NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ANALYSIS OF DEPARTMENT OF DEFENSE (DOD) TRANSPORTATION MODE STRATEGIES FOR SHIPPING FRESH FRUITS AND VEGETABLES (FFV) TO GUAM

by

Glen T. Stafford

March, 1998

Thesis Advisor: Jim Kerber

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE March 1998	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE Analysis of Department of Defense (DOD) Transportation Mode Strategies for Shipping Fresh Fruits and Vegetables (FFV) to Guam			5. FUNDING NUMBERS
6. AUTHOR(S) Glen T. Stafford			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE
13. ABSTRACT *(maximum 200 words)* The objective of this thesis is to identify the Department of Defense (DOD) transportation mode alternatives used to ship fresh fruits and vegetables (FFV) to Guam, to discuss which alternatives provide the highest service level in terms of prolonging FFV shelf life under what circumstances, and to identify those additional considerations that affect shelf life during transportation. The entire transportation process from the Continental United States (CONUS) through final delivery to the customer will be documented and analyzed, and recommendations for its improvement included.			
14. SUBJECT TERMS Shipment of Fresh Fruits and Vegetables, Guam, Controlled Atmosphere Shipping, Transportation, Perishables.			15. NUMBER OF PAGES 48
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

Approved for public release; distribution is unlimited.

ANALYSIS OF DEPARTMENT OF DEFENSE (DOD) TRANSPORTATION MODE STRATEGIES FOR SHIPPING FRESH FRUITS AND VEGETABLES (FFV) TO GUAM

Glen T. Stafford
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1986

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
March 1998

Author: ______________________
Glen T. Stafford

Approved by: ______________________
Jim Kerber, Thesis Advisor

____
Kevin Gue, Associate Advisor

____
Reuben Harris, Chairman
Department of Systems Management

ABSTRACT

The objective of this thesis is to identify the Department of Defense (DOD) transportation mode alternatives used to ship fresh fruits and vegetables (FFV) to Guam, to discuss which alternatives provide the highest service level in terms of prolonging FFV shelf life under what circumstances, and to identify those additional considerations that affect shelf life during transportation. The entire transportation process from the Continental United States (CONUS) through final delivery to the customer will be documented and analyzed, and recommendations for its improvement included.

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

Transportation management is a complex logistics process regardless of the end item being shipped. However, it is even more complex when the end item has a limited shelf life, or is perishable, as in the case of fresh fruits and vegetables (FFV). Each year the Department of Defense (DOD) must transport FFV to far reaching destinations to support forward deployed troops and to sustain commissary activities. Such shipments are required given the high cost of procuring FFV locally in Guam. Prices are high due to limited supply and a high demand from luxury hotels and restaurants [Crowe, 1998].

The availability of FFV is generally considered a quality of life issue for forward deployed personnel who seek typical U.S. staples, including FFV, to minimize the impact of cultural and dietary changes often associated with overseas deployment. Therefore, the quality of FFV upon its arrival from the continental United States (CONUS) is of particular importance if the commodities are to be marketable to defense personnel.

Due to the great distances that FFV must be shipped to reach its customers in the Pacific Rim, it has been difficult to ensure that high quality FFV is consistently delivered to its final destination. While speed of delivery has often been considered the key to solving the quality problem, recent developments in controlled atmosphere shipping techniques demonstrate that speed of transit may not be as important as once believed.

Routinely, decisions must be made as to the transportation mode and associated handling techniques to be used for shipping a variety of FFV commodities to overseas customers. However, little research has been done by DOD to identify what factors within the transportation chain help sustain FFV quality during shipment. And while the cost tradeoff between air and surface modes is well understood, the shelf life impact of these varying modes is not as clear. That is, the speed of air travel does not necessarily ensure a high quality for the customer.

B. OBJECTIVES

This thesis examines the modal decision and related handling processes as they affect FFV quality and analyzes the effectiveness of the current shipping process. The purpose is to identify how best to extend the shelf life of perishable items during transportation from CONUS to the Pacific Rim, specifically Guam, in order to ensure high quality FFV is turned out to the customer in a cost effective manner. Furthermore, it discusses the many considerations with which the decision maker must be familiar to ensure high quality FFV is maintained throughout the shipment process.

C. SCOPE

The scope of this thesis includes:

1. Research on the existing transportation procedures and relative costs of shipping FFV to customers on Guam;

2. Research on the advantages and disadvantages of surface and air shipments;

3. Research on transportation containerization, including controlled atmosphere containers; and

4. Research on additional factors related to the transportation decision.

The customer base on Guam consists of the two defense commissaries, Andersen and Orote, and the Fleet and Industrial Supply Center (FISC). This thesis focuses only on the two commissaries, since these are the only customers using both surface and air transport for delivery of FFV. The FISC receives only surface shipments.

D. METHODOLOGY

The methodology is:

- Determine existing transportation mode decision processes and identify current pitfalls via interviews with Defense Subsistence Office (DSO) personnel.
- Identify transportation mode differences in terms of scheduling requirements, containerization requirements, and transit time.
- Evaluate shelf life as a function of the transportation mode chosen.
- Research the topic of controlled atmosphere shipping by reviewing available literature and evaluate its potential for extending shelf life.
- Research how commodity compatibility affects shelf life during transportation.

Literature references include a variety of postharvest technology texts and articles from universities specializing in agricultural studies.

E. ORGANIZATION OF THESIS

Chapter II provides a detailed discussion of the factors affecting FFV quality during transit. Chapter III discusses the details associated with the DOD transportation processes for FFV, including mode alternatives and related containerization. It also discusses those additional factors currently affecting door-to-door delivery of FFV to Guam. Chapter IV extends earlier discussions, evaluates the effectiveness of the current transportation process and makes recommendations for its improvement. Chapter V provides conclusions and identifies areas for further research.

II. BACKGROUND

A. PERISHABLES MANAGEMENT

Perishables may be described as items that are subject to deterioration over time, including items such as meats, seafood, dairy products, fresh flowers, fresh fruits, and fresh vegetables. In the context of this paper, perishables will refer to FFV. Specific emphasis will be placed on the issue of perishability during transportation.

There is a variety of factors affecting the shelf life of perishables throughout the supply chain, from harvesting to final delivery. The following sections address specific factors that must be considered and properly managed during the transportation leg of the supply chain.

1. Temperature

In general, the deterioration rate for a specific commodity is proportional to the respiration rate for that item, where respiration is defined as:

> ...the process by which stored organic materials (carbohydrates, proteins, fats) are broken down into simple end products with a release of energy. Oxygen (O_2) is used in this process and Carbon Dioxide (CO_2) is produced....The energy released as heat, known as vital heat, affects postharvest technology considerations, such as estimations of refrigeration and ventilation requirements. [Kader, 1992a]

Therefore, temperature control during transportation influences the respiration rate and thus the rate of deterioration.

Improper temperature control can lead to adverse circumstances including freezing injury, chilling injury, and heat injury. Each of these disorders can occur when temperatures are not appropriately maintained relative to commodity-specific storage temperatures. Because recommended storage temperatures vary by commodity, some item segregation must occur during transportation, if shelf life is to be prolonged. The idea of commodity compatibility is unique to the shipment of perishables and complicates the transportation decision process. [Kader, 1992a]

2. Humidity

Relative humidity is another critical factor in prolonging shelf life during transportation. The results of poor humidity control include product dessication due to dry air, or mold and bacteria growth due to very damp air. [Frith, 1991]

According to the Shipowner's Refrigerated Cargo Association,

> Generally levels between 90% and 95% are recommended for fresh vegetables and up to 98% for root crops. For fresh fruit levels vary but are generally between 85% and 95% depending on the fruit and variety. [Frith, 1991]

As a result, commodity-specific humidity levels, like temperature, require an understanding of item compatibility during transportation, further complicating the transportation decision process.

3. Air Circulation

Related to and affecting both temperature and humidity during transportation is the adequacy of air circulation. Inadequate air circulation can

> adversely affect localized product temperatures and result in a wide spread of temperature through the load. This together with the effect of localized humidity and weight loss combine to reduce the quality of shelf life. [Frith, 1991]

4. Stowage

Stowage is important because it must prevent undesired handling damage and must also permit adequate air circulation. Therefore, less than adequate stowage can not only result in physical damage, but also in temperature-related or humidity-related injuries.

5. Packaging

Packaging is an additional factor affecting perishable shelf life in terms of temperature control, air circulation and protection. At present, DSO permits the FFV supplier to determine the types of cartons provided. However, the quality of packaging can have a substantial effect on FFV condition upon delivery. According to Mitchell, the use of proper commodity-specific packaging can facilitate temperature management, protect against water loss, assist in uniform ripening, and provide physical protection during handling [Mitchell, 1992].

6. Ventilation

Ventilation affects shelf life due to the need to regulate respiration, as well as ethylene (C_2H_4)production. [Frith, 1991] Regarding the latter,

> the effects of ethylene on harvested horticultural commodities can be desirable or undesirable, thus it is of major concern to all produce handlers. Ethylene can be used to promote faster and more uniform ripening of fruits picked at the mature-green stage. On the other hand, exposure to ethylene can be detrimental to the quality of most non-fruit vegetables....[Kader, 1992a]

Therefore, ventilation should vary by commodity to extend shelf life. This is unique to the shipment of perishables and complicates the transportation decision process.

7. Atmospheres

Finally, atmospheric control is concerned with ensuring that appropriate conditions exist in terms of O_2, CO_2, and C_2H_4 to extend shelf life for given commodities. Although ventilation and atmospheres are related, atmospheric control can also be influenced by other agents. For instance, ethylene can be absorbed by charcoal filters or silica gel and liquid nitrogen refrigerants can contribute to low oxygen levels. [Frith, 1991]

B. COMMODITY COMPATIBILITY

Knowledge of the conditions affecting perishables contributes to the successful shipment of mixed loads of FFV. When commodities are to be shipped for periods greater than two or three days, mixed loads are only acceptable if the temperature and humidity requirements of the items being shipped are identical. Table 1 shows which vegetables should not be shipped with which others.

0° to 1.5° C (32° to 34° F) RH 95-100%	**4.5° to 7.5° C (40° to 45° F) RH 90-95%**	**10° to 13° C (50° to 55° F) RH 85-90%**	**13° to 18° C (55° to 65° F) RH 85-90%**
Artichokes, Asparagus, Beets, Cabbage, Carrots, Cauliflower, Celery, Lettuce, Mushrooms, Onions (green), Peas, Radishes, Sweet corn	Snap beans, Okra, Sweet peppers, Summer Squash, Tomatoes, pink, Watermelons, Cantaloupes	Cucumbers, Eggplant, Late crop potatoes, Pumpkins, Winter Squash	Early crop potatoes, Sweetpotatoes, Green Tomatoes, Honey Dew melons

Table 1. Grouping of Compatible Vegetables for Transport in Mixed Loads [From Ryall and Lipton, 1979]

Grouping of commodities poses a problem for DOD FFV shipments for two reasons. First, the idea of commodity groupings is not an issue familiar to most DOD transportation personnel due to the lack of specific training available in this area. Second, the volume of FFV to be shipped to Guam within a specific grouping for a single week may be relatively limited. This results in either shipping partial container loads, or in shipping a small volume of a single commodity with commodities with which it should not otherwise be mixed.

As a result of the conditions affecting perishables and the issue of commodity compatibility, numerous considerations must be made in connection with transporting FFV overseas. This complicates both the modal decision and the packaging decision for DOD transportation planners. Chapter III discusses the current DOD system for transporting perishables and identifies the various transport modes employed.

III. DOD TRANSPORTATION OF PERISHABLES

A. TRANSPORTATION PROCESS OVERVIEW AND CHARACTERISTICS

The Defense Supply Center Philadelphia (DSCP) has overall responsibility for providing FFV shipments to customers on Guam. However, DSO-San Francisco, a component of DSCP, actually coordinates the daily operational requirements necessary to meet this objective. DSO-San Francisco procures FFV from the source and awards transportation contracts to effect product delivery overseas. [Jones, 1997]

1. Transportation Modes

In executing the transportation function, DSO-San Francisco uses an intermodal approach. A commercial trucking firm picks up FFV directly from the terminal market or from DSO's warehouse stock depending on the quantity ordered and the available time-frame. Then the trucking firm delivers the FFV to the overseas port of embarkation (POE) which varies by transportation mode. For commercial air shipments the POE is San Francisco; for commercial surface shipments the POE is either Oakland or Los Angeles. Military transportation is no longer used for the shipment of FFV to Guam. [Crowe, 1998]

Upon delivery to the port of debarkation (POD) in Guam, commercial trucking completes the delivery process. For air shipments a commercial freight forwarder is employed to complete the final delivery leg. For surface shipments, the surface transport contractor utilizes its own trucking resources to accomplish final delivery. [Crowe, 1998]

2. Inspections Required by Mode

Shipments sent by air must be inspected by Guam officials prior to transferring the

FFV into the custody of the trucking firm since the air containers are open at the top and do not prevent the release of potentially harmful insects. Air shipments generally arrive at 0030 and government inspections occur at approximately 0600, leaving the FFV exposed to the environment for up to six hours. [Crowe, 1998] Since Guam has an average temperature of eighty-one degrees Fahrenheit and a relative humidity ranging from seventy to eighty percent, this exposure results in reduced product quality in spite of the rapid transportation time.

For surface transport the required inspection need not be performed until the first delivery stop where the containers are opened, since the sealed surface shipping containers prevent against the release of insects. This normally results in inspections occurring at the Orote Commissary, the first of two stops along the delivery route, without substantial delay because such deliveries are made during daylight hours. This results in the FFV being inspected and transferred directly to a refrigerated environment much more rapidly than is true for air shipment. [Crowe, 1998]

3. Transportation Lead Time by Mode

For commercial surface shipments to Guam orders can be accepted by DSO up to eight days prior to the sailing date. The eight day minimum equates to procurement lead time (PCLT) which is required to allow time for purchase, inspection, truck delivery and surface container loading of FFV.

The PCLT for surface shipments is longer than air PCLT for three reasons. First, the higher volume of FFV shipped by surface mode means that greater quantities and types of FFV must be procured by an increased number of buyers.

Second, the surface carrier requests one week's notice to reserve the exact number of containers required to accommodate the forthcoming FFV shipment since these containers are in limited supply and are not always returned to the inventory pool on time, due to the inherent variability in ocean shipping schedules. Therefore, DSO runs the risk of not having sufficient containers if the contractor is not notified in advance of its requirements.

Third, FFV for surface shipments is frequently procured by field buyers purchasing items directly from the source (source-loading) as opposed to obtaining similar products at the terminal market, a type of wholesale marketplace located near the POE. While source-loading is often used in order to obtain goods at a lower unit cost than at the terminal market, it also requires additional administrative time. With source-loading, the field buyers, who report directly to DSCP and not to DSO, must be provided with order requirements three days prior to the required delivery date based on existing guidelines. This is not true for DSO's own buyers who usually can obtain FFV at the terminal market with only one day's notice. [Crowe, 1998]

In total then, the minimum transportation lead time (TLT) is twenty-two days because surface shipments take fourteen days in transit. Presently, surface shipments are scheduled to depart the POE once per week. [Crowe, 1998] This implies that the surface lead time may increase to twenty-eight days in a worst-case scenario in which the eight day procurement lead time window is just missed by the customer.

For commercial air shipments the transportation lead time is as little as six days with flights departing the POE every Monday. To accommodate Monday departures, customer orders must be received by the preceding Thursday to permit for three days of procurement lead time. PCLT is shorter for air shipments due to the lower volume of goods required and because DSO's own buyers require less lead time to procure goods at the terminal market than do field buyers for surface shipments.

However, a further two day lead time reduction could still be achieved by eliminating the impact of the weekend and scheduling departures on Wednesdays, although the current air service contract provides only for Monday departures as currently written [DOD contract, 1995]. A representative comparison of the air and surface lead times is shown in Figure 1.

Surface Mode

Order received by DSO	PCLT = 8 days	TLT = 14 Days

Air Mode

Order received by DSO	PCLT = 3 days	TLT = 2 days

Figure 1. Lead Time Comparison

4. Transportation Lead Time Implications

Transportation lead time represents the longest portion of the total supply chain for FFV and the longest period during which perishables must be properly maintained in transit. Even under ideal circumstances the shelf life of most FFV is extremely limited, further emphasizing the need to achieve optimal conditions throughout the transportation cycle. Table 2 shows a measure of how long perishables can be expected to survive without substantial deterioration based on research performed in 1992 [Kader, 1992a].

Relative perishability	Potential storage life (weeks)	Commodities
Very high	<2	Apricot, blackberry, blueberry, cherry, fig, raspberry, strawberry; asparagus, bean sprouts, broccoli, cauliflower, cantaloupe, green onion, leaf lettuce, mushroom, peas, spinach, sweet corn, tomato (ripe)
High	2 to 4	Avocado, banana, grape (without SO_2 treatment), guava, loquat, mandarin, mango, melons (honeydew, crenshaw, Persian), nectarine, papaya, peach, pepino, plum; artichoke, green beans, Brussel sprouts, cabbage, celery, eggplant, head lettuce, okra, pepper, summer squash, tomato (partially ripe)
Moderate	4 to 8	Apple and pear (some types), grape (SO_2 treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate, pummelon; table beet, carrot, radish, potato (immature)
Low	8 to 16	Apple and pear (some types), lemon, potato (mature), dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam
Very low	>16	Tree nuts, dried fruits and vegetables

Table 2. Fresh horticultural crops classified according to their relative perishability and potential storage life in air at near optimum temperature and relative humidity

5. Modal Costs

Although transportation lead times vary greatly between surface and air, so do the costs associated with these two modes. Under the current DOD contract F11626-95-D0040, air transportation services are provided at a rate of $1.60 per gross pound [DOD contract, 1995]. Surface rates are not available on a price per pound basis, but are established per container meaning that per pound costs may only be determined by dividing the container fee by the number of pounds of FFV shipped on a given date. This type of price per pound computation is not normally tracked.

However, according to an estimate from DSO-San Francisco air transport costs approximately four times that of surface transport [Crowe, 1998]. This approximation is consistent with the 1994 thesis findings of Lieutenant Commander Gerard Brenner in which he identified the air to surface cost ratio as three and a half times [Brenner, 1994].

Since the use of air transport by the Andersen and Orote commissaries is limited by transport funding allocations authorized by the Defense Commissary Agency (DeCA) only a limited volume of FFV may be transported by airlift each week. As a result, both commissaries focus on making an appropriate modal decision in order to operate within cost constraints. [Crowe, 1998]

B. MODAL EFFICACY IN TRANSPORTING PERISHABLES

Within the DOD transportation process, perishable management varies depending on mode of transport. As such, the air and surface modes differ in their treatment of conditions affecting perishables (temperature, humidity, etc.) and commodity compatibility. This section examines these differences for the surface transport mode, both standard and controlled atmosphere, and for the air transport mode.

1. Standard Surface Transport

Standard surface transport means basic refrigerated or non-refrigerated container transport, with or without humidity control. This mode of shipment is used exclusively for commodities which are known not to benefit from controlled atmosphere technology which will be discussed later in this chapter. Commodities normally shipped by standard surface transport include beets, potatoes, carrots, and radishes. [Crowe, 1998]

a. Temperature/humidity/air circulation

Temperature and humidity can be controlled by sophisticated refrigeration plants. In recent years,

> the marine container industry has made significant improvements in temperature control which are of particular importance for the carriage of chilled produce over long distances involving total time spans of six to eight weeks. Temperatures are controlled to within +/-0.25C° of set point while the differential between supply and return air temperatures is minimized by high continuous rates of air circulation. [Frith, 1991]

As for humidity control, newer refrigerated containers can provide for humidity to be controlled in the range of 50% to 95% which is desirable for most FFV. [Frith, 1991]

b. Stowage

Normal stowage does not restrict air circulation since stacking heights are limited by lines etched on the interior of the container at heights that permit air flow above and around commodities. The use of appropriately placed dunnage can further protect the product and assist in forcing the desired air flows. [Crowe, 1998]

c. Ventilation

Ventilation of the load compartment is achieved via air exchange units to reduce undesirable gas concentrations, to eliminate odors, and to prevent depletion of oxygen to harmful levels.

d. Commodity Compatibility

Compatibility is an important issue for long transit surface shipments. This means that the factors of carriage temperature and humidity, ethylene production rates, stowage patterns for circulation, and sensitivity to odors of other products must be considered prior to stowing a mixed load.

2. Controlled Atmosphere (CA) Surface Transport

While refrigeration and proper humidity control are the most effective ways to retard spoilage, additional treatments have been found beneficial in prolonging shelf life. The application of CA is one such treatment currently used by DOD in the shipment of FFV to Pacific Rim locations.

CA surface transport possesses the same characteristics discussed above, but also uses CA technology as applied by Transfresh Corporation, DSO's contractual agent. CA storage does not improve the quality FFV relative to its original condition at time of purchase, however it has been proven to retard further deterioration and help maintain the quality of FFV for periods longer than would be expected in normal atmospheric conditions. CA is

> a technique for maintaining the quality of produce in an atmosphere that differs from air in respect to the proportion of oxygen, carbon dioxide, or nitrogen. The process involves refrigerating an insulated gastight [container] and controlling the atmosphere within so that it is higher in carbon dioxide and lower in oxygen than normal. [How, 1991]

CA's potential benefit for extending the life of perishables varies by commodity. Table 3 provides a baseline for CA benefits to specific commodities when stored at prescribed temperatures with the appropriate gas mix based on Kader's research. Under "Remarks," the extent of commercial use of CA technology as of 1992 is indicated for most commodities. [Kader, 1992b]

Commodity	Temp. (C)°	%O_2	%CO_2	Potential for benefit	Remarks
Tree Fruits					
Apple	0-5	1-3	1-5	A	
Cherry	0-5	3-10	10-15	B	Some commercial use
Grape	0-5	2-5	1-3	C	Incompatible with SO_2 fumigation
Peach	0-5	1-2	3-5	B	Limited commercial use
Raspberry	0-5	5-10	15-20	A	Increasing use during transport
Strawberry	0-5	5-10	15-20	A	Increasing use during transport
Tropical fruits					
Banana	12-15	2-5	3-10	B	Limited commercial use
Grapefruit	10-15	3-10	5-10	C	No commercial use
Lemons, limes	10-15	5-10	0-10	B	No commercial use
Mango	10-15	3-5	5-10	C	Limited commercial use
Pineapple	8-13	2-5	5-10	C	No commercial use
Vegetables					
Broccoli	0-5	1-2	5-10	A	Limited commercial use
Cantaloupes	3-7	3-5	10-15	B	Limited commercial use
Lettuce	0-5	1-3	0	B	Some use with 2-3% CO added
Mushrooms	0-5	air	10-15	C	Limited commercial use
Onions, dry	0-5	1-2	0-5	B	No commercial use; 75% RH
Potatoes	4-12	None	None	D	No commercial use
Tomatoes, ripe	8-12	3-5	0-5	B	Limited commercial use

A = Excellent, B = Good, C = Fair, D = slight or none

Table 3. Summary of recommended CA conditions during transport for selected fruits and vegetables at relative humidities of 90-98%, unless otherwise indicated

As a result of recent and continuing advances in CA technology, its application since 1992 has been expanded to additional commodities and the marginal benefit to commodities previously shipped under CA conditions has continued to improve from that of the baseline shown in Table 3.

For instance, according to Transfresh, Mangos can now be transported in a CA environment for transits from fourteen to twenty-five days with improved arrival quality, lower ripeness levels, and less incidence of decay. Additionally, CA can now be successfully applied for surface shipments of cherries, lettuce, and peaches for periods up to twenty-one, twenty-five, and thirty days, respectively [Transfresh, 1998]. This represents an improvement over Kader's 1992 perishability findings from Table 2 in which he ranked the potential storage life of lettuce and cherries at less than two weeks and peaches at two to four weeks.

3. Air Transport

The management of conditions affecting perishables is relatively less complex in the air transport case due to the shorter in-transit time. However, deterioration can still occur when these conditions are neglected by management. In fact, according to Kasmire and Ahrens, product warming and weight loss often present serious problems in air shipments due to delays at destination terminals where products are subject to ambient temperatures after aircraft offload. [Kasmire and Ahrens, 1992]

a. Temperature/Humidity/Stowage

FFV is block stacked in either A-2 or LD3 air shipment containers and is insulated with thermal blankets. The FFV is then cooled with portable ice packs placed on top of the stack. However, this cooling method presents temperature control problems because the exact degree of cooling required by the specific commodity and the cooling efficiency of a specific number of packs is not known. However, a more sophisticated cooling method is not available because installed aircraft refrigeration continues to prove impractical due to weight and payload tradeoffs. Finally, humidity control is not provided by this mode.

b. Air Circulation

Block stacking is used within the A-2 and LD3 containers to minimize shifting of cartons during transit [Crowe, 1998]. However, block stacking also results in decreased air circulation in the interior of the stack.

c. Ventilation

Ventilation is available through the open tops of both the A-2 and LD3 containers. However, the exact degree of ventilation achieved is unclear because circulation is minimized by the use of thermal blankets placed over the block stack to aid in temperature regulation.

d. Atmospheres

Atmoshperic control is not available in air shipments, nor would it be necessarily beneficial given the relatively short transit times involved. The absence of installed refrigeration represents a much greater present challenge for the airline industry.

e. Commodity Compatibility

Compatibility is not considered due to the relatively short transit time involved. [Crowe, 1998] As stated earlier, this compatibility issue only arises for shipments of two to three days duration. Since air transport accommodates worldwide shipments in less than thirty-six hours, compatibility is not problematic.

C. CURRENT DOD PROCESSES

At present, the modal decision is made by the commissary customer based on relatively limited criteria: expected shelf life, product weight and required delivery date. [Mallorca, 1998] Using this criteria, customers most often request air shipment of lighter weight items and highly perishable items as well as urgent requirements to counteract stock outages.

Items commonly air-shipped on a recurring basis include prepacked salads, tomatoes, cherries, strawberries, mangoes, red leaf lettuce, green leaf lettuce and romaine lettuce. [Crowe, 1998] These items all range from high to very high on the perishability scale as illustrated in Table 2 of Chapter 2, making these items reasonable candidates for air shipment. However, CA surface shipments also represent a viable modal alternative for commodities such as cherries, lettuce, and mangos, as previously mentioned.

For items designated surface shipment, the need for a CA environment is determined by DSO relying on well-established industry guidelines and recommendation provided by Transfresh. These guidelines group commodities by atmosphere and temperature and codify the recommended gas mixture to be applied based on Transfresh proprietary information. [Crowe, 1998]

Despite these well-established procedures for transporting perishables, FFV quality upon arrival continues to be a problem at both the Orote and Andersen Commissaries. [Mallorca, 1998]. The next section analyzes problems related to the current shipping process and makes recommendations for its improvement.

IV. PROCESS EVALUATION AND RECOMMENDATIONS

A. RECENT RESULTS

Despite the use of multiple transport modes to reduce product deterioration in transit, recent results of FFV shipments to Guam have not been satisfactory. A review of the December, 1997 and January, 1998 FFV arrival reports revealed that 44 of 377 line items shipped by both transport modes were received in a deteriorated condition, and that weekly losses were greater than $4,500.

According to Andersen's Deputy Commissary Officer, air transport losses frequently include items such as watercress, cabbage and other leafy greens that are regularly quarantined due to insect infestation, while tomatoes and green onions are often not marketable due to over-ripening [Mallorca, 1998]. As for CA surface transport, a report provided to DSO-San Francisco by NITEC Corporation, based on its monitoring of a November, 1996 shipment revealed the types of problems often experienced in surface shipments. Of 43 line items container-shipped from Oakland on November 5th in three different controlled atmospheres, 14 line-items arrived in "poor" condition. The report further indicated that according to the Orote Commissary Officer these results were consistent with his week-to-week experience during that time frame. [NITEC, 1996]

While recent discussions with representatives from DSO-San Francisco and from both commissaries indicated that the product quality for both transport modes has improved over the last year, there was general agreement that quality and consistency could improve further if problems in the current system could be overcome. These problems included both process and mode-specific issues.

B. MANAGEMENT CHALLENGES

Problems with the current transportation logistics process can be broken into the following categories: contractual performance, order volume, order administration, customer feedback, and infrastructure.

1. Contractual Performance

DSO-San Francisco has noted that the service levels provided by both air and surface contractors are not always consistent, based on feedback it has received from both commissaries. DSO further points out that monitoring of contractor performance is difficult due to the absence of required contractor reporting of temperature control on each weekly delivery. The absence of routine reporting makes it difficult to identify when and where temperature control, or other shipping problems, have been encountered during transport.

a. Air Transport

The flight route to Guam requires a layover of approximately four hours in Japan where all cargo is offloaded from the inbound aircraft and reloaded onto another plane. Although the contractor is required to maintain the temperature of FFV within ± 5° F of its original loading temperature, temperature measurements are not reported to DSO, and this contractual obligation is not enforced by the Government. DSO states that based on recent discussions with the air service provider, re-icing of the product to maintain desired product temperature is not presently occurring during the Japan layover [Crowe, 1998]; however, upon arrival in Guam, FFV are often exposed to the prevailing environment while awaiting agricultural inspection. While the physical limitations discussed above result in FFV often arriving at a higher temperature than desired, based on pulp temperature readings performed by the DOD receipt inspectors, the absence of contractor temperature reporting means that the point in time at which temperature control was lost cannot be determined precisely. Only with such information can DSO and the air carrier begin to identify possible solutions for improved temperature control.

DSO could improve this process in two ways. First, DSO must educate the air service provider on why temperature control is such an important issue from a customer viewpoint, and must re-emphasize the existing contractual requirement for temperature maintenance in the $\pm 5°$ F range. Second, DSO should require temperature readings from the contractor upon arrival in Japan, prior to departure from Japan, and upon arrival in Guam in order to form a basis for evaluating service quality. This reporting mechanism would permit DSO to properly identify if and when temperature control is lost during transit so that an improved control process could be designed, if necessary.

If such reporting indicated that temperature control could not be achieved by this particular carrier, then DSO would face three possibilities. One, DSO could evaluate other potential air service providers and award a contract to a more qualified shipper. Two, it could place an even greater emphasis on shipping more and varied commodities via surface transport and reduce the corresponding use of air shipping. Or three, DSO could continue to air ship with the knowledge that a certain percentage of FFV would not be marketable upon arrival in Guam.

b. Surface Transport

Deficiencies cited by DSO include the lack of sufficient powered tractortrailer chassis and drivers and the absence of an established feedback mechanism regarding performance. The lack of powered trailers means that some CA containers, once offloaded from the ship, have no power source to support continuous operation of their refrigeration units. As a result, the high temperatures of Guam quickly warm the shipping container. The rising temperature of the container warms the FFV inside to unsatisfactory levels and also causes condensation to gather on the floor of the container. The condensation frequently weakens the cartons in which the FFV is stored, tending to collapse the commodity stow and causing physical damage to the FFV.

The lack of drivers in Guam means that immediate drayage is not always possible, potentially exposing FFV to undesirable environmental conditions for prolonged periods as a result of a lack of refrigeration. However, even if additional powered tractor-trailers were available to provide for continuous temperature control, the lack of drivers unnecessarily delays delivery to the commissaries. This means that these perishable products have less marketable shelf life once they are received by the commissaries and can even contribute to occasional stock outages.

Both the lack of powered tractor-trailers and the lack of drivers are issues under the surface shipper's responsibility, given its contractual requirement to make delivery from POE to POD and also from POD to the commissaries' warehouses. DSO recently has directed that the contractor resolve these equipment and personnel issues in order to remain in compliance with contractual requirements. Additionally, DSO has evaluated the capacity of other surface contractors to meet its requirements in the future, should the current contractor fail to respond to DSO's directions. [Crowe, 1998] The potential for

DSO to replace the current contractor will likely provide an appropriate stimulus to resolve these issues promptly, but DSO must remain prepared to award the FY 1999 contract to an alternate contractor, should difficulties continue in these areas.

As for surface reporting to DSO, although container temperatures are monitored by the contractor during transit, DSO obtains temperature logs only upon request and is not necessarily made aware of problems encountered in transit, such as refrigeration failure or high temperature readings. As in the case of air transport, DSO must insist on routine reporting so that it can monitor and evaluate contractor performance with respect to temperature control and to identify problem areas, if any, in the current shipping process. DSO should view repeated loss of temperature control as contractor noncompliance and take appropriate actions, consistent with the legal terms of the contract, to withhold payments or terminate the agreement. Alternatively, for instance, DSO could amend its existing contract to state that loss of temperature control will result in a charge against the contractor in an amount equal to the value of FFV damaged in transit. Regardless of the exact approach undertaken by DSO, the contractor's service level and incentives with respect to temperature control must be linked.

2. Order Volume

The quantity of FFV ordered by Guam commissaries on any given week is often not adequate to maximize use of container capacity while permitting ideal mixed loads to be formed in support of CA surface shipments. This has two adverse effects. First, DSO must resort to temperature and CA settings that accommodate the majority, but not the entirety, of the loads being shipped in order to avoid the cost-prohibitive practice of loading a small volume of a single commodity into its own container. Second, this means that some line items are forced into mixed loads that deviate from the commodity groupings recommended in Table 1.

For instance, most weekly CA shipments to Guam are loaded in containers set to temperatures of 33° and 45° F (.5° and 7.2° C, respectively) to accommodate the majority of the line items. This means, for example, that a cucumber shipment too heavy for air transport would be loaded into the 45° F van, not only too cool for this commodity but also creating an improper mixed load. While DSO representatives recognize the problems created by such loads, the practice is driven by the need to reduce shipping costs.

This problem of container under-utilization could be solved in two ways. First, DSO could consolidate its current commissary FFV requirements with those of the FISC. Such a consolidation of FISC and commissary requirements formerly was occurring until late 1996. However, when the commissaries and the FISC could not agree on procedures for sharing personnel for common offloading tasks, requests for separate shipments originated from the commissary activities [Crowe, 1998]. Re-establishing a relationship among these activities would benefit DSO by creating a higher aggregate demand. This would allow DSO to maximize container utilization and to increase the number of temperature and CA container variants shipped to Guam on a weekly basis, thus improving product quality. Due to the relatively small size of the island of Guam, such a consolidation would have little effect on the scheduling and transport aspects of delivering consolidated shipments.

Second, DSO could identify opportunities to ship non-FFV line items such as canned provisions, uniform items, or other goods shipped by DOD activities along with FFV to Guam. Such a concept was applied with success in the early 1990's, but was not sustained after the officer-in-charge of DSO, who had established this process, departed due to a normal tour rotation. [Kerber, 1997] While this approach to resolving container utilization is more administratively intensive and may possess more transportation tradeoffs than that of the FISC and commissary consolidation, DSO could examine this opportunity further to determine if overall efficiencies could be achieved.

3. Order Administration

The current FFV ordering system is a "pull" system in which the commissaries identify their requirements to DSO on a weekly basis and the customer order is "pulled" from the source. This approach adversely affects the procurement lead time for surface CA shipments because orders must be received by DSO at least eight days in advance to allow DSO to book its exact CA container requirements with the contractor. This eight day requirement stems from the fact that CA containers are not always available due to the variation in container demand associated with unexpected voyage schedule changes or unexpected demurrages.

However, if a push system were established for specific commodities using FFV demand forecasts based on past usage, customer ordering could occur on an exception basis for the relatively small balance of FFV required above the "normal" scheduled shipment. This would permit the DSO to establish a fixed recurring requirement for CA containers with the surface contractor based on the "normal" delivery level. Only in the case of receiving an exception order for a commodity that did not suitably fit into one of the existing van configurations, with respect to temperature and atmosphere, would a tradeoff arise regarding whether to book an additional van for a given volume of commodity. However, if FISC and commissary demand were consolidated as discussed above, aggregate demand would increase as would the likelihood that additional van configurations could be used cost effectively.

The reason such a system is not currently in place is largely because the commissaries view the push concept as an impediment to their control and feel that seasonal demand is too dynamic to accurately forecast [DSRPAC, 1994]. As a result, the success of a push system would rely on the development of a proven forecasting system which is not currently in place at DSO. Therefore, DSO must develop and validate such a forecasting system in collaboration with its customers. Prior to the implementation of such a system DSO needs to satisfy its customers, based on a trail run or simulation, that the forecasting system can adequately meet the customer desires. Additionally, DSO, the commissaries, and FISC must collaborate to design exception ordering guidelines that continue to provide customer flexibility while creating a more static operating process for DSO.

4. Customer Feedback

Feedback is provided to DSO from the commissaries via Arrival Condition Reports for Perishable Subsistence. These reports are used to identify product conformance or deteriorative conditions such as mold, over-ripeness, or bruising. Information from these reports can be used to assist DSO in identifying positive or negative trends regarding shipment results down to the commodity-specific level.

However, DSO is not currently maintaining a database to determine such trends due to manning constraints [Crowe, 1998]. In order for DSO to take corrective steps to improve future shipments, it must establish, monitor, and update an FFV database that provides information supporting the transportation and commodity mixing decision processes.

5. Infrastructure

There are two significant infrastructure shortfalls on Guam with respect to the FFV transportation logistics process. The first shortfall is that both commissaries have only one chill box each to store the total volume of inbound FFV meaning that ideal storage temperatures cannot be achieved for all commodities. [DSRPAC, 1994]

To rectify this problem, three options must be evaluated based on a cost-benefit basis to identify the most appropriate solution. Option one is for both commissaries to reduce order volume and increase order frequency, an option that would likely be more costly from the transportation perspective. Option two is for both commissaries to request additional financial resources to support installation of inherent refrigerated storage facilities at both the Andersen and Orote Commissaries, making both locations completely self-sufficient. Option three is for both commissaries to prepare a joint request for installation of shared refrigerated storage facilities located at either commissary or at a centralized location. This option would create an FFV distribution center for both commissaries, and possibly the FISC.

Shortfall number two is that refrigeration capacity is not available at Guam's airport for temporary overnight storage of FFV pending its agricultural inspection at approximately 0600. Although DSO has sought to resolve this issue through appeals to the air carrier, the carrier has indicated that the airport will not permit it to install a temporary refrigeration capability on site, citing security concerns [Crowe, 1998].

Regarding this issue, DSO needs to negotiate directly with airport authorities, rather than with the commercial carrier, to pursue approval for installing a refrigerated storage capability within the confines of the airport. This would provide DSO, the commissaries, and the FISC with increased flexibility in being able to receive and appropriately store FFV shipments after hours regardless of the air carrier flight schedule. However, if approval ultimately cannot be obtained for such an installation, DSO will need to identify if other air carrier candidates provide day time service to Guam, which would reduce the impact of not possessing an inherent refrigeration capacity at the airport since same-day agricultural inspections could occur during normal working hours.

V. CONCLUSION

The transportation of perishables to Pacific Rim countries is a complex process due to the numerous factors that contribute to their rapid deterioration in transit. In order to consistently achieve optimal FFV quality at the final destination, DOD managers must improve the current transportation logistics system.

A. FINDINGS

1. Contractual Performance

Contractor performance for both transport modes is inconsistent and no requirement exists for shipment status reporting by the contractor to DSO. As a result, it is not possible to evaluate contractor performance on a week-to-week basis.

2. Order Volume

The quantity of FFV ordered by Guam commissaries on any given week is often not adequate to maximize use of container capacity and achieve cost efficiencies. Furthermore, low order volume makes it difficult to ship ideal mixed commodity loads in support of CA surface shipments.

3. Order Administration

The current "pull" type ordering system adversely affects procurement lead time for CA surface shipments and complicates DSO's forecasting of weekly CA container requirements.

4. Customer Feedback

Customer feedback regarding FFV quality upon arrival is not analyzed for trends. As such, DSO cannot adequately evaluate if poor arrival quality is a function of ineffective shipping practices.

5. Infrastructure

Both commissaries have inadequate refrigerated storage capacity and no refrigerated storage exists at the airport to provide for temporary holding of air-shipped FFV upon arrival.

B. RECOMMENDATIONS

1. Contractual Performance

Transport service contracts must be written to provide contractual incentives or penalties based on the contractor service level, particularly with respect to temperature control. Contracts should also require routine contractor reporting to DSO on temperature control for all FFV shipments so that contractor performance can be evaluated objectively.

2. Order Volume

FFV requirements generated by the commissaries and the FISC should be consolidated to achieve cost efficiencies and improve product quality at its destination. Consolidation improves surface container utilization and provides DSO with flexibility to increase the number of container variants, in terms of temperature and atmosphere, that are routinely used for FFV shipments to Guam.

3. Order Administration

The current "pull" system of ordering should be modified so that the majority of weekly FFV is "pushed" to the customer based on historical demand forecasts. A "push" system helps resolve the issue of CA container booking, and reduces order lead time except for FFV quantities requested above the forecast threshold.

4. Customer Feedback

DSO must track and analyze customer feedback on FFV arrival quality by establishing a database. This will assist DSO in determining trends regarding successful and unsuccessful shipping practices.

5. Infrastructure

DSO must negotiate directly with Guam authorities to pursue approval to install refrigerated storage at the airport to provide for adequate storage of inbound air-shipments of FFV while products await agricultural inspection. It should also collaborate with the commissaries and the FISC to obtain financial resources necessary to improve the inherent refrigerated storage capacities for these activities.

C. FURTHER RESEARCH

1. Development of a Forecasting Model

The development of forecasting model is essential to the implementation of a "push" delivery system. Development of such a model could also include factors to optimize commodity mixing while minimizing the number of surface containers required.

2. Evaluation of Alternative Sources of Supply

While this thesis has focused on shipping FFV from CONUS and reducing the effect of this lengthy transit, opportunities exist to identify sources of supply closer to Guam such that transit time issues are lessened. Documenting alternative origins for specific commodities and their barriers to importation, if any, would prove useful in improving the quality of FFV upon its arrival in Guam.

LIST OF REFERENCES

[Brenner, 1994] Gerard Brenner, LCDR, SC, USN. 1994. Costs to Ship Fresh Fruits and Vegetables from Defense Subsistence Office, Alameda via Controlled Atmosphere Containers. Master's thesis, Naval Postgraduate School.

[Crowe, 1998] Dwin Crowe, LCDR, SC, USN, Defense Subsistence Office. 1998. Series of interviews by author from November, 1997 to March, 1998.

[DOD contract, 1995] DOD contract, F11626-95-D0040, Option Year Two covering 2 August 1997 to 1 August 1998.

[DSRPAC, 1994] Defense Subsistence Region Pacific (DSRPAC). 1994. Pacific Surface Initiative and Produce Shipment Losses to Guam. Alameda, California: DSRPAC. Photocopied.

[Frith, 1991] John Frith, editor. 1991. *The Transport of Perishable Foodstuffs*. United Kingdom: Shipowners Refrigerated Cargo Research Association.

[How, 1991] R. Brian How. 1991. *Marketing Fresh Fruits and Vegetables.* New York: Van Nostrand Reinhold.

[Jones, 1997] David Jones, LCDR, SC, USN. 1997. Analysis of Department of Defense (DOD) Overseas Shipment Operations to Japan. Master's thesis, Naval Postgraduate School.

[Kader, 1992a] Abdel A. Kader. 1992. *Postharvest Biology and Technology: An Overview*. Edited by Abdel A. Kader. *Postharvest Technology of Horticultural Crops*. Publication 3311, University of California Division of Agriculture and Natural Resources.

[Kader, 1992b] Abdel A. Kader. 1992. *Modified Atmospheres during Transport and Storage*. Edited by Abdel A. Kader. *Postharvest Technology of Horticultural Crops*. Publication 3311, University of California Division of Agriculture and Natural Resources.

[Kasmire and Ahrens, 1992] Robert F. Kasmire and M. Joseph Ahrens. 1992. *Transportation of Fresh Market Horticultural Crops.* Edited by Abdel A. Kader. *Postharvest Technology of Horticultural Crops.* Publication 3311, University of California Division of Agriculture and Natural Resources.

[Kerber, 1997] Jim Kerber, CDR, SC, USN, Naval Postgraduate School. 1997. Interview by author 13 November, 1997.

[Mallorca, 1998] Roger Mallorca. 1998. Facsimile from Roger Mallorca to Glen Stafford, 23 February.

[Mitchell, 1992] F. Gordon Mitchell. 1992. *Packages for Horticultural Crops*. Edited by Abdel A. Kader. *Postharvest Technology of Horticultural Crops.* Publication 3311, University of California Division of Agriculture and Natural Resources.

[NITEC, 1996] David Kidder. 1996. Mixed load CA test to Guam. Spokane, Washington: NITEC, Inc. Photocopied.

[Ryall and Lipton, 1979] A. Lloyd Ryall and Werner J. Lipton. 1979. *Handling, Transportation and Storage of Fruits and Vegetables,* Volume 1, Second Edition. Westport, Connecticut: AVI Publishing Company, Inc.

[Transfresh, 1998] Transfresh Corporation. 1998. Tectrol Atmospheres Marketing Publication. Salinas, California: Transfresh Corporation.

INITIAL DISTRIBUTION LIST

No. of copies

1. Defense Technical Information Center 2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library 2
   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, CA 93943-5101

3. Chairman, Code SM 1
   Systems Management Department
   Naval Postgraduate School
   Monterey, CA 93943

4. CDR Jim Kerber, Code SM/Ke 1
   Systems Management Department
   Naval Postgraduate School
   Monterey, CA 93943

5. CDR Bill Gast, USNR 1
   5711 East Nancy Lane
   Mead, WA 99021

6. LCDR Glen Stafford 2
   213 First Avenue
   Haddon Heights, NJ 08035