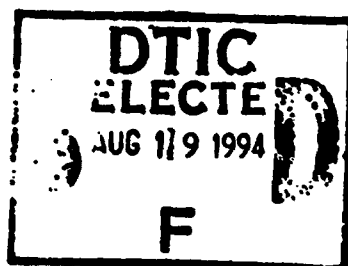


NAVAL POSTGRADUATE SCHOOL
Monterey, California

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THESIS

**A MULTI-COMMODITY NETWORK DESIGN FOR
THE DEFENSE LOGISTICS AGENCY**

by

Robert D. Holmes Jr.

June 1994

Thesis Advisor:

Robert F. Dell

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A Multi-Commodity Network Design for the Defense Logistics Agency

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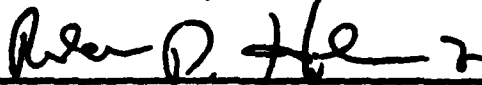
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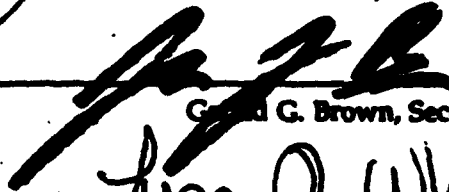


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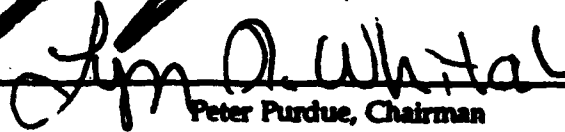
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ABSTRACT

The Defense Logistics Agency (DLA) currently operates 28 depots in the United States from which it supplies over 45,000 customers with over three million products procured from over 10,000 suppliers. DLA plans to reduce its infrastructure and proposes to analyze its distribution system using the Strategic Analysis of Integrated Logistics Systems (SAILS) model - a mixed integer linear programming model widely used by civilian organizations to make facility location and logistics network design decisions. The size of DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. This thesis derives a 29 product, 113 customer aggregation scheme which facilitates SAILS execution and appears to adequately capture sufficient detail to accurately model DLA. Extensive comparisons between this aggregation scheme and others (44, 49, and 67 product; and 199 and 113 customer aggregations) at 100, 90, 80, 50, and 30 percent of derived depot throughput capacity show solutions to different aggregations result in virtually identical closure recommendations and total annual costs. This thesis shows how DLA can save over 300 million dollars annually through depot closure and reorganization.

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EXECUTIVE SUMMARY

This thesis shows how the Defense Logistic Agency (DLA) can save over 300 million dollars annually through depot closure and reorganization. This conclusion follows extensive analysis of DLA's distribution network using the Strategic Analysis of Integrated Logistics Systems (SAILS) model - a mixed integer linear programming model widely used by civilian organizations to make facility location and logistics network design decisions. This thesis derives a 29-product, 113-customer aggregation scheme which facilitates SAILS execution and appears to adequately capture sufficient detail to accurately model DLA. Extensive comparisons between this aggregation scheme and others (44-, 49-, and 67-product; and 199- and 113-customer aggregations) at 100, 90, 80, 50, and 30 percent of derived depot throughput capacity show solutions to different aggregations result in virtually identical closure recommendations and total annual cost.

The Defense Logistics Agency (DLA) currently operates 28 depots in the United States from which it supplies over 45,000 customers with over three million products procured from over 10,000 suppliers. DLA must reduce operating costs to accommodate declining Defense budgets. Consequently, a number of facilities has been slated for closure or realignment under the Defense Base Realignment and Closure (BRAC) Commission's 1991 and 1993 recommendations. DLA will plan further closures for 1995 using the Strategic Analysis of Integrated Logistics Systems (SAILS)

model. The size of DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. Without aggregation, data input and output would be overwhelming even if sufficient computer memory, computational ability, and storage exist to solve the resulting SAILS' mixed integer linear program.

Even with aggregation, modeling of DLA's extensive distribution system requires enormous amounts of data. This thesis uses the following information supplied by DLA: the 1992 Material Release Order files containing over 17 million material shipment transactions totaling over 1 billion pounds from which demand and customer information is obtained, depot fixed and variable costs, and depot throughput capacity information. Because of difficulty obtaining and manipulating the required files, this thesis does not directly model subsistence material which accounts for approximately 25 percent of total demand weight. Instead, it uses a conservative estimate of the depot throughput capacity. From all data, a 29-product, 113-customer aggregation scheme is developed and extensively tested on a 586 66 MHz personal computer with 261 megabytes of extended memory.

Solutions produced using the various aggregation schemes indicate that significant annual savings of over 300 million dollars can be realized from depot closures and reorganization. Recommended closures decrease fixed and variable costs by approximately 349 million dollars while increasing transportation costs by 13.5 million dollars.

I. INTRODUCTION

The Defense Logistics Agency (DLA) must reduce its operating costs to accommodate declining Defense budgets. Consequently, a number of facilities has been slated for closure or realignment under the Defense Base Realignment and Closure (BRAC) Commission's 1991 (BRAC Commission [1991]) and 1993 (BRAC Commission [1993]) recommendations. DLA will plan further closures for 1995 using the Strategic Analysis of Integrated Logistics Systems (SAILS) model (INSIGHT Inc. [1993]). SAILS is a computer program widely used by civilian companies to make plant location, warehouse location, and inventory positioning decisions (Appendix A contains the underlying mixed integer linear program at the heart of SAILS). The size of the DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. Without aggregation, data input and output would be overwhelming even if sufficient computer memory, computational ability, and storage exist to solve the resulting SAILS' mixed integer linear program. This thesis defines aggregation schemes for DLA products, customers, and suppliers for use in SAILS.

A. DEFENSE LOGISTICS AGENCY

DLA's primary mission is timely provisioning of consumable material to Department of Defense activities during either peacetime or wartime. DLA's problem is how to maintain the current level of customer service while closing existing facilities and reducing operating costs. House [1978] succinctly states DLA's dilemma:

The importance of the facility location problem is due primarily to the fact that distribution centers represent significant cost centers in the distribution channel... distribution depots represent points where customer service is provided through the maintenance of inventories. In many situations, it can be shown that as more facilities are sited there is a proportional increase in the amount of customer service provided...[House 1978 p. 1]

The DLA distribution system is primarily a two-echelon system where materials flow in large shipments from suppliers to depots and from these depots in smaller order quantities to the ultimate consumers. A small amount of material flows directly from vendor to customer but suppliers do not necessarily remain constant over time, and therefore this thesis models DLA's distribution system as a pure two-echelon system with no direct vendor to customer flows.

DLA manages a diverse mix of material including subsistence items, aircraft repair parts, clothing, paper products, fuel, medicines, and construction material (DLA, [1992]). To operate the distribution system, DLA has:

- six inventory control points responsible for inventory management of over three million line items.

- 28 distribution depots located throughout the United States responsible for the receipt, storage, and distribution of this material [DLA, 1992].

DLA has recently assumed greater responsibilities as the Department of Defense (DOD) attempts to reduce operating costs by consolidating operations. As the result of Defense Management Review Decisions (DMRD) issued by the Secretary of Defense [1989], the following actions have increased DLA's responsibilities:

- Consumable items previously managed by the individual services have been transferred to DLA; this action has the potential to increase the range of materials managed by 981,000 line items (DMRD 926 [1989]).
- Distribution depots previously operated by the individual services have been transferred to DLA which increased DLA's total number of depots to thirty two (DMRD 902 [1989]).

B. OBJECTIVE OF CURRENT RESEARCH

This study develops aggregation schemes for DLA products, customers, and suppliers which allow DLA's distribution system to be modeled within SAILS and allows SAILS' underlying mathematical model to be solved in a reasonable time without significant loss of fidelity. To evaluate the validity of the aggregation techniques, several commodity and customer aggregation schemes are formulated. Comparisons are made between the solutions generated from the different techniques highlighting significant variation. The base year for

purposes of this study is fiscal year 1992. Historical files for fiscal year 1992 show that DLA:

- procured material from over 10,000 suppliers;
- processed and shipped over fifteen million requisitions with a total weight of over one billion pounds; and
- served over 45,000 customers including all military services and other government activities.

C. THESIS OUTLINE

Chapter II discusses the 1978 Department of Defense Material Distribution System (DODMDS) study and related literature. Chapter III discusses the aggregation schemes developed. Chapter IV provides computational experience. Chapter V presents conclusions and recommendations. Appendix A contains the underlying mathematical model used by SAILS. Appendix B provides a listing of the material groupings managed by DLA. Appendix C presents a statistical summary of the material transaction file supplied by DLA for this study. Appendix D details the four different commodity aggregation schemes. Appendix E describes the customer aggregation schemes.

II RELATED STUDIES

The DLA distribution system was examined in 1978 by the Department of Defense Material Distribution System (DODMDS) study, a joint service effort commissioned after the Vietnam War to reduce DOD operating costs. The purpose of this study was to examine the existing distribution system and recommend improvements which would support individual Service operational requirements in an effective and efficient manner. This chapter reviews this study and studies accomplished on civilian distribution networks which are useful as a foundation for developing aggregation schemes.

A. DEPARTMENT OF DEFENSE MATERIAL DISTRIBUTION SYSTEM (DODMDS) STUDY

The DODMDS study, undertaken in April 1975, examined the distribution systems operated by the Army, Air Force, Navy, Marines, and DLA within the fifty United States. This study examined the entire DOD distribution network which included maintenance depots as well as storage facilities. All material managed by these services and required within the United States and overseas was included with the exception of the following products: bulk petroleum, perishable subsistence; ammunition; chemical, biological, and

radiological items; industrial plant equipment; and some major end items (i.e., ships, aircraft, and strategic missiles) (DODMDS [1978] Vol I p. 9). Because of the inclusion of repairable components and the need for this type of material to be returned to maintenance facilities for repair, the material return network was examined as well. Released in 1978, the study provided an optimal distribution network for DOD, but these results were never implemented.

The DODMDS study group acknowledged a problem which is inherent in any examination of a system this extensive where data aggregation is required:

Large scale studies have frequently been criticized for aggregating a problem out of existence and unwittingly biasing the results through the aggregation process. (DODMDS [1978] Vol I p. 27)

DLA agreed with this criticism. In their opinion, data aggregation significantly reduces the variability associated with individual items and demand locations (DLA [1978]). The major assumption underlying the DODMDS study is demand stability and this situation is not always the case with DLA's demand patterns. Hobbs and Lanagan [1992] find that demand stability for DLA requirements is an erroneous assumption. According to their study, demand variability exists on three levels:

- Examining total demand across all commodities and over a 10 year period, annual demand experiences a 33 percent decrease from a peak year to the minimum period;

- Within two commodities examined individually (Electronics and General), annual demand decreases approximately 25 and 30 percent respectively over a seven year period;
- Using two different populations of items and the six original DLA depots (Mechanicsburg, Richmond, Memphis, Columbus, Ogden, and Tracy), Hobbs and Lanagan examine the workload variability for these depots over a two year period. For population A (103,000 items), these depots experience shifts in the number of transactions from an increase of 10 percent to a decrease of 3 percent and decreases in shipment quantities from 12 percent to 20 percent. For population B (219,000 items), the number of transactions vary from an increase of 9 percent to a decrease of 7 percent and the quantities shipped vary from a plus of 2 percent to a minus 23 percent;
- Using the same two population groups (population A, 103,000 items and population B, 219,000 items) and 11 customer groupings, Hobbs and Lanagan examine the variability of demand within customer clusters over a two year period. For population A, the number of transactions processed vary from a plus 8 percent to a minus 6 percent and the actual quantities shipped varies from a minus 3 percent to a minus 29 percent. For population B, the number of transactions vary between a plus 4 percent to a minus 16 percent while the actual quantities shipped varies from a minus 3 percent to a minus 26 percent.

These results show that customer demand may not be stable between periods for a geographic location but offer no predictive estimates of future demand patterns. Experience with SAILS in the private sector (Karrenbauer [1994]) has shown that demand variability with commercial organizations far exceeds that reported by Hobbs and Lanagan [1992] and that DLA's distribution network can be meaningfully accommodated by SAILS. SAILS develops a optimal strategic distribution network (i.e., determines optimal depot locations for the network operating over a long time-frame) as opposed to a tactical or operational plan designed to make daily decisions.

This study, like the DODMDS study, bases its analysis and conclusions on one year's historic data.

The aggregation techniques utilized in the DODMDS study are used as a template for the schemes of this current study. Specific similarities and differences between the aggregations of the DODMDS study and the ones presented in this thesis are addressed in follow on chapters.

B. OTHER STUDIES

In recent years substantial research has been accomplished discussing location analysis for plants, distribution facilities, retail activities, and service centers (House [1978]; Geoffrion [1976]; Geoffrion and Graves [1974]; Ghosh and McLafferty [1987]; Khumawala and Whybark [1971]; Klinecicz [1985]; Neebe and Khumawala [1981]; Cooper [1967]; Geoffrion and Powers [1993]). According to Geoffrion and Powers [1993 p. 2], these studies have resolved the following basic distribution network planning questions:

- How many distribution centers should there be and where should they be located?
- What size should each distribution center be and what products should it carry?
- What distribution center (plant) should service each customer?
- Should all stocking points carry all products or specialize by product line?
- How should each plant's output be allocated among distribution plants/customers?

- What should the annual transportation flows be? Should pool points be used, and if so where should they be?
- For a given level of customer service, what is the cost savings for the proposed system?

On the other hand, there has been limited research conducted on the aggregation techniques necessary to facilitate data input into these models and the results these schemes have on final solutions. As House and Jamie [1981] state:

Research conducted in the past several years has focused almost exclusively on techniques employed in planning... very little research appears to have been conducted in determining the sensitivity of planning results to the methods employed in aggregating data. (House and Jamie [1981])

Recent improvements in computers and the location models allow inputs to be much more voluminous and detailed than previously, but data aggregation is still necessary. Eender acknowledges the importance of aggregating data correctly:

The most critical step in the analysis and design process is to determine the right level of data aggregation: the more aggregated the data, the greater the potential errors in analysis, but the simpler it is to analyze, and the cheaper it is to assemble. (Bender [1985] p. 157)

1. PRODUCT AGGREGATION

DLA manages over three million line items. Recognition of each of these products individually is impractical for any facility location model thus some product aggregation is required.

To aggregate products there are four factors according to Bender which must be considered: (Bender [1985] p. 157)

- Market: identify the top products which account for the bulk of material shipped; account for the different sales ratios in the various markets;
- Logistic: aggregate products with similar transportation rates, handling, and storage characteristics;
- Production: aggregate products with similar unit production costs and those produced in the same plants; and
- Organizational: aggregate products based on any unique requirements of the organization.

The aggregation studies reviewed in this thesis have not concentrated on product aggregations. These studies (House and Jamie [1981]; Ballou [1991] and [1993]) examine distribution systems comprised of a limited number of consumer oriented products or product lines where the need to aggregate has not been considered or the aggregation scheme is straightforward. With product aggregation, the variability inherent in individual products is reduced. Ballou [1991] diminishes the importance of product differences concluding that these differences did not play a major factor in demand cluster determinations:

Different transport rates associated with different products do not significantly affect the number of clusters to be used or the manner in which the clusters are formed... product differences and their shipment sizes can be eliminated as an important variable in the selection of demand clusters. (Ballou [1991] p. 14)

Civilian distribution systems typically manage similar products. Conversely, DLA handles a varied line of products. This study determines whether product aggregation schemes have an impact on depot location decisions.

2. GEOGRAPHIC CUSTOMER AGGREGATION

DLA has over 45,000 customers. Recognition of each of these customers individually is impractical for any facility location model thus some customer aggregation is required.

A number of approaches has been used by analysts to aggregate customers including grouping customers by: geographic proximity, type of customer, type of export, or specific customer service requirements. Georeferencing approaches typically rely on Standard Metropolitan Statistical Areas, individual states, and postal zip code sections to aggregate customers.

Ballou [1993] uses a method that is particularly suited for this study whereby the 900 three-digit zip codes are used as a starting point. The pair of zip codes closest to one another are combined to form one cluster. This process is repeated until the desired number of clusters is attained. The center of the cluster is determined and this point becomes the demand location for that grouping of customers.

Errors arise as transportation costs are calculated based on distance measurements from the service center to the midpoint of a cluster region as opposed to an actual location.

Hillsman and Rhoda [1978] state that three types of errors are created as the result of this estimation:

- Cost error: cost errors results from measuring distance to the service center from the aggregated point instead of from the actual demand points;
- Error is created when the service center is located at the aggregated point in which case the distance from service center to demand is zero. This measurement underestimates the true transportation costs as the center is actually serving dispersed demand; and
- Errors are created when distances from aggregated demand points to service center are used to assign demand to the nearest center. In this situation some demand may be assigned to the wrong center.

Hillsman and Rhoda [1978] analyze the magnitude of these types of errors for contrived demand patterns. They conclude that demand aggregation causes distance measurement errors up to 8% for their contrived demand patterns and expect higher percentages for actual systems.

Extending Hillsman and Rhoda's research, Casillas [1987] conducts a study which determined the effects certain factors have on the facility location problem. Casillas defines the following two types of errors created as the result of demand aggregation:

- Cost-estimate error: the difference between the cost to service aggregated demand from the optimal service location and the true cost of servicing the unaggregated demand from that location;
- Optimality error: the effect of misallocating demand to service centers and the resultant mislocation of these centers based on the use of aggregated rather than unaggregated demand.

Varying "the level of aggregation, the location of aggregated demand points, and the number of service centers to be located," his study determines the effect these factors have on the objective function and the location of the service centers. Casillas' results show that the cost-estimate error is monotonically increasing with the number of source points and the level of aggregation. The results for the optimality error are not as conclusive in that there is no established pattern relating the optimality error with the number of source points and the level of aggregation. Casillas' conclusion is that in general customer aggregation does not have a significant effect on the location of service centers.

Current and Schilling [1987] also extend the research of Hillsman and Rhoda. They state that demand aggregation results in the loss of locational information which may result in suboptimal service center location. Their study devises a method of formulating the aggregated customer regions such that all but the third error (assigning demand to the nearest center) are eliminated. They compare their method to the traditional methods of forming clusters. Current and Schilling's study is accomplished on a distribution network consisting of 681 nodes aggregated into 30 and 70 demand units; five, seven, and nine source points; and uses four different sets of demand data. Using Casillas' definitions for optimality and cost errors, their study yields the following results:

- both optimality and costing errors increase monotonically with the number of sources; and
- both optimality and costing errors decrease as the number of demand clusters increase.

Research conducted by House and Jaimie [1981] on a distribution system consisting of seven market demand systems, eight warehouse networks, three shipment size groupings, and three consumer-oriented products reaches the following conclusions:

- as the number of markets increases, the outbound freight errors decreases;
- error in outbound transportation cost estimation can not be reasonably controlled with market systems of less than 100 aggregated customer points;
- shipment errors can be maintained within 2 - 3 percent with at least 150 markets; and
- as the number of distribution points increases relative to the number of markets transportation costing error increases.

Ballou [1991 and 1993] extends the research conducted by House and Jaimie [1981] examining the transportation costing error occurring in a distribution system. Ballou determines the effect the number of clusters, size of the clusters, and the number of source points have on the transportation costing error. Examining a distribution network consisting of source points ranging in number from 1 to 100, market clusters ranging in number from 50 to 900, and

shipment sizes ranging from 500 pounds to a full truckload ,
Ballou [1993, p. 15] arrives at the following conclusions:

- the usual practice of using 100 to 200 clusters is not applicable to all problems;
- controlling the cluster size during cluster formation can significantly reduce transportation costing error;
- grouping customers by proximity is a reasonable way to form clusters and reduces transport costing error;
- costing error does not exceed 1.5 percent for carefully-formed clusters;
- as the number of sources increases the costing error also rises;
- costing errors are reduced with increased numbers of clusters; and
- costing errors increase as the number of facilities increases relative to the number of clusters.

Ballou [1993, p. 17] presents recommendations for total customer aggregations based on the number of source points, allowable error, and cluster size expressed as a percentage of total demand existing in the distribution network.

In summary, all literature suggests that as the number of customer groupings is reduced the area of the aggregated zone increases resulting in an increase in transportation costing errors. In the formulation of these customer groupings, these authors agree that:

- aggregation by proximity is a reasonable approach; and
- as the number of sources or depots increase relative to the number of customers, transportation costing error increases.

Ballou [1993] suggests that customer groupings in the 100 to 200 range is not applicable to all situations. For distribution networks with 25 source points (DLA's size), his study suggests that the number of customer groupings should be in the 300 to 500 range. This recommendation seems inapplicable to DLA because the top 100 three-digit zip codes account for approximately 84 percent of the material processed. The contention here is that a significant increase in transportation accuracy will not be gained through increasing the number of customer groupings much above 100. This study tests a range of customer groupings between 100 and 200.

3. SUPPLIER AGGREGATION

DLA has over 10,000 suppliers. Recognition of each of these suppliers individually is impractical for any facility location model thus some supplier aggregation is required.

Other than the procurement source aggregation scheme presented in the DODMDS study, there appears to be no other literature on supplier aggregation. The DODMDS study identifies the rationale for aggregating material sources as: "the large number and geographical dispersion of procurement sources; the dimensional limitations of the analytical models; and the need to make the data comprehensible to facilitate analysis" (DODMDS Vol III [1978] Section 4 p. 4.2). Because of the similar objectives, it seems reasonable to aggregate

suppliers in the same fashion as customers, whereby a georeferencing system is used to identify major supplier zones and those remaining are aggregated with the major ones based on proximity. The specific approach used in the DODMDS study is addressed in subsequent sections.

III AGGREGATION SCHEMES

This chapter discusses aggregation schemes for DLA's products, customers, and suppliers. Similarities and differences between aggregations in this thesis and the DODMDS study are highlighted.

A. PRODUCT AGGREGATIONS

DLA manages over three million line items. Recognition of each of these products individually is impractical for any facility location model: Some product aggregation is required. The goal in this aggregation process is to develop categories which are sufficiently homogeneous for modeling purposes: Product groupings should have similar management, shipping, and handling characteristics. Because the DODMDS study is the only study of the literature reviewed which examines product aggregations, the DODMDS study provides the template for the schemes employed in this study.

Each item managed within the Federal supply system is assigned a national stock number (NSN) which uniquely identifies the item. The first four digits of the NSN is referred to as the Federal Supply Classification (FSC) and the last nine digits are the National Item Identification Number (NIIN). Figure 3.1 provides an example of the NSN for a steel wood screw. The four-digit FSC categorizes all material

managed within the Federal system. The first two digits of the FSC identifies the major material groupings (in the example shown in Figure 3.1, FSC group 53 signifies that this item belongs to the Hardware and Abrasives group).

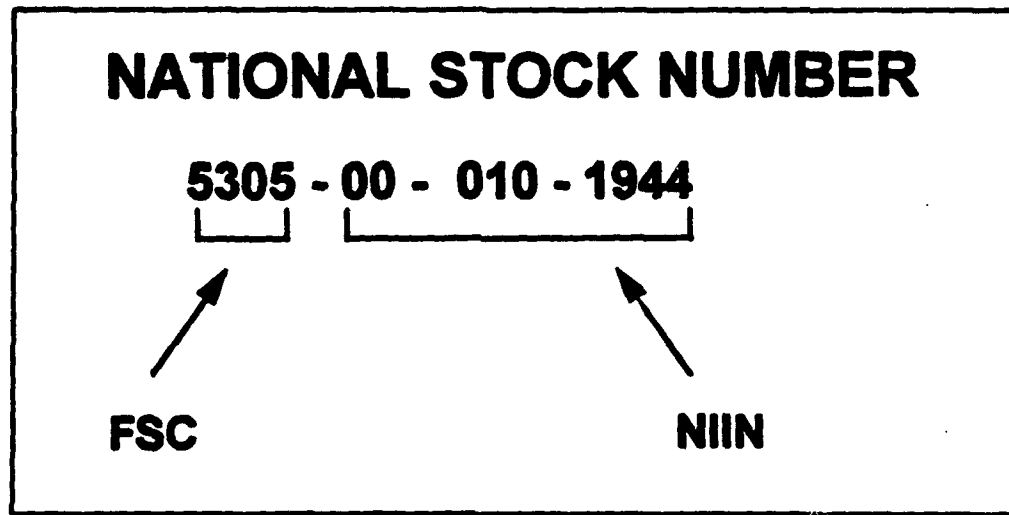


Figure 3.1: National Stock Number for a steel screw. The FSC 5305 expresses the group and class for the item: Group 53 signifies this item belongs to the Hardware and Abrasives Group and Class 05 signifies the item is a screw. The NIIN 00-010-1944 uniquely identifies this particular steel screw.

There are sixty-eight different groups managed by DLA which are listed in Appendix B. The second two digits represent the FSC class which provides a more detailed description of the type of material included in a group (Appendix B provides a detailed description of the classes available in FSC group 53 Hardware and Abrasives). The FSC forms a natural grouping mechanism since it "relates like items of supply and

conversely separates unlike items of supply" (DLA H1 [1985]). Because of the large number of items and the diversity of material managed by DLA, the ease with which an aggregation scheme based on this system could be implemented, as well as the unique requirements of each service, aggregation strategies based on FSC are the most appealing approach.

The product aggregations developed are based on the Material Release Order files for fiscal year 1992 looking at the commodities listed in Table 3.1. These files are provided by the Defense Operations Research Office (DORO) and detailed material shipments for the specific commodities for the year.

Table 3.1: DLA provided the Material Release Order files for FY 1992 which lists all depot-to-customer shipments for FY 1992. All material in the Material Release Order files are labelled according to the following commodities.

Commodity	Material Description
C	Construction
E	Electronics
G	General
I	Industrial
M	Medical
T	Textiles

Because of difficulty obtaining and manipulating the required files, subsistence items (which accounted for 25 percent of total shipment weight in the DODMDS study) are excluded from

this study. This exclusion is modeled by using a conservative estimate of capacity as discussed in the following chapter.

FSC offers an initial grouping of like items based mainly on management criteria. Shipping and handling characteristics are obtained by a statistical analysis of these groupings which shows the degree of homogeneity within FSC. The DODMDS study (DODMDS [1978] Vol III Section 4) subdivided all items within a FSC into fifteen intervals by unit weight, unit cube, and unit price. Statistical analysis of these groupings was accomplished to determine homogeneity within FSC. Four independent groups of analysts determined that like FSC's could be aggregated based on physical characteristics using the following ranking scheme:

- primary importance was placed on unit weight within FSC;
- secondary emphasis was placed on the issue weight for items within FSC; and
- the number of issues of individual items and the quantity of items issued were considered within FSC.

This aggregation process was performed iteratively where statistical analysis (calculation of mean and variance for the above characteristics) of the groupings determined whether aggregations were sufficiently homogeneous. The study derived 72-aggregate products which the DODMDS study concluded were sufficiently homogeneous for modeling purposes. These 72-aggregate products were further aggregated until 27-aggregate products resulted.

In addition to the DODMDS study, a number of other aggregation studies (See House and Jamie [1981]; Ballou [1991] and [1993]; Current and Schilling [1987]) have focused on shipment weight in transportation rate determination. As a result of conclusions derived from these studies and on DLA's evolution toward use of innovative depot-to-customer shipping modes, this thesis concentrates on weight characteristics to determine product aggregations.

A statistical analysis of the transaction files reveals the following:

- 91% of the total weight issued is composed of just 90 FSC's;
- 90% of the total issues is accounted for by just 90 FSC's; and
- 56 of the FSC's appear in both of these categories.

Because repairable components are not included, variability within FSC groupings is not as significant as that found in the DODMDS study. However, as Appendix C shows, significant variability still exists within FSC groupings. Further analysis reveals that 92% of the material shipments are less than fifty pounds. The material in the large weight categories is significantly different from the norm which helps explain the large variance found within each grouping.

The following four product aggregation schemes are developed and provided in detail in Appendix D:

- 67-aggregate products: Accomplished strictly by FSC product groupings. No distinction is made within product groupings between aviation and non-aviation related material.
- 44-aggregate products: The 67 aggregate products are further aggregated by grouping like items. A distinction is made within groupings between aviation and non-aviation related material.
- 29-aggregate products: The 44 aggregate products are further aggregated by grouping like items.
- 49-aggregate products: This approach is based on demand. Taking the top 75 FSC's by frequency of demand and total weight requisitioned, the FSC's which appear in both categories are the focus of a aggregate product and like items are grouped with these major FSC's. No distinction is made between aviation and non-aviation material within these aggregate products. Those products annotated with an asterisk in Appendix D7 represent aggregate products which are not centered around an item appearing on any of the top 75 list. Because this material is not similar to material found within any of these major groupings, separate aggregate products are created.

B. CUSTOMER AGGREGATIONS

Customer aggregation is required to model the material flows from the distribution facilities to the more than 45,000 individual DLA customers. As the DODMDS study states: "Retaining the accuracy of demand location was most significant since the structure of a distribution system (distribution center location) is heavily influenced by the geographical location of the demand and sources of supply" (DODMDS Vol III [1978] Section 2 p 2.1).

The DODMDS study (DODMDS Vol III [1978] Section 2) identifies the major installations by total demand and

aggregates remaining activities with these major installations based on proximity. This process is accomplished with three-digit zip codes and the Department of Defense Automatic Address Code (DODAAC), a six-digit code which identifies individual activities. DODMDS examined the material flows from depot to customer as well as material returns from customer to depot and created 205 aggregated groupings. Where feasible, uniformed service identity was retained.

This thesis uses the three-digit zip code aggregation facilities available in SAILS to aggregate customers. Aggregation schemes are developed based on the top 259 major American cities (as identified in SAILS, see Appendix E). These cities are initially identified as the major nodes. All customers outside these zones are aggregated with these major areas based on proximity. Demand for deploying and overseas activities is assigned to the two containerization facilities: Mechanicsburg, Pennsylvania on the East coast and Tracy, California on the West coast. Of the top 250 DLA customers (as identified by three-digit zip code and total weight received), 149 have three-digit zip codes corresponding directly to the three-digit zip codes of the 259 major American cities. Attempts to use this 259-customer model in SAILS have been unsuccessful: The model dimensions are too large to permit timely solutions. Using the transaction information from the 259-customer model, two customer aggregation schemes of 199 and 113 customers are developed.

Those cities which had less than 100,000 pounds (1 million pounds for the 113-customer aggregation) of shipment activity are deleted as major nodes. The total weight received by these cities amounts to 2.6 million pounds which accounts for less than one percent of total weight shipped (39 million pounds and less than 4 percent for the 113-customer aggregation). The cities included in both aggregation schemes are provided in Appendix E and a map of the cities comprising the 113-customer aggregation is provided in Figure 3.2.

An analysis of the transaction file shows that of the top 100 three-digit zip codes (according to total weight shipped), 66 three-digit zip codes directly correspond to the three-digit zip codes of the 113 major cities. These 66 three-digit zip codes account for 51 percent of total demand weight and 70 percent of the total requisitions.

C. SUPPLIER AGGREGATIONS

Supplier aggregations are accomplished to facilitate dealing with the 10,000 material sources for the DLA distribution system. For procurement source aggregation, the DODMDS study (DODMDS Vol III [1978] Section 4) examines a number of alternate strategies and selected "the 80/20 rule" (80 percent of the procurement activity represented by 20 percent of the three-digit zip codes) as the preferred strategy: The DODMDS study identified the three-digit zip codes which provide 80 percent of the weight, 80 percent of

the procurement dollar value, and 80 percent of the total transactions processed. Identified as nodes, these zip codes represent fifteen percent of the total United States zip codes



Figure 3.2: Cities comprising the 113-customer aggregation scheme. These aggregated locations are formed by taking the 259 major cities identified in SAILS and deleting those cities which account for less than 1 million pounds of demand activity (total weight received by these cities is 39 million pounds and less than four percent of total weight shipped).

and account for approximately ninety percent of the procurement activity in all three categories. The remaining sources identified by three-digit zip codes are grouped with these nodes based on proximity.

Initially this study chose to follow the same approach as the DODMDS study by identifying major supplier locations by three-digit zip codes and aggregating minor supplier zones with these primary locations. Because of difficulty with the procurement file supplied by DLA, accurate replenishment information is unavailable and therefore this study uses a supersource or single location as the sole procurement source. This location is a centralized location in Memphis, Tennessee three-digit zip code 375. The DODMDS study uses a supersource concept where the transportation rate from depot to customer is calculated as if each customer receives the aggregate product from all suppliers at the percentage of the total each supplier provides systemwide. This thesis calculates the transportation rates by aggregate product from the centralized location to each depot (i.e., assuming all suppliers are located at the supersource).

D. Transportation Mode Aggregations

The DOD transportation system moves material via the shipment modes identified in Table 3.2. This study acknowledges a requisition priority by retaining the mode

structure. To facilitate data input into the SAILS model, the modes which experience limited use are aggregated with the

Table 3.2: This table provides the shipment modes, frequency, and percentage of total shipments for the DLA material shipments for FY 1992 as specified in the Material Release Order files. Obtained from DLA, these files provide all depot-to-customer material shipments for FY 1992.

Description	Mode	Frequency	% of Total
Motor, truckload	A	1992099	0.1262
Motor, less truckload	B	3568067	0.2261
Van	C	5	0.0000
Driveway	D	75	0.0000
Busline	E	1	0.0000
Military Airlift Command	F	37571	0.0024
Surface, parcel post	G	953134	0.0604
Air, parcel post	H	624534	0.0396
Govt truck	I	147486	0.0093
Small package carrier	J	1741819	0.1104
Rail, carload	K	2877	0.0002
Rail, less carload	L	168	0.0000
Freight forwarder	M	7	0.0000
LOGAIR	N	17168	0.0011
Organic Military Air	O	594	0.0000
Bill of Lading	P	2452	0.0002
Air freight/express	Q	301755	0.0191
Expedited air freight	R	311	0.0000
Scheduled truck	S	98961	0.0061
Air freight forwarder	T	98742	0.0063
QUICKTRANS	U	11299	0.0007
SEAVAN	V	152730	0.0097
Water, river, lake	W	10	0.0000
Bearer walk-thru	X	5469	0.0003
Intra-theater air lift	Y	7549	0.0005
Military Sealift Command	Z	631	0.0000
Govt watercraft	2	80	0.0000
Roll on/ Roll off	3	120	0.0000
Armed Forces Courier	4	142	0.0000
United Parcel Service	5	5017392	0.3179
Military Ordinary Mail	6	1128	0.0001
Express Mail	7	29481	0.0019
Pipeline	8	56	0.0000
Local Delivery	9	701173	0.0444
Missing/ erroneous		267551	0.0170

major modes as reflected in Table 3.3.

An analysis of the transaction files shows that 84 percent of the material is shipped using five modes of shipment.

The SAILS model has Yellow Freight and United Parcel Service rate tables available to determine transportation rates. Additionally, user-defined rates can be incorporated into the model. This rate information is used to determine an average rate per hundredweight (CWT) for each aggregate product and depot-to-customer combination.

Because rate information for the transportation modes utilized by the DOD system are not readily available, this study chose to use the UPS and Yellow Freight rates available in SAILS to estimate these averages. When the eleven aggregated modes identified in Table 3.3 are used in the SAILS model, the results produce excessive SAILS execution times. These 11 modes are therefore consolidated into six shipment categories and a shipment profile is created based on an analysis of the transaction file. Table 3.4 details the percentage of usage for each of the six modes and their categories.

Table 3.3: Aggregation of limited-use shipment modes into the 11 major mode categories for initial input into the SAILS model.

MAJOR MODE	EXPLANATION	AGGREGATED MODES	EXPLANATION
A	MOTOR, TL	C	VAN
		D	DRIVEAWAY
		P	TGBL
		V	SEAVAN
		S	SCHEDULED TRUCK SERVICE
		3	ROLL ON/ROLL OFF
		M	FREIGHT FORWARDER
		L	RAIL, LESS THAN CARLOAD
		R	EXPEDITED AIR FREIGHT
		T	AIR FREIGHT FORWARDER
B	MOTOR, LTL	X	BEARER PICKUP
K	RAIL, CARLOAD	I	GOVT TRUCK
Q	AIR FREIGHT	O	ORGANIC MILITARY AIR
	AIR EXPRESS	N	LOGAIR
9	LOCAL DELIVERY	6	MILITARY ORDINARY MAIL
U	QUICKTRANS	E	BUSLINE
G	SURFACE PARCEL POST	J	SMALL PACKAGE CARRIER
		5	UPS
		7	EXPRESS MAIL
H	AIR PARCEL POST		
	1ST CLASS MAIL		
F	MILITARY AIRLIFT		
	COMMAND		
2	MILITARY SEALIFT		
	COMMAND		
9	MISC	4	COURIER
		8	PIPELINE
		Y	INTRA THEATER AIRLIFT
		W	RIVER, LAKE
		2	GOVT WATERCRAFT
			MISSING & ERRONEOUS ENTRIES

Table 3.4: This table details the six alternate aggregated transportation modes used with model runs, the SAILS rate category used for each of these modes, and the usage percentages. This information is used by SAILS to calculate an average rate per hundredweight for each depot-to-customer link.

Mode	Rate Category	Percent
Truck Load	10000 TO 20000 lbs	32.95
Less Than Truckload	0 to 5000 lbs	42.94
Air Freight/Air Express	UPS Next Day Air	2.72
Local Delivery/Rail	400k to 999k	12.07
Surface Parcel Post	UPS Surface Parcel Post	8.38
First Class Mail MAC/QUICKTRANS	UPS Second Day Air	0.94

E. DEPOT AGGREGATIONS

This study includes the major depots examined by the DODMDS study with the addition of Naval Supply Centers in Charleston, Pensacola, and Puget Sound. In 1992, DLA used a number of secondary storage facilities which were subsequently closed. The secondary sites shown in Table 3.5 have been aggregated herein with the major depots based on proximity. With the exception of those depots identified for closure in 1993 under BRAC (Charleston, Oakland, and Pensacola) (BRAC [1993]), the major depots identified in Table 3.5 are the remaining facilities subject to the next base closure examination. Collocated depots (such as Tracy and Sharpe) are

Table 3.5: This table provides a listing of the major depots and the aggregation process this study uses to combine the secondary storage sites with the major depots. Depots that are annotated with an asterisk are slated for closure under BRAC 1993.

DEPOT CODE	MOON DEPOT	SEC DEPOT CODES	SECONDARY DEPOTS
AD	BRIDGE ARMY DEP LATHROP, CA 95211	ADN	BRIDGE ARMY DEP OT LATHROP, CA 95211
BB	BAY JORDON/7 TRACY, CA 95279	BBN	BAY JORDON, CA 95279
BB	BRIDGE ARMY DEP LATHROP, TX 75114	BBN	BAY JORDON, TX 75114
BA	BUSINESSMAN MECHANICSBURG 17088	BA1/BA2	BUSINESSMAN, MECHANICSBURG, PA 17088
BC	COLUMBUS 43218	BC1/BC2	COLUMBUS, OH 43218
BU	BUFFALO CREDIT 14207	BU1/BU2	BUFFALO CREDIT, BUFFALO, NY 14207
BY	YONKONA, PA 19388	BY1/BY2	YONKONA, PA 19388
YP	YONKONA, TX 75211	YP1/YP2	YONKONA, TX 75211
BR	BRIDGE ARMY DEP LATHROP, TX 75114	BRN	BRIDGE ARMY DEP LATHROP, TX 75114
NO	NEW ORLEANS, CA 94558	NO1/NO2	NEW ORLEANS, CA 94558
NY	NEW YORK ARMY DEP LATHROP, CA 95211	NY1/NY2	NEW YORK ARMY DEP LATHROP, CA 95211
ND	NEW DENVER, CA 94558	ND1/ND2	NEW DENVER, CA 94558
NS	NEW SPAIN, CA 94558	NS1/NS2	NEW SPAIN, CA 94558
NR	NEW RICHMOND, CA 94558	NR1/NR2	NEW RICHMOND, CA 94558
NU	NEW UNION, CA 94558	NU1/NU2	NEW UNION, CA 94558
NV	NEW VICTORY, CA 94558	NV1/NV2	NEW VICTORY, CA 94558
OB	OBAMA ARMY DEP LATHROP, CA 95211	OB1/OB2	OBAMA ARMY DEP LATHROP, CA 95211
OC	OCALA ARMY DEP LATHROP, CA 95211	OC1/OC2	OCALA ARMY DEP LATHROP, CA 95211
OD	ODessa ARMY DEP LATHROP, CA 95211	OD1/OD2	ODessa ARMY DEP LATHROP, CA 95211
OE	OEConnell ARMY DEP LATHROP, CA 95211	OE1/OE2	OEConnell ARMY DEP LATHROP, CA 95211
OF	OFficer ARMY DEP LATHROP, CA 95211	OF1/OF2	OFficer ARMY DEP LATHROP, CA 95211
OG	OGden ARMY DEP LATHROP, CA 95211	OG1/OG2	OGden ARMY DEP LATHROP, CA 95211
OH	OHio ARMY DEP LATHROP, CA 95211	OH1/OH2	OHio ARMY DEP LATHROP, CA 95211
OI	OId ARMY DEP LATHROP, CA 95211	OI1/OI2	OId ARMY DEP LATHROP, CA 95211
OJ	OId ARMY DEP LATHROP, CA 95211	OJ1/OJ2	OId ARMY DEP LATHROP, CA 95211
OK	OKlahoma ARMY DEP LATHROP, CA 95211	OK1/OK2	OKlahoma ARMY DEP LATHROP, CA 95211
OL	OLd ARMY DEP LATHROP, CA 95211	OL1/OL2	OLd ARMY DEP LATHROP, CA 95211
OM	OMaha ARMY DEP LATHROP, CA 95211	OM1/OM2	OMaha ARMY DEP LATHROP, CA 95211
ON	ONd ARMY DEP LATHROP, CA 95211	ON1/ON2	ONd ARMY DEP LATHROP, CA 95211
OO	OOd ARMY DEP LATHROP, CA 95211	OO1/OO2	OOd ARMY DEP LATHROP, CA 95211
OP	OPd ARMY DEP LATHROP, CA 95211	OP1/OP2	OPd ARMY DEP LATHROP, CA 95211
OS	OSd ARMY DEP LATHROP, CA 95211	OS1/OS2	OSd ARMY DEP LATHROP, CA 95211
OT	OTd ARMY DEP LATHROP, CA 95211	OT1/OT2	OTd ARMY DEP LATHROP, CA 95211
OU	OUd ARMY DEP LATHROP, CA 95211	OU1/OU2	OUd ARMY DEP LATHROP, CA 95211
OV	OVd ARMY DEP LATHROP, CA 95211	OV1/OV2	OVd ARMY DEP LATHROP, CA 95211
OW	OWd ARMY DEP LATHROP, CA 95211	OW1/OW2	OWd ARMY DEP LATHROP, CA 95211
OX	OXd ARMY DEP LATHROP, CA 95211	OX1/OX2	OXd ARMY DEP LATHROP, CA 95211
OY	OYd ARMY DEP LATHROP, CA 95211	OY1/OY2	OYd ARMY DEP LATHROP, CA 95211
OZ	OZd ARMY DEP LATHROP, CA 95211	OZ1/OZ2	OZd ARMY DEP LATHROP, CA 95211
PA	PAID ARMY DEP LATHROP, CA 95211	PA1/PA2	PAID ARMY DEP LATHROP, CA 95211
PB	PBID ARMY DEP LATHROP, CA 95211	PB1/PB2	PBID ARMY DEP LATHROP, CA 95211
PC	PCID ARMY DEP LATHROP, CA 95211	PC1/PC2	PCID ARMY DEP LATHROP, CA 95211
PD	PDID ARMY DEP LATHROP, CA 95211	PD1/PD2	PDID ARMY DEP LATHROP, CA 95211
PE	PEID ARMY DEP LATHROP, CA 95211	PE1/PE2	PEID ARMY DEP LATHROP, CA 95211
PF	PFID ARMY DEP LATHROP, CA 95211	PF1/PF2	PFID ARMY DEP LATHROP, CA 95211
PG	PGID ARMY DEP LATHROP, CA 95211	PG1/PG2	PGID ARMY DEP LATHROP, CA 95211
PH	PHID ARMY DEP LATHROP, CA 95211	PH1/PH2	PHID ARMY DEP LATHROP, CA 95211
PI	PIID ARMY DEP LATHROP, CA 95211	PI1/PI2	PIID ARMY DEP LATHROP, CA 95211
PJ	PJID ARMY DEP LATHROP, CA 95211	PJ1/PJ2	PJID ARMY DEP LATHROP, CA 95211
PK	PKID ARMY DEP LATHROP, CA 95211	PK1/PK2	PKID ARMY DEP LATHROP, CA 95211
PL	PLID ARMY DEP LATHROP, CA 95211	PL1/PL2	PLID ARMY DEP LATHROP, CA 95211
PM	PMID ARMY DEP LATHROP, CA 95211	PM1/PM2	PMID ARMY DEP LATHROP, CA 95211
PN	PNID ARMY DEP LATHROP, CA 95211	PN1/PN2	PNID ARMY DEP LATHROP, CA 95211
PO	POID ARMY DEP LATHROP, CA 95211	PO1/PO2	POID ARMY DEP LATHROP, CA 95211
PP	PPID ARMY DEP LATHROP, CA 95211	PP1/PP2	PPID ARMY DEP LATHROP, CA 95211
PQ	PQID ARMY DEP LATHROP, CA 95211	PQ1/PQ2	PQID ARMY DEP LATHROP, CA 95211
PR	PRID ARMY DEP LATHROP, CA 95211	PR1/PR2	PRID ARMY DEP LATHROP, CA 95211
PS	PSID ARMY DEP LATHROP, CA 95211	PS1/PS2	PSID ARMY DEP LATHROP, CA 95211
PT	PTID ARMY DEP LATHROP, CA 95211	PT1/PT2	PTID ARMY DEP LATHROP, CA 95211
PU	PUID ARMY DEP LATHROP, CA 95211	PU1/PU2	PUID ARMY DEP LATHROP, CA 95211
PV	PVID ARMY DEP LATHROP, CA 95211	PV1/PV2	PVID ARMY DEP LATHROP, CA 95211
PW	PWID ARMY DEP LATHROP, CA 95211	PW1/PW2	PWID ARMY DEP LATHROP, CA 95211
PX	PXID ARMY DEP LATHROP, CA 95211	PX1/PX2	PXID ARMY DEP LATHROP, CA 95211
	</		

maintained as separate entities. Figure 3.3 provides the relative locations of the 28 major depots.

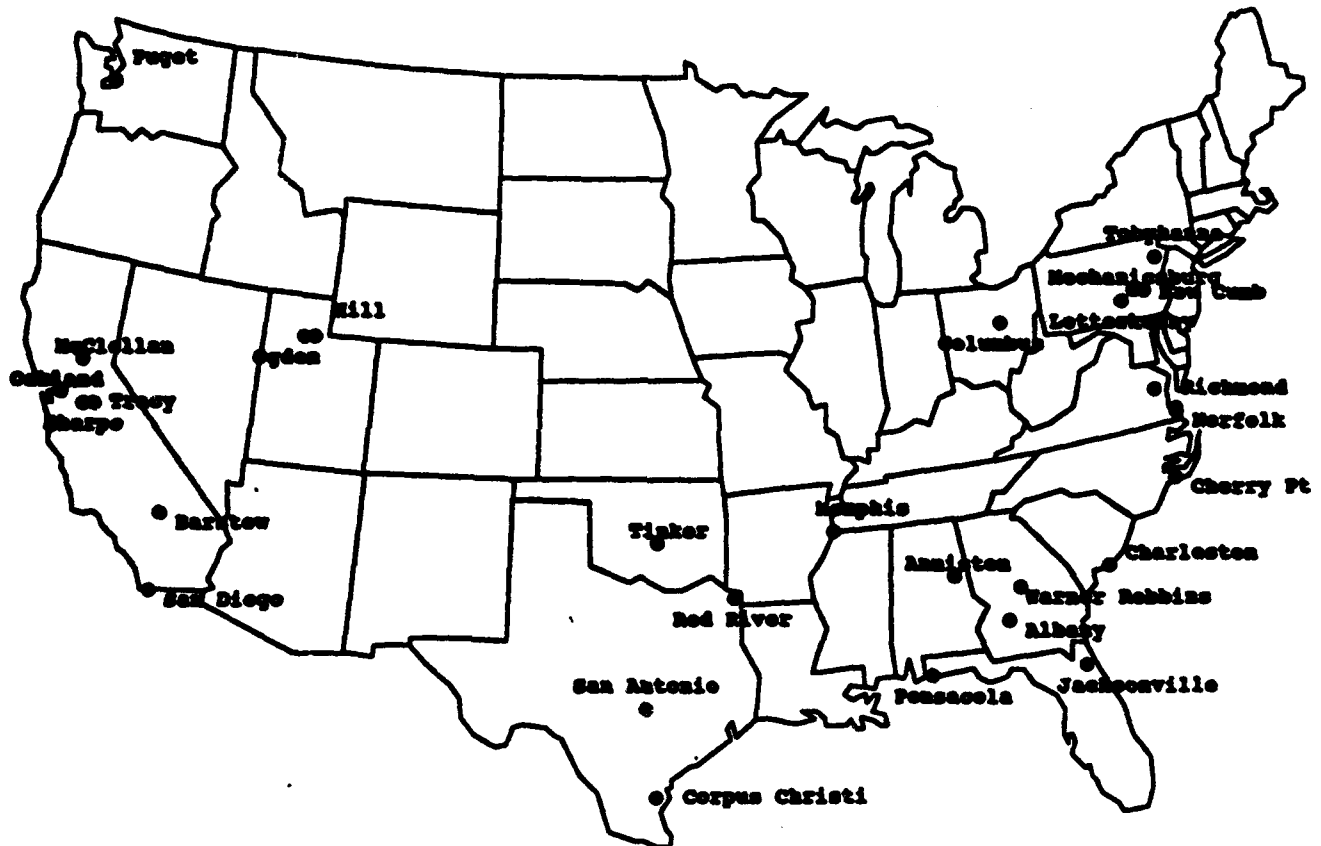


Figure 3.3: The relative location of the 28 major depots where secondary storage facilities are aggregated with the major depots based on location proximity.

IV. COMPUTATIONAL EXPERIENCE

This chapter contains detailed information on test data, scenarios tested, and solutions obtained using SAILS.

A. DATABASE

1. TRANSACTION FILE

The Material Release Order files for fiscal year 1992 are obtained from the Defense Operations Research Office (DORO) in Richmond, Virginia. Using the SAS software package (SAS Institute Inc [1990]) on an AMDAHL 5995-700A mainframe, data from the Material Release Order files are summarized and manipulated into a transaction file (which is customer demand data) in the correct format for SAILS model input. Initially, the Material Release Order file is comprised of approximately 17 million records. After extracting those requisitions created during the base year and removing erroneous records, a transaction file comprised of 15.8 million material shipments and totalling 1.032 billion pounds is created.

Due to the size of this transaction file, product aggregation is accomplished outside the SAILS model. Four separate transaction files representing each of the product aggregation schemes detailed in Chapter 3 is created for input into SAILS. These files are formatted in the outbound

transaction file format (TF4) (INSIGHT Inc., SAILS Users Manual [1993]) required for input into the SAILS model as depicted in Table 4.1. To limit the size of the input file herein, shipment date information is not retained. As a result, all transactions for the period examined are assumed to be processed on julian date 92001. This process can underestimate total transportation costs as the model develops transportation rates based on the shipment profile depicted in Table 3.4.

Table 4.1: SAILS Outbound Transaction File Data Elements. Four separate transaction files representing each of the alternate product aggregation schemes is created for input into SAILS.

Data Element	DESCRIPTION
Customer Class	shipment mode information
Customer Aggregation Code	three-digit customer zip code
Stock Code	aggregate product number
Quantity	total number of transactions
Original DC code	3-character Depot Code
Julian Date	92001 (total annual demand)
Extended Weight	total weight shipped for that aggregate product, depot-to-customer link

The transaction file is sorted and summarized by aggregate product number, three-digit customer zip code, depot, and shipment mode. The total weight shipped for each aggregate product and depot-to-customer link is calculated by multiplying the total number of transactions for that link by the mean extended weight (an average calculated by multiplying requisition quantity times unit weight). File sizes for the four transaction files are provided in Table 4.2.

Table 4.2: Four different Outbound Transaction Files are generated based on the alternate product aggregation schemes employed. This table details the total number of transactions and file sizes for each of these files.

Product Aggregation Scheme	Total # of Aggregate Transactions	File Size (megabytes)
"29"	309,300	36.2
"44"	360,497	42.2
"49"	464,955	54.4
"67"	388,001	45.4

2. FACILITIES

Cost and throughput capacity information for the distribution depots identified in previous sections are developed based on information provided by DORO and DLA Headquarters. Estimates of depot fixed and variable costs

are based on information provided by DORO and are listed in Table 4.3. This information represents fiscal year 1989 estimates of depot costs. Since these figures are estimates, no attempt to convert these costs to fiscal year 1992 is considered. Fixed costs are explicitly expressed and are input into the model to the nearest hundred thousand dollars. Cost information for Marine Corps facilities at Barstow, Albany, and Cherry Point are not provided. Fixed costs for these facilities are estimated at ten million dollars.

Variable costs provided by DORO are in unit cost per transaction. Because all transactions in the SAILS model are based on CWT, conversion is required. This study finds an estimated average weight per transaction and multiplies this figure by the number of transactions processed by each depot as a rough estimate of total weight processed by the depot. The variable cost per CWT is then determined by dividing the total variable cost for that depot by the total CWT processed. Both depot fixed and variable costs are provided in Table 4.3.

Depot throughput capacity is calculated based on estimates provided by DLA headquarters. These estimates are based on the number of transactions a facility could handle in a day at peak capacity. Since all model calculations are based on CWT, conversion to the amount of CWT each facility could handle is required. Additionally, these calculations need to be annualized. The conversion process is similar to the variable cost calculation where an average weight per

transaction is estimated. This average is multiplied by the maximum number of transactions the facility could handle daily and a conservative estimate of the number of work days in a year (250): Only 250/365 (68 percent). The resulting throughput capacity is shown in Table 4.3. Because of the close proximity of Mechanicsburg and New Cumberland, DLA Headquarters expresses their throughput capacity as one total which this study splits in half and reports for each facility separately. This situation also exists for Sharpe and Tracy on the West coast.

Table 4.3: The depot fixed and variable costs and throughput for FY 92 used in the SAILS model.

Depot	Fixed Cost (000)	Variable Cost per CWT	Model Throughput (million pounds)
Columbus	17900	10.7775	150
Memphis	31200	11.9834	310
Mechanicsburg	24700	10.1336	510
Tracy	30200	11.9571	290
Ogden	18200	2.5638	380
Richmond	21200	10.8428	230
Lebanon	18000	43.18488	50
New Cumberland	22700	28.8313	510
Anniston	6000	45.688	40
Sharpe	14800	39.0388	290
Tobytanna	5400	45.0523	37
Red River	17900	38.2448	140
Corpus Christi	2400	21.7888	50
Oakland	19000	12.8446	67
San Diego	15100	9.1073	180
Puget Sound	6900	12.3212	60
Norfolk	28700	13.325	210
Charleston	8200	9.8788	170
Jacksonville	6800	9.7052	84
Pensacola	6000	9.2828	60
McClellan AFB	13600	30.3438	97
San Antonio	15200	27.1729	150
Tinker AFB	16500	21.7179	70
Hill AFB	9800	22.0198	170
Werner Robbins	13700	24.8788	140
Cherry Point	10000	10.00	40
Barstow	10000	10.00	17
Albany	10000	10.00	16

B. RUN DESCRIPTIONS

The SAILS model is run under Windows NT on a 586 66MHz personal computer with 261 megabytes of extended memory and one gigabyte of disk space. With the smaller models (less than 49 products and 113 customers), SAILS requires about 125 megabytes of extended memory to operate. The maximum level of extended memory required is 225 megabytes occurring with 199 customer aggregations.

The approach here is to systematically reduce throughput capacity across all depots to examine the effects these reductions have on total costs and the recommended depot closures. Five separate versions of the model are run for each of the aggregation schemes at full depot throughput capacity, and at 90%, 80%, 50% , and 30% of that capacity. Additionally, the throughput capacity violation penalty (available in the SAILS model) is maintained at a high level to ensure no capacity violations within a depot.

Recall that DLA subsistence items which account for approximately 25 percent of total demand weight are not directly modeled in this thesis. The subsistence demand weight is indirectly modeled by using a conservative estimate of depot throughput capacity where a 250 day work year is used instead of a 365 day work year (possible during peak periods).

Runs are accomplished under the four alternate product aggregation schemes, with 113-customer aggregations, and at

the five alternate depot throughput capacity levels. To determine the effects of a different customer aggregations, additional runs are accomplished with a 199-customer aggregation, 29-aggregate products scheme and at five alternate depot throughput capacity levels.

Within SAILS, the ability exists to specify a maximum distance between depot and customer. For all runs with the exception of one test case, this distance is set at the default setting of 7500 miles - essentially unrestricted.

C. RESULTS

Table 4.4 provides the number of variables and constraints for the different models. Intuitively, it would be reasonable for the number of variables to increase as the number of aggregate products increases, but this is not always the case. Recall that the 67-aggregate product scheme is created by aggregating products by the two-digit product group. The 44- and 29-aggregate product schemes are simply further aggregations of the 67-aggregate product scheme. Table 4.4 shows that different aggregation schemes for the 44- and 29-aggregate product schemes create different depot-to-customer grouping combinations. Recall that the approach is slightly different for the 49-aggregate product scheme: Aggregate products are created around those FSC's which experience significant demand. This accounts for the higher number of variables. By expanding the number of customer

aggregations, both the number of constraints and variables increases dramatically as expected.

Table 4.4: Five versions of a model depicting the DLA distribution system are created in SAILS based on different product and customer aggregation schemes. This table describes the number of constraints and variables for each of these SAILS models. By expanding the number of customer aggregations, both the number of constraints and variables increases dramatically as expected.

Aggregate Products	Customer Aggregations	Constraints	Variables
29	113	3,308	78,971
44	113	3,308	74,708
49	113	3,308	80,132
67	113	3,308	67,609
29	199	5,802	132,777

The SAILS model develops an optimal strategic distribution network (i.e., determines optimal depot locations for a network operating over a long time-frame) as opposed to a tactical or operational plan. As part of this strategic modeling, SAILS sole-sources aggregate products to a specific depot. SAILS creates two reports to help show the effect of sole-sourcing. The accounting baseline reports the tactical statistics on actual day-to-day operations and the model

baseline reports the same statistics prior to optimization where aggregate products are sole-sourced to a specific depot.

Table 4.5 summarizes accounting baseline (actual depot-to-customer shipments by "product bundle" - an aggregate product before sole-sourcing), model baseline (depot-to-customer shipments after sole-sourcing or assignment of an aggregated product group to a specific depot) and the optimal solution for the 29-aggregate products, 113-customer aggregation, full-capacity model. Comparisons between the baseline and depot capacities reveal that Albany is the only depot which exceeds calculated capacity (this deviation is only 29,000 CWT; a minimal amount in comparison to total weight shipped). Test runs show that increasing Albany's throughput capacity by this amount has no effect on solutions.

Figures 4.1 and 4.2 graphically depict depot throughput capacity, accounting baseline, and model baseline for the 29-aggregate products, 113-customer aggregation, full capacity model. Apparent in these graphs and in Table 4.5 is the fact that the depots are not operating at or even near full capacity.

Table 4.5: FY 1992 Transaction Files show by depot the accounting baseline (actual depot-to-customer weight shipped), the model baseline (depot-to-customer shipment weight after the aggregate product has been sole-sourced to a specific depot), and the optimal solution for the 29-aggregate product, 113-customer aggregation SAILS model.

Depots	Depot Code	Model Throughput (cwt)	Model Baseline Weight (cwt)	Accounting Baseline Weight (cwt)	Optimal Solution Weight (cwt)
Sharpe AD	AQ	2900000	45352	141888	0
San Jose/ Tracy	SB	2900000	2334277	1677985	0
Memphis	SM	3100000	2038131	2282073	0
Mech	SA	5100000	1548083	1574424	4521065
Columbus	SC	1500000	684681	647122	0
Ogden	SU	3800000	886238	1228332	3778513
Tobyhanna	BY	370000	88	3844	0
San Antonio	FP	1500000	8775	31888	0
Richmond	SR	2300000	1637889	1311881	0
Oakland	NO	670000	312544	282013	0
McClellan AFB	FF	970000	0	5788	0
San Diego	ND	1600000	51428	64716	0
Barstow	MV	170000	11731	13104	0
Jacksonville	NB	640000	137385	115344	638065
Norfolk	NN	2100000	4284	20577	0
Charleston	NR	1700000	0	8163	0
Anniston AD	BA	400000	33	9024	0
Albany	MA	160000	220204	189139	0
Puget-Shererton	NU	600000	52	13343	422889
Letterkenny	BK	500000	16849	21409	0
Red River	BR	1400000	55883	112362	0
Hill AFB	FG	1700000	4275	16279	562752
Tinker AFB	FH	700000	41833	35435	0
Warner Robbins AFB	FL	1400000	202	5883	0
NSC Pensacola	NA	600000	0	1891	0
MCS Cherry Pt	PT	400000	1910	2273	0
New Cumberland	SN	5100000	179007	314284	0
Corpus Christi	BS	500000	39	782	397003
Dummy Dist		0	0	0	0

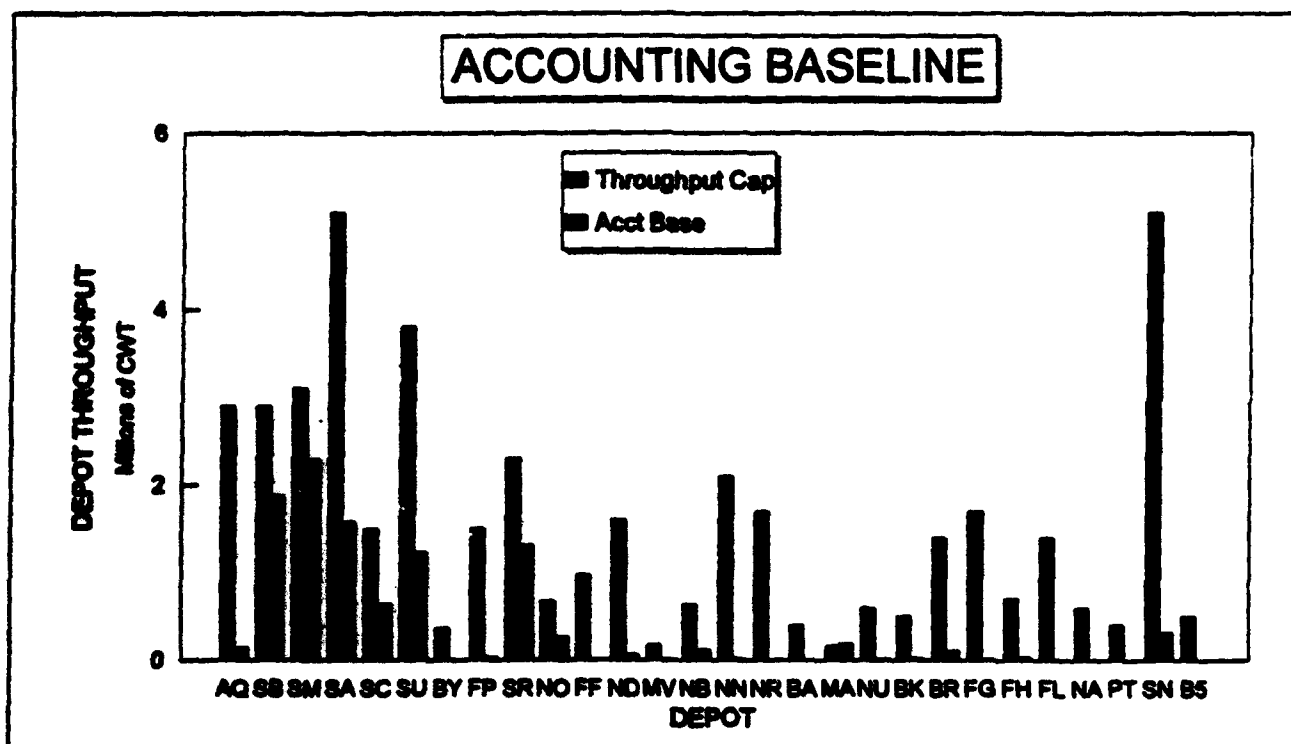


Figure 4.1: FY 92 Comparison of the depot throughput capacity to actual throughput for the 29-aggregate product, 113-customer aggregation SAILS model. For example, Mechanicsburg (depot code SA) has an estimated throughput capacity over five million CWT but has actual throughput of less than two million CWT.

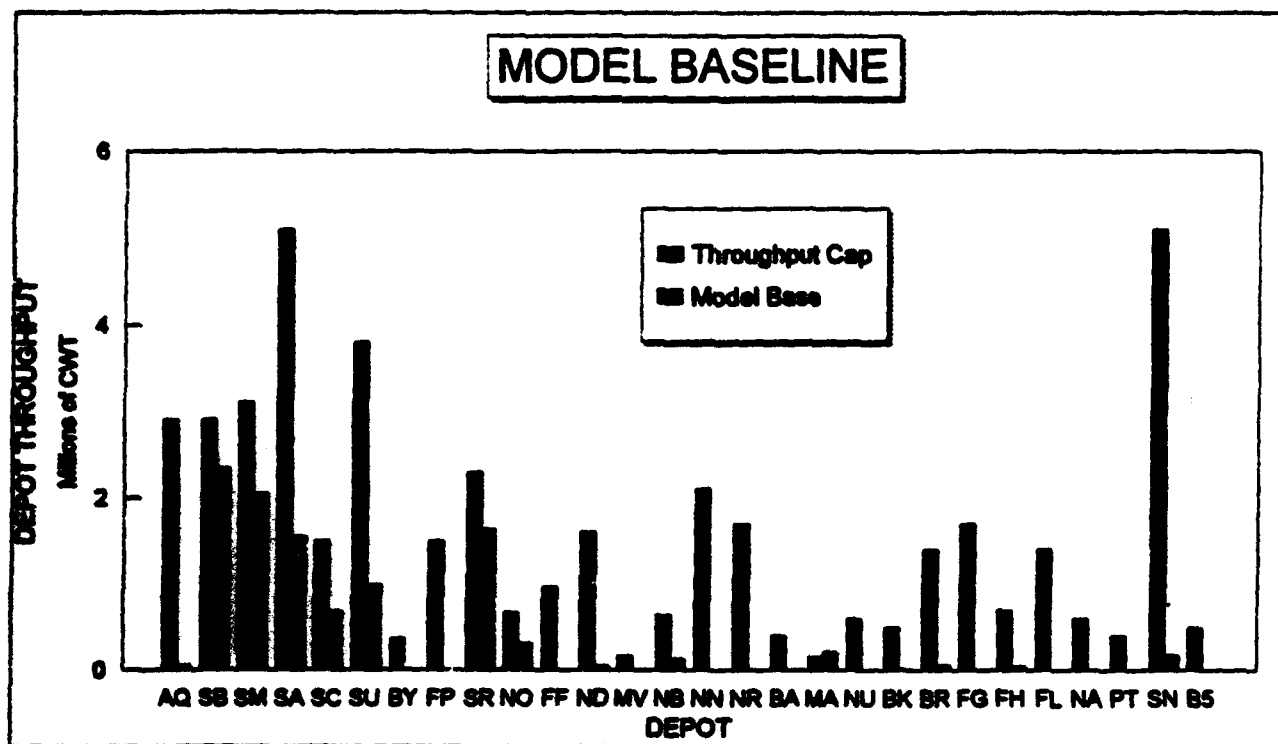


Figure 4.2: Comparison of the depot throughput capacity to baseline model throughput for the 29-aggregate product, 113-customer aggregation SAILS model. When compared to the accounting baseline this shows the minimal effect sole-sourcing aggregate products has on individual depot capacity utilization.

As depot throughput capacities are reduced, this restriction should increase total costs. Figure 4.3 shows that, as expected, throughput capacity is reduced and total operating costs increase.

Table 4.6 summarizes costs for accounting baseline, model baseline, and the optimal solution. Significant cost savings are suggested: Modeled savings total over 300 million dollars.

Figure 4.3: Depicts the total operating costs for each of the five depot throughput capacities examined for the 29-aggregate products, 113-customer aggregation SAILS model.

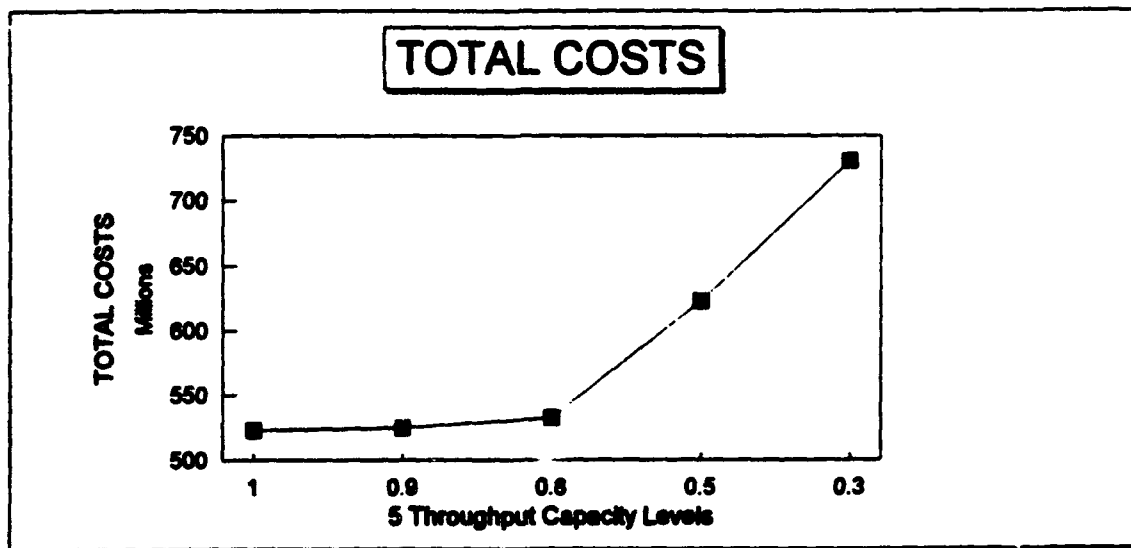


Table 4.6: Cost Summarization for the 29-aggregate products, 113-customer aggregation SAILS model.

Costs	Accounting Baseline	Model Baseline	Optimal
Fixed Costs	418,200	391,000	68,700
Variable Costs	119,550	114,777	87,990
Capacity Viol	291,385	621,511	
Replenishment	10,092	10,756	12,470
Outbound	408,202	342,182	353,999
Total (excluding penalty)	956,044	858,715	523,159

For purposes of this study, the solution gap (the difference between a bound on the best possible solutions and the best solution obtained) is three percent or less of total costs. A detailed discussion of each model run is presented in the following paragraphs.

Results of the runs accomplished at full depot capacity are presented in Table 4.7. The solutions for the 29-, 44-, and 49-aggregate product schemes are indistinguishable: Total costs differ by only \$30,000 between the different versions and the recommended depot closures are identical. The total costs for the 67-aggregate products are slightly higher, but within the required solution gap. More importantly, the recommended depot openings differ by one facility. Unlike alternate solutions, this solution recommends that San Diego remain open instead of Puget. Table 4.7 shows that if the common configuration from the 29-, 44-, and 49-aggregate products model is fixed in the 67-aggregate product model, a smaller solution gap results. This shows that a number of alternate DLA depot configurations are realizable, all with comparable cost savings.

Table 4.8 presents results obtained when all depots are only allowed 90 percent of their estimated throughput capacity. As expected, total costs for the 29-aggregate product model are higher than at full capacity.

Table 4.7: Solutions to the full capacity model with 113-customer aggregation. Alternate product aggregations produce the same depot closure decisions. The solution gap represents the difference between a bound on the best possible solution and the best solution obtained.

Aggregate Products	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29		59	523,159	10	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
44		27	523,191	5.225	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
49		35	523,181	10	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
67		44	525,329	10	6	Mech/ Ogden/ San Diego/ Jax/ Hill/ Corpus
67	Locked all depots closed except 6 open in the 29-aggregate products solution	25	523,223	7.894	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus

Table 4.8: Solutions to the 90 percent capacity model with 113-customer aggregation. Alternate product aggregations produce the same depots closure decisions. Solution gap represents the difference between a bound on the best possible solution and the best solution obtained.

Aggregate Products	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29		57	524,982	11	5	Mech/ Ogden/ San Diego Jax/ Hill
29	Locked open depot solution from the full capacity run	31	525,985	12	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus
44		35	525,051	1.258	5	Mech/ Ogden/ San Diego Jax/ Hill
48		57	526,512	2.71488	5	Mech/ Ogden/ San Diego Jax/ Hill
67		37	528,018	10	6	Mech/ Ogden/ San Diego Jax/ Puget/ Hill
67	Locked all depots closed except 5 open in the 29-aggregate product solution	28	524,884	8.886	5	Mech/ Ogden/ San Diego Jax/ Hill

A reduction in the number of open depots is apparent when comparing the full and 90 percent capacity versions: San Diego, a larger depot, replaces both Puget and Corpus Christi. Because total throughput capacity available at both Puget and Corpus Christi is less than that available at San Diego, this alternative is a viable one.

When the solution for recommended depot closures from the full capacity run is established in the 90 percent capacity version, both the recommended number of open depots and total costs increase as expected. However, both solutions are within the required solution gap reinforcing the idea that a number of alternate solutions is possible.

In the 90 percent capacity model, the recommended depot configuration for 67-aggregate product version differs from the others. In this version, Puget remains open which results in six total depots remaining open as opposed to five from the other versions. As the depot configuration from the others is established in the 67-aggregate product model, total costs and the solution gap are less than the previous version.

With 80 percent capacity, total operating costs are expected to increase. Table 4.9 shows that all versions result in these cost increases and that depot configurations are varied among the different models: 29- and 67-aggregate product versions agree with low solution gaps and the 44- and 49-aggregate product versions agree with slightly higher solution gaps. When the depot configuration from the 29-

aggregate product version is fixed in the 44- and 49-aggregate product models, solution gaps increase. Solution gaps from these subsequent runs are still within study requirements and therefore represent viable alternate solutions.

At 50 percent capacity, the restricted models become much more difficult to solve and the results vary. Solution gaps are higher than three percent of total costs and attempts to reduce them result in run times in excess of four hours. Furthermore, attempts with all models to "lock in" the 29-aggregate product solution for comparison purposes also result in long run times. The results provided in Table 4.10 reflect solutions that are within solution gaps of less than five percent.

Table 4.9: Alternate solutions to the 80 percent capacity model with 113-customer aggregation. Alternate product aggregations produce the same depot closure decisions.

Aggregate Products	Remarks	Run Times (min)	Total Costs (\$000)	Soln Gap	Number of Open Depots	Open Depots
28		129	532,002	2.964	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hll/ Corpus
44		82	532,486	10	5	San Jose/ Mech/ Ogden Jax/ Corpus
44	Locked open 7 depots from the 28-aggregate products solution	48	535,251	12.798	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hll/ Corpus
48		73	535,278	10	5	San Jose/ Mech/ Ogden Jax/ Puget
48	Locked open 7 depots from the 28-aggregate products solution	30	535,347	12.94053	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hll/ Corpus
67		80	531,874	2.48	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hll/ Corpus

Table 4.10: Solutions to 50 percent capacity model with 113-customer aggregation. Run times in excess of four hours are experienced when attempting to remain within the three percent solution gap. Although depot closure recommendations are not uniform among all models, six common depots are recommended to remain open.

Aggregate Products	Run Times (min)	Total Costs (\$000)	Soln Gap	Number of Open Depots	Open Depots
28	54	622,512	28	9	San Jose/ Memphis/ Mech Columbus/ Ogden/ San Antonio Richmond/ San Diego/ Barlow
44	41	601,640	20	9	San Jose/ Memphis/ Mech Columbus/ Ogden/ Richmond San Diego/ Jax/ Puget
48	58	611,568	25	11	San Jose/ Memphis/ Mech Ogden/ Richmond San Diego/ Barlow/ Jax/ Puget Hll/ Cherry Pt
67	37	636,576	30	12	San Jose/ Memphis/ Mech Columbus/ Ogden/ Richmond San Diego/ Jax/ Albany Puget/ Tinker/ Cherry Pt

Run times for the 30 percent capacity models are excessive. Results are obtained for the 44-, 49-, and 67-aggregate product models, but not within the required solution gap (three percent of total costs). As shown in Table 4.11, a successful run is attained for the 29-aggregate product version, but requires over eight hours of run time. An interesting situation occurs at the 30 percent capacity levels for all versions of the model: Hill is forced into the solution. Regardless of the throughput violation penalty setting, Hill consistently exceeds capacity by 53,000 CWT. Therefore, to achieve any results, the throughput capacity for Hill is increased by 53,000 CWT.

Table 4.11: Solutions to the 30 percent capacity model with 113-customer aggregation. Run times in excess of eight hours are experienced when attempting to remain within the three percent solution gap. All aggregations report some depot closures and four common depot closures are recommended regardless of which model is used.

Aggregate Products	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Closed Depots
29	811	730,515	10.12137	16	Tobyhanna / McClellan / Barstow Norfolk / Anniston / Albany / Letterkenny Tinker / Cherry Point
44	28	782,601	50	19	Tobyhanna / McClellan / Anniston Letterkenny / Red River / Corpus Christi
49	68	782,845	45	19	Tobyhanna / McClellan / Anniston Letterkenny / Red River / Corpus Christi
67	29	777,775	50	17	Tobyhanna / McClellan / Anniston Albany / Letterkenny / Red River / Cherry Point / Corpus Christi

A 29-aggregate product, 199-customer aggregation model has been created to determine the effect additional customer zones have on total costs. Recall that numerous studies report a decrease in transportation costing errors when the number of customers is increased. Results from this model are compared to the solutions from the 29-aggregate product, 199-customer aggregation model. At full capacity, no real difference is noted as the same six depots remain open and total costs are near equivalent. Results from the 90, 80, 50, and 30 percent depot throughput capacity models for this version differ from those of the 29-aggregate product, 113-customer aggregation version. Additional runs have been required where the solution for 29-aggregate product, 113-customer aggregation model is fixed in these subsequent models. Table 4.12 shows that these additional runs provide equivalent or lower solution gaps. Based on these results, additional customer zones would not result in increased detail or significant differences in total operating costs.

All model versions up to this point have not restricted the maximum distance between depot and customer. As this distance is limited, more depots may be required to satisfy customer demand or the solution may retain high cost and less efficient facilities just to meet this restriction. These additional facilities improve delivery times and customer service yet increase total operating costs. With recent improvements in transportation services, delivery times have

been improved significantly. Therefore, the additional cost to retain depots to maintain customer service levels may not be warranted under current conditions. This study ran a model with the depot to customer distance restricted to 1000 miles for the 29-aggregate products, 113-customer aggregation, full capacity model. Table 4.13 compares the results between the restricted and unrestricted versions.

Table 4.12: Solutions for the 29-aggregate products, 199-customer aggregation model demonstrate that different customer aggregations produce essentially the same depot closure decisions.

Depot Closure Capacity %	Remarks	Run Times (min)	Total Costs (\$000)	San Cost	Number of Open Depots	Open Depots
100		113	\$23,188	10	8	Mech/Ogden/Jax Pugot/HB/Corpus
95		132	\$24,630	11	8	Mech/Ogden/San Diego Jax/HB/Corpus
90	Locked open the depot solution from the 29-aggregate products 95% capacity run	83	\$24,885	11,284	5	Mech/Ogden/San Diego Jax/HB
85		175	\$33,781	10	5	San Joseq/Mech/Ogden Jax/HB
80	Locked open the depot solution from the 29-aggregate products 85% capacity run	141	\$33,821	9.77	7	Mech/Ogden/San Diego Jax/Pugot/HB/Corpus
75		82	\$34,851	30	12	San Joseq/Memphis/Mech Columbus/Ogden/Richmond San Diego/Bartow/Albany Jax/HB/Cherry Point
70	Locked open the depot solution from the 29-aggregate products 80% capacity run	29	\$51,861	27.87	9	San Joseq/Memphis/Mech Columbus/Ogden/San Antonio Richmond/San Diego/Bartow
65		84	762,861	40	20	all open except Toluca McAllen/Aniston Lubbock/Lubbock/Rod River
60	Locked open the depot solution from the 29-aggregate products 60% capacity run	58	777,864	25	16	all open except Toluca McAllen/Bartow/Mech Aniston/Albany/Lubbock Tulsa/Cherry Point

When this distance is restricted, total operating costs rise: The increase is the result of retaining higher-cost facilities sufficiently close to "reach" customers. Figure 4.4 shows that a small percentage of total demand is satisfied beyond a 1,000 mile range even when there is no range restriction: This implies that there should not be a significant change in outbound costs as range is restricted to 1,000 miles which is the case.

An additional run is made with a 300-mile limitation to determine the effects on total costs and the number of recommended depots remaining open. As expected total costs increase dramatically and the number of open depots increases to 16. In this solution, both capacity violation penalties and lost demand penalties (where it is more economical to not satisfy certain levels of customer demand) are incurred.

Table 4.13: Two models are created where the maximum distance between depot and customer is set at 7500 miles (unrestricted) and 1000 miles (restricted). This table shows that cost for the two models only varies slightly.

	Fixed Costs	Variable Costs	Replenishment Costs	Outbound Costs	Total Costs	Depots
Restricted 1000 mile limit	83200	105825	10859	354993	554777	Sharpe / Mech / Ogden Jax / Tinker / Corpus
Unrestricted 7500 mile limit	88700	87990	12470	353999	523159	Mech / Ogden / Jax Puget / Hill / Corpus

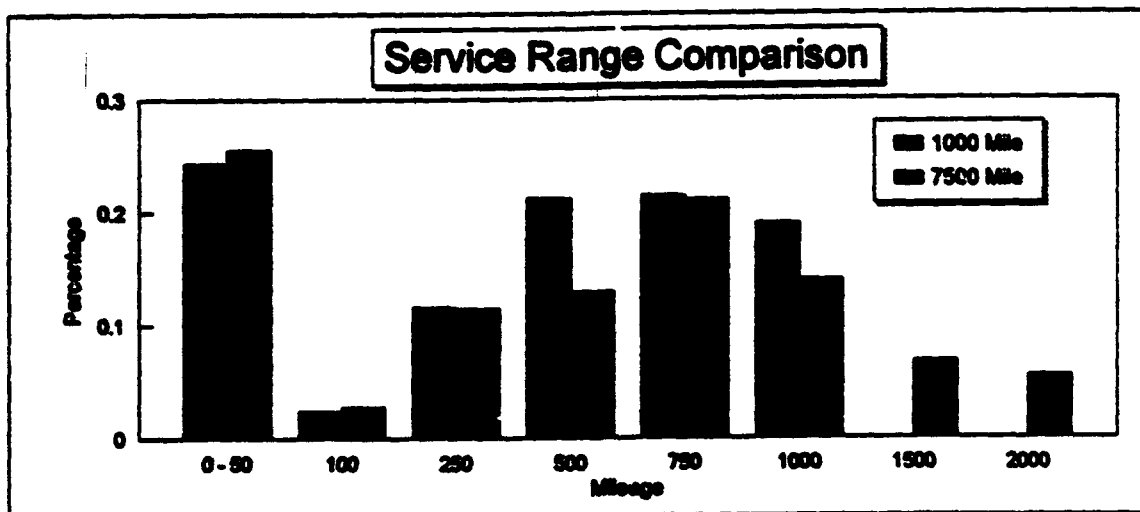


Figure 4.4: Two models are created where the maximum distance between depot and customer is either 7500 miles (unrestricted) and 1,000 miles (restricted). This histogram presents the percentage of customer demand satisfied at the various depot to customer distances. Because most demand is satisfied within the 1,000 mile range even when range is unrestricted, there is not a significant increase in total costs.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis shows how the Defense Logistics Agency (DLA) can save over 300 million dollars annually through depot closure and reorganization. This conclusion comes from extensive analysis of DLA's distribution network using the SAILS model. This thesis derives a 29-product, 113-customer aggregation scheme which renders a SAILS model of DLA that is easy to use and retains essential fidelity. Extensive comparisons between this aggregation scheme and others (44-, 49-, and 67-product; and 199- and 113-customer aggregations) at depot throughput capacities of 100, 90, 80, 50, and 30 percent of remaining capacity show that:

- DLA depots currently have excess throughput capacity available; and
- alternate solutions are possible under the current DLA distribution network.

A discussion of each of these points is presented in the following paragraphs.

DLA depots currently have excess capacity. Even when customer service range is restricted to 1,000 miles from the supplying depot, significant cost reductions in distribution network costs can be achieved without a corresponding decrease in customer service levels.

Results from the different aggregation schemes show that alternate solutions are possible at about the same cost level. As the solution from the recommended model version is fixed in those models which deviate from the 29-product, 113-customer aggregation version equivalent solutions are obtained. For this reason and the fact that the smaller version results in responsive SAILS execution, the 29-product, 113-customer aggregation model is recommended to model the DLA distribution network.

Recall that a customer service restriction where the maximum distance between depot and customer is restricted to 1000 miles led to an increase in total operating costs of over 30 million dollars. As this distance is limited, more depots may be required to satisfy customer demand or the solution may retain high cost and less efficient facilities just to meet this restriction. This study contends that with recent improvements in transportation services and delivery times no significant improvement in customer service is obtainable by ensuring depots are located "close" to or even collocated with all customers.

B. RECOMMENDATIONS

Though the personal computer version of the SAILS model used in this study accommodates a large transaction file, certain aspects of model setup should still be performed outside SAILS . Because SAILS does not possess all of the

rate structures for modes used by DOD, this study recommends that transportation rates for each product aggregation, depot, and customer link be developed outside the model and provided as user-defined values. Because of the limited nature of this study and the lack of readily available data, this approach has not been feasible.

DLA depots currently have excess capacity. Depot closure and reorganization is inevitable under declining Defense budgets. This thesis has demonstrated the flexibility of the SAILS model and its usefulness as a tool to make these closure decisions. Though major concerns exist within DLA about data aggregation, this thesis has shown that data aggregation does not lead to significant modeling discrepancies within SAILS. The 29-aggregate product, 113-customer aggregation model is the means to model DLA's distribution network and SAILS is the tool to make these depot closure decisions.

APPENDIX A

The following mathematical formulation is the general form of the SAILS model:

MODEL FORMULATION

Indices

- i Products (aggregated groups of National Stock Numbers)
- v Suppliers (aggregated supplier regions)
- d Distribution depots
- c Customers (aggregated customer regions)

Data

- $SUP_{i,v}$ Supplies of each product by supplier
- $BUY_{i,v}$ Cost of each product by supplier
- $INB_{i,v,d}$ Inbound transportation cost per product unit, by vendor/depot
- $VCST_{i,d}$ Variable handling cost by product/depot
- $FCST_d$ Fixed cost of operating the depot
- $BRDN_{i,d}$ Burden rate per product unit by depot
- $LCAP_d$ Lower/Upper capacity of depot (in burden units)
- $UCAP_i$
- $OUTB_{i,d,c}$ Outbound transportation cost per product unit, by depot/customer
- $OUTBD_{i,v,c}$ Outbound transportation cost by product from vendor to customer
- $DEM_{i,c}$ Demand by product/customer

VARIABLES

- $X_{i,v,d}$ Inbound flows by product from supplier to depot
 $Y_{i,d,c}$ Outbound flows by product from depot to customer
 Z_d Binary variable to open/close depot
 $Q_{i,d,c}$ Binary variable for sole sourcing by product/depot to customer
 $P_{i,v,c}$ Plant direct shipments by product from supplier to customer

FORMULATION

$$\text{MIN } \sum_{i,v,d} (\text{BUY}_{iv} + \text{INB}_{ivd} + \text{VCST}_{id}) X_{ivd} + \sum_{i,d,c} (\text{OUTB}_{idc} Y_{idc}) + \sum_d (\text{FCST}_d Z_d) + \sum_{i,v,c} (\text{BUY}_{iv} + \text{OUTBD}_{ivc}) P_{ivc}$$

subj to

- 1) $\sum_d X_{ivd} + \sum_c P_{ivc} \leq \text{SUPPLY}_{iv} \quad \forall i,v$
- 2) $\sum_d Y_{idc} + \sum_v P_{ivc} \geq \text{DEM}_{ic} \quad \forall i,c$
- 3) $\sum_{i,v} (\text{BRDN}_{id} X_{ivd}) \leq \text{UCAP}_d Z_d \quad \forall d$
 $\sum_{i,v} (\text{BRDN}_{id} X_{ivd}) \geq \text{LCAP}_d Z_d \quad \forall d$
- 4) $\sum_d (\text{FCST}_d Z_d) \leq \text{BUDGET}$
- 5) $Q_{i,d,c} \leq Z_d \quad \forall i,d,c$
- 6) $\sum_v X_{ivd} \geq \sum_c Y_{idc} \quad \forall i,d$
- 7) $Y_{idc} \leq \text{DEM}_{i,c} Q_{i,d,c} \quad \forall i,d,c$
 $\sum_d Q_{i,d,c} = 1 \quad \forall i,c$

CONSTRAINT EXPLANATION

- 1) Demand can not exceed supplier's capacity.
- 2) All customer demand must be met.
- 3) For each depot, throughput must not exceed depot capacity. Since handling of aggregate products is not uniform, a burden rate is determined for each aggregate product.
- 4) The fixed cost of operating depots must remain within budgetary constraints.
- 5) This constraint ensures that "sole sourcing" a customer zone assignments can only be made to open depots.
- 6) This is the flow balance constraint.
- 7) Customers are sole sourced for each product to a specific depot.

APPENDIX B

Table B1. Represents the eighty-eight FSC product groupings managed by DLA

FSC PRODUCT GROUP	DESCRIPTION	FSC PRODUCT GROUP	DESCRIPTION
10	Weapons	53	Hardware & Abrasive
12	Fire Control Equip	54	Prefabricated Structures & Scaffolding
14	Guided Missiles Equip	55	Lumber, Millwork, Plywood, & Veneer
15	Air & Airframe Structural Comps	56	Construction & Building Materials
16	Air Comps & Accessories	58	Communication Equip
17	Air Launching, Ldg, & Grnd Handling	59	Electrical & Electronic Equip/Comp
20	Ship & Marine Equip	60	Fiber Optic Mats, Comps, Assys
22	Railway Equip	61	Electric Wire & Power & Dist
24	Tractors	62	Lighting Fixtures & Lamps
25	Vehicular Equip Components	63	Alarm & Signal Systems
26	Tires	65	Medical, Dental, & Veterinary Equip
28	Engines, Turbines, & Comps	66	Instruments & Laboratory Equip
29	Engine Accessories	67	Photographic Equip
30	Mechanical Power Transmission	68	Chemicals & Chemical Products
31	Bearings	69	Training Aids & Devices
32	Woodworking Machinery & Equip	70	General Purpose ADPE, Software
34	Metalworking Machinery	71	Furniture
35	Service & Trade Equip	72	Household & Coml Furnishings
36	Special Industry Machinery	73	Food Preparation & Serving Equip
37	Agricultural Machinery & Equip	74	Office Machines, Visible Record Equip
38	Construction, Mining, Excavating	75	Office Supplies & Devices
39	Materials Handling Equip	76	Books, Maps, & Other Publications
40	Rope, Cable, Chain, & Fittings	79	Cleaning Equip & Supplies
41	Refrigeration & Air Cond Equip	80	Brushes, Paints, Sealers, & Adhesives
42	Fire Fighting, Rescue & Safety Equip	81	Containers, Packaging, & Packing Supplies
43	Pumps & Compressors	83	Textiles, Leather, Furs, Notions, Yarn, Tents
44	Furnaces, Steam, Plant, Drying Equip	84	Clothing & Individual Equip
45	Plumbing, Heating, & Sanitation Equip	85	Toiletries
46	Water Purification & Sewage Treat	86	Substance
47	Pipe, Tube, & Hose	91	Fuels, Lubricants, Oils, & Waxes
48	Valves	93	Nonmetallic Fabricated Materials
49	Maintenance & Repair Shop Equip	95	Metal Bars, Sheets & Shapes
51	Hand Tools	96	Ores, Minerals, & their Primary Products
52	Measuring Tools	99	Miscellaneous

Table B2. Represents a detailed breakdown of the product classes available in FSC product group 53.

FSC	Description
5305	Screws
5306	Bolts
5307	Studs
5310	Nuts & Washers
5315	Nails, Keys & Pins
5320	Rivets
5325	Fastening Devices
5330	Packing & Gasket Materials
5335	Metal Screening
5340	Miscellaneous Hardware
5345	Disks & Stones Abrasive
5350	Abrasive Materials
5355	Knobs & Pointers
5360	Coil, Flat, & Wire Springs
5365	Rings, Shims & Spacers

APPENDIX C

Table C1 Listing of P&C's represented in the material release order files for FY 92. Additionally, this table provides the mean unit wt standard deviation, mean extended weight (request quantity multiplied by unit weight), and standard deviation extended weight.

P&C	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1005	Guns 30 MM	52976	1.08	3.33	41 01	508 86
1010	Guns Over 30 MM Up To 76 MM	4000	1.44	1.48	20 38	159 9
1015	Guns 76 MM Thru 125 MM	6886	4.08	7.47	25 43	295 3
1020	Guns Over 125 MM Thru 150 MM	2505	2.47	7.14	8 47	53 13
1025	Guns Over 150 MM Thru 200 MM	3587	4.62	8.88	28 83	151 88
1030	Guns Over 200 MM Thru 300 MM	27	1.02	1.44	3 25	6 35
1035	Guns Over 300 MM	58	2.85	0.48	12 55	13 71
1040	Chemical Weapons and Equip	488	1.38	0.83	4 88	17 75
1045	Launchers Torpedo & Depth Charge	442	1.88	0.19	8 31	24 87
1050	Launchers Torpedo & Pyrotechnic	1548	1.88	1.78	15 43	88 7
1055	Launchers & Miss Launcher Equip	183	1.83	0.45	51 06	312 32
1060	Commissary & Compton Equip	223	1.88	0	108 87	248 38
1065	WVH Army Interchange	388	8.18	8.38	27 45	80 82
1070	Missiles Weapons	3545	1.3	2.03	34 72	288 41
1110	Pie Control Division	23	2.19	1.74	3 28	3 08
1120	Pie Control Components, Shields & Devices	387	0.8	0.88	5 28	12 85
1130	Control Switching & Transfer Equip	3587	1.38	5.91	9 21	48 88
1135	Pie Control Switching Mechanisms	1	1.84		8 84	
1140	Pie Control Displaying Indicating Equip	287	0.14	0.11	0 8	1 88
1145	Pie Control Equip Control Airframe	83	1.31	0.51	2 56	3 51
1150	Arm & Gunner Pie Control Comp	878	0.53	0.3	2 88	8 98
1155	Arm & Gunner Pie Control Comp	447	0.24	0.15	0 87	2 88
1160	Pie Control Motor Equip Control Air	1038	3.01	7.07	8 73	28 3
1165	Pie Control Equip	7	1.48	0	1 48	0
1170	Missiles Pie Control Equip	2811	0.81	1.23	4 24	12 13
1175	Control Missile Components	643	1.8	4.28	17 85	71 54
1180	Control Missile Remote Control Systems	3088	1.88	3.31	11 32	42 38
1185	Launchers Control Missile	8830	1.88	2.77	13 27	86 82
1190	Control Missile Handling Servicing Equip	1338	8.05	8.92	31 1	107 41
1195	Artillery Structural Comp	125447	3.48	8.47	13 88	77 31
1200	Control Projectile	2882	2.11	4.12	12 03	88 88
1205	Artillery Motor Vehicle Drive Mech	13844	1.18	3.33	7 68	36 83
1210	Artillery Launching Equip	8328	2.18	8.83	18 8	178 48
1215	Artillery Motor & Drive Systems	7470	2.15	4.08	22 62	113 48
1220	Artillery Hydraulic Vehicle Operating Comp	28878	1.38	14.81	8 88	83 87
1225	Artillery Air Conditioning Heating Equip	10744	0.83	0.87	3 61	13 88
1230	Artillery Motor Vehicle & Tire Equip	8510	4.12	8.9	144 38	881 82
1235	Artillery Motor Vehicle Comp	81288	1.33	6.28	7 62	63 3
1240	Artillery Ammunition Storage & Equip	817	12.17	0.48	58 28	144 84
1245	Artillery Launching Equip	112	12.21	0.88	238 78	638 48
1250	Artillery Ammunition Servicing Equip	22445	12.38	38.4	82 1	387 12
1255	Artillery Ammunition Storage & Equip	1880	18.84	44.41	123 38	728 22
1260	Artillery Ammunition Storage & Equip	3020	28.87	50.88	183 88	1412 77
1265	Artillery & Motor Vehicle Equip	48	18.38	8.31	87 88	187 74
1270	Artillery & Motor Vehicle Equip	1283	8.48	12.28	18 13	88 17
1275	Artillery Ammunition	8187	21	88.48	488 33	18388 63
1280	Artillery	33	8.75	2.78	388 88	1188 81
1285	Artillery Motor Vehicle & Motor Equip	3808	38.33	81.78	1348 88	88178 87
1290	Artillery & Motor Vehicle Accessories	127	21.82	18.38	388 78	727 82
1295	Artillery Ammunition	37	8.18	15 88	1308 88	1828 87
1300	Artillery Motor Vehicle Low Speed	19	85.48	187 23	188 18	278 2
1305	Artillery Wheeled	15	11.5	15 81	11 88	18 88
1310	Artillery Motor Vehicle Prime Structural Comp	147888	22.08	38 83	88 21	432 38
1315	Artillery Motor Transmission Comp	80748	11.83	38 08	88 02	882 87
1320	Artillery Motor Steering Axle Wheel Comp	204882	11.82	47 08	82 42	3277 37
1325	Artillery Fuel System & Accessories	311448	8.88	21 88	28 88	388 88
1330	Artillery Motor Vehicle Comp	87477	8.38	27 43	28 83	338 48
1335	Artillery & Motor Vehicle Ammunition	1881	14.88	11 81	50 37	117 03
1340	Artillery Ammunition Storage Ammunition	18810	14.38	41 8	51 18	782 08
1345	Artillery Ammunition Storage Ammunition	402	1.43	3.18	1 08	7754 08
1350	Artillery Ammunition & Equip	44384	18.21	53 1	1 24	888 88
1355	Artillery Ammunition Servicing & Equip	8	8.28	4.75	8 37	8 74
1360	Artillery Fuel System & Equip	8320	7.44	44 82	18 4	108 08
1365	Artillery Fuel System Wheel & Equip	1	27		108	
1370	Artillery & Motor Vehicle Ammunition	8783	3.18	8 83	32 87	348 44
1375	Artillery & Motor Vehicle Ammunition	17719	0.88	1.88	37 84	773 87
1380	Artillery Motor Vehicle & Equip	1	20 85		1042 7	
1385	Artillery Ammunition & Equip	174	3.4	11 03	4 83	11 78
1390	Artillery Fuel System Components Ammunition	128847	3.11	13 33	12 5	118 87
1395	Artillery Fuel System Components Ammunition	8824	1.27	8 85	12 47	143 88

Table G1. Continued

PSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
2220	Other Electrical Sys Comp Nonresid	111821	4.29	10.48	13.78	89.91
2220	Other Electrical Sys Comp Alcoh	4873	0.82	0.88	18.88	388.88
2220	Other Electrical Sys Comp Nonresid	38072	14.8	38.88	81.83	882.81
2220	Other Electrical Sys Comp Alcoh	891	18.8	47.82	1881.33	43048.8
2220	Other Al & Oil Pumps - Nonresid	118112	3.7	7.3	23.8	308.34
2220	Other Al & Oil Pumps - Alcoh	2834	0.37	0.88	4.88	42.1
2220	Other Pumps	831	18.88	18.43	48.22	144.48
2220	Other Engine Accessories Nonresid	63088	8.83	14.48	30.33	1113.38
2220	Other Engine Accessories Alcoh	8188	8.77	2.83	3.87	18.88
2220	Other Converters & Special Changers	17887	18.87	44.88	47.28	238.43
2220	Other Pulleys, Sprockets & Tension Chains	48482	4.78	18.13	27.8	703.18
2220	Other Drive Shafts, Pin Shafts & Axles	77888	3.13	14.7	24.88	283.88
2220	Other Transmission Power Transmission Equip	88883	7.31	28.18	27.88	811.83
2220	Other Transmission Unpowered	178888	1.87	7.91	18.1	281.41
2220	Other Parts Unpowered	181838	5.88	33.88	12.12	887.82
2220	Other Milling	8882	4.17	8.84	27.87	288.11
2220	Other & Planing Mill Machinery	8	1.28	2.88	4.27	8.81
2220	Other Milling Machinery	343	183.8	382.27	178.8	388.88
2220	Tools - All purposes For Woodworking Mach	2283	0.88	1.87	18.18	43.3
2220	Other & Planing Machinery	128	72.81	287.31	87.78	288.88
2220	Other & Planing Machinery	237	288.82	1.84	388.88	288
2220	Other Milling Machinery	888	87.8	78.77	88.21	121.84
2220	Other Lathes	28	48.88	117.47	288.78	818.23
2220	Other Milling Machinery	238	28.28	88.8	37.18	188.43
2220	Other Milling Machinery	172	78.1	177.14	282.88	1418.74
2220	Other Milling Machinery	11	437.3	388.84	888.38	882.82
2220	Other Milling Machinery	288	8.88	48.84	38.21	148.27
2220	Other Arc Welding Equip	4814	17.81	88.8	48.88	387.38
2220	Other Resistance Welding Equip	78	38.14	78.84	47.7	78.82
2220	Other Welding Heat Cutting Metalworking Equip	8478	4.78	13.88	14.38	118.2
2220	Other Welding Equipment & Accessories	33	112.38	81.8	182.38	184.38
2220	Other Welding Equipment	183	32.3	88.88	88.18	78.38
2220	Other Welding Equipment & Supplies	88884	2.88	7.27	88.88	818.8
2220	Other & Planing Machinery	382	178.88	482.33	277.87	1121.34
2220	Other & Planing Machinery	14	138.81	282.88	138.88	282.48
2220	Other & Planing Machinery	12	3.18	8.88	8.88	7.84
2220	Other Planing	287	278.18	818.23	882.48	888.82
2220	Other & Planing Machinery	238	48.23	82.78	113.48	387.4
2220	Other Machinery & Accessories	21	88.87	188.78	88.88	138.48
2220	Other Machinery	12	3.38	18.38	3.88	18.28
2220	Other Secondary Metal Forming-Cutting Mach	178	88.88	34.18	82.1	1878.81
2220	Other Tools	87	88	32.38	78.38	48.38
2220	Other Tools For Machine Tools	22813	8.83	2.88	14.7	448.38
2220	Other Tools For Secondary Metal Mach	434	1.82	8.88	8	28.47
2220	Other Tool Accessories	18234	3.18	12.34	28.38	218.81
2220	Production Jigs, Fixtures & Templates	718	8.18	8.4	2.88	8.88
2220	Other & Planing Machinery	1837	11.88	88.88	88.88	271.72
2220	Other Milling Equip	11	182.18	387.81	183.18	387.1
2220	Industrial Sewing Machines & Mobile Tools	1818	88.88	148.34	78.88	228.87
2220	Other & Planing Machinery	83	18.11	8.87	88.12	83.88
2220	Other Machinery Service & Trade Equip	38	8.88	8	1.18	1.83
2220	Other Machinery & Accessories	2882	31.38	88.8	184.8	1887.48
2220	Industrial Milling Machinery	274	4.88	17.2	7.82	34.11
2220	Other & Planing Machinery	78	42.88	88.27	288.88	1488.38
2220	Other Industrial Machinery	1	338		338	
2220	Other & Planing Machinery	1	28.44		412.3	
2220	Other & Planing Machinery	13	473	8	473	8
2220	Chemical & Pharmaceutical Machinery	7	18.78	43.31	18.88	43.38
2220	Other & Planing Machinery	1888	8.88	22.88	18.88	82.88
2220	Industrial Gas Production Machinery	4	1.3	8	4.88	8.87
2220	Other & Planing Machinery	1	388.81		1188.83	
2220	Other Machinery - Industrial Equip & Sup	88	28.88	38.48	817.18	3088.27
2220	Industrial Metal Container Mill Mach	2	43	8	188.3	182.83
2220	Industrial Assembly Machinery	8	1.3	8.88	1.83	8.41
2220	Other Work Station Environment Equip	223	31.81	138.83	102.4	283.77
2220	Manufacturing Special Industry Machinery	888	14.4	28.28	28.88	81.84
2220	Other Production Equip	24	88.87	148.88	188.1	214.84
2220	Other Climate & Frost Control Equip	1881	38.43	148.81	28.18	418.32
2220	Other & Planing Machinery	884	8.84	8.88		14.74
2220	Other & Planing Machinery	2887	73.88	178.21	388.18	1488.82

Table C1. Continued

FEC	Description	Freq	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
3978	Cement & Cement Mortar	788	18.34	37.48	38.23	176.38
3979	Cement & Cement Mortar Attachments	481	128.88	341.2	287.88	658.81
3980	Machine Tools (Grinding, Earth, Boring, Etc.)	1288	28.64	88.88	82.21	137.28
3981	Hand Chiseling & Chiseling Equip	1727	83.47	148.38	638.34	888.78
3982	Tool & Tooling Attachments	3788	78.38	281.87	283.83	1384.18
3983	Automated Production Distribution Equip	88	14.38	88.34	887.88	4888.88
3984	Man Construction Equip	3811	31.13	188.82	72.88	274.88
3985	Compressor	811	81.88	78.48	817.82	3127.8
3986	Hand Handling Equip - Hossell Prop	2818	128.17	178.44	488.81	2837.88
3987	Workshop Tools & Workshop Tool Prop	4542	28.34	88.13	48.8	147.8
3988	Machine Tools (Grinding & Boring)	3732	87.88	132.88	288.88	888.21
3989	Machine Tools (Grinding & Boring)	4283	83.82	147.3	187.7	833.83
3990	Workshop Tools (Grinding & Boring)	184	28.83	18.47	288.47	871.34
3991	Man Construction Equip	3881	88.21	188.84	8878.84	88842.83
3992	Chain & Wire Rope	4888	88.88	188.88	817.43	88277.88
3993	Power Rope Cable & Ties	27177	84.82	138.43	388.41	4881.8
3994	Wire Rope Cable & Chain	47878	4.88	38.38	42.8	387.84
4000	Construction Equip	3874	318.71	348.81	812.88	7388.48
4001	Air Conditioning Equip	1888	184.3	131.88	812.34	2378.8
4002	Refrigeration & Air Conditioning Equip	27883	18.38	88.44	134.3	8848.78
4003	Power Air Conditioning & Motor Equip	28838	11.88	84.88	44.88	1888.88
4004	Power Air Conditioning	38887	28.42	47.8	381.34	3882.22
4005	Machine Tools (Grinding & Boring)	12478	8.48	88.83	77.23	788.87
4006	Refrigeration & Interconnection Equip	1887	8.31	12.38	88.34	888.88
4007	Hand & Machine Equip	48834	2.83	12.88	82.81	888.8
4008	Construction & Machine Power	21818	18.78	72.33	48.43	417.48
4009	Power & Motor Power	81888	12.84	83.81	48.3	3848.7
4010	Construction, Refrigeration, & Power	74428	3	8.41	28.81	288.38
4011	Industrial Equip	1848	82.48	187.17	383.38	3888.18
4012	Hand Construction & Power Construction	1134	87.73	138.88	138.83	388.84
4013	Industrial Construction (Man Labor & Equip)	88	188	287.17	148.73	227.78
4014	Power Construction & Construction	7888	11.21	37.84	88.38	2448.83
4015	Power Construction Equip	1378	18.88	88.88	218.71	1488.8
4016	Power Construction & Accessories	28882	8.88	28.18	112.38	788.87
4017	Power Construction Equip & Motor Power	12884	28.18	121.88	118.18	488.8
4018	Power Construction Equip	4131	4.48	14.41	34.87	88.11
4019	Man Construction (Grinding & Boring) Equip	18888	11.88	38.8	84.11	378.88
4020	Power Construction Equip	388	21.7	81.84	218.88	1888.88
4021	Power Construction Equip	88	8.43	28.83	28.2	87.34
4022	Power Construction Equip (Motor & Industrial)	188	7.78	18.88	11.72	18.78
4023	Power Construction Equip	188	4.41	38.38	283.81	8888.38
4024	Power & Ties	28884	3.88	22.88	77.72	13871.48
4025	Power & Ties (Power)	28884	8.7	8.82	8.73	182.28
4026	Power & Ties (Power)	21883	8.4	48.87	14.81	84.34
4027	Power & Ties (Power)	188887	8.38	27.31	24.88	881.38
4028	Power Construction Equip	24238	17.22	88.38	74.83	1887.88
4029	Power Construction Equip	8888	7.71	13.37	44.37	287.37
4030	Power Construction Equip & Construction Equip	73	8.37	0	88.83	181.48
4031	Power Construction Equip	28	2.34	1.88	18.82	18.48
4032	Power Construction Equip	38888	8.48	22.18	38.1	883.38
4033	Power Construction Equip	818	1.88	1.88	4.88	18.22
4034	Power Construction Equip	1814	2.18	4.81	22.81	838.88
4035	Power Construction Equip	1888	8.88	8.88	8.8	28.82
4036	Power Construction Equip	18884	17.37	42.81	111.12	812.32
4037	Power Construction Equip	178	8.84	1.84	8.44	17.14
4038	Power Construction Equip	1483	8.87	8.83	2.8	8.88
4039	Power Construction Equip	11	7.47	3.8	28.72	38.88
4040	Power Construction Equip	1	1.28	0	1.28	0
4041	Power Construction Equip	183	1.28	0	4.17	8.84
4042	Power Construction Equip	18	1.28	0	2.18	1.38
4043	Power Construction Equip	21	1.88	1.23	2.84	3.83
4044	Power Construction Equip	1882	2.34	5.17	8.81	83.88
4045	Power Construction Equip	2	2.31	0	3.48	1.83
4046	Power Construction Equip	887838	8.8	1.88	18.87	431.5
4047	Power Construction Equip	388184	8.48	2.88	8.2	187.88
4048	Power Construction Equip	31384	8.38	1.83	14.82	188.34
4049	Power Construction Equip	882388	8.38	8.3	8.18	373.71
4050	Power Construction Equip	243888	8.88	7.81	18.77	487.88
4051	Power Construction Equip	283482	8.38	2.48	18.23	878.33
4052	Power Construction Equip	182883	8.14	8.48	2.88	81.88

Table C1. Continued

PIC	Description	Freq	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
8338	Painting & Coating Materials	1087188	0.72	12.53	4.38	128.01
8339	Metals Screenings	1411	34.34	88.84	288.54	1288.34
8340	Min Handways	883283	1.18	8.41	13.3	308.71
8341	Chalk & Gypsum Abrasive	27	1.21	0.34	8.88	8.87
8342	Abrasive Media	38	32.87	21.18	43.14	34.83
8343	Grains & Polishes	88882	8.88	8.41	8.48	2.88
8344	Coil, Plug & Wire Springs	124338	0.38	3.81	3.18	81.78
8345	Nails, Shims, & Spacers	232781	0.23	4.88	2.82	88.78
8410	Prefabricated & Portable Building	848	28.88	48.48	148.38	733.83
8411	Steel Wall Sections	184	0.41	1.13	1.88	1.82
8420	Refrigerated Piping & Plumbing	881	23.77	28.88	884.88	8188.83
8430	Storage Tanks	1011	14.88	88.88	48.88	278.87
8440	Refrigerating Equip & Controls Forms	1884	48.27	47.34	127.88	288.8
8441	Refrigerating Tank Structures	28	38.7	17.88	84.82	84.81
8480	Mass Prefabricated Structures	1137	87.87	444.71	1888.37	7787.31
8490	Lumber & Related Basic Wood Mats	4234	8.38	18.82	1288.88	8884.73
8500	Aluminum	2	88.48	0	1388.7	284.38
8510	Plumbing & Vectors	285	44.84	18.48	4878.88	24881.38
8520	Plumbing Fixtures & Gates	1018	82.33	72.38	4238.82	24881.31
8530	Mass Construction Mats	3	1888.78	1372.71	188288.88	284278.8
8540	Telephone & Telegraph Equip	13801	3.22	7.48	88.12	382.22
8550	Communications Security Equip	218	2.88	0.82	11.27	18.18
8560	Other Cryptologic Equip & Comp	88	2.88	0.84	8.2	8.28
8570	Telephone & Facsimile Equip	8788	0.43	1.78	2.87	18.3
8580	Radio TV Equip Except Airborne	4877	8.48	11.12	38.88	218.88
8591	Radio TV Equip Airborne	1037	0.34	1.83	8.28	87.88
8592	Radio Navigation Equip- Non Airborne	188	7.38	18.2	18.81	28.31
8593	Radio Navigation Equip- Airborne	1233	8.38	8.8	1.81	8.83
8594	Intercom Public Address Sys-Non	818	8.88	8.32	18.8	28.83
8595	Intercom Public Address Sys-Air	288	8.78	1.38	2.83	8.88
8596	Signal Reception & Reproduction Equip	2787	1.81	3.88	187.38	1872.33
8597	Video Recording & Reproduction Equip	2784	1.88	1.23	88.23	188.88
8600	Radio Equip Except Airborne	1888	2.87	3.7	83.11	1328.32
8601	Radio Equip Airborne	2174	0.88	8.8	3.84	28.2
8610	Underwater Sound Equip	1188	8.88	8.88	28.88	277.88
8620	Unidentified Light Gun Equip	344	3.18	4.88	12.72	28.81
8630	Anti Vehicle Equip	8831	8.8	1.38	8.81	28.88
8640	Unidentified Chemical Radiation Devices	113	1.48	1.81	3.87	8.88
8650	Steel Construction & Civil Work	1388	8.87	8.88	8.88	18.88
8660	Mass Communication Equip	14881	1.37	8.88	14.84	148.18
8670	Antennas	238883	8.18	2.88	1.88	48.1
8680	Cables	117881	8.17	1.87	1.37	18.48
8690	Wires & Networks	28888	1.12	4.78	4.84	127.31
8700	Power & Lighting Arresters	148148	8.2	1.88	3.88	28.27
8710	Ground Breakers	88817	1.34	8.7	8.8	217.43
8720	Switches	274878	0.88	3.12	2.42	111.88
8730	Connectors Electrical	488888	0.23	7.18	3.83	228.88
8740	Loop Terminals & Terminal Strips	138482	0.87	2.82	12.87	1888.14
8750	Relays & Solenoids	118378	8.74	1.87	2.78	38.38
8760	Cable & Transformers	88878	3.73	21.18	18.84	123.88
8770	Photoelectric Controls	11381	8.2	2.87	8.73	3.82
8780	Electric Tubes & Assoc Hardware	38848	2.22	7.82	14.82	1881.81
8791	Semiconductor Devices & Assoc Hardware	188721	8.88	8.38	1.48	47.28
8792	Microcircuits - Electronics	188888	8.11	14.81	8.78	48.34
8793	Electronic Modules	3881	8.31	2.84	1.82	88.88
8794	Hydraulic Hydraulic Manometers & Sensors	42848	2.38	7.81	18.88	131.88
8795	Gas Insulators & Insulating Mats	83128	1.38	8.84	28.38	888.82
8796	Electrical Hardware & Supplies	128887	2.38	18.88	84.33	384.77
8797	Electrical Control Switches & Electrodes	18888	0.41	4.87	8.15	282.88
8798	Optoelectronic Devices & Assoc Hardware	12448	0.87	8.82	8.88	7.81
8799	Antennas Waveguides & Related Equip	88834	2.33	8.43	8.28	83.88
8800	Switches & Relays	7888	1.87	2.84	8.82	488.91
8801	Cable Cord wire Assemblies- Comm Equip	88834	1.88	3.88	8.41	88.8
8802	Mass Electrical Equip	38832	8.88	1.2	2.48	18.81
8803	Mass Electronic Components	184884	0.28	1.18	8.7	187.88
8810	Fiber Optic Cables	8	0.81	0	8.88	8.18
8820	Fiber Optic Cable Assy & Harness	187	0.88	0.88	0.34	8.78
8821	Fiber Optic	8	0.83	0	18.34	11.34
8822	Fiber Optic	14	0.83	0	4.84	2.88
8830	Fiber Optic Devices	18	8.88	1.78	1.88	3.21

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
0000	Paper Goods	4	0.83	0	2.98	0.92
0000	Paper Goods	1	0.83		4.38	
0000	Paper Goods Instruments	146	0.18	0.32	12.73	48.74
0000	Paper Goods Accessories & Supplies	24	0.1	0.02	6.08	0.63
0000	Paper Goods Ink & Toner	3	0.83	0	28.37	44.87
0000	Paper Goods Misc	1	0.83		1.08	
0000	Paper Goods Misc	24888	12.3	61.5	88.88	7888.82
0000	Paper Goods Misc	13218	8.14	78.88	38.88	1132.41
0000	Paper Goods Misc	7484	18.88	88.82	44.88	378.78
0000	Paper Goods & Computer Ink & Toner	872	118.18	184.88	388.87	784.81
0000	Paper Goods & Computer Ink & Toner	628	8.88	21.21	48.78	288.38
0000	Paper Goods & Computer Ink & Toner	13888	8.38	21.88	28.88	114.13
0000	Paper Goods & Computer Ink & Toner	33388	1.8	2.38	84.31	1218.17
0000	Paper Goods & Computer Ink & Toner	41872	18.37	27.3	113.78	4188.81
0000	Paper Goods & Computer Ink & Toner	118221	3.13	18.73	484.3	17887.88
0000	Paper Goods & Computer Ink & Toner	88888	8.12	28.88	31.14	318.88
0000	Paper Goods & Computer Ink & Toner	4888	3.88	6.12	8.82	28.82
0000	Paper Goods & Computer Ink & Toner	81188	1.18	8.38	28.81	1484.78
0000	Paper Goods & Computer Ink & Toner	188184	1.37	2.81	7.88	318.18
0000	Paper Goods & Computer Ink & Toner	38888	4.81	11.34	88.7	488.38
0000	Paper Goods & Computer Ink & Toner	287788	0.42	1.38	28.38	428.82
0000	Paper Goods & Computer Ink & Toner	13887	1.48	3.8	28.88	128.82
0000	Paper Goods & Computer Ink & Toner	21331	1.84	1.88	38.87	184.88
0000	Paper Goods & Computer Ink & Toner	8	2.34	1.7	2.74	1.7
0000	Paper Goods & Computer Ink & Toner	484	12.32	28.88	38.18	288.84
0000	Paper Goods & Computer Ink & Toner	2778	0.82	1.81	2.87	11.78
0000	Paper Goods & Computer Ink & Toner	13788	2.48	6.88	18.88	444.2
0000	Paper Goods & Computer Ink & Toner	88888	1.37	8.8	88.87	1888.87
0000	Paper Goods & Computer Ink & Toner	3888	3.88	8.77	138.83	787.38
0000	Paper Goods & Computer Ink & Toner	78888	2.81	8.12	88.38	378.38
0000	Paper Goods & Computer Ink & Toner	28877	1.88	4.87	87.8	888.88
0000	Paper Goods & Computer Ink & Toner	114881	1.78	18.81	18.81	888.82
0000	Paper Goods & Computer Ink & Toner	488	42.38	388.38	888.88	11884.81
0000	Paper Goods & Computer Ink & Toner	88881	14.38	28.88	288.88	1873.87
0000	Paper Goods & Computer Ink & Toner	11888	7.88	18.88	141.88	1877.2
0000	Paper Goods & Computer Ink & Toner	88878	8.88	7.18	18.18	288.81
0000	Paper Goods & Computer Ink & Toner	14888	41.88	288.81	888.88	2788.44
0000	Paper Goods & Computer Ink & Toner	18717	1.88	8.88	24.77	414.41
0000	Paper Goods & Computer Ink & Toner	4888	1.8	18.88	11.2	88.38
0000	Paper Goods & Computer Ink & Toner	8888	8.88	3.81	4.88	38.71
0000	Paper Goods & Computer Ink & Toner	2824	0.42	1.18	4.42	38.73
0000	Paper Goods & Computer Ink & Toner	28848	0.84	2.34	3.81	81.84
0000	Paper Goods & Computer Ink & Toner	78888	0.88	8.1	3.48	38.77
0000	Paper Goods & Computer Ink & Toner	12888	2.77	8.87	28.81	113.78
0000	Paper Goods & Computer Ink & Toner	8187	0.88	38.38	18.48	88.87
0000	Paper Goods & Computer Ink & Toner	28888	3.88	18.38	88.1	448.31
0000	Paper Goods & Computer Ink & Toner	18788	0.88	2.32	3.27	18.88
0000	Paper Goods & Computer Ink & Toner	7888	1.87	3.88	8.48	23.88
0000	Paper Goods & Computer Ink & Toner	381	1.88	1.81	138.88	1288.2
0000	Paper Goods & Computer Ink & Toner	3881	1.34	4.88	22.81	244.38
0000	Paper Goods & Computer Ink & Toner	8888	2.18	1.81	18.88	88.88
0000	Paper Goods & Computer Ink & Toner	3878	23.88	48.88	88.48	247.41
0000	Paper Goods & Computer Ink & Toner	8887	8.88	21.22	18.14	183.34
0000	Paper Goods & Computer Ink & Toner	88888	1.84	7.88	8.87	188.88
0000	Paper Goods & Computer Ink & Toner	77848	1.24	7.74	8.81	288.38
0000	Paper Goods & Computer Ink & Toner	8882	2.87	8.84	7.87	42.81
0000	Paper Goods & Computer Ink & Toner	188	1.38	1.77	21.18	88.34
0000	Paper Goods & Computer Ink & Toner	888	1.82	3.88	7.81	23.38
0000	Paper Goods & Computer Ink & Toner	2888	18.81	28.38	37.41	78.8
0000	Paper Goods & Computer Ink & Toner	1728	3.48	18.78	28.22	182.82
0000	Paper Goods & Computer Ink & Toner	24847	8.47	41.2	188.88	1288.81
0000	Paper Goods & Computer Ink & Toner	2887	2.18	4.88	24.88	148.38
0000	Paper Goods & Computer Ink & Toner	18	8.8	8.48	1.88	2.38
0000	Paper Goods & Computer Ink & Toner	88	14.74	12.8	88.81	288.47
0000	Paper Goods & Computer Ink & Toner	28881	37.81	88.37	888.82	6788.88
0000	Paper Goods & Computer Ink & Toner	131	7.47	23.33	37.12	82.38
0000	Paper Goods & Computer Ink & Toner	4128	44.87	84.87	2848.18	88122.34
0000	Paper Goods & Computer Ink & Toner	13113	11.88	48.27	231.88	1771.31
0000	Paper Goods & Computer Ink & Toner	88871	87.27	188.72	717.8	4784.71
0000	Paper Goods & Computer Ink & Toner	881	8.31	8.3	87.43	382.21

Table C1. Continued

PIC	Description	Freq	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
6800	Advanced Training Devices	1763	16.81	58.73	238.31	4831.84
6820	Operational Training Devices	341	1.86	12.83	6.86	18.01
6820	Communication Training Devices	88	0.82	0.38	3.66	7.84
7010	ADPE Configuration	1187	2.17	8.1	3.87	9.4
7020	ADP Control Processing Unit - Analog	137	4.78	0.89	14.88	16.86
7021	ADP Control Processing Unit - Digital	188	0.33	0.28	0.78	1.07
7022	ADP Control Processing Unit - Hybrid	6081	2.27	4.87	18.81	128.41
7030	ADP Input/Output & Storage Devices	88	4.28	2.48	37.31	68.17
7030	ADP Software	1471	0.78	1.44	3.47	18.14
7040	ADP Support Equip	184	0.7	0.88	28.28	83.33
7040	ADP Supplies & Support Equip	14828	1.44	3.4	64.44	338.78
7050	ADP Components	1478	2.08	2.38	8.42	17.10
7100	Household Furniture	8822	18.78	18.71	884.83	9118.11
7110	Office Furniture	880	81.02	27.42	788.78	3387.82
7120	Cabinets Lockers Bins & Shelving	1388	242.08	80.2	888.38	1838.83
7130	Mass Furniture & Fixtures	83	88.84	84.38	887.37	1888.72
7210	Household Furnishings	13834	7.37	12.74	888.81	8888.4
7220	Household & Commercial Util Containers	8848	4.07	4.83	148.88	788
7230	Mass Household Furnishings Appliances	723	3.08	0	88.77	187.18
7310	Food Cooking Baking Serving Equip	28372	30.88	182.38	184	884.82
7320	Kitchen Equip & Appliances	8388	78.81	248.37	178.83	437.88
7330	Kitchen Hand Tools & Utensils	2833	13.88	18.88	837.88	8788.34
7340	Cutlery & Flatware	2328	0.17	0.13	11.88	32.83
7350	Trinkets	1388	1.88	3.47	82.88	488.33
7360	Stain Kits & Cutlery Food Prep & Serving	8381	14.31	38.13	88.88	388.88
7370	Typewriters & Office Type Composing	88	87.27	0	488.88	841.47
7380	Office Type Sound Recording Repro Mach	84	2.28	3.8	3.78	8.18
7400	Vehicle Record Equip	42	11.88	28.32	38.18	87.37
7410	Office Supplies	888	3.21	87.7	8.81	118.88
7420	Office Desks & Accessories	1123	0.88	0.78	18.38	48.88
7430	Stationery & Record Forms	1728	81.84	388.14	888.88	3881.38
7440	Stenciled Forms	188	0.8	0.88	18.43	43.88
7450	Books & Pamphlets	888	4.12	0.84	38.21	82.88
7460	Encyclopedias & Periodicals	1	3	0	3	0
7470	Mass Address Cards & Clones	82	0.48	0.8	0.82	21.34
7470	Memoranda Processed	2	0.34	0	0.34	0
7480	Mass Printed Matter	28888	0.22	0.78	0.48	278.8
7490	Mass Publications & Various Clones	184	74.41	0.48	888.88	1848.87
7500	Various Household Mass & Supplies	381	1.12	3.3	11.78	87.72
7510	Clothing - Children's Garments & Pies	187	28.88	14.81	141.87	484.82
7520	Foot & Adult Clothing	82	2.78	0	17.17	23.77
7530	Footwear & Clothing Components	8	2.78	0	22.88	28.8
7540	Accessories	18	2.48	0.8	7.88	8.91
7550	Shoes & Socks	3881	12.08	11.1	822.88	12817.78
7560	Shirts & Coats	8788	48.48	84.71	1128.38	3321.88
7570	Women Coats & Cloaks	1488	37.88	47.78	188.1	281.38
7580	Men Coats	4478	82.43	84.51	1884.23	8848.8
7590	Suits & Jans	3482	4.2	4.88	88.88	138.23
7610	Shirts & Socks	382	18.83	28.44	288.33	714.88
7620	Footwear & Clothing Bulk Materials	48	7.37	8	788.88	3217.81
7630	Accessories & Clothing Components	4471	1.72	7.8	33.82	87.21
7640	Household Storage & Storage Containers	288	11.84	81.4	288.14	888.8
7650	Trunk Trunks	21814	2.31	17.78	3881.87	18882.2
7660	Vans & Trunks	2734	2.18	8.51	14.84	87.47
7670	Bedding & Apparel Packages	21483	0.4	1.88	48.32	372.31
7680	Footwear & Clothing Materials	38	3.33	4.87	878.88	11288.88
7690	Leather	1188	1.42	1.81	48.8	183.38
7700	Mass Furniture & Selling Materials	2830	0.8	3.67	18.88	88.2
7710	Text & Textiles	28387	88.18	181.87	888.88	8881.18
7720	Mass & Textiles	28888	1.8	2.82	12.21	238.28
7730	Children's Mass	283243	1.88	1.44	37.88	232
7740	Children's Mass	188814	1.14	1.18	14.21	188.88
7750	Children's Special Purpose	412132	1.73	1.87	78.88	1238.3
7760	Children's & Household Mass	38888	0.3	0.1	88.88	438.88
7770	Children's Mass	248721	4.82	1.32	184.44	4228.88
7780	Children's Mass	18888	2.18	0.32	13.38	37.38
7790	Children's Mass	48887	0.23	0.22	44.82	388.8
7800	Children's Mass	8888	0.88	0.84	28.48	228.67
7810	Children's Mass	128808	0.88	0.33	18.88	223.2
7820	Children's Mass	8883	0.24	0.88	178.88	1188.88

Table G1. Continued

POC	Description	Proj	Mean Weight	Std Dev Weight	Mean Est Weight	Std Dev Est Weight
0000	Capital Equip	57280	7.33	2.37	108.87	3012.18
0000	Asset Personal	11488	2.7	3.87	178.78	2882.1
0000	Yacht Soap Shaving Prep - Dandruff	2	11.78	0	111.88	25
0000	Personal Yachting Activities	1180	2.42	0.92	32.87	248.48
0000	Yachting Paper Products	888	25.88	4.82	528.18	1832.83
0000	Special Yachting Foods - Specialty Prep	8	13.07	0.88	1888.87	3548.25
0110	Perk Solid	308	0.11	0.08	57.9	121.41
0180	Oil Grease Cutting Lubricants & Hyd	108870	80.32	141.44	884.8	11423.01
0180	Miss Venus Oil & Fat	1884	28.82	88.88	544.11	8877
0210	Paper & Paperboard	51	2828.27	628.12	48128.84	81738.88
0220	Plastic Fabricated Materials	11888	8.48	8.93	77.33	823.33
0220	Plastic Fabricated Materials	22410	17.33	28.38	188.48	808.42
0240	Glass Fabricated Materials	14273	14.18	22.82	88.03	288.78
0280	Plasticates & Pvc Surfacing Mats	887	38.88	80.88	1482.74	2848.12
0280	Miss Fabricated Nonmetallic Mats	21424	1.87	8.93	21.88	230.42
0300	Wire Nonferrous Iron & Steel	14888	3.13	10.18	38.83	232.38
0310	Iron & Steel Iron & Steel	28128	7.28	20.42	200.18	843.38
0315	Plate Sheet & Strip Iron & Steel	17848	334.81	851.01	1837.81	18281.34
0320	Structural Shapes Iron & Steel	13217	8.17	7.4	833.43	2774
0325	Wire Nonferrous Nonferrous Base Metals	8740	2.88	8	28.48	280.48
0330	Iron & Steel Nonferrous Base Metal	19088	8.01	33.18	80.51	342.47
0335	Plate Sheet Strip Nonferrous Base Metal	30087	78.43	148.87	338.72	1330.58
0340	Structural Shapes Nonferrous Base Metal	10818	1.13	4.28	81.88	482.88
0345	Plate Sheet Strip & Wire Precious Metal	39	0.03	0.03	0.88	1.82
0350	Aluminum Nickel & Synthetic	108	2.08	3.18	8.71	11.31
0355	Aluminum Metal Materials & Master Alloys	48	1	0.01	134.81	448.81
0360	Iron & Steel Primary & Semi-finished Prod	188	24.11	18.34	448.88	1384.83
0365	Nonferrous Base Metal Primary	887	3.72	11.88	1481.88	11078.15
0370	Precious Metals Primary Forms	138	8.88	0	83388.11	18288.83
0375	Steel Advertising Displays	182	24.13	40.41	124.38	448.38
0380	Nonferrous Alloys & Metals	88	13.48	0	80.51	103.81
0385	Construction Equip Furnishings & Supply	848	11.83	14.84	47.08	283.21
0390	Nonferrous Cemetery Machinery Equip	327	10.37	18.3	282.82	888.11
0395	Miss Iron	11	10.03	20.33	348.78	778.24

APPENDIX D

Table D1: 87-Product Aggregation Scheme.

Aggregate Product	Product Group	Material Description
1	1000	Weapons
2	1200	Fire Control Equipment
3	1400	Guided Missile Components
4	1600-1699	Air & Airframe Street Comp, Air Corps & Accessories
5	1700	Air Launch, Ldg & Gnd Handling Equip
6	2000	Ship & Marine Equip
7	2200	Airway Equip
8	2400	Tractors
9	2600	Vehicle Equip Corps
10	2800	Air Ties
11	2900	Engines, Turbines, & Comps-Air & Non-Air
12	2900	Engine Accessories-Air & Non-Air
13	3000	Motor Power Transmission Equip
14	3100	Bearings
15	3200	Woodworking Machinery & Equip
16	3400	Manufacturing Machinery
17	3600	Service & Trade Equip
18	3800	Special Industry Machinery
19	3700	Agricultural Machinery
20	3900	Crust, Mining, Excavation & Equip
21	4000	Mineral Handling Equip
22	4200	Rope, Cable, Chain, & Piling
23	4100	Submersibles & Air Craft Equip
24	4300	Fire Fighting, Rescue & Safety Equip
25	4500	Pumps & Compressors
26	4400	Pumps, Steam Plant, Drying Equip
27	4600	Pumping, Heating & Sanitation
28	4800	Water Purification & Sewage Treatment Equip
29	4700	Pipe, Tube & Hose
30	4900	Wires
31	4900	Maintenance & Repair Shop Equip
32	5100	Hand Tools
33	5200	Measuring Tools
34	5300	Hardware & Hardware
35	5400	Paints, Varnishes & Staining
36	5500	Lumber, Millwork, Plywood & Veneer
37	5600	Construction & Building Material
38	5800	Communication Equip
39	5900	Electrical & Electronic Equip Corps
40	6000	Photo Equip, Photo, Camera, Access
41	6100	Battery Wire, & Power & Distribution
42	6200	Lighting Fixtures & Lamps
43	6300	Alarm & Signal Systems
44	6400	Medical Dental & Veterinary Equip
45	6500	Instruments & Laboratory Equip
46	6700	Photographic Equip
47	6800	Chemicals & Chemical Products
48	6900	Training Aids & Devices
49	7000	General Purpose Aides, Software, Supplies
50	7100	Furniture
51	7200	Household & Cond Furnishings & Appliances
52	7300	Kitchen & Food Prep Equip
53	7400	Office Machinery, Visible record Equip
54	7500	Office Supplies & Devices
55	7600	Books, Maps & Other Pubs
56	7800	Cleaning Equip & Supplies
57	8000	Brushes, Paints, Sealers, & Adhesives
58	8100	Containers, Packaging & Packing Supplies
59	8300	Vehicles, Parts, Motors, Tents
60	8400	Clothing
61	8500	Telephones
62	8600	Specialty Prep
63	8700	Fuels, Lubricants, Oils & Waxes
64	9000	Nonmetallic Fabricated M'tls
65	9100	Metal Bars, Sheets and Shapes
66	9200	Crust Minerals & Their Primary Products
67	9300	Miscellaneous

Table C2. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 67-product aggregation scheme.

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	70004	1.2001	4.003	38.00	437.00
2	8000	1.2001	4.003	8.4	31.30
3	10000	2.5000	4.014	10.10	62.00
4	200000	2.2000	8.000	10.00	102.11
5	24004	12.0400	30.02	60.00	302.07
6	10000	24.0100	71.002	800.21	3500.30
7	104	10.7410	10.007	070.07	1074.23
8	34	02.0001	100.413	07.41	210.0
9	020000	12.0000	34.004	41.00	1007.43
10	1001	14.0042	11.012	00.37	117.00
11	00223	11.4100	43.143	70.20	000.00
12	470040	0.1000	10.007	34.2	1017.00
13	250000	0.3000	20.302	20.17	700.00
14	337007	1.3014	23.011	14.40	030.00
15	2004	20.7007	100.000	32.00	103.44
16	100070	0.0000	40.470	01.34	704.07
17	3071	32.0100	113.000	00.02	247.27
18	0000	20.0004	00.272	100.70	1300.20
19	2100	27.2000	100.070	72.00	340.00
20	13122	00.7004	100.700	200.00	2104.37
21	10120	01.0004	100.000	1000.37	2000.00
22	120000	37.0004	144.134	332.31	34704.00
23	02700	00.0700	101.000	00.30	7441.00
24	07000	0.0007	30.10	104.12	2101.00
25	147000	0.0000	40.001	37.00	2001.20
26	11000	20.0100	00.100	100.30	2200.00
27	00000	10.0110	00.000	01.71	007.22
28	3700	10.1000	00.000	170.30	000.00
29	000220	1.0004	10.000	00.70	7370.30
30	214740	0.3710	20.000	21.02	000.14
31	70000	11.0042	30.000	00.00	044.2
32	1700	0.700	1.000	3.00	0.20
33	1000	2.00	0.100	0.70	03.30
34	400100	0.0100	0.100	0.07	300.41
35	0000	41.0000	100.000	400.07	3000.30
36	4000	0.100	20.004	1170.30	03700.00
37	1010	04.0000	100.00	4077.00	20710.00
38	01047	2.0000	0.000	20.00	300.00
39	201000	0.0000	7.000	7.07	340.04
40	300	0.1700	0.000	0.70	20.00
41	300000	7.0000	30.000	214.02	11100.30
42	00000	1.1001	4.000	23.00	000.43
43	10077	2.0000	0.007	13.70	400.00
44	1200001	2.0000	30.000	00.00	1000.00
45	300040	1.0441	10.001	14.01	1207.02
46	32100	0.0000	37.000	122.07	1110.4
47	113441	40.0010	100.000	770.31	10001.00
48	3000	0.0071	40.000	104.44	3470.0
49	20374	1.0070	3.714	30.00	200.43
50	0104	01.0007	02.00	040.13	7001.17
51	22000	0.7004	10.000	000.00	0301.01
52	40770	32.3147	104.300	123.04	1002.00
53	104	40.407	40.004	102.41	304.01
54	3000	40.4172	204.001	401.00	2000.00
55	21000	0.3000	2.377	7.3	273.10
56	712	20.0700	30.170	107.01	040
57	70	2.0001	0.000	10.7	21.00
58	20400	32.0000	00.407	003.34	4000.00
59	101007	10.0000	00.110	004.00	00000.00
60	1001400	1.0011	2.120	04.27	2000.00
61	2121	12.1004	11.004	200.31	1140.2
62	0	10.07	0.007	1000.07	3040.20
63	111002	00.4701	140.407	070.30	1133.11
64	70701	11.0070	00.702	130.42	2100.07
65	130000	02.074	300.000	401.27	0004
66	1141	0.7077	13.342	10700.14	00001.04
67	1147	12.0700	10.404	124.20	040.40

Table D3. 44-Product aggregation scheme

Aggregate Product	FSC's	Material Description
1	1000 - 1099	Weapons
2	1210 - 1299	Fire Control Equip, Optical Sighting Equip
3	1420 - 1499	Guided Missile Corps
4	1580	Air & Airframe Brunt Corps
	1610 - 1699	Air Corps & Accessories
	3520	Tires
5	1710 - 1749	Air Launch, Landing, & Ground Handling Equip
6	2010 - 2099	Ship & Marine Equip
	2250/2260/2280	Harbor Equip
7	2410/2430	Traction
	2610 - 2699	Vehicle Equip
	2800/2810/2820/2830/2840/2850/2860/2870/2880/2890	Engine, Turbine, & Comp - Non Air
8	2890	Gas Reciprocating & Diesel Engines, Rocket Engines
9	2910/2920	Steam & Water Turbines, Gas Turbines
10	2910/2920/2930	Engines, Turbines, & Comp - Air
	2940/2950/2960	Engine Accessories - Non Air; Fuel Systems
11	2910/2920/2930	Electrical, Control Systems, Air & Oil Filters, Turbo
	2940/2950/2960	Engine Accessories - Air; Fuel Systems, Electrical Control Systems, Air & Oil Filters
12	3010 - 3049	Marine Power Transmission Equip
	3110 - 3130	Boatage
13	3210/3220/3230	Woodworking Machinery & Equip
	3400 - 3499	Metal Working Machinery & Equip
14	3610 - 3699	Service & Trade Equip: Laundry & Dry Cleaning, Shoe Repair, Sewing Machines
15	3810 - 3899	General Industry Equip
	3710 - 3770	Agricultural Machinery & Equip: Soil Prep & Harvesting Equip
16	3900 - 3999	Construction Mining, Excavating, & Hvy Equip
17	3910 - 3999	Material Handling Equip
18	4010/4020/4030	Refrig, Cabin, Chiller, & Piping
19	4110 - 4149	Refrigeration & Air Cond Equip
20	4210 - 4249	Fire Fighting, Rescue & Safety Equip
21	4310/4320/4330	Pumps & Compressors
	4410 - 4499	Pumps, Steam Plant, & Driven Equip
22	4610 - 4649	Pumps, Heating & Sanitation Equip
	4610 - 4699	Water Pollution & Sewage Treatment Equip
23	4710 - 4749	Pipe, Tube & Hose
24	4810/4820	Valves
25	4910 - 4949	Maintenance & Repair Shop Equip
26	5000 - 5099	Hardware & Abrasives
	5240 - 5299	Metal Forming
27	5410 - 5499	Paints, Enamels & Surface Finishes
	5510 - 5599	Leather, Lumber, Plastics & Veneer
	5610 - 5699	Textiles - Woven, Non Woven, Knitted, Lace, Cord, Mesh, Netting, Tulle, Canvas, Mail
28	5710 - 5799	Communication Equip
29	5810 - 5899	Electrical & Electronic Equip: Control
	5910 - 5999	Power Cable, Cable, Cable, & Accessories
30	6100 - 6199	Electric Wire, & Power & Distribution
31	6210 - 6299	Lighting Fixtures & Lamps
	6310 - 6399	Alarm & Signal Systems
32	6500 - 6599	Medical, Dental, & Veterinary Equip
33	6600 - 6699	Instruments & Laboratory Equip
34	6710 - 6799	Photographic Equip
35	6810 - 6899	Chemicals & Chemical Products
36	6910 - 6949	Training Aids & Devices
37	7010 - 7099	Small Power Equip, Software, Supplies
	7100 - 7199	Furniture
	7210/7220/7230	House Furnishings
38	7310 - 7399	Food Prep & Serving Equip
	7430 - 7499	Office Machines
	7510 - 7549	Office Supplies & Devices
	7610 - 7699	Books, Maps & Other Publications
	7710 - 7799	Measuring Instruments, Photographs, & TV
	8000/8010/8020/8030	Paint Brushes, Preservative Components, Adhesives
39	8100 - 8149	Containers, Packaging & Packing Supplies
	8200 - 8249	Textiles, Furs, Notions, Yarns
40	8300 - 8349	Clothing
	8410 - 8449	Textiles
41	8110/8120/8130	Fuels, Lubricants, Oils & Waxes
42	8510 - 8599	Nonmetallic Fabricated Mats
43	8600 - 8649	Metal Bars, Sheets and Shapes
	8820 - 8899	Ores, Minerals
	8900	Ores, Minerals & Their Primary Products
44	8940	Specialty Prep Dietary Foods
	5110/5120/5130	Hand Tools
	5210/5220/5230	Measuring Tools

Table D4. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 44-product aggregation scheme.

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	78884	1.65	4.57	35.88	437.06
2	8829	1.22	4.58	6.40	33.39
3	10888	2.30	4.61	15.16	62.66
4	254677	2.58	8.70	15.31	161.85
5	24884	12.85	35.62	66.95	352.67
6	16455	24.51	71.96	585.21	33568.32
7	842758	12.06	34.84	41.73	1657.32
8	75102	14.00	47.70	83.03	668.31
9	18121	0.70	2.00	63.57	1394.80
10	457152	5.32	15.71	21.10	481.74
11	21088	1.62	11.20	91.44	8853.98
12	571975	3.37	24.40	20.11	688.19
13	109829	6.44	52.37	50.67	715.65
14	3571	32.92	113.27	66.82	247.27
15	5285	20.48	60.27	109.75	1308.28
16	15311	52.55	162.18	233.93	1963.73
17	19128	61.89	150.28	1055.37	23566.05
18	122856	37.47	144.13	332.31	34794.65
19	52785	35.87	131.05	158.26	7441.85
20	87903	9.63	36.12	154.12	2191.95
21	158725	9.11	47.37	45.27	2281.74
22	52803	13.92	68.89	97.80	595.54
23	943225	1.95	18.07	55.73	7379.39
24	214740	5.37	28.96	23.82	835.14
25	78983	11.88	39.62	56.69	644.20
26	4389777	0.80	7.95	7.98	308.58
27	13752	32.04	141.79	4840.62	54528.19
28	61247	2.05	5.85	28.02	358.85
29	2813619	0.69	7.06	7.56	342.82
30	306500	7.68	33.49	214.62	11169.38
31	479885	1.17	4.37	23.34	678.66
32	1282831	3.00	35.30	69.99	1695.08
33	356349	1.94	10.68	14.91	1267.82
34	32102	9.03	37.21	122.07	1115.40
35	112441	49.53	125.21	775.21	18081.48
36	3040	8.09	45.53	154.44	3476.80
37	25374	1.69	3.71	36.95	265.43
38	101209	22.37	98.28	271.90	3674.63
39	25426	32.54	50.43	663.34	4925.69
40	1425544	3.19	22.75	126.08	23087.42
41	111262	59.48	140.49	875.38	11333.11
42	70701	11.86	60.79	135.42	2109.67
43	136230	62.50	359.09	488.23	8485.96
44	4519	4.35	11.40	39.17	321.37

Table D5 29-Product aggregation scheme

Aggregate Product	FSC	Mainline Description
1	1005 - 1095	Weapons
2	1210 - 1290	Fire Control Equip, Optical Sighting Equip
	1420 - 1450	Guided Missile Components
	1560	Acft & Airframe Structural Components
	1610-1660	Acft Components & Accessories
	1710 - 1740	Acft Launch, Landing, & Ground Handling Equip
3	2620	Tires
	2610/2640	Engines, Turbines, & Components - Acft
	2915/2925/2935/2945	Engine, Accessories - Acft, Fuel Systems
	2995	Electrical, Cooling Systems, Air & Oil Filters
4	2010 - 2090	Ship & Marine Equip
	2230/2240/2250	Railway Equip
5	2410/2420	Tractors
	2510-2590	Vehicle Equip
	2605/2615/2620/2630/	Engines, Turbines, & Comps - Non Acft
	2635/2645/2650/2665	Gas Reciprocating & Diesel Engines, Steam & Water
6		Turbines, Gas Turbines, Rocket Engines
	2910/2920/2930/2940/	Engine Accessories - Non Acft, Fuel Systems, Electrical
	2950/2990	Cooling Systems, Air & Oil Filters, Turbo Superchargers
7	3010 - 3040	Mech Power Transmission Equip
	3110 - 3130	Bearing
	3210/3220/3230	Woodworking Machinery & Equip
	3405 - 3485	Metal Working Machinery & Equip
8	3510 - 3560	Service & Trade Equip, Laundry & Dry Cleaning Equip,
		Shoe Repair, Sewing Machines
	3610 - 3665	Special Industry Equip
	3610 - 3690	Materials Handling Equip
9	3710 - 3770	Agricultural Mach & Equip, Soil Prep & Harvesting Equip
	3805 - 3895	Construction, Mining, Excavating, & Highway Equip
10	4010 - 4030	Rope, Cable, Chain, & Filings
	4110 - 4140	Refrigeration & Air Conditioning Equip
11	4610 - 4640	Plumbing, Heating, & Sanitation Equip
	4610 - 4630	Water Purification & Sewage Treatment Equip
	4710 - 4730	Pipe, Tube & Hose
12	4210 - 4240	Fire Fighting, Rescue, & Safety Equip
13	4310 - 4330	Pumps & Compressors
	4410 - 4460	Furnace, Steam Plant, & Drying Equip
14	4610 - 4620	Valves
15	4610 - 4640	Maintenance & Repair Shop Equip
	5305 - 5385	Hardware & Abrasives
16	5410 - 5460	Prefab Structures & Scaffolding
	5510 - 5530	Lumber, Millwork, Plywood & Veneer
	5620/5630/5640	Fencing, Mass Construction Mat
17	5605 - 5695	Communication
18	5805 - 5860	Electrical & Electronic Equip Comps
	6010 - 6060	Fiber Optic Mats, Comps & Asys
	6105 - 6150	Electric Wire, & Power & Distribution
19	6210 - 6260	Lighting Fixtures & Lamps
	6310 - 6350	Alarm & Signal Systems
20	6505 - 6550	Medical, Dental, & Veterinary Equip
21	6605 - 6699	Instruments & Laboratory Equip
	6710 - 6760	Photographic Equip
22	6810 - 6840	Training Aids & Devices
	7010 - 7050	General Purpose ADPE, Software, Supplies
23	6810 - 6850	Chemicals & Chemical Products
	7105 - 7540	Furniture
	7210/7240/7260	House Furnishings
	7310 - 7360	Food Prep & Serving Equip
	7430 - 7460	Office Machines
24	7510 - 7540	Office Supplies & Devices
	7610 - 7660	Books, Maps, & Other Publications
	7710 - 7730	Musical Instruments, Phonographs, & TV
	8020/8030/8040	Paint Brushes, Preservative Components, Adhesives
	8105 - 8145	Containers, Packaging, & Packing Supplies
	8305 - 8345	Tentiles, Furs, Notions, Tents
25	8405 - 8470	Clothing
	8510 - 8540	Toiletries
26	8110/8150/8160	Fuels, Lubricants, Oils, & Waxes
27	8310 - 8360	Nonmetallic Fabricated Mats
28	8605 - 8645	Metal Bars, Sheets, & Shapes
	8620 - 8660	Ores, Minerals
	8900	Miscellaneous
29	8940	Specialty Prep Dietary Foods
	9110/9120/9130	Hand Tools
	9210/9220/9280	Measuring Tools

Table D6. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 29-product aggregation scheme.

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	78884	1.85	4.57	35.88	437.09
2	18717	1.82	4.63	11.23	51.83
3	318850	3.21	13.27	27.12	2307.51
4	18455	24.51	71.98	585.21	33588.32
5	842758	12.08	34.84	41.73	1857.32
6	532254	6.54	23.28	29.84	512.68
7	571875	3.37	24.40	20.11	688.19
8	137823	15.38	78.55	193.16	8830.46
9	15311	52.55	162.18	233.83	1953.73
10	122858	37.47	144.13	332.31	34794.85
11	1048793	4.26	37.35	63.00	7195.74
12	87903	9.63	38.12	154.12	2191.85
13	158725	9.11	47.37	45.27	2291.74
14	214740	5.37	28.98	23.82	835.14
15	78893	11.88	39.82	58.69	844.20
16	4403529	0.70	11.35	22.45	3073.53
17	81247	2.05	5.85	28.02	358.85
18	2813919	0.89	7.08	7.57	342.82
19	788485	3.70	21.42	98.00	6883.49
20	1262831	3.00	35.30	69.69	1685.08
21	356349	1.94	10.88	14.91	1287.82
22	80516	5.90	29.28	88.01	1139.51
23	112441	49.53	125.21	775.21	18081.48
24	128836	24.41	80.82	350.49	3880.78
25	1425644	3.19	22.75	126.08	23087.42
26	111282	59.48	140.49	875.38	11333.11
27	70701	11.88	80.79	135.42	2109.67
28	138230	62.50	359.09	748.23	8485.98
29	4519	4.35	11.40	17.17	321.37

Table D7: 49-Product aggregation scheme.

Aggregate Product	FSC	Material Description
1	1005-1095	Weapons
2	1210-1287	Fire Control Equipment
	1420-1450	Guided Missile Components
	1560	Airframe Structural Comps
3	1610-1680	Aircraft Comps & Accessories
	1710-1740	Aicft Launching,Ldg, & Gnd Handling Equip
	2620	Tires
4	2010-2090	Ship & Marine Equip
	2230-2250	Railway Equip
5	2410/2420	Tractors
	2510	Vehicular Cab Body Frame; Structural Comps
6	2520	Vehicular Power Transmission Comps
7	2530	Vehicular Brake Steering Axle; Wheel Comps
8	2540	Vehicular Furniture & Accessories
9	2590	Misc Vehicular Comps
10	2805-2895	Engines, Turbines, & Comps
	2910-2995	Engine Accessories
11	3010-3040	Mech Power Transmission Equip
12	3110-3130	Bearings
	3210-3230	Woodworking Machinery & Equip
13	3405-3485	Metaworking Equip
	3510-3590	Service & Trade Equip
	3610-3695	Special Industry Equip
	3710-3770	Agricultural Machinery & Equip
14	3805-3895	Const, Mining, Excavating & Hwy
	3910-3990	Matts Handling Equip
15	4010-4030	Rope, Cable, Chain & Fittings
16	4210-4240	Fire Fighting, Rescue & Safety Equip
	4110-4140	Refrigeration & Air Cond
	4310-4330	Pumps & Compressors
17	4410-4460	Furnace, Steam Plant, Drying Equip
	4510-4540	Plumbing, Heating & Sanitation Equip
	4610-4630	Water Purification & Sewage Treatment Equip
18	4710	Pipe & Tube
19	4720	Hose & Tubing Flexible
20	4730	Fittings, Hose, Pipe, & Tube
21	4810-4820	Valves
	4910-4940	Maintenance & Repair Shop Equip
22	5110-5133	Hand Tools
	5210-5280	Measuring Tools
23	5305	Screws
24	5306	Bolts
	5307	Studs
	5310	Nuts & Washers
	5340	Misc Hardware
25	5355	Knobs & Pointers
	5360	Coil, Flat & Wire Springs
	5365	Rings Shims & Spacers

Table D7. Continued

Aggregate Product	FSC	Material Description
26	5315	Nails, Keys & Pins
27	5320	Rivets
	5325	Fastening Devices
28	5330	Packing & Gasket Mats
	5335	Metal Screening
	5345	Disks & Stones Abrasives
29	5350	Abrasive Mats
	5410-5450	Prefabricated Structures, Scaffolding
	5510-5530	Lumber, Millwork, Plywood & Veneer
	5620-5680	Construction & Building Mats
	5805-5895	Communication Equip
30	5905-5970	Electrical Equip: Resistors, Capacitors, Filters, Networks, Circuit Breakers
31	5975-5999	Electrical Hardware
	6010-6099	Fiber Optics
32	6105-6140	Electric Wire & Power & Distribution
	6150-6160	Misc Power & Distribution
33	6145	Electrical Wire & Cable
34	6210-6260	Lighting Fixtures & Lamps
	6310-6350	Alarm & Signal Systems
35	6505	Drugs, Biologicals
	6508	Medicated Cosmetics & Toiletries
36	6510	Surgical Dressing Mats
	6532	Hospital & Surgical Clothing
	6515	Medical Surgical Instruments Equip
37	6540	Opticians Instruments Equip
	6545	Medical Sets Kits & Outfits
	6550	In Vitro Diagnostic Substances
38	6520	Dental Instruments Equip
	6525	X-Ray Equip Supplies-Medical/Dental
39	6530	Hospital Furniture Equip
40	6810-6850	Chemical & Chemical Products
41	6910-6940	Training Aids & Devices
	7010-7050	Adps, Software, Supplies
	7105-7195	Furniture
42	7210-7290	Household & Coml Furniture
	7310-7390	Food Prep & Serving Equip
	7430-7450	Office Machines
	7510-7540	Office Supplies
43	7610-7680	Books, Maps & Other Publications
	7810-7830	Cleaning Equip & Supplies
	8020-8040	Brushes, Paints, Sealers & Adhesives
44	8105-8145	Containers, Packaging & Packing Supplies
	8310-8390	Nonmetallic Fabricated Mats
45	8305-8345	Textiles
	8405-8410	Outerwear
46	8415-8470	Clothing
	8510-8540	Toiletries
47	8640	Special Prep Dietary Foods
	9110-9160	Fuels, Lubricants, Oils & Waxes
	9505-9545	Metal Bars & Sheets
48*	9620-9690	Ores, Minerals
	9805-9899	Misc
49*	9905-9995	Instruments & Laboratory Equip
	9710-9780	Photographic Equip

Table D8. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 49-product aggregation scheme.

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	76864	1.65	4.57	35.68	437.09
2	19717	1.62	4.63	11.23	51.83
3	279741	3.49	13.79	19.90	187.45
4	16455	24.51	71.96	585.21	33568.32
5	148096	22.06	38.66	55.79	433.91
6	80748	11.53	36.06	56.02	662.87
7	204892	11.92	47.08	52.42	3277.37
8	311445	8.68	21.89	28.09	350.68
9	97477	8.39	27.43	29.63	338.48
10	571463	6.18	22.62	33.18	1788.67
11	234908	6.26	25.33	28.17	756.06
12	337067	1.35	23.51	14.49	636.56
13	118495	7.87	55.80	53.98	743.17
14	34439	57.73	155.75	660.17	17637.96
15	122656	37.47	144.13	332.31	34794.65
16	87903	9.63	36.12	154.12	2191.95
17	264293	15.41	78.37	78.32	3779.35
18	106685	4.41	30.36	263.81	8003.25
19	237074	3.93	22.65	77.72	13671.49
20	566466	0.70	5.52	6.73	192.25
21	214740	5.37	28.96	23.82	635.14
22	82357	11.46	38.87	54.61	826.87
23	587630	0.50	1.68	10.67	431.50
24	386548	0.48	2.77	6.67	113.36
25	1773715	0.64	6.67	6.74	301.44
26	243668	0.66	7.61	10.77	467.65
27	365445	0.24	2.05	7.79	466.42
28	1062186	0.72	12.53	4.38	125.01
29	13817	31.99	141.47	4618.92	54400.68
30	2222066	0.58	7.04	5.43	360.98
31	453100	1.42	7.10	20.80	237.93
32	190279	10.43	40.44	68.71	3233.20
33	116221	3.13	15.73	454.30	17657.65
34	479665	1.17	4.37	23.34	678.68
35	640667	1.58	5.63	60.05	1963.62
36	91173	3.58	6.33	68.28	513.56
37	351566	3.34	48.83	70.72	924.78
38	119174	3.46	73.10	42.09	2305.57
39	56601	14.35	32.93	228.59	1813.67
40	112441	49.53	125.21	775.21	18061.48
41	28414	2.37	15.42	49.52	1166.37
42	74856	27.72	101.36	344.57	4228.77
43	26253	7.11	67.13	64.40	968.95
44	66127	17.33	58.64	275.06	3121.70
45	460784	5.31	39.78	228.17	40455.04
46	984750	2.17	2.41	77.32	2432.62
47	111270	58.47	140.48	675.43	11332.74
48	137377	62.09	357.63	485.19	8450.67
49	388451	2.53	14.92	23.77	1256.27

APPENDIX E

Table E1: Top 250 U. S. cities as identified in SALS (table continued on the next page)

City	State	3-Digit Zip
Springfield	MA	011
Pittsfield	MA	012
Worcester	MA	016
Boston	MA	021
New Bedford	MA	017
Providence	RI	029
Manchester	NH	031
Portsmouth	NH	038
Portland	ME	041
Leviston	ME	042
Bangor	ME	044
Burlington	VT	054
Hartford	CT	061
New London	CT	063
Stamford	CT	068
Newark	NJ	071
Paterson	NJ	076
Long Branch	NJ	077
Atlantic City	NJ	084
Trenton	NJ	086
New Brunswick	NJ	089
New York	NY	100
Nassau-Suffolk	NY	115
Albany	NY	122
Newburgh	NY	125
Glens Falls	NY	128
Syracuse	NY	132
Utica	NY	135
Binghamton	NY	139
Buffalo	NY	142
Rochester	NY	146
Schenectady	NY	148
Pittsburgh	PA	152
Johnstown	PA	159
Sharon	PA	161
Erie	PA	165
Altoona	PA	168
State College	PA	168
Harrisburg	PA	171
York	PA	174
Lancaster	PA	176
Williamsport	PA	177
Allentown	PA	181
Northwest Penna	PA	185
Philadelphia	PA	191
Hooding	PA	198
Wilmington	DE	198
Washington	DC	200
Baltimore	MD	212
Cumtland	MD	215
Hagerstown	MD	217
Charlottesville	VA	229
Richmond	VA	232
Norfolk	VA	235
Petersburg	VA	238
Roanoke	VA	240
Lexington	VA	245
Charleston	WV	253
Huntington	WV	257
Martinsburg	WV	260
Parkersburg	WV	261
Greensboro	NC	274
Wilmington	NC	278
Charlotte	NC	282
Fayetteville	NC	283

City	State	3-Digit Zip
Wilmington	NC	284
Jacksonville	NC	285
Hickory	NC	286
Asheville	NC	287
Columbia	SC	292
Charleston	SC	294
Florence	SC	295
Greenville	SC	296
Rock Hill	SC	297
Atlanta	GA	303
Athens	GA	306
Augusta	GA	309
Macon	GA	312
Savannah	GA	314
Albany	GA	317
Columbus	GA	319
Jacksonville	FL	322
Tallahassee	FL	323
Panama City	FL	324
Pensacola	FL	325
Gainesville	FL	326
Orlando	FL	328
Melbourne	FL	329
Miami	FL	331
West Palm Beach	FL	334
Tampa	FL	336
Lakeland	FL	338
Fort Myers	FL	339
Birmingham	AL	352
Tuscaloosa	AL	354
Florence	AL	356
Huntsville	AL	358
Gadsden	AL	359
Montgomery	AL	361
Anniston	AL	362
Mobile	AL	366
Nashville	TN	372
Chattanooga	TN	374
Johnson City	TN	376
Knoxville	TN	379
Memphis	TN	381
Jackson	MS	392
Biloxi	MS	395
Louisville	KY	402
Lexington	KY	405
Owensboro	KY	423
Columbus	OH	432
Toledo	OH	436
Steubenville	OH	439
Cleveland	OH	441
Akron	OH	443
Youngstown	OH	445
Canton	OH	447
Mansfield	OH	448
Cincinnati	OH	452
Dayton	OH	454
Lima	OH	458
Indianapolis	IN	462
Gary	IN	464
South Bend	IN	466
Fort Wayne	IN	468
Kokomo	IN	469
Muncie	IN	473
Bloomington	IN	474
Evansville	IN	477

Table E1: Continued

City	State	3-DIGIT ZIP
Terre Haute	IN	478
Lafayette	IN	479
Detroit	MI	482
Flint	MI	485
Saginaw	MI	486
Lansing	MI	489
Kalamazoo	MI	490
Jackson	MI	492
Grand Rapids	MI	495
Des Moines	IA	503
Waterloo	IA	507
Sioux City	IA	511
Dubuque	IA	520
Cedar Rapids	IA	524
Des Moines	IA	528
Milwaukee	WI	532
Madison	WI	537
Green Bay	WI	543
Wausau	WI	544
La Crosse	WI	546
Eau Claire	WI	547
Appleton	WI	549
Minneapolis-St Paul	MN	554
Duluth	MN	558
Rochester	MN	559
St Cloud	MN	563
Sioux Falls	SD	571
Fargo	ND	581
Grand Forks	ND	582
Bismarck	ND	585
Billings	MT	591
Great Falls	MT	594
Chicago	IL	606
Kankakee	IL	608
Rockford	IL	611
Peoria	IL	616
Bloomington	IL	617
Champaign	IL	618
Springfield	IL	627
St Louis	MO	631
Kansas City	MO	641
St Joseph	MO	645
Columbia	MO	652
Springfield	MO	658
Lawrence	KS	660
Topeka	KS	666
Wichita	KS	672
Omaha	NE	681
Lincoln	NE	685
New Orleans	LA	701
Lafayette	LA	705
Lake Charles	LA	708
Baton Rouge	LA	708
Shreveport	LA	711
Monroe	LA	712
Alexandria	LA	713
Pine Bluff	AR	716
Little Rock	AR	722
Fayetteville	AR	727
Fort Smith	AR	729
Oklahoma City	OK	731
Lawton	OK	735
Enid	OK	737
Tulsa	OK	741

City	State	3-Digit Zip
Dallas-Ft Worth	TX	752
Texarkana	TX	755
Long View	TX	756
Tyler	TX	757
Wichita Falls	TX	763
Killeen	TX	765
Waco	TX	767
San Angelo	TX	769
Houston	TX	770
Galveston	TX	775
Beaumont	TX	777
Bryan	TX	778
Victoria	TX	779
San Antonio	TX	782
Corpus Christi	TX	784
McAllen	TX	785
Austin	TX	787
Amarillo	TX	791
Lubbock	TX	794
Arlene	TX	796
Odessa	TX	797
El Paso	TX	799
Denver	CO	802
Fort Collins	CO	805
Greeley	CO	806
Colorado Springs	CO	809
Pueblo	CO	810
Casper	WY	826
Boise	ID	837
Salt Lake City	UT	841
Provo	UT	846
Phoenix	AZ	850
Tucson	AZ	857
Albuquerque	NM	871
Las Cruces	NM	880
Las Vegas	NV	891
Reno	NV	895
Los Angeles	CA	900
San Diego	CA	921
Riverside	CA	925
Anaheim	CA	928
Ontario	CA	930
Bakersfield	CA	933
Fresno	CA	937
Sacramento	CA	958
San Francisco	CA	941
Vallejo	CA	945
San Jose	CA	951
Stockton	CA	952
Santa Rosa	CA	954
Sacramento	CA	958
Chicago	CA	959
Redding	CA	960
Portland	OR	972
Salem	OR	973
Eugene	OR	974
Medford	OR	975
Seattle	WA	981
Bellingham	WA	982
Tacoma	WA	984
Olympia	WA	985
Yakima	WA	989
Spokane	WA	992
Richland	WA	993

Table E2. This table provides the 113-customer aggregations by city and three-digit zip code.

CITY	STATE	3-DIGIT ZIP CODE
LOS ANGELES	CA	800
CHICAGO	IL	606
PHILADELPHIA	PA	191
BOSTON	MA	021
SAN FRANCISCO	CA	941
WASHINGTON	DC	200
DALLAS-FT WORTH	TX	752
NASSAU-SUFFOLK	NY	115
ST LOUIS	MO	631
BALTIMORE	MD	212
ATLANTA	GA	303
ANAHEIM	CA	926
NEWARK	NJ	071
SAN DIEGO	CA	921
MIAMI	FL	331
DENVER	CO	802
SEATTLE	WA	981
TAMPA	FL	336
RIVERSIDE	CA	925
PHOENIX	AZ	850
PORTLAND	OR	972
NEW ORLEANS	LA	701
INDIANAPOLIS	IN	462
COLUMBUS	OH	432
SAN ANTONIO	TX	782
SACRAMENTO	CA	958
ROCHESTER	NY	146
SALT LAKE CITY	UT	841
MEMPHIS	TN	381
LOUISVILLE	KY	402
PROVIDENCE	RI	028
NASHVILLE	TN	372
OKLAHOMA CITY	OK	731
DAYTON	OH	454
NORFOLK	VA	235
JACKSONVILLE	FL	322
ORLANDO	FL	328
WORCESTER	MA	016
NE PENNA	PA	188
RICHMOND	VA	232
OMAHA	NE	681
AUSTIN	TX	787
TUCSON	AZ	857
OSCARO	CA	930
RALPH	NC	276
WILMINGTON	DE	198
LONGBRANCH	NJ	077
TACOMA	WA	984
EL PASO	TX	799
LAS VEGAS	NV	891
ALBUQUERQUE	NM	871
HARRISBURG	PA	171
CHARLESTON	SC	294
CHATTANOOGA	TN	374
PORTSMOUTH	NH	038
COLUMBIA	SC	292
SACRAMENTO	CA	933

CITY	STATE	3-DIGIT ZIP CODE
LITTLE ROCK	AR	722
DAVENPORT	IA	528
SHREVEPORT	LA	711
STOCKTON	CA	952
SPOKANE	WA	992
VALLEJO	CA	945
AUGUSTA	GA	309
CORPUS CHRISTI	TX	784
JACKSON	MS	392
COLORADO SPRINGS	CO	809
UTICA	NY	135
EVANSVILLE	IN	477
HUNTSVILLE	AL	358
TRENTON	NJ	086
SALINAS	CA	939
PENSACOLA	FL	325
MELBOURNE	FL	329
MONTGOMERY	AL	361
NEWBURGH	NY	125
MACON	GA	312
FAYETTEVILLE	NC	283
COLUMBUS	GA	319
NEW LONDON	CT	063
SAVANNAH	GA	314
KILLEEN	TX	765
LUBBOCK	TX	794
SPRINGFIELD	MO	658
RENO	NV	895
ATLANTIC CITY	NJ	084
BILOXI	MS	395
TOPEKA	KS	666
BOISE	ID	837
GREEN BAY	WI	543
ALEXANDRIA	LA	713
WILMINGTON	NC	284
BANGOR	ME	044
PETERSBURG	VA	238
TEXARKANA	TX	755
PUEBLO	CO	810
ANNISTON	AL	362
ALBANY	GA	317
HAGERSTOWN	MD	217
JACKSONVILLE	NC	285
LAWTON	OK	735
BELLINGHAM	WA	982
GADSDEN	AL	359
COLUMBIA	MO	652
GRAND FORKS	ND	582
LEWISTON	ME	042
PANAMA CITY	FL	324
LA CROSSE	WI	546
SHERMAN	TX	750
BISMARCK	ND	585
GREAT FALLS	MT	594
CASPER	WY	826
LAWRENCE	KS	660

Table E3 This table provides the 1992-customer aggregations by city and three-digit zip code (table continued on the next page)

CITY	STATE	3-DIGIT ZIP CODE
LOS ANGELES	CA	900
CHICAGO	IL	606
PHILADELPHIA	PA	191
BOSTON	MA	021
SAN FRANCISCO	CA	941
WASHINGTON	DC	200
DALLAS-FT WORTH	TX	752
NASSAU-SUFFOLK	NY	115
ST LOUIS	MO	631
BALTIMORE	MD	212
ATLANTA	GA	303
ANAHEIM	CA	928
NEWARK	NJ	071
SAN DIEGO	CA	921
MIAMI	FL	331
DENVER	CO	802
SEATTLE	WA	981
TAMPA	FL	336
RIVERSIDE	CA	925
PHOENIX	AZ	850
PORTLAND	OR	972
NEW ORLEANS	LA	701
INDIANAPOLIS	IN	462
COLUMBUS	OH	432
SAN ANTONIO	TX	782
SACRAMENTO	CA	958
ROCHESTER	NY	146
SALT LAKE CITY	UT	841
MEMPHIS	TN	381
LOUISVILLE	KY	402
PROVIDENCE	RI	029
NASHVILLE	TN	372
OKLAHOMA CITY	OK	731
DAYTON	OH	454
NORFOLK	VA	235
JACKSONVILLE	FL	322
ORLANDO	FL	328
WORCESTER	MA	016
NE PENNA	PA	185
RICHMOND	VA	232
OMAHA	NE	681
AUSTIN	TX	787
TUCSON	AZ	857
OXNARD	CA	930
RALEIGH	NC	276
WILMINGTON	DE	198
LONGBRANCH	NJ	077
TACOMA	WA	984
EL PASO	TX	799
LAS VEGAS	NV	891

CITY	STATE	3-DIGIT ZIP CODE
ALBUQUERQUE	NM	871
HARRISBURG	PA	171
CHARLESTON	SC	294
CHATTANOOGA	TN	374
PORTSMOUTH	NH	038
COLUMBIA	SC	292
BAKERSFIELD	CA	933
LITTLE ROCK	AR	722
DAVENPORT	IA	528
SHREVEPORT	LA	711
STOCKTON	CA	952
SPOKANE	WA	992
VALLEJO	CA	945
AUGUSTA	GA	309
CORPUS CHRISTI	TX	784
JACKSON	MS	392
COLORADO SPRINGS	CO	809
UTICA	NY	135
EVANSVILLE	IN	477
HUNTSVILLE	AL	358
TRENTON	NJ	086
SALINAS	CA	939
PENSACOLA	FL	325
MELBOURNE	FL	329
MONTGOMERY	AL	361
NEWBURGH	NY	125
MACON	GA	312
FAYETTEVILLE	NC	283
COLUMBUS	GA	319
NEW LONDON	CT	063
SAVANNAH	GA	314
KILLEEN	TX	765
LUBBOCK	TX	794
SPRINGFIELD	MO	658
RENO	NV	895
ATLANTIC CITY	NJ	084
BILOXI	MS	395
TOPEKA	KS	666
BOISE	ID	837
GREEN BAY	WI	543
ALEXANDRIA	LA	713
WILMINGTON	NC	284
BANGOR	ME	044
PETERSBURG	VA	238
TEXARKANA	TX	755
PUEBLO	CO	810
ANNISTON	AL	362
ALBANY	GA	317
HAGERSTOWN	MD	217
JACKSONVILLE	NC	285

Table E3. Continued

CITY	STATE	3-DIGIT ZIP CODE
LAWTON	OK	735
BELLINGHAM	WA	982
GADSDEN	AL	359
COLUMBIA	MO	652
GRAND FORKS	ND	582
LEWISTON	ME	042
PANAMA CITY	FL	324
LA CROSSE	WI	546
SHERMAN	TX	750
BISMARCK	ND	585
GREAT FALLS	MT	594
CASPER	WY	826
LAWRENCE	KS	660
CLEVELAND	OH	441
CINCINNATI	OH	452
MILWAUKEE	WI	532
KANSAS CITY	MO	641
BUFFALO	NY	142
GREENSBORO	NC	274
BRIDGEPORT	CT	066
ALBANY	NY	122
TOLEDO	OH	436
TULSA	OK	741
AKRON	OH	443
SYRACUSE	NY	132
GREENVILLE	SC	296
YOUNGSTOWN	OH	445
FRESNO	CA	937
BATON ROUGE	LA	708
PATERSON	NJ	075
JOHNSON CITY	TN	376
FORT WAYNE	IN	468
MADISON	WI	537
HUNTINGTON	WV	257
MCALLEN	TX	785
KALAMAZOO	MI	490
MANCHESTER	NH	031
CHARLESTON	WV	253
DULUTH	MN	558
JOHNSTOWN	PA	159
ROANOKE	VA	240
GALVESTON	TX	775
LINCOLN	NE	685
WHEELING	WV	260
FAYETTEVILLE	AR	727
TERRE HAUTE	IN	478
CHAMPAIGNE	IL	618
PARKERSBURG	WV	261
MONROE	LA	712
FARGO	ND	581

CITY	STATE	3-DIGIT ZIP CODE
FLORENCE	AL	356
ATHENS	GA	306
MANSFIELD	OH	449
SIOUX CITY	IA	511
ODESSA	TX	797
CHARLOTTESVILLE	VA	229
FLORENCE	SC	295
SIOUX FALLS	SD	571
BILLINGS	MT	591
GLENS FALLS	NY	128
KOKOMO	IN	469
KANKAKEE	IL	609
BLOOMINGTON	IN	474
PINE BLUFF	AR	716
SAN ANGELO	TX	769
ENID	OK	737
NEW YORK	NY	100
DETROIT	MI	482
HOUSTON	TX	770
PITTSBURGH	PA	152
MINNEAPOLIS - ST PA	MN	554
HARTFORD	CT	061
BIRMINGHAM	AL	352
CHARLOTTE	NC	282
SPRINGFIELD	MA	011
KNOXVILLE	TN	379
NEW BEDFORD	MA	027
LANSING	MI	489
MOBILE	AL	366
WICHITA	KS	672
PEORIA	IL	616
DES MOINES	IA	503
LEXINGTON	KY	405
ROCKFORD	IL	611
PORTLAND	ME	041
SAGINAW	MI	486
FORT SMITH	AR	729
SPRINGFIELD	IL	627
YAKIMA	WA	989
ST CLOUD	MN	563
FORT COLLINS	CO	805
CHICAGO	CA	959
ABILENE	TX	796
TUSCALOOSA	AL	354
MEDFORD	OR	975
WICHITA	TX	763
BURLINGTON	VT	054
CUMBERLAND	MD	215
LAS CRUCES	NM	880

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