

Postharvest Handling: Transportation Aspects

Report of a 1986-87 Study Group on:
Marketing California Specialty Crops:
Worldwide Competition
and Constraints

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Agricultural Issues Center



MARKETING CALIFORNIA SPECIALTY CROPS: WORLDWIDE COMPETITION AND CONSTRAINTS

Postharvest Handling: Transportation Aspects

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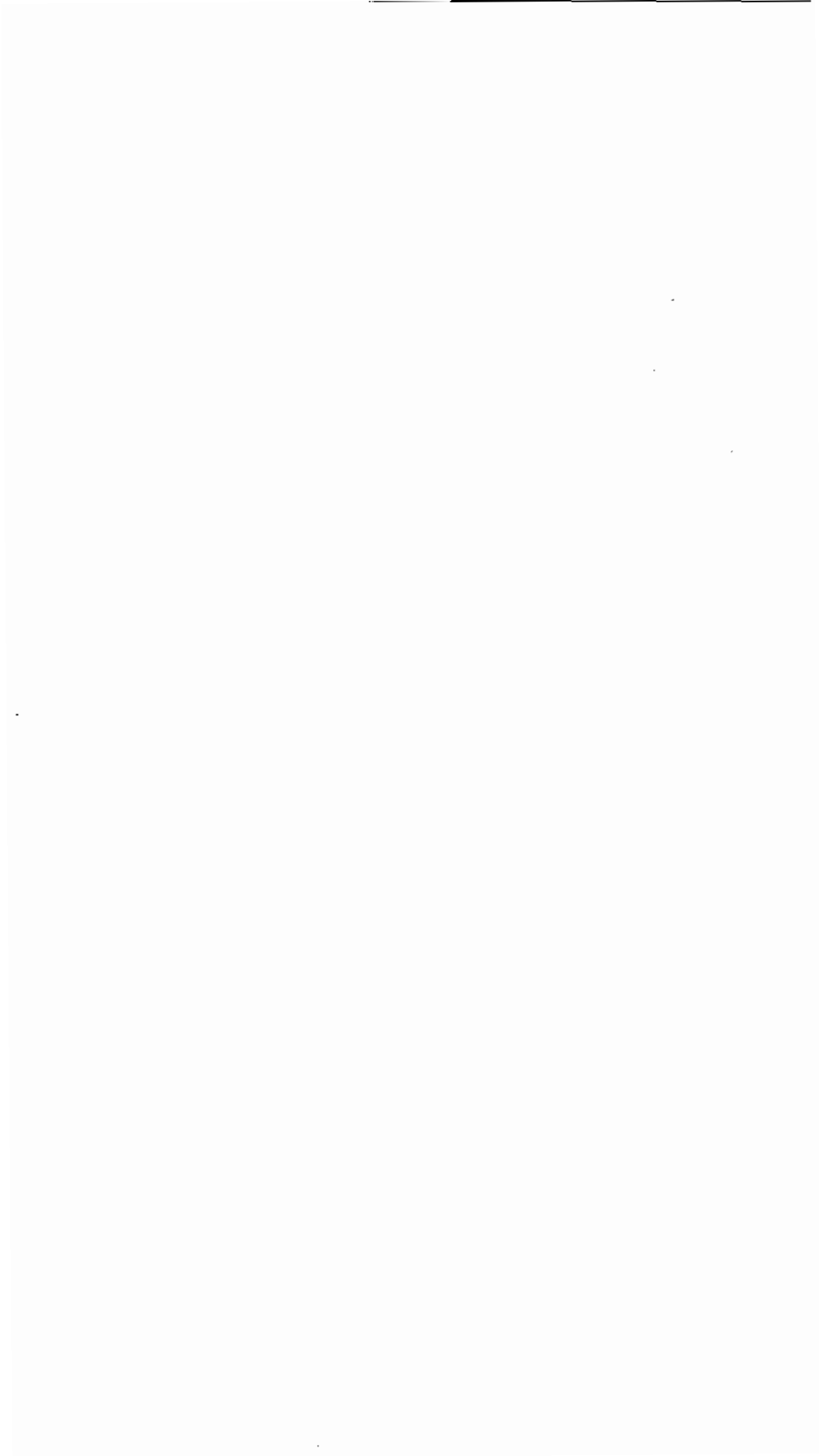
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Preface

Harold O. Carter and Carole Frank Nuckton

This is the second in a series of reports stemming from the U.C. Agricultural Issues Center's major study in 1986-87:

Marketing California Specialty Crops: Worldwide Competition and Constraints.

The study explored ways to expand markets for the state's specialty crops, examined constraints in the way of expanding these markets, and looked at the competition faced in these markets at home and abroad. (By "specialty crops" is meant the state's fruit, vegetable, and tree nut crops.) Constraints to expanding trade for particular specialty crops in interstate and international markets include institutional tariff and nontariff barriers to trade; quality and safety restrictions; certain product characteristics, such as shelf life of perishables; availability of transportation to move products to potential purchasers; and certain other conditions for postharvest handling within the nation and abroad.

The approach was multidisciplinary, involving university research and extension staff in several departments on the Davis and Berkeley campuses and drawing as well from experts in industry and government. Six study groups worked independently during the academic year, each receiving grants for research assistance and operating expenses. They selected industry and government experts and other academic personnel for consultation and review of their documents. The groups' efforts were integrated by the Center so that the product of the study was unified.

The six study groups were:

- People, Income, and Lifestyles: Demand Factors
- Competitiveness at Home and Abroad
- Innovation: New Products, New Markets
- Policies and Institutions: Impacts on Trade
- The Delivery System: Technology and Coordination

•Food Quality and Safety: Impacts on Marketability

The studies led up to a major symposium held June 1-2 at the Sacramento Hilton. Each study group presented key findings in a paper delivered by the study group leader. Reacting and adding to the study group papers presented at the symposium were experts chosen from industry, government, and academia. Questions and comments from the audience followed each panel discussion. Proceedings of the symposium, available from the Center, include the study group presentations. However, each study group also produced a longer, more complete report. The one on the delivery system is published here. A few key findings of this study include:

- There are many constraints to moving products and maintaining their quality until they reach the ultimate consumers.
- Latent demand for California's specialty crops may be frustrated by potential importing countries' lack of infrastructure in handling and distributing the products. Consider, for example, how the lack of home refrigeration discourages specialty crop purchases.
- Because of changed export-import patterns in the United States, i.e., the shift from European- to Pacific Rim-dominated trade patterns, California produce no longer enjoys backhaul rates for eastbound shipments.
- At the height of the summer and fall shipping seasons there is a shortage of well-equipped trucks and containers, especially refrigerated transport for fresh produce within the United States.
- Standardization in packing containers means less than ideal packing for some new

(especially, larger) varieties of produce.

- Product quality for the ultimate consumer requires an incentive system with no weak links in any part of the delivery system.

There are a number of issues related to marketing California's agricultural bounty that remain for the research and extension staff of the university to address. An important start

has been made, particularly in identifying the issues. The Center's format for its major study during the 1986-87 year facilitated considerable progress in understanding this topic so crucial to the state's agricultural sector. With this and subsequent reports in the series, the Center shares its findings with the agricultural industry, policy makers, university research and extension workers, and the general public.

Acknowledgements

Harold O. Carter, Director, UC Agricultural Issues Center

Many persons participated in the six study groups on marketing California specialty crops. Biographical sketches for those participating in the group studying the delivery system—Postharvest Handling: Transportation Aspects—are found at the end of this report. Carole Nuckton coordinated the study groups during the year and served as technical editor of this report. John Woolcott produced the camera-ready copy for this report.

Industry personnel and others served as study group consultants and as study group paper reviewers. The names of those helping the study group on the delivery system are listed below.

Kurt Austin, California Trucking Association
Dave Cayton, Cayton Associates, Salinas
Hal Davis, Tenneco West
George Elliot, Driscoll Strawberry Associates, Inc.
Richard Johanson, Johanson Transportation Service
John Lange, The Atchinson, Topeka and Santa Fe Railway Company
Barney Radovich, Driscoll Strawberry Associates, Inc.
Maitland Pennington, California Department of Food and Agriculture, Export Promotion Program
Patrick J. Smith, TRI Transport, Inc.

Postharvest Handling: Transportation Aspects

INTRODUCTION

California's climate is naturally suited to the production of a wide variety of crops for many months of the year with consistently high quality; however, the production areas are remote from major markets. The need to reach these markets drives the development of handling and transportation technologies. It is not immediately apparent whether handling and/or transportation currently constrain expansion of sales in distant markets, but there is a real danger if California agriculture continues to rely on the pull of demand in existing and potential markets to drive the development or adoption of the technology needed to serve those markets. For that same demand may be more than sufficient to attract competitive producers in other production areas.

Expansion of markets for California specialty crops can come about by increasing California's share of an existing market, maintaining a constant percentage share of an

increasing market, or opening a new market. From the standpoint of postharvest handling and transportation, the ability to expand markets for the state's specialty crops depends on a number of factors. First, the system must have the ability to maintain product quality. Second, the cost to deliver products to the market must not result in a product price that is no longer competitive. Third, there must be compatibility of equipment among products, packages, transport modes, and storage and handling facilities. Lack of any of these or other related characteristics constrains market expansion. It is important that specific constraints to expansion be identified and classified as due to limitations in capacity, technology, incentive, or policy. Improved technology will likely be adopted only if market demand can justify the cost of implementation to those who would make the investment.

THE HANDLING AND TRANSPORTATION PROBLEM

AGRICULTURAL INPUTS

Besides handling and transportation of agricultural products, there is the timely and economic supply of inputs to consider. These production inputs include fuel, fertilizer, chemicals, seeds, transplants, and packaging materials. With the exception of transplants,¹ most can be transported ahead of time and stockpiled, and the timing of need is predictable. Because there is a storage cost for

stockpiled inputs and sometimes constraints on space and equipment, a prudent manager trades off the inventory cost for having materials immediately available against the cost of not having the materials when they are needed. For agriculture, failure to carry out an operation at the proper time can reduce yield, quality, and the price received. However, transportation and handling of inputs do not appear to limit expansion of production or of markets for California's specialty crops.

1. Transplants are usually produced close to the location of use. Close coordination is necessary to ensure that seedlings are delivered to the field at the proper time. Special equipment is sometimes utilized to handle and transport seedlings with minimum disturbance. The cost of such equipment and the bulky nature of the product, tend to make the process relatively costly. These and other costs may affect a producer's choice of direct seeding versus transplant. The use of transplants, for appropriate crops, can allow production to begin at an earlier time or to be carried out in a shorter period of time in the field.

AGRICULTURAL PRODUCTS

There is a large number of California specialty crops; for each there are seasonal and varietal differences. Each crop has unique physical and biological properties which limit how it can be handled and transported. We gave special consideration to broccoli, cauliflower, grapes, lettuce, peaches, strawberries, and tomatos because more information is available for these crops than for others. Other commodities were considered in special circumstances. Many of the constraints to market expansion will also apply to other crops. Postharvest handling and transportation constraints are likely to have greater effects on minor crops; these constraints may be the very reason why they remain minor crops.

Many crops are produced in several areas of the state and at different times of the year, a fact that creates complex patterns of demand for transportation. Figure 1 shows the production areas for major fruit and nut crops in California; Figure 2, for vegetable crops. For each crop, various production areas tend to have different harvest dates which, when aggregated, provide a supply over a longer period of time than could any single area. Table 1 shows the time distribution for production of lettuce in various areas. Production areas, to some extent, compete with each other; but they are also complementary. Many producers operate in more than one area in order to supply their markets over a long period of time; others have established cooperative marketing arrangements with producers in other areas. Some handling equipment is moved and used in several production areas. But in some areas handling practices differ, due in part to differing climatic conditions, precluding equipment transfer.

Weather conditions can alter quickly the time a local harvest begins or ends and the *time of transition* of supply from one production area to another. When this

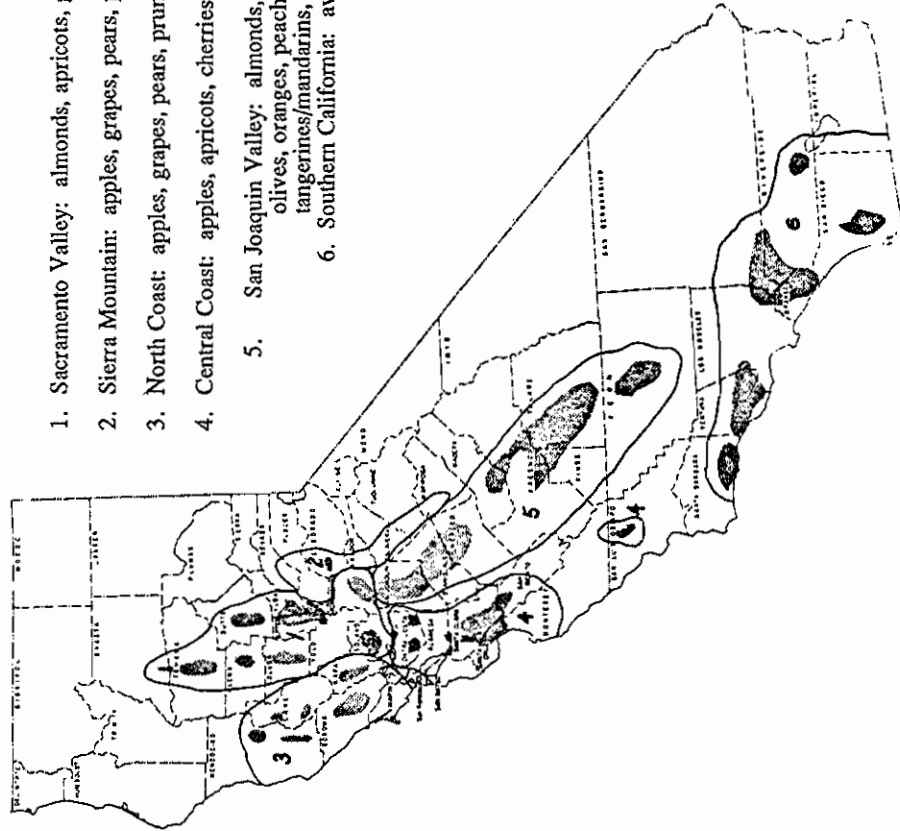
happens, transportation equipment allocated to a crop may not be in the right place at the right time.

Yield and quality are always uncertain, because of weather and other factors, although California's climate is more predictable than many competing areas. Market demand depends not only on the amount and quality of production, but also on factors such as seasonal weather conditions in the market region and in areas which produce competitive products. Demand for salad vegetables, for instance, increases in hot weather. These uncertainties complicate the problem of having an adequate, but not excessive, supply of transportation equipment.

Some specialty crops are marketed in both *fresh and processed forms*. While some, tomatos for example, have different cultivars for fresh and processed markets, most crops, such as broccoli, use the same varieties for both. Processed forms have unique handling and transportation problems, especially from time of harvest until after primary processing. But because distances and time periods are generally short, these problems are usually less critical than are those associated with the fresh market. When fresh market cultivars are diverted to processing, growers usually receive much less for the product, so they may suffer dearly if lack of transportation capacity forces diversion of their product to processing. Furthermore, processors may not be able to accommodate unplanned diversions.

Sometimes the *quantity* of a single commodity shipment destined for a particular customer is so *small* that a combined load of two or more types of products is formed. And for small quantities of product which pose special handling and transportation problems, compromises in the transportation environment may prevent its delivery in prime condition. That is, the lack of a market large enough to warrant the special handling the product requires, may well inhibit development of that market.

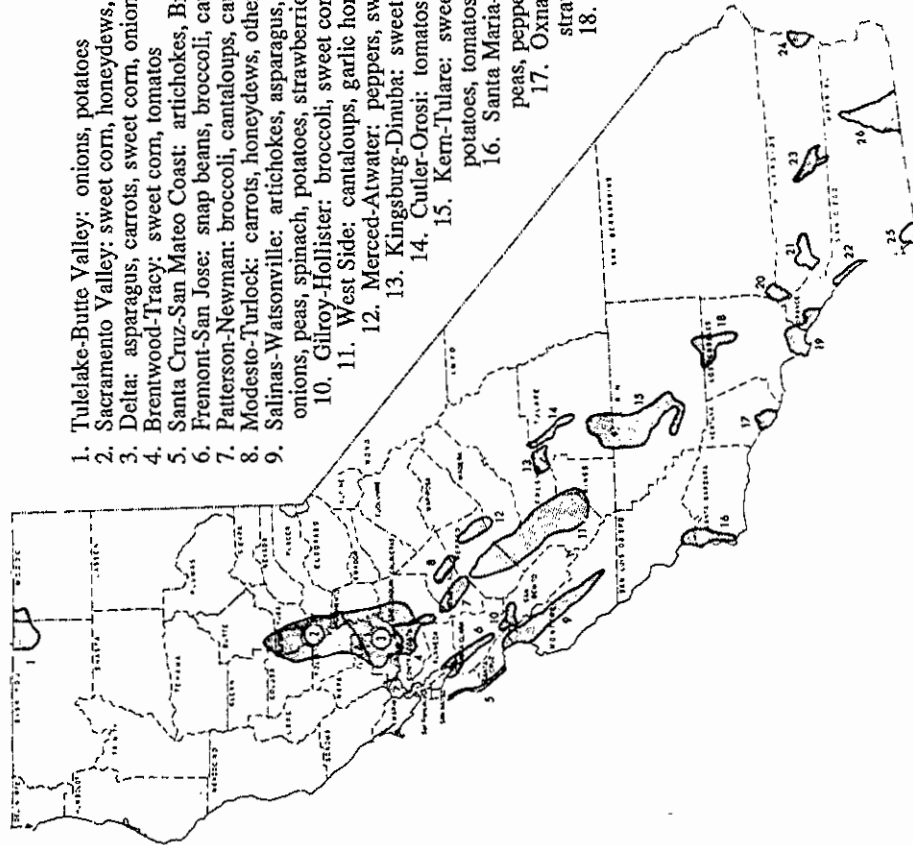
Figure 1. Major Producing Districts - California Fruit and Nut Crops



1. Sacramento Valley: almonds, apricots, grapes, kiwifruit, olives, peaches, pears, pistachios, prunes, walnuts
2. Sierra Mountain: apples, grapes, pears, plums
3. North Coast: apples, grapes, pears, prunes, walnuts
4. Central Coast: apples, apricots, cherries, grapes, pears, prunes, walnuts
5. San Joaquin Valley: almonds, apricots, avocados, cherries, figs, grapes, kiwifruit, lemons, nectarines, olives, oranges, peaches, persimmons, pistachios, plums, pomegranates, prunes, tangerines/mandarins, walnuts
6. Southern California: avocados, dates, grapes, grapefruit, jojoba, lemons, oranges, walnuts

Source: California Fruit and Nut Acreage, 1985. California Crop and Livestock Reporting Service.

Figure 2. Major Producing Areas - California Vegetable Crops



1. Tulelake-Butte Valley: onions, potatoes
2. Sacramento Valley: sweet corn, honeydews, persians, other melons, tomatos, watermelons
3. Delta: asparagus, carrots, sweet corn, onions, peppers, potatoes, tomatos
4. Brentwood-Tracy: sweet corn, tomatos
5. Santa Cruz-San Mateo Coast: artichokes, Brussels sprouts, broccoli, cauliflower, peas
6. Fremont-San Jose: snap beans, broccoli, cauliflower, sweet corn, garlic, lettuce, onions, peas, peppers, strawberries, tomatos
7. Patterson-Newman: broccoli, cantaloups, cauliflower, honeydews, persians, other melons, sweet corn, lettuce, tomatos, peppers
8. Modesto-Turlock: carrots, honeydews, other melons, strawberries, sweet potatoes, tomatos, watermelons
9. Salinas-Watsonville: artichokes, asparagus, snap beans, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, celery, garlic, lettuce, onions, peas, spinach, potatoes, strawberries, tomatos
10. Gilroy-Hollister: broccoli, sweet corn, garlic, lettuce, onions, potatoes, peppers, peas, tomatos
11. West Side: cantaloups, garlic honeydews, lettuce, persians, other melons, onions, tomatos
12. Merced-Atwater: peppers, sweet potatoes, tomatos, tomatos, watermelons
13. Kingsburg-Dinuba: sweet potatoes, watermelons
14. Cutler-Orosi: tomatos, other spring vegetables
15. Kern-Tulare: sweet corn, cantaloups, carrots, garlic, honeydews, lettuce, onions, peas, potatoes, sweet potatoes, tomatos, watermelons
16. Santa Maria-Oceano: artichokes, snap beans, broccoli, cabbage, carrots, cauliflower, celery, lettuce, peas, peppers, potatoes, strawberries
17. Oxnard: broccoli, cabbage, carrots, cauliflower, celery, cucumbers, lettuce, peppers, spinach, strawberries, tomatos
18. Antelope Valley: cantaloups, onions
19. Los Angeles-Orange County: asparagus, snap beans, cabbage, carrots, cauliflower, celery, sweet corn, lettuce, peppers, strawberries, tomatos
20. Chino-Ontario: sweet corn, onions, sweet potatoes
21. Perris-Hemet: cantaloups, other melons, carrots, onions, potatoes, watermelons
22. Oceanside-San Luis Rey: snap beans, cabbage, lettuce, peppers, strawberries, sweet potatoes, tomatos
23. Coachella Valley: asparagus, snap beans, broccoli, carrots, cauliflower, celery, sweet corn, cantaloups, onions, peppers, tomatos, watermelons
24. Blythe: sweet corn, cantaloups, honeydews, lettuce, other melons, onions
25. Chula Vista: snap beans, cabbage, celery, sweet corn, cucumbers, lettuce, strawberries, peppers, tomatos
26. Imperial Valley: asparagus, broccoli, cabbage, cantaloups, carrots, cauliflower, celery, cucumbers, garlic, lettuce, onions, tomatos, watermelons

Source: California Vegetable Crops Acreage, Production and Value. 1984-85. California Crop and Livestock Reporting Service.

Table 1. Shipments of California Lettuce^a, 1985

DISTRICT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Salinas-Watsonville												
Rail	--	--	--	--	18	89	51	31	27	6	--	--
TOFC	--	--	--	150	2209	1886	1393	1306	1366	1117	--	--
Truck	--	--	3	620	6497	5545	5050	5247	6156	4275	109	--
Santa Maria-Guadalupe												
Rail	--	--	--	1	--	4	4	8	2	--	--	--
TOFC	--	--	--	92	181	99	164	134	125	95	60	1
Truck	--	--	--	244	1312	1234	1269	1302	1119	360	7	--
San Francisco Bay												
Rail	--	--	--	--	--	--	--	--	--	--	--	--
TOFC	--	--	--	--	--	--	--	--	--	--	--	--
Truck	--	--	--	--	7	18	51	45	9	2	--	--
Central San Joaquin Valley												
Rail	--	--	--	8	--	--	--	--	--	1	1	--
TOFC	--	--	--	1008	--	--	--	--	--	440	753	42
Truck	--	--	--	3427	56	--	--	--	--	1756	2230	55
Southern San Joaquin Valley												
Rail	--	--	--	--	--	--	--	--	--	--	--	--
TOFC	--	--	--	77	4	--	--	--	--	24	55	5
Truck	--	--	26	1007	27	--	--	--	--	372	768	98
Ventura County												
Rail	--	--	--	--	2	--	--	--	--	--	--	--
TOFC	--	--	--	--	--	--	--	--	--	--	26	1
Truck	--	--	29	280	198	--	--	--	--	41	64	18
Blythe												
Rail	--	--	--	--	--	--	--	--	--	--	--	--
TOFC	88	80	436	170	--	--	--	--	--	--	61	139
Truck	760	546	2306	595	--	--	--	--	--	--	1111	1483
Imperial Valley												
Rail	6	35	11	--	--	--	--	--	--	--	--	--
TOFC	604	620	237	--	--	--	--	--	--	--	--	107
Truck	4198	4098	1479	--	--	--	--	--	--	--	--	1536

^a Rail shipments, 60,000 pound units; TOFC, 43,000 pounds; Trucks, 50,000 pounds.
Source: Federal-State Market News Service, *Marketing Lettuce*, 1985.

All commodities taken together cause an aggregate seasonal peak in demand for transportation equipment. This is true both from field to processing plant as shown in Figure 3 and from packing shed to the fresh market as shown in Figure 4. The sharp peaks in demand shown in both figures illustrates the heavy burden placed on the handling and distribution system in the summer and early fall.

PRODUCT STRESSES

Handling and transportation subject agricultural products to a variety of stresses. These may be grouped as mechanical, environmental, and time-related. These stresses may be unavoidable, but they should be recognized and minimized.

Mechanical Stresses

Produce may suffer from *compression* stresses from a variety of operations beginning at the time of picking. If not careful, the hand that removes the product from the plant may bruise it—a major consideration in handling strawberries. Stacking fruit on fruit in containers produces further compression stresses; in severe cases, rupture with juice loss may result. Processing tomatoes, enroute to the processing plant, suffer from compression stress. Produce that is packed excessively tightly in cartons may be crushed by compressive loading; compression increases as other cartons are stacked on top. This is a major problem with crisphead lettuce.

Thrown or dropped produce is exposed to *impact* stress. While still a compression stress, the high loading rate may produce damage even when the stress level is too low to cause damage if slowly applied. Cartons, dropped onto conveyors or into position in a stack, transmit impact stress to the product inside.

Shear stresses can occur when produce is transferred from collection containers, handled on conveyors or packed

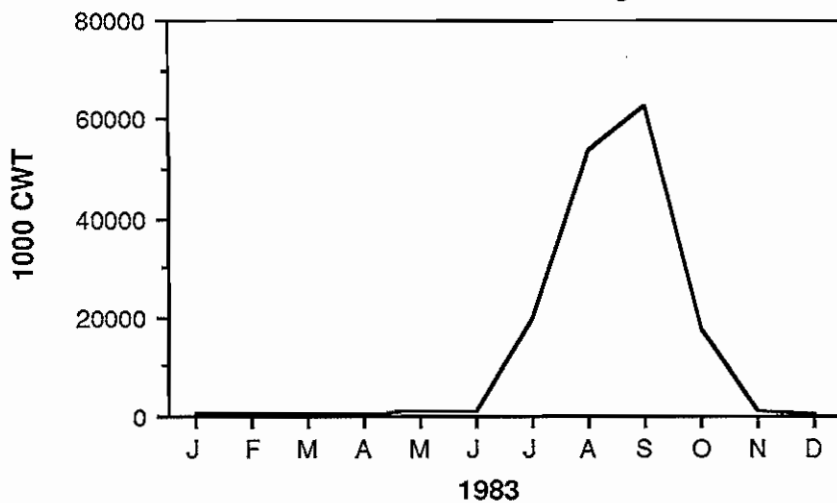
into cartons—whenever one object rubs past another. The most obvious effect of shear stress is abrasion of the surface, but fractures of internal tissue can also result. Broccoli and cauliflower are particularly sensitive to shear stress damage.

Vibration, resulting from rough roads and engine vibrations, causes cyclic compression and shear stresses. Because individual fruits act as spring-mass systems, vibratory forces are amplified from bottom to top in a stack of fruit. Fruit on the surface of a container may be vibrated so severely it floats freely even though the magnitude of vibration input at the bottom of the container is relatively small. Top fruit suffers roller bruising as it receives repeated impacts over a large portion of its surface. Roller bruising can be reduced or eliminated by providing a light compressive load to the top fruit. Air suspension systems on highway trailers have been shown to reduce vibration stress significantly, but they are rarely used because of their cost and added weight.

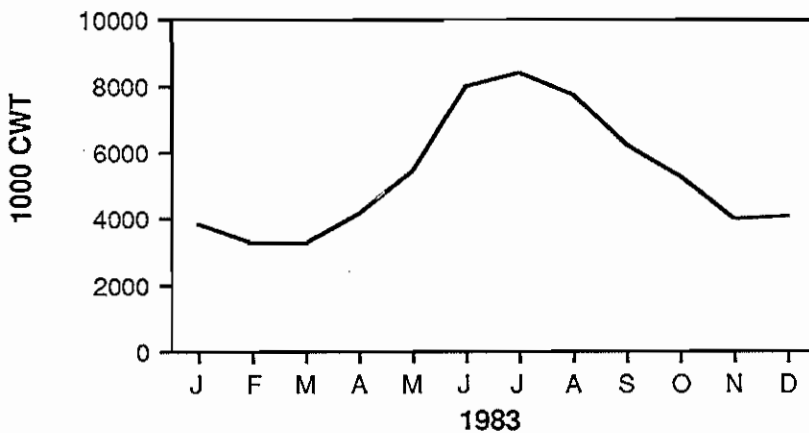
Environmental Stresses

Quality loss results more from *temperature* stress than any other environmental stress. Whether products are destined to be processed or marketed fresh, it is important to lower the product temperature as soon as possible after harvest. Food products are subject to bacterial activity and, fresh products, to respiration. These processes are minimized at reduced temperatures. Once fruits and vegetables are canned, temperature variations cause few problems; however, prolonged storage in warm environments results in quality loss. Frozen foods must be kept frozen, preferably at temperatures below -18 C. They suffer severe deterioration if allowed to thaw and then re-freeze. Fresh commodities need to be kept as cool as possible. Many should be kept just above their freezing points. But fruits and vegetables are also subject to chilling injury—various low (but above freezing) temperature disorders,

**Figure 3. Demand for Transportation Equipment:
California Fields to Processing Plants**



**Figure 4. Demand for Transportation Equipment:
California to Fresh Markets**



Source: California Public Utilities Commission. 1985. Report to the Commission Monitoring the Fresh Fruit and Vegetable For-Hire Motor Carrier Transportation Industry after Deregulation.

such as decay, surface pitting or failure to ripen. The thresholds for chilling injury for different commodities range from about 2 to 13 C. Sensitivity to chilling injury is particularly a problem when shipping mixed loads of produce.

Moisture stress is responsible for weight and quality loss in fresh produce. If temperature is kept low, relative humidity of the air immediately adjacent to the produce will rise and prevent excess moisture loss. Low temperature, however, increases the potential for condensation of free water which aids bacterial growth. High relative humidity and condensation of moisture weaken most carton materials. And weakened cartons provide reduced support and protection from mechanical stresses. Temperature fluctuations cause condensation and moisture loss problems.

During respiration, oxygen is consumed and carbon dioxide and heat are produced. In addition, plant tissue may produce other gases such as ethylene. *Gas concentrations* must be kept within limits which depend on the particular product and are related to temperature. Because oxygen is necessary for respiration, reduced levels of oxygen can result in reduced rates of respiration; if oxygen levels are too low, however, fermentation may take place causing undesirable odors and/or flavors. High levels of carbon dioxide should be avoided unless commodities are known to be tolerant to it. Ethylene is important for ripening of some fruit, and it is produced naturally. It can cause serious disorders, however, in leafy vegetables and flowers at concentrations as low as 1 part per million. Ethylene is also present in exhaust from truck and forklift engines and from decaying organic matter.

Air circulation is essential to control temperature, humidity, and gas concentrations. Circulation is most critical for temperature control; generally, if uniform temperature is maintained, the other factors

will be within tolerance. Respiring fresh produce generates heat. This heat must be removed by circulating cool air around the produce; however, excessive air movement past fresh produce can increase moisture loss. Major heat gains in transport vehicles occur through the floor, ceiling, walls and through openings around poorly sealed doors and from product respiration. Pressure differences associated with the ram effect of a fast moving truck, and to a lesser extent with elevation changes, cause *air interchange* in the transport unit. Large amounts of air interchange, as can occur with poorly sealed doors, make temperature control difficult and disrupt maintenance of special modified environments. Air leakage may also allow undesirable pollutant gases into the van. Transport vehicles for fresh or frozen produce should be well-insulated and have tightly sealed doors, adequate temperature control and air circulation. Produce should be loaded and secured in the unit so as to ensure air circulation around the load and, to some extent, through the load.

Time-Related Stress

Products lose quality over time as a result of physiological, biochemical and pathological activity. Processing minimizes these effects. Canning extends shelf life to months or years; freezing, to weeks or months. Fresh product shelf life generally is on the order of days to a few weeks, although some fresh products can be stored for several months. Time in transit is, therefore, particularly important for fresh market produce.

Table 2 lists typical transit times to a few major markets by truck, rail and ship. While distance is the major factor affecting time in transit, ships and trains, because of the large quantities of material they carry, require time for loading and assembly and also for unloading and disassembly for distribution to retail or institutional outlets.

Table 2. Estimated Time of Arrival from California

By Truck:	Chicago	3rd morning
	Atlanta	3rd morning
	New York	4th morning
	Toronto	4th morning
	Montreal	5th morning
By Rail:	Kansas City	3rd morning
	Chicago	4th morning
	New York	7th morning
	Toronto	7th morning
By Ship:	Japan	10-11 days
	Taiwan	12-14 days
	Hong Kong	15-22 days
	Singapore	21-28 days
	Persian Gulf (TransPacific)	30-35 days

Source: Telephone survey of people in the industry. 1987.

Quality of Product Delivered

A major factor offsetting California's disadvantages in long distances to market, high land cost, and high irrigation costs is the quality of its produce. Quality of produce delivered, whether to the fresh market or to a processing plant, is dependent on the *initial quality* of the produce, the *environmental* and *mechanical* stresses to which the product is subjected, and the *time* interval over which the product is stressed. For fresh produce, appearance of freshness and absence of surface blemishes are critical. For processed products, handling is not as critical, provided the products are processed quickly. And bruises and surface defects may not be as important.

The *initial quality* of fresh produce destined for distant markets needs to be very good if the product is to survive transit stresses. While initial quality is somewhat dependent on weather conditions, the time of harvest selected may not be the time of best physiological product quality. If supply is abundant and the market is weak, there is a tendency to delay harvest in anticipation of a strengthening of the market, resulting in overmature products. Conversely, when the market is strong, produce will sometimes be harvested prematurely.

Night harvesting while produce is cool is being used for wine grapes, sweet corn and canning tomatoes, and is under experimentation for broccoli cantaloups, and table grapes. The practice, explored for its energy saving potential, results in better quality. One wine producer labels his product as produced from night harvested grapes.

However, harvesting premium quality produce does not always ensure that premium quality produce will be shipped. Continuous postharvest environmental control is essential to maintain quality in fresh and frozen produce while awaiting shipment. Quality degradation may occur in bins of produce being transported from the field to packing plants when there is excess exposure to airflow which causes moisture loss. Delayed cooling can also reduce quality—so can allowing properly cooled produce to warm up before loading. Quality loss due to mishandling in this early stage is rarely visible, but will be manifested later.

Sometimes transport equipment is loaded without having been precooled, resulting in heat in the walls, floor and ceiling being transferred to the load. The ability of transport equipment currently in service to maintain a uniform and proper environment is highly variable. In addition, not all handling

procedures give the transport equipment its best chance to work effectively. Technology is available, but there seems to be a fairly widespread lack of understanding of the limited air circulation capabilities of the refrigeration equipment and of the importance of maintaining optimum product temperatures in transit. This lack of understanding extends to shippers and buyers and to transport equipment fabricators and operators. Fortunately, more and more shippers do understand their product and the equipment and are becoming increasingly particular about the quality of the transport equipment into which they load their produce. And packaging technology could be developed to improve the microenvironment around produce during transit.

Mechanical damage occurs during harvesting and shipping to the packing plant, during packing and handling of cartons, and in transit. Sorting at the time of packing allows removal of produce severely damaged during harvesting and in the early stages of handling; minor damage may escape detection and result in deterioration in transit. Over packing, a common cause of mechanical damage, is partly due to requirements to pack by count into standard sized cartons even though the produce may be larger than what the carton was originally designed for. Also some buyers seem to believe they are getting more for their money in a bulged carton. Cartons are frequently stacked in patterns which result in the load being carried by the produce rather than by the side walls of the cartons. Some stacking patterns call for cartons to be stacked on side or end; in these positions they have much less stacking strength. Bulged cartons also have reduced stacking strength. All of these practices cause increased mechanical damage with resulting increased respiration and product deterioration.

Vibrations damage both processed and fresh products, but fresh produce is most easily damaged. Vibrations due to rough roads and rails are passed through suspensions

to the bottom cartons in a stack and through the stack to the entire load. Top layer cartons have the greatest amounts of vibration injury, especially if they are over the rear wheels in highway trailers or trailers on flat cars (TOFC). Resonant frequencies of leaf spring suspensions can aggravate the problem. Air bag suspensions can reduce vibration damage, but they are not widely used. Containers on flat cars (COFC) benefit from removal of trailer suspensions. Specially designed low-slung flat cars on which containers are stacked (stack trains) give smoother rides than standard flatcars or trailers. The vibration resulting in the load is substantially reduced.

Sideways and jerking motions impose horizontal loading which can damage product. Horizontal movement is minimized if the load is restrained by bracing along the sides and at the end of the vehicle. However, care must be taken to prevent restriction of air circulation by this bracing.

Technology for providing smoother rides is available, but the benefits are not widely understood. Produce is frequently shipped in a slightly immature condition so that it can withstand transit stresses and arrive in acceptable condition. With better equipment, it might be possible to ship produce in closer to a "vine-ripened" condition and, by improving consumer acceptance, expand markets.

Product quality declines with *time*; hence, reducing time from harvest to the consumer would reduce the amount of product deterioration. If there is a storage interval in the distribution chain, the storage environment must be carefully controlled.

Delays in loading can occur because equipment does not arrive on time or because of extra time needed to accumulate loads. Equipment scheduling is extremely complex and may benefit from high technology information management. Delays resulting from equipment failures are somewhat unpredictable, but they can be minimized by careful maintenance and better

communications. Shippers should load only well-maintained equipment.

Travel time depends on lag time before the trip starts, time spent transferring enroute, travel speed, and the hours per day spent traveling. Trains travel at high speeds (tracks permitting) and for many hours per day, but time is lost in assembling the train and in transferring loads between trains and trucks at destination. Trucks begin the trip immediately and go directly to their destination. They are limited to highway speeds; and, unless they use multiple drivers, they are limited in the number of hours per day they can travel. Planes offer short transit time, but the cost is high. The lowest air rates are obtained on a space available basis. The high value, highly perishable produce most able to afford air rates may not be able to stand being left on the tarmac until space becomes available, and airports generally do not provide refrigerated storage for produce. Ships move at a slow speed and may require a few days for loading and unloading. To compensate, marine carriers have resorted to high quality containers with very accurate environmental control.

There are some opportunities to reduce transit times by intermodal networking. Compatibility of equipment restricts this practice at present.

When product quality has deteriorated by the time it arrives at market, fault is difficult to pinpoint, for incentives for all parties to do a good job are not always clear. For producers who wish to expand markets, however, future sales depend on proper handling by all parties.

THE HANDLING AND TRANSPORTATION SYSTEM

The handling and transportation system, in general, does an excellent job of delivering California specialty crops to all parts of the country and many parts of the world at all times of the year. (Table 3 lists major destinations for several commodities

moving through California ports. Exports overland, especially to Canada, are not included.) Still, the system must continually be improved if California agriculture is to remain competitive.

To speak of the delivery system is somewhat of a misnomer. We have, in effect, several fairly distinct systems. First, we have the delivery of fresh products from the field to a point at which they are cooled, packed, processed, or stored before shipment. Because of the unique characteristics of each commodity, the methods of handling and transporting in this stage differ considerably. Next in the distribution system, we must distinguish between produce that is distributed in the fresh state from that which is frozen and from that which is processed, such as by canning. Fresh produce requires the most careful handling, and our ability to deliver fresh produce without loss of quality appears to be our biggest problem. Hence, it will be given the most consideration in this report. Next, we note that equipment for the export market differs from that used for domestic distribution. Transportation equipment used in these separate systems is not readily interchangeable.

Carriers differ in their understanding of the transportation requirements for California specialty crops and in their dedication to transportation of those crops. In fact, their dedication tends to vary with time of the year and the availability of competing freight. Each transport mode functions somewhat independently of the others and to some extent in competition with the others.

Figure 5 is a simplified illustration of the different paths a product may follow in the distribution chain from field to consumer. Products are harvested from fields which may be hundreds of miles distant from the next stage of handling. Some products are packaged in the field; others are transported to a packing facility where they are cooled before or after packaging. Fresh market products are occasionally stored briefly; frozen and canned

Table 3. Exports through California Ports

Crops	Percentage of		Major Destinations
	California	US	
Almonds	53.3	100.0	West Germany, Japan, United Kingdom, France
Apricots	8.1	100.0	Switzerland, Japan, West Germany, Australia
Avocados	6.4	97.7	Japan, France, Mexico, United Kingdom
Asparagus	9.2	42.8	Japan, United Kingdom, Hong Kong, French Pacific Islands
Broccoli	14.4	90.1	South Korea, Hong Kong, United Kingdom, Japan
Carrots	16.2	66.5	Japan, United Arab Emirates, United Kingdom, Sweden
Celery	9.8	72.5	Hong Kong, Mexico, Singapore, Taiwan
Dates	10.3	100.0	Australia, Switzerland, Norway, Indonesia
Figs	9.6	100.0	Hong Kong, Canada, West Germany, New Zealand
Garlic	22.5	100.0	Venezuela, West Germany, Australia, Japan
Grapefruit	14.3	7.9	Japan, New Zealand, Netherlands, Australia
Grapes, fresh	22.4	95.8	Hong Kong, Singapore, Taiwan, Japan
raisins	14.1	100.0	Japan, United Kingdom, Sweden, West Germany
processed	1.4	75.9	Japan, United Kingdom, West Germany, Hong Kong
Kiwi	29.0	100.0	Japan, Netherlands, Australia, Austria
Lettuce	8.1	72.5	Hong Kong, United Kingdom, Mexico, Taiwan
Lemons	34.7	77.3	Japan, Hong Kong, Netherlands, Australia
Olives	2.5	100.0	Japan, Sweden, South Korea, Singapore
Onions	30.3	53.2	Japan, United Kingdom, West Germany, Australia
Oranges	24.1	64.5	Japan, Hong Kong, Singapore, Malaysia
Pears	5.9	27.3	Mexico, Panama, Singapore, Indonesia
Pistachios	16.1	100.0	Australia, United Kingdom, Japan, France
Plums	17.2	96.9	Hong Kong, Singapore, Malaysia, Taiwan
Potatoes	0.6	32.7	Mexico, Hong Kong, Saudi Arabia, Singapore
Prunes	39.1	100.0	Japan, West Germany, Italy, France
Strawberries	7.7	84.6	Japan, West Germany, United Kingdom, United Arab Emirates
Tangerines	22.0	69.8	Hong Kong, Australia, Sweden, Malaysia
Tomatoes, fresh	7.2	32.0	Hong Kong, Mexico, United Kingdom, West Germany
processed	1.5	85.8	Hong Kong, Japan, Saudi Arabia, Singapore
Walnuts	29.5	100.0	Spain, Italy, Australia, West Germany

Source: California Crop and Livestock Reporting Service, *Exports of Agricultural Commodities Produced in California, 1985*

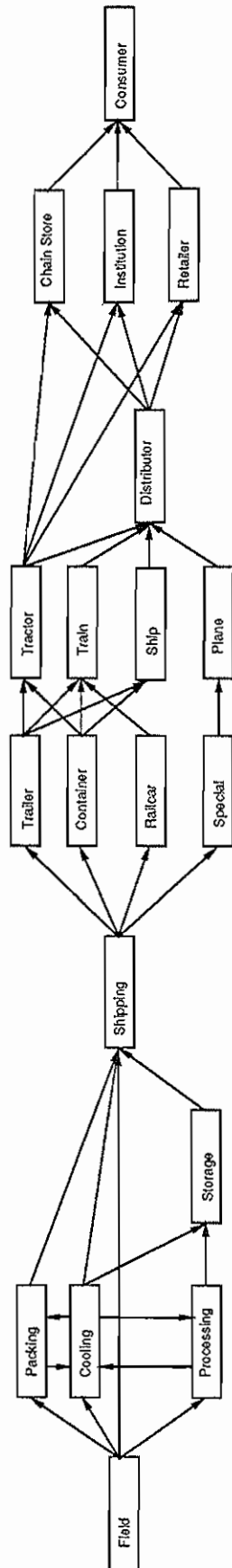


Figure 5. Some paths in the Distribution Chain

products are usually stored. Products are removed from storage when demanded by the buyer, usually on a first in-first out basis. Sometimes unsold loads of highly perishable commodities are shipped in hopes of selling them while enroute. If still unsold, the loads may be auctioned at destination markets.

Handling and transportation *techniques differ* among crops. Each commodity has its own peculiar characteristics which influence how it should be handled. Strawberries, for example, are packed in the field in trays of the familiar pint-sized plastic baskets in which retailers display the berries. Handling and storage of the fragile berries are minimized to protect their quality. Citrus, on the other hand, is frequently stored on the tree for extended periods until needed for the market. Then it is picked into bags, dumped into bins, transported to packing sheds, washed, sorted, and sometimes waxed before being packed in a variety of different sized cartons or bags. At the retail store, the citrus is typically removed from the cartons for display; bagged fruit is generally displayed as is.

Individual items in a harvest lot vary in size, and the average size of individual items in harvest lots varies with season, weather conditions, production area and cultivar. This situation complicates the problem of establishing *carton sizes*. Most carton sizes are limited to what a worker can lift, but some produce, e.g., watermelon, is often shipped and displayed in pallet bins which can only be moved by special equipment. Table 4 lists common carton sizes for several commodities.

Interests and attitudes have an impact on carton sizes. To some extent these reflect customer needs, but they also reflect tradition. Cartons originally sized to fit some produce remain unchanged in size even though the size of the produce from new cultivars has changed. Some buyers insist on standard counts and bulged cartons. Standardized carton regulations inhibit attempts to change carton sizes; some shippers are reluctant to relax the regulations.

Table 4. Carton Sizes and Packing Densities
for Fresh Fruit and Vegetables

Commodity	Carton Dimensions, Outside			Volume ft ³	Weight lbs	Density lb/ft ³
	In	In	In			
Apples	20.67	12.87	12.40	1.91	45.60	28.60
Asparagus	19.53	11.69	11.22	1.48	37.90	25.60
Avocados	17.52	14.02	5.87	0.83	23.20	27.90
Beans	24.76	10.04	10.04	1.44	33.20	23.10
Beets	22.05	16.65	10.39	2.21	34.10	15.40
Blueberries	18.54	13.35	3.90	0.56	13.80	24.70
Broccoli	22.09	11.65	10.28	1.53	34.40	22.50
Cabbage	22.36	16.42	11.26	2.39	60.90	25.50
Cantaloupe	17.00	12.87	10.00	1.27	45.00	35.53
Carrots	16.50	13.50	10.63	1.37	50.00	36.51
Cauliflower	23.19	18.23	6.42	1.57	27.30	17.40
Celery	22.05	16.61	10.47	2.22	70.50	31.80
Cherries	17.40	13.94	4.84	0.67	21.90	32.30
Collards	22.01	16.42	10.43	2.18	41.50	19.00
Corn	15.31	12.24	7.44	0.81	22.40	27.60
Cucumbers	17.44	14.02	7.13	1.01	34.40	34.40
Eggplant	17.48	13.94	7.99	1.13	26.00	23.00
Escarole	18.70	12.24	12.52	1.66	27.70	16.70
Grapefruit	17.20	11.54	10.51	1.21	35.00	28.90
Grapes	17.60	15.20	6.61	1.02	28.20	27.60
Honeydews	22.01	16.57	8.39	1.77	45.80	27.40
Lemons	17.83	16.26	7.32	1.23	37.40	30.40
Lettuce	21.89	16.34	11.26	2.33	45.50	19.50
Limes	13.19	10.51	4.09	0.33	10.80	32.90
Mushrooms	19.65	13.46	4.09	0.63	4.04	6.40
Nectarines	17.56	13.94	6.38	0.90	24.80	27.50
Onions, dry	17.91	13.86	10.04	1.44	42.80	29.70
Onions, green	16.26	11.06	12.17	1.27	24.60	19.40
Oranges	17.24	11.46	10.94	1.25	19.70	31.80
Peaches	17.56	13.98	6.57	0.93	24.80	26.60
Pears	19.41	12.17	9.21	1.26	51.20	40.60
Peppers	18.74	13.58	11.65	1.72	32.30	18.80
Plums	17.52	13.94	6.42	0.91	28.70	31.70
Potatoes	18.03	13.90	10.24	1.48	52.80	35.70
Prunes	15.24	11.97	7.99	0.84	32.30	38.20
Radishes	15.83	9.92	5.55	0.50	14.60	29.00
Spinach	23.62	10.43	8.62	1.23	11.30	9.19
Squash, summer	17.56	13.90	6.18	0.87	27.40	31.40
Strawberries	19.57	12.87	4.21	0.61	12.30	20.00
Sweet potatoes	17.52	11.81	10.91	1.31	42.40	32.40
Tangelos	17.90	11.38	8.50	0.97	25.90	26.70
Tangerines	17.20	11.46	8.54	0.97	29.20	30.00
Tomatos	17.44	13.94	6.38	0.90	26.00	29.00
Turnips	17.20	8.43	9.13	0.77	20.40	26.60

U.S. Department of Agriculture, *Marketing Research Report*, No. 991, 1974.

Some cartons are hand stacked in transport vehicles, although an increasing amount is being palletized. The pallet is moved by fork lift. Dry processed products are often shipped on a fiberboard or plastic "slip sheet." Slip sheets should not be used for fresh or frozen products unless the floor design allows adequate air circulation under the load.

Standard sized pallets, 48 by 40 inches, have been adopted by the dry grocery industry where the palletized unit is intended to be handled on the pallet or a slip sheet throughout most of the distribution chain. Inside dimensions of refrigerated vans, which once restricted use of standard pallets, are now widened, thanks to changes in allowable outside widths of trucks on major highways and improvements in insulation materials. There is a trend toward shipping fresh produce on standard pallets, but buyers have been reluctant to share in the cost of the pallet. Furthermore, carton dimensions do not always fit the standard pallet. In most cases nonstandard, disposable pallets are used for convenience of loading or to provide for air circulation while taking full advantage of available volume in the transit vehicle. The cartons are expected to be repalletized by the receiver.

Approximately 85 percent of California's fresh domestic produce moves by over-the-road trucks. The remaining 15 percent moves by train and most of that is TOFC. Most new trailers are 48 feet long with about 46.5 feet inside; there are some that are 53 feet long. Many trailers 45 feet long are still in service; a few are 42 feet and even 40 feet long. Federal regulations now allow exterior trailer widths of 102 inches on major roads and direct access routes, but these units are not legal on all streets and roads. These larger units have internal widths of approximately 96.5 inches. Units built to the previous legal width of 96 inches are about 90.5 inches wide inside. The greater internal volume of the new, larger trailers does not necessarily mean they can haul more of all products, because, for

some produce, weight limits are reached before volume limits. As a result of the variability in both length and width, buyers are uncertain how much produce to order. They need to make full use of capacity to minimize unit transportation costs, but they cannot always be sure how much a given transport unit can haul.

The normal length of ocean-going containers is 40 feet. Furthermore, the containers, needing sufficient strength to withstand lifting and stacking, are heavier than highway trailers. (TOFC trailers are also more heavily constructed than highway trailers to withstand stresses when lifted onto and off of flat cars while full loaded.) Because over-the-road cargo loads are restricted by highway weight limits, containers loaded at produce shipping points are frequently topped off at the dock—an additional cost and possibility for quality reduction.

Methods of loading transit vehicles vary by commodity and by shipper. Some shippers use forklift trucks and "shoe horn" guides to load two 48-inch wide pallets at the same time in the wider trailers. This procedure maximizes use of volume but it does not allow adequate air circulation along the side of the load. Product heating may result.

Strawberries, hand packed in the field in pint baskets in trays, are stacked at the field on 39-inch square pallets. These pallets, even when loaded in trucks with 90.5-inch inside width, leave excess space along the sides beyond that needed for loading and air circulation. Berries, in larger baskets and trays sized to fit standard pallets, would utilize payload capacity and reduce transportation cost and still retain quality.

Pallets of celery and grapes are sometimes loaded alternately, two side by side followed by one centered, in wide trucks. This pattern allows adequate weight to be loaded and gives a weight distribution on axles within legal limits. Unfortunately, the pallets placed side by side suffer from improper cooling along the sides; and cartons on the centered

pallets, lacking stability, tend to shift on the pallet and fall off. This loading pattern would also allow short circuiting of air, particularly when air is delivered under the load.

Transport units are loaded at many locations: Products are loaded into transport vehicles at packing, cooling, processing and storage facilities. Trucks offer a high degree of versatility; an estimated 70 percent of fresh produce trucks loaded in California are mixed loads, often loaded through multiple pickups, destined for a single customer. Loaded railcars are picked up at the shipping point by switch engines, but TOFC and COFC are transferred by truck to special loading sites.

Destinations are widely scattered. Shipments may be routed to distribution terminals in major cities or, increasingly, direct to warehouses of chain stores or food service institutions. While trucks can reach essentially any destination, planes, trains and ships are limited to specific locations. Many chain stores have their own warehouses with facilities for handling rail deliveries; nevertheless, for TOFC and COFC, the need for special equipment to unload them limits the number of distribution points. These trailers and containers, must be transferred by truck to the distributor, chain store, institution or retailer.

Before reaching the consumer, most produce is stored one to four days in a distribution warehouse and in a retail market. Items requiring refrigeration usually share the same cold room. Because of the product mix, the environmental conditions can hardly be ideal for all, if for any. Most stores will receive deliveries two to four times weekly. Some fresh market products require special handling and preparation for display. Most will require continuous monitoring of quality and possible changes in pricing to reflect quality and market changes.

The consumer is not only the final judge of product acceptability, but also the final link in the distribution chain. Some commodities have earned undeserved

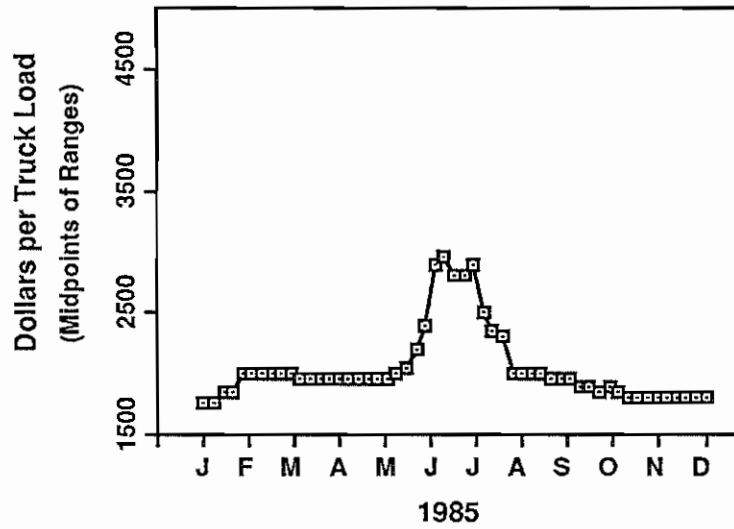
reputations because consumers do not know how to handle, store or prepare them. Fresh tomatoes, generally delivered to the consumer in a firm and durable pink or light red stage, need to be ripened at home. They should be stored at room temperature and high humidity. Refrigeration will prevent normal ripening and cause chilling injury, moisture loss, and decay. Frozen foods in the freezing compartments of frostless refrigerators will degrade quickly due to the defrosting cycle; they should not be kept in such conditions more than a few days to a few weeks. Even canned goods kept on the shelf more than a few months will begin to show signs of quality loss.

COST TO DELIVER THE PRODUCT

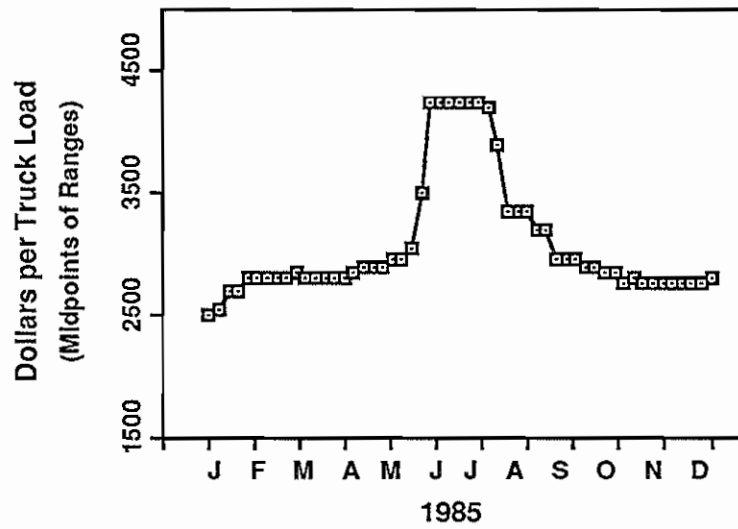
Transportation costs add substantially to the cost of delivered products and may inhibit expansion of markets. Figures 6 and 7 illustrate California's problem: The farther from the market, the higher the cost to deliver. A comparison of Figures 6 and 7 with Figures 3 and 4 shows the sensitivity of transportation cost to demand.

The cost problem is highly variable, however, and difficult to evaluate. Deregulation has caused transportation costs to follow supply and demand, including availability of hauls of other materials. In recent years, a shift in the balance of U.S. imports from Europe to Pacific Rim countries has resulted in a shift in the balance between eastbound and westbound freight. Container ships deposit containers on the West Coast. These loads are distributed across the country and, on the return trip, they compete with produce trucks for hauls from the east. Export reductions resulting from the high value of the dollar have further compounded the situation. Shifts in production in other sectors of the economy have also made an impact. For example, publications, which used to be produced in the East and transported to the West Coast, can now be transferred

**Figure 6. Truck Rates to Chicago
From Southern California**



**Figure 7. Truck Rates to New York
From Southern California**



Source: USDA, 1985. Fruit and Vegetable Truck Rate and Cost Summary.

electronically to western branch production facilities, thus eliminating an important source of westbound freight. In previous years eastbound produce was considered a back haul for units moving dry freight westbound. Now, particularly in the summer with seasonal peaks in the amount of produce to be transported, the situation is reversed. The net result is that, particularly during the period of peak demand, produce transportation rates must cover the likely cost of an empty return, and there are coincident peaks in the cost of transportation.

Transportation costs vary widely as a *percentage of product value*. When the supply of produce is abundant, its price is likely to be depressed. Price fluctuations for loads of grapes, strawberries and tomatoes are shown in Figure 8 and for broccoli, cauliflower and lettuce, in Figure 9. At the same time that prices are depressed, transport equipment is in great demand and its cost is inflated. Figures 10 and 11 show the resulting variability in truck cost as a fraction of the price received by the shipper for broccoli and lettuce, respectively.

The magnitude of the price depression depends to a great extent on the available supply of produce from competing production areas. For many of those competing areas, the supply is greatly dependent on local weather conditions. They tend to be in the market for short periods of time and can be out of the market suddenly if weather conditions are adverse. California producers, with less variable weather conditions, tend to grow for the market that would exist if their competitors are unsuccessful. They try to supply their regular customers on a continual basis even though the cost of transportation, relative to product value, may be momentarily very high.

Costs of transportation are of concern to all parties. Truckers have widely adopted the use of wind deflectors to reduce fuel costs. Other improvements such as low profile tires and variable speed transmissions are being tested. The influence of fuel cost savings on

overall costs varies with energy prices. Truckers also are concerned with investment costs. They want well-built equipment, but they frequently leave off such items as return air bulkheads, deep floors, and air distribution chutes on the ceiling. These items are essential to ensure proper air circulation around and through fresh and frozen products. Precooling of the trailer and continuous operation of the air circulation unit are also essential, but operators frequently neglect them to save a few dollars. Air bag suspensions would significantly reduce vibration damage to produce, but almost no trucks are equipped with them. Unfortunately, the benefits of improved equipment and operating procedures are not always distributed in a manner that provides adequate incentive to those who would be making the improvements.

Given high transportation costs, it behooves California shippers to make the most of the equipment used. Produce lost during shipment represents a waste of transportation equipment and cost. Lettuce is an example of a bulky product which fills the available cubage in transport equipment before weight limitations are reached. Approximately 60 percent of the lettuce is shipped in what is referred to as a naked pack. A few wrapper leaves from the plant are left on the head and used as packing material in the cartons. At the retail store these leaves are removed and the head is generally wrapped for display. Approximately one-fourth to one-third of the weight of lettuce shipped is discarded before display, including the common loss of one or two heads out of a carton of 24 due to mechanical damage. It is as if every third load is carrying garbage. (The cost of the trimming operation in the retail store approximates the farmer's cost to produce the head.) About 30 percent of the lettuce shipped is trimmed in the field to the bald head which is then wrapped in a plastic film. With film wrapped lettuce an equal or greater number of heads can be shipped in any

Figure 8. Price to California Shippers

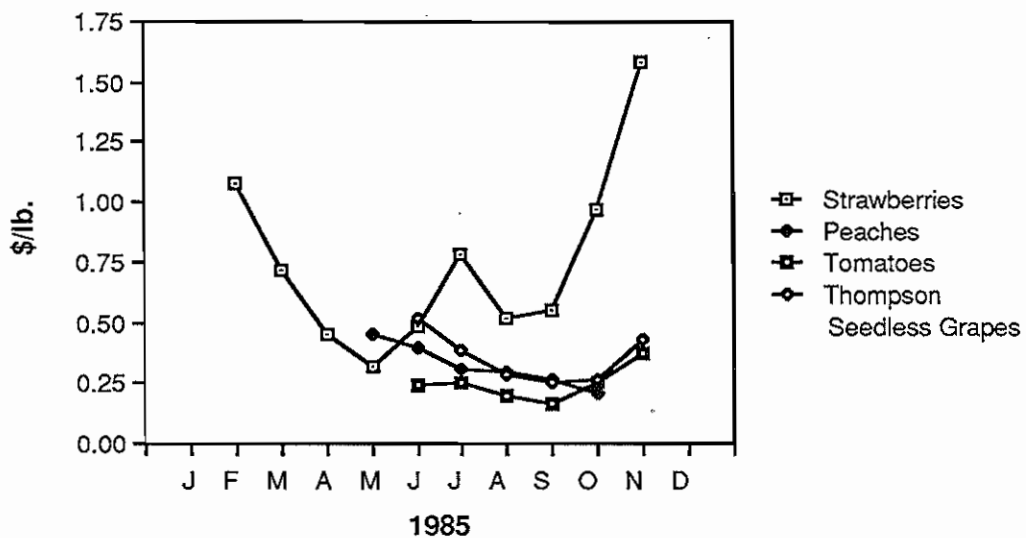
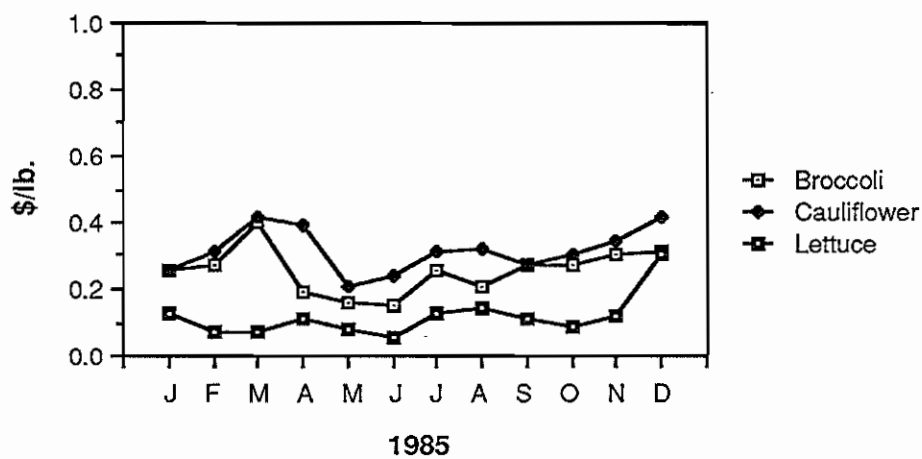


Figure 9. Price to California Shippers



Source: CDFA, 1985. California Agricultural Market Review.

given load. While weight capacity is still under utilized, typically less product is discarded because of shipping damage or deterioration. However, if wrapped lettuce does deteriorate to the point that additional trimming is required at the retail store, the cost to trim and rewrap is greater than for the naked pack lettuce. Alternative packaging schemes have been suggested for lettuce which could increase the utilization of weight capacity, but California's standard container regulations have inhibited such innovation.

Produce damaged during transport from the field to packing or processing plants also represents a loss of product and transportation capacity. Overfilled containers spilling along the road are considered a traffic hazard and carriers are liable for fines. Damaged produce must be sorted out at the packing or processing plants and disposed of as waste material. Processed products share the characteristics of fresh market products during the stage of transportation from the field to the processing facility, and quality is highly vulnerable. Presently, little attention is given to protecting the product at this stage; the emphasis is on getting the product to the plant in a short time. Even when delivered rapidly, environmental conditions can result in significant quality degradation. In general, these problems are less significant for processed products than for fresh market products because of the shorter time in transit and because processing can remove some of the damaged material. Nevertheless, some attention to protecting the product from wind

and sun may well improve the quality and quantity of useable product processed. It may be that produce is the least cost material for protecting other produce, but the product wasted also represents a waste of transportation capacity.

Tomato juice concentrate is an example of a commodity which has been *reduced in volume and weight* to take better advantage of transportation and storage facilities. The concentrate is reconstituted near the point and time of consumption.

Claims and renegotiations of price for damaged or deteriorated produce are an additional cost. Transportation of fresh produce is typically arranged for and paid for by the buyer. However, the shipper retains at least a portion of the liability for the quality of the product when delivered. The shipper is in an extremely vulnerable position. The product is out of sight, and it may have been in transit several days. If a claim is lodged, the shipper must try to minimize losses. Whether the claim is the result of poor initial product quality, poor environment or handling in transit, or a change in the market is difficult to establish; and the shipper does not have the alternative of reclaiming and redirecting the product. Associated with poor arrival quality is a hidden cost of lost future sales which the producer bears.

Frozen products require temperature control throughout the distribution chain; hence, they are subjected to costs of refrigerated transport and storage and are vulnerable to related claims.

CONSTRAINTS TO MARKET EXPANSION

Market expansion, either foreign or domestic, depends on consumer demand and the supplier's ability to maintain product quality and to deliver the product at an acceptable unit cost. Constraints are of four types:

(1) transportation capacity limitations, especially at seasonal peaks;

(2) technological limitations, including those resulting from lack of technology transfer;

(3) lack of incentive in some part of the system;

(4) policy restrictions, whether intentional or otherwise.

CAPACITY

The high cost of transportation relative to product prices during the midsummer and early fall, as shown in Figures 10 and 11, suggests capacity is at least on the verge of limiting further market expansion. Anecdotal evidence of the poor quality of some transportation equipment utilized during the peak season further attests to a limitation of capacity. A lack of railcars in 1985 plagued potato growers in the Bakersfield area. The lack may have been due to their better utilization for the longer season in Idaho and Washington. Reductions in acreage of potatoes in California reflect losses in markets, due in part to a shortage of transportation capacity and also due to competition from other varieties in other producing areas.

Lack of capacity is related to lack of incentive. If the benefits are sufficient, the capacity will be provided. As the potato example illustrates, however, it is difficult for a short season demand to justify allocation of equipment that can be utilized for longer periods elsewhere.

There are, no doubt, some countries which lack facilities for storing and distributing fresh and frozen produce. It is not clear that lack of these facilities is constraining market development, however. Countries affluent enough to afford fresh and frozen produce seem to be able to afford the proper facilities.

Technological approaches may reduce limitations in capacity. The use of unit trains, dedicated to rapid assembly and delivery of exclusively perishable products, combined with "cross dock" loading to highway trailers at points such as Kansas City, St. Louis or Chicago, intermediate to eastern markets, would expedite movement of the railcars enroute and permit them to be returned quickly. Effective capacity could be increased. Information processing and communication technology has the potential

to improve scheduling, reduce time lost in waiting, and have the dual benefit of increasing effective capacity and reducing labor cost per unit handled.

New technologies, such as cryogenic refrigeration and super insulated containers, are being considered as cost reducing technologies. While that may help, refrigeration operating costs are not a major factor. If these technologies could be useful in reducing weight of transportation equipment, however, payload capacities could be increased.

Another way of coping with limitations in capacity is to reduce the demand for transportation equipment. Shifting production to off peak periods would level out the demand and take advantage of higher off peak prices for the product. There is incentive to shift to earlier and later production for many specialty crops, and crop scientists are trying to develop appropriate varieties. Shifts may also be accomplished by modification of microclimate to protect plants from late spring or early fall frosts or by genetic engineering efforts to replace frost forming bacteria. Transplants give early season plants a headstart and permit a short, late season planting.

From the consumer's point of view, supply of products from regions close to major markets would reduce transportation costs, but this would further depress prices for California producers and add further uncertainty to the market for their produce.

For highway transportation, labor cost is estimated at approximately 40 percent of the total. Techniques for making more effective use of labor could have significant impact on the delivered cost of produce. Paying more for labor, however, may be worth it. The versatility to pick up loads at multiple locations and deliver direct to the consumer is a significant advantage and eliminates other costs and time for transfer and coordination. The trick is to take advantage of transport modes which offer labor efficiency without

losing the control and identification of responsibility which dedicated truck drivers provide. Multiple trailers are allowed in some states. Coordinated systems may be able to take advantage of them where they can be used.

TECHNOLOGY

The ability to deliver consistently high quality produce is widely recognized as a major, if not the major, barrier to expansion of markets. High quality fresh produce, thoroughly cooled, loaded in a precooled transit vehicle with adequate refrigeration and air circulation capacity in a manner which allows air circulation around and through the load, reasonably protected from mechanical stresses, stands an excellent chance of arriving in good condition. Some seagoing containers provide superb environmental control. Unfortunately, not all carrier operators are aware of the proper specifications for equipment, and not all shippers are aware of the proper loading procedures. Nor do all shippers take proper care of their produce before or while loading it.

Fortunately, there is a move underway to correct this situation. A recently formed Refrigerated Transportation Foundation is setting out to educate transport equipment fabricators and operators and produce handlers about needed design features for equipment and proper handling procedures. There is, however, much that remains to be learned about the responses of various products to the transportation environment. The ability to characterize product quality is highly subjective in most cases.

The normal practice of moving products in the sequence in which they entered the distribution chain does not necessarily ensure delivery of the best quality. There may well be cases where a weak product should be accelerated through the chain and delivered while it is still acceptable; whereas, a stronger

product may be capable of sustaining a short delay if it is kept in carefully controlled conditions. The use of time-temperature indicators to track the history of products in storage and transit would provide a basis for making such decisions. Methods for objectively evaluating the initial quality would also be useful. Some time-temperature indicators are available, but better indicators are needed, and their responses need to be related to the keeping quality of products. Objective methods of determining initial quality also remain to be developed.

Road trailer units, which have both rail and highway wheels and can be connected together as a train, are being used to a limited extent along the eastern seaboard. They can be connected individually to road tractors for local distribution. The stack train, already mentioned is another intermodal concept.

While technological innovations may be enticing, they are no substitute for educating people about the nature of the products they handle and transport, and providing the incentives for people to do the best job possible.

INCENTIVE

Fault for delivery of reduced quality is difficult to pinpoint and the incentive to do a good job is not always clear. There is some question whether the present patterns of ownership transfer and liability provide the proper incentives to minimize product loss and transportation costs. The distribution of liability is somewhat arbitrary. Benefits of improvements are not always distributed to those who must bear the costs. Insurance rates that differentiated according to the quality of packaging and handling procedures and the quality of transport equipment would provide additional incentive to make improvements. For the producer, however, protecting or developing future sales should be incentive enough.

POLICY

Policies affecting the length, width and weight of highway trailers, and the number of trailers which may be combined, directly affect their design and indirectly affect the design of rail and ship equipment. In turn, they directly affect the unit costs for transportation.

Policies affecting labor utilization, such as railroad crew and mileage rules and highway speed laws, also have a direct effect on the delivered cost of produce.

Rates for export shipments are issued from port to port. Produce must be transported to the port and loaded on an export container (the order of these two operations can be reversed). If the produce is destined for European markets it will travel by land bridge (train) from a west coast port to an east coast port where it will be loaded on board ship. Containers may not be added to that land bridge except at the port even though the train may pass through the city where the produce originated. Thus produce may have to travel hundreds of extra miles. This rate policy affects energy use, transportation costs and product quality.

Deregulation has removed many artificial restrictions that were once imposed on the transportation industry and has resulted in a relatively free market situation. There are some who argue that safety and quality of equipment have suffered; others disagree. The policy does appear to have led to some restructuring of the transportation industry. The number of independent owner-operators seems to be declining and small fleets, increasing. It is not clear what effects, if any, this restructuring will have on expansion of markets for California specialty crops.

Tax policies affecting capital investment decisions will no doubt affect the cost of transportation. Immigration reform policies may also impact postharvest handling and transportation. What the effects of these policies will be remains to be seen. It is important to recognize, however, that these changes in policies have been brought about with little or no coordinated effort to ensure consideration of the impacts they might have on postharvest handling and transportation of California specialty crops.

NEEDS FOR IMPROVEMENTS

Some improvements in postharvest handling and transportation can and will be made by aggressive individuals or small groups. There is a need, however, for a *focal point* for those interested in making improvements. The lack of a focal point can result in changes at cross purposes to each other. Furthermore, the market forces necessary to prompt such independent action may be more than sufficient to attract production from competitive areas.

The U.S. Department of Agriculture's Office of Transportation has drastically curtailed its activities in recent years, and the agricultural industry has no voice in the US Department of Transportation. The result is

little support for research pertinent to agricultural transportation problems and no coordination of the various agricultural industry organizations which try to express their concerns. A focal organization is needed which can formulate and articulate needs for policy changes and for support of research and educational programs.

The University of California has a systemwide Transportation Institute; however, that unit has given little attention to problems of transportation related to agricultural products. The institute should expand its scope and increase its commitment to research on transportation of agricultural products. There are several individuals within

the university with interests and expertise related to agricultural transportation. These span the spectrum from harvesting through handling, storage, processing, packaging, and transportation equipment and systems. They include also expertise in economic, legal and public policy aspects. There is an opportunity—indeed there is an obligation—for the university to coordinate these interests and work together with the agricultural and transportation industries. There is a loose affiliation of researchers on the Davis campus in a Postharvest Biology and Technology of Horticultural Crops Program. This group conducts short courses periodically on postharvest handling. The university devotes extensive resources to the problems of producing specialty crops in California, but postharvest handling and transportation is a weak link in the long chain required to get those commodities to the consumer.

Data on which to base decisions to change handling and transportation practices are often unavailable or unreliable. Export and distribution data lack accuracy; secondary, and sometimes tertiary, destinations confound the data. Time lags in collecting and publishing data limit their usefulness. Separate studies and analysis made by various organizations from their individual perspectives need to be pulled together and put in a larger perspective. Data need to be collected on movements of materials other than produce, which either compete with produce or provide necessary backhauls. Data on claims is largely anecdotal; accurate costs and accounting for lost material are needed. Methods and procedures should be developed for accumulating useful data and putting them rapidly into forms which are readily accessible to those who need them.

Once adequate data are available, a variety of studies of trends and impacts could be pursued. Models of transportation systems need to be developed to the point that potential

impacts of proposed changes in procedures or technologies could be evaluated. The following are but a few of the challenging and important questions that need to be answered:

- How can costs and benefits of technological improvements be distributed equitably to assure adoption of the technology?
- What are the costs and benefits of unitization?
- What is the likely limit and impact of the decline of TOFC?
- What is the likely impact of the introduction of stack trains on California specialty crops?
- What would be the relative costs and benefits of various multimodal systems?
- What would be the costs, benefits and impacts of major structural changes such as vertical integration either by institutional buyers or by grower/shipper organizations?
- What are the likely implications of the recently enacted immigration reform legislation on produce handling?
- What are the likely impacts of the new tax code on capital investment decisions and operating costs in the transportation industry?

The imagination is the limit of technological innovations that could be explored. A few suggestions are:

- Methods of modifying crop environment to permit shifting of seasons.
- Improved handling practices and package designs which will provide better protection against mechanical stresses.
- Package design which will maintain a beneficial modified environment.
- Low cost methods of retaining loads in position in transport vehicles.
- Methods of providing smoother rides either through improved vehicle suspension or shock absorbing pallets.
- Extra axles on container trailers to permit movement of fully loaded containers.

- Objective measures of quality.
 - Inexpensive indicators of quality degradation related to time-temperature-humidity history.
 - Powerful and user-friendly information handling systems.
 - Routines for optimizing routing and combinations of products in loads.
 - Data systems for identifying back hauls.
 - Data systems for identifying potential markets.
 - Consumer packages or appliances for maintaining quality on the way home and at home.
- Education of produce handlers will*

require development of accurate and effective teaching materials. The university can assist industry in preparing these materials and designing appropriate educational programs. Consumer education should also be included. Market demand for some commodities is limited because consumers are unaware of proper procedures for handling, storing and preparing the products.

It is time for all parties involved in postharvest handling and transportation of California specialty crops to heed the advice of Benjamin Franklin at the signing of the Declaration of Independence: "We must all hang together or, most assuredly, we will all hang separately."

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BIOGRAPHIC SKETCHES OF STUDY PARTICIPANTS

Jill Shore Auburn has studied the distribution of California's fresh fruits and vegetables, and other topics in agricultural systems analysis, at U.C. Davis since 1978. Her dissertation described the intrastate flows of fresh produce, and developed computer models to simulate alternative patterns of flow and their associated energy use. Currently in the Civil Engineering Department at Davis, she is developing a database on interstate shipments of California produce and models to predict patterns of flow. Her work outside the university includes developing software for the specialty produce industry, and analyzing market information for the organic produce industry.

Harold O. Carter is director of the U.C. Agricultural Issues Center and professor in the Agricultural Economics Department, U.C. Davis. He was chair of the department from 1970 to 1976, and is again chair since July 1987. His B.S. and M.S. are from Michigan State University; his Ph.D. is from Iowa State University. He was elected fellow of the American Agricultural Economics Association, has served as chair of the U.C. World Food Taskforce, as senior staff economist of the U.S. Council of Economic Advisers, and as co-director of the Economics project of the U.C.-Egypt program.

Roger Garrett is professor of Agricultural Engineering at U.C. Davis. After receiving his B.S. and M.S. degrees from the University of Missouri, he worked for John Deere's

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Robert Kasmire is an extension vegetable marketing specialist at U.C. Davis. He has been a friend of the fruit and vegetable industry for many years, conducting education programs with grower shipper groups, commodity groups, and marketing associations. He has done research in cooling, transportation, and packing methods, shipping containers, market quality factors, and marketing losses; has served as a consultant on perishables handling problems; and is the author of numerous articles in scientific and trade publications.

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