be greater than the effect resulting from changes in consumption of other pallet

types, particularly those using softwood raw material in pallet production. However, until more precise estimates of the regional production levels for pallets of all types become available, such a comparision cannot be quantified.

Grocery pallet production was shown to be located in areas where food manufacturing and distribution facilities are located. Because 72 percent of the wood raw material required by the grocery pallet industry in 1986 was estimated to be consumed in the Central and Eastern regions, the regional estimates of hardwood raw material consumed in grocery pallet construction appear to reflect reported actual consumption. Census data for 1982 indicated that the pallet industries in the Central and Eastern regions were in fact the largest users of hardwood materials.

Grocery pallet users will be reluctant to specify higher cost, alternate materials for construction of grocery pallets as long as they can continue to purchase low-cost pallets made from hardwood lumber in sufficient quantity to satisfy their needs. Continued use of hardwood pallets can be expected in grocery distribution for some time.

However, long-term growth in the demand for grocery pallets will not necessarily result in a proportional increase in wood raw material use. As pallet manufacturers begin to make more use of design procedures incorporating strength properties of wood and properties of fasteners, more efficient pallets with satisfactory performance characteristics will be produced. These new design procedures and

better fastening devices will in all probability result in even less wood raw material used per pallet. Thus, increases in the volume of wood raw material used in grocery pallet production will still depend on continued increases in the volume of grocery and related products moved and stored on pallets, but the rate of increase for wood raw material consumption may be less than the rate of increase in the volume of products moved.

The recent renewal of industry interest in increased standardization should result in a better quality pallet in use in the future. As the quality of pallets improves, increased service life and reduced rates of repair should be expected. Both of these factors would have the effect of further reducing the rate of growth in the demand on the timber resource by grocery pallets in the future.

FUTURE RESEARCH

Limited data availability for estimation of the models presented suggests that one area for future research includes the development of additional sources of data relating to regional production of pallets, specified in terms of price, quantity, and dimensions as well as expected end use. Other data items needed to estimate the stock adjustment model include dollar volume of grocery and related products retail sales either for specific regions or for individual market areas over an extended time period rather than just one year as presented in this study. Institutions such as Progressive Grocers Information Sales,

Inc., or the Food Marketing Institute are the most likely candidates for future collection of data regarding dollar volume of grocery and related products retail sales. The collection of the above data could be a part of a broader data collection effort on the part of a continuing U.S. Forest Service research effort aimed at identifying both the present and future regional use of the hardwood resource.

Having acquired the necessary price and quantity information relating to grocery pallets, the second priority for any future research should be the actual estimation of the demand and supply models presented in this study. Until these or similar models are estimated, I cannot quantify the effect of changes in grocery pallet demand on the timber resource in the different regions of the country. Specific benefits of having these data and being able to estimate the conceptual models formulated earlier are dependent on how critical the information provided by estimation of the models is to development of long-term forest policy and to understanding the long-term potential in the grocery pallet segment of the overall pallet industry. The impact of such information remains to be determined in future research.

Measuring the effect of changes in grocery pallet demand on the timber resource was an objective in this study that could not be reached, given the absence of estimated grocery pallet demand and supply relationships. Therefore, the next priority for any future research after the estimation of grocery pallet demand and supply relationships should be the application of these relationships in a more detailed

analysis of the wood raw material demand derived from the production of grocery pallets.

Another opportunity for future research lies in developing more complete information on the extent and location of grocery pallet use in the manufacturing segment of the grocery and related products industry. Although this was considered to be outside the scope of the present study, on further reflection it would have made a considerable difference in the accuracy of the regional estimates of grocery pallet consumption.

Finally, the importance of the relationship between price of new pallets and the price of repaired pallets has been discussed in theoretical terms in this study. However, a more exact estimation of the effect of changes in the price of new grocery pallets on the quantity of grocery pallets repaired remains to be determined by future research.

I will conclude the discussion of future research by reiterating the statement that the impact of continuing research in this area on long-term forest policy and better understanding of the long-term potential in the grocery pallet market cannot be known until more information is made available. For this reason, I believe that additional research in this area is required until such time when a definite statement regarding the impact of developing that information can be made.

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APPENDIX A

The following are commonly accepted definitions of terms used in the grocery industry:

SUPERMARKET: A complete, departmentalized grocery store with minimum annual sales of $2,000,000.

CHAIN: A company which operates eleven or more stores in total. A chain store unit is a store operated by such a company.

INDEPENDENT: A firm which operates from one to ten stores.

UNAFFILIATED INDEPENDENT: Operator from one to ten stores having no affiliations with any organization and buying entirely from wholesalers or suppliers on an independent basis.

COOPERATIVE: Independent grocers who jointly own and operate their own wholesale organization.

VOLUNTARY: A group of independent grocery stores jointly sponsored by an independent wholesaler.

CONVENIENCE STORE: A small store handling a limited variety of items in general use in most households and patronized for fill-in home requirements.

APPENDIX B

DERIVATION OF THE INVENTORY STOCK ADJUSTMENT MODEL

Net change in quantity of pallets in the system, after adjusting for the effect of pallets that have been discarded, constitutes the quantity of new pallets demanded in the grocery distribution system in a given time period. This quantity, noted earlier in Chapter 5 as $Q_{NP,t}$, is expressed as a function of changes in the dollar volume of retail sales for grocery and related products:

(1) $Q_{NP,t} = f \{ X_t - (1 - w^*)X_{t-1} \}$

or, in terms of the quantity of pallets in the system:

(2) $Q_{NP,t} = Q_t - (1 - w^*)Q_{t-1}$

By rearranging the terms in this equation, we can express the inventory quantity of pallets in the system in the current time period, Q_t, in terms of the demand for new pallets, Q_{NP}, and some portion of the inventory quantity of pallets in the preceeding time period, or

$$Q_t = Q_{NP} + (1 - w^*)Q_{t-1}$$

This relationship is assumed to hold for preceeding time periods so that we can express the quantity of pallets in the system in the previous time period, Q_{t-1}, in terms of the demand for new pallets in that time period, $Q_{NP,t-1}$, and some portion of the quantity of pallets in the system in the preceeding time period, or

$$Q_{t-1} = Q_{NP,t-1} + (1 - w^*)Q_{t-2}$$

Substituting this expression for Q_{t-1} in the above equation for Q_t yields:

$$Q_t = Q_{NP} + (1 - w^*)Q_{NP,t-1} + (1 - w^*)^2 Q_{t-2}$$

Expanding this expression to the t-nth time period yields:

$$Q_t = Q_{NP} + (1 - w^*)Q_{NP,t-1} + (1 - w^*)^2 Q_{NP,t-2} + \cdots + (1 - w^*)^n Q_{t-n}$$

Since w^* is expressed as a positive percentage, the value of $(1-w^*)$ must be less than one. Thus, at the limit, in expansion of the above equation to include successively earlier levels of demand, the value of the last term, $(1 - w^*)^n Q_{t-n}$, reduces to zero. This occurs because as the value of n approaches infinity, the fraction, $(1 - w^*)$, raised to the nth power approaches zero. Thus, the inventory quantity of pallets in the system can be expressed as the sum of the demand for new pallets in the current time period and a decreasing portion of the demand for new pallets in all previous time periods.

APPENDIX C

TYPICAL GROCERY PALLET SPECIFICATIONS

I. Size and Type of Pallet

Pallet shall be 48" x 40"; flush, non-reversible, four-way modified.

II. Type and Quality of Lumber

Lumber shall be sound, square edge, free of mold, decay, and noxious odors. The following hardwood species may be used for stringers: Beech, Birch, Eucalyptus, Hackberry, Hard Maple, Hickory, Oak (except Swamp Oak), Pecan, Rock Elm, White Ash. In addition to the above list, the following hardwood species shall be used for deckboards: Ash, Butternut, Magnolia, Red Alder, Soft Elm, Soft Maple, Sweet Gum, Sycamore, Tupelo, Walnut, Yellow Poplar.

Any degree of seasoning is acceptable.

The diameter of sound knots shall be no greater than one-third the width of the piece in which they occur; there shall be no more than two such maximum diameter knots in any one piece. Loose or hollow knots shall not exceed one-half the diameter of sound knots.

No knots over 1/2" shall be allowed in the stringer immediately over the notched areas.

Length of crack or grain separation must be no longer than two-thirds the width of the piece in end deckboards and no longer than

twice the width of the piece in stringers and inside boards. Splits running through full thickness of the piece (not to be confused with nail splits) are permitted in any number, but when appearing in endboards must be straddled by nails. Shakes are permitted in any piece if contained by nailing.

Wane within limits is permitted on any piece provided it is not on exposed edge of end deckboards. Wane may appear on surface or edge of other pieces but in no cases are nails to be driven into or through wane. No more than one-half of the pieces in an individual pallet may contain wane.

No individual piece on any one pallet shall have deviation due to warp which is greater than the following percent of its measured dimension: bow - 2%; crook - 2%; cup - 3%.

Pin-worm and grub worm holes in pallet parts are permissible defects, providing that they do not affect the structural strength of the pallet. Infestation of wood-destroying insects is not permitted in pallet parts.

No combination of defects which will materially weaken any piece or pallet shall be allowed.

III. Lumber Preparation

Stringers and deckboards shall be smooth sawn or surfaced to square edge, uniform dimensions.

No bearded ends are permitted; all ends and edges shall be clean and square.

Preservatives not permitted.

IV. Type and Quality of Fastener

Hardened steel screw nail (or tempered) , 2-1/4" x 0.110", to bend not more than 28 degrees on the MIBANT Nail Tester or equal. Wire diameter 0.110", threaded O.D. body diameter 0.138", flat head nail diameter 9/32", or snag free head average diameter 21/64". Point shall be diamond (not longer than 5/32") or chisel provided that the width does not exceed wire diameter. Helically threaded with four flutes; helical angle of thread at the pitch diameter shall be 60 degrees plus or minus 5 degrees with a plane perpendicular to the axis.

V. Dimensions, Spacing, and Arrangement

Deckboard dimensions shall be thickness: 13/16" to 15/16" range; length: 39-7/8" to 40-1/8" range.

Extreme top end deckboards will be 5-5/8" minimum width. All intermediate top deckboards may be random widths, and will be minimum 3-5/8". Maximum 3" spacing will be maintained. Deckboards must provide a minimum actual cumulative surface of 30".

Bottom end deckboards shall be 5-5/8" to 6" range in width. Two outside boards in the center cluster shall be minimum 3-5/8". The center board shall be minimum 5-5/8". Spacing of center cluster of

bottom deckboards shall not exceed 2-1/2" and the outer edges of the cluster shall be flush with the inside of the notches. Bottom deckboards shall not protrude over any notch opening; ends of all deckboards shall be flush with outside of stringers. The center cluster of deckboards shall provide a minimum actual cumulative surface of 13".

Chamfer inner and outer edges of bottom deck edge boards and wheel space edges of center cluster boards to within 1/2" of bottom face. All chamfers to be cut at 45 degrees angle and to extend within 2" but not closer than 1" of stringers at each end of chamfer.

Stringer dimensions shall be width: 1-3/4", plus 1/4", minus 0; length: 48", plus or minus 1/8"; height: 3-3/4", plus 1/4", minus 0.

Notch openings shall be 9" wide, plus 1/4", minus 0. Notch openings shall be no closer than 6" from the ends of the stringers, plus 1/4", minus 0. Stringer notches shall have a depth of 1-1/2" and shall have round corners with a radius of 3/4"; the top of the notch shall be flat cut between the corner radii.

Center stringers shall be parallel to and equidistant between outside stringers.

VI. Assembly

Predrilling of deckboards shall be required when nails are hand driven. When pallets are assembled by nailing machines, predrilling of deckboards is not required.

The number of nails which shall be employed at all bearing points for the various widths of deckboards is as follows: 3-5/8" to 5-1/2" width - 2 nails; 5-5/8" to 7-1/2" width - 3 nails; 7-1/2" to 8" width - 4 nails.

Nails shall be staggered. Flat head nails shall be counter sunk at least 1/16" deep. Oval concave "snag free" head nails shall be driven flush with the deckboards.

VII. Workmanship

Protruding nail heads or points are not permitted. Bent over nails must be driven below surface of deckboards.

Deviation in dimension of assembled pallets shall be limited to 3/8" out-of-square (3/4" difference in diagonals), plus or minus 3/16" in overall pallet length or width.

No combination of defects in workmanship, including nail splits, which will adversely affect the strength of the pallet to a material extent will be permitted.

Source: Eichler, J. R. 1976. Wood Pallet Manufacturing Practices. Eichler Associates: Cape Coral, Fla.

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REGIONAL UTILIZATION OF REUSABLE PALLETS BY THE GROCERY AND RELATED PRODUCTS INDUSTRY

by

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(ABSTRACT)

Since 1960, pallet production has quadrupled, increasing the pallet industry's use of hardwood lumber from 14 percent to almost 50 percent of total hardwood lumber production. Part of this growth can be attributed to the grocery and related products industry, which should continue as a major growth area for pallet usage over the next decade.

The general objective of this study is to provide information that can be used to understand the long-term potential and long-term trends in the grocery pallet market which relate to future regional timber demands by the pallet industry. Specific objectives are: (A) Provide information on current use of grocery pallets in the grocery distribution industry; (B) Provide theoretical framework for future analysis of the regional demand for grocery pallets; and (C) Provide information on demand for regional timber resources resulting from grocery pallet production within specified regions.

Models are presented representing demand and supply in the grocery and related products and grocery pallet markets. In the grocery pallet model, demand for new grocery pallets is expressed

as an 'excess demand' where demand for new grocery pallets equals the difference between aggregate supply of pallets to grocery distribution and available inventory of grocery pallets in the system. Inventory of grocery pallets in grocery distribution is expressed as a function of dollar volume of retail sales, based on application of a stock adjustment model for durable inputs.

Consumption of grocery pallets by the grocery distribution industry is shown to be an important part in overall new pallet production even though the pallet used, 48"x40", only constitutes about 11 percent of total new pallet production in 1986. Estimates of national consumption of new grocery pallets in 1986 are broken down into regional estimates of new pallet consumption.

Volume of wood raw material used in 1986 for production of grocery pallets is estimated to exceed 838 million board foot of wood raw material, or potentially 18 percent of total hardwood raw material consumed in production of all types of pallets. National trends effecting wood use in grocery distribution are considered. Specific regional trends effecting wood raw material use are not identified.