A Joint Environmental Material Management Service (JEMMS) Hazardous Materials (HAZMAT) Distribution Center Location Model for the Continental United States (CONUS)

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Acronyms

APO	Army Post Office
CONUS	Continental United States
DCs	Distribution Centers
DoD	Department of Defense
DLA	Defense Logistics Agency
DODAAC	DoD Activity Address Code
DORRA	DLA Operations Research Analysis
ESRI	Environmental Systems Research Institute, Inc.
GIS	Geographic Information System
HAZMAT	Hazardous Materials
JEMMS	Joint Environmental Material Management Service
ORNHN	ORNL National Highway Network
OCONUS	Outside of Continental Unites States

Executive Summary

An analysis was performed that used a Revenue Model to locate potential Joint Environmental Material Management Service (JEMMS) Distribution Centers (DCs) in the Continental United States (CONUS). The Revenue Model focused on locating JEMMS DCs near the largest volume high revenue customers. The analysis found that a maximum of five to eight JEMMS DCs could be located in order to provide hazardous materials (HAZMAT) to the highest revenue military service customers. This number would be the upper limit to support sustainable operations. With this number, the JEMMS DCs would be making between 50% and 80% of the HAZMAT shipments to CONUS military service customers, depending on the delivery distance of the DCs. The suggested delivery distance for each JEMMS DC should be greater than 100 miles in order to support a diversified number of military service customers.

Purpose

The purpose of this research was to develop a location and allocation optimization Revenue Model for use by the Defense Logistics Agency (DLA) in the evaluation of potential sites for HAZMAT DCs in CONUS. The results of this analysis are presented in this report.

Background

DLA is responsible for the operation of DCs and the shipment of supplies to military service customers. DLA operations include receipt, storage, issue, and transportation of over 25 million orders annually. Over 2 million of these orders are for HAZMAT that are shipped to over 10,000 customers. The main types of HAZMAT include paints, batteries, and petroleum products.

There are a number of concerns related to the current HAZMAT acquisition and distribution system that could be addressed with a more consolidated logistics system. First, there is no one consolidated source for all HAZMAT. HAZMAT is acquired from a number of different sources, including DLA DCs, other government agencies (General Services Administration), and the private sector. Second, individual military services have visibility over their own requirements and resources, but there is no visibility between military services. This eliminates the possibility of sharing resources or allowing one military service to use surplus materials from another military service. Third, multiple orders for HAZMAT are sometimes made due to change in personnel and lack of knowledge of the current inventory. Fourth, materials that are not used can expire after a specified time period. This results in HAZMAT moving directly from DC inventory into the waste stream.

DLA is evaluating the feasibility of establishing a series of specialty HAZMAT DCs for its primary military service customers in CONUS. The purpose of these centers would be to increase the efficiency of the HAZMAT operations and reduce the waste stream for HAZMAT that comes from the military services. The JEMMS program has been

established to determine the feasibility of this concept. The philosophy behind the JEMMS program is to establish a single integrated logistics support service for HAZMAT.

An initial test of the JEMMS program is currently underway at US military facilities in Okinawa. A single integration contractor has taken over the HAZMAT distribution and returns of unneeded HAZMAT operations for the US military services on the island. This allows a single focal point for distribution operations and the return of surplus HAZMAT. A major advantage of this program is the ability of the single DC to distribute the material that has been returned for reuse by other customers. This reduces the amount of money spent purchasing HAZMAT and reduces the amount of HAZMAT going into the waste stream.

Data for CONUS and OCONUS

DLA Operations Research and Resource Analysis (DORRA) provided a database file that associated each CONUS Department of Defense (DoD) Activity Address Code (DODAAC) with a zip code region. Unfortunately, there is no detailed Outside of Continental United States (OCONUS) geographic information system (GIS) dataset to associate DODAACs customer sites with a longitude and latitude position. The US zip code GIS data used in this analysis was obtained from the GIS and Mapping Software Company, Environmental Systems Research Institute, Inc. (ESRI). This study focuses on an analysis of CONUS JEMMS DC locations. The information on revenue and shipments for OCONUS has been extracted from the database (Appendix A), but because of a lack of information on specific DODAAC locations in OCONUS, the analysis does not consider OCONUS operations.

Model Discussion

Now that the test is underway in Okinawa, DLA is evaluating the possibility of extending this concept to CONUS. The question that must be addressed is "How can JEMMS be efficiently implemented for military customers in CONUS?" To answer this question, a mathematical model (called the Revenue Model) was developed to evaluate the location potential of JEMMS DCs for HAZMAT being distributed to military customers in CONUS. The Revenue Model locates a number of DCs that serve as many customers as possible, while maximizing revenue return to ensure operational sustainability. The Revenue Model is a maximum covering model that maximizes revenue by covering as many demands as possible within a specified delivery distance. Please see Appendix A for details on the Revenue Model.

The following assumptions are made in the model

Service Locations

Since there are no GIS data for military customers at the DODAAC level, this analysis aggregated military customer sites to a geographic center of zip code regions associated with each DODAAC's zip code. The data obtained from DORRA for this analysis contained 9,467 DODAACs (including CONUS and OCONUS). There was a total of 2,143,511 shipments, and the total revenue was $49 million[1]. The revenue and shipment data were from FY2000. The CONUS DODAACs were aggregated into 2,764 zip codes [Army Post Offices (APOs) and fleets were not included because they do not have geographic locations]. Figure 1 shows the 2,764 zip code centers with demand. Table 1 shows the demand distribution of HAZMAT for the DODAACs by revenue.

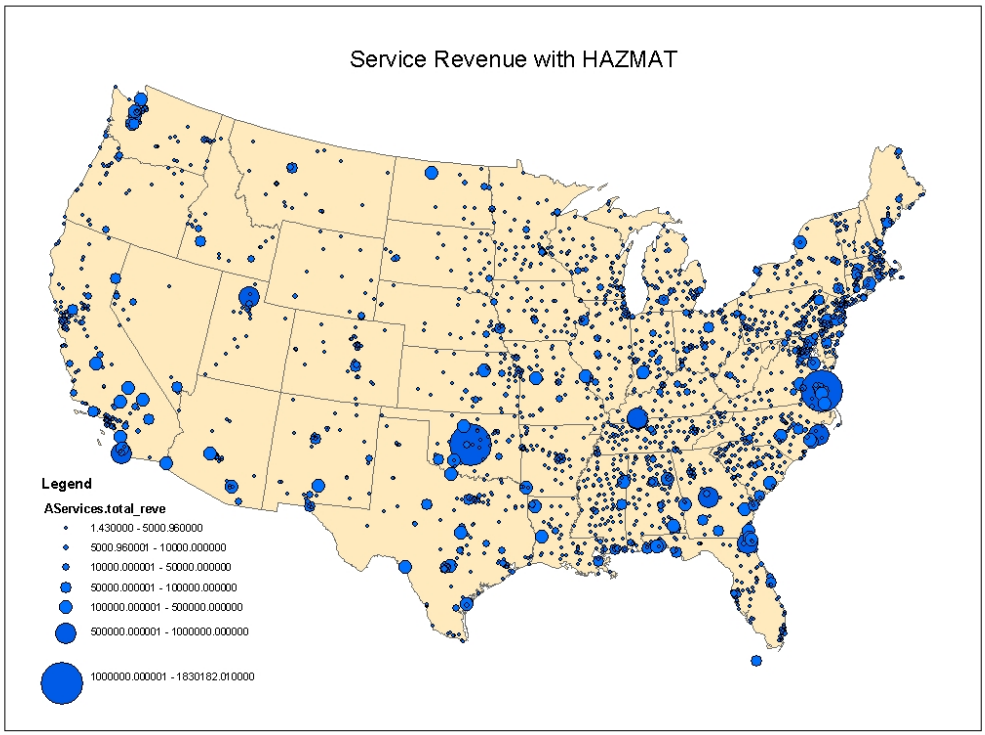

Figure 1

[1] We also received data from the DLA HQ Environmental Office that indicates that the HAZMAT sale for FY2000 is $144.8M. This discrepancy has to do with the method of data extraction and the definition of HAZMAT. This analysis uses data obtained from DORRA.

Table 1: DODAACs HAZMAT demand distribution by revenue.

Revenue	Number of DODAACs
> $1M	2
$500,000 - $1M	5
$100,000-$500,000	62
$50,000-$100,000	52
$10,000-$50,000	174
$5,000-$10,000	109
< $5,000	2360

DC Delivery Distance

From Figure 1, it is determined that it is not efficient to serve all customers. In fact, the majority of customers have very low demand (less than $5,000 per year). Table 1 shows that there are just a few very large customers. The analysis assumed that the JEMMS DCs would be co-located in close proximity to military customer locations. Only the top 50 customer zip code zones with highest revenue were considered as potential JEMMS DC locations. Those customers with low demand and locations in outlying areas are not included in the model.

The delivery distance for each JEMMS DC is important. The larger the delivery distance, the greater the amount of revenue that will be obtained. However the velocity of transportation logistics is also an important factor for choosing JEMMS DC delivery distances. If the delivery distance is too short, the DC acts as a retail center, rather than a DC. But, if the delivery distance is too long, the customer will not receive timely service. The analysis used 50, 100, and 200 miles as alternative delivery distances. This is the maximum one-way delivery distance from the DC to a customer. The distances are calculated using the ORNL National Highway Network (ORNHN) database. There is no consideration of consolidation of shipments between DCs and customer locations in the analysis. Therefore, each shipment is calculated as an independent delivery. The 50-mile delivery distance would apply to a congested urban area where travel times are slow. The 200-mile distance would apply to less congested regions. The 100-mile distance is a middle number between these two extremes. Figure 2 shows the covered area for 50 potential JEMMS DCs with distance 50 (green area), 100 (blue area), and 200 (red area) miles, respectively.

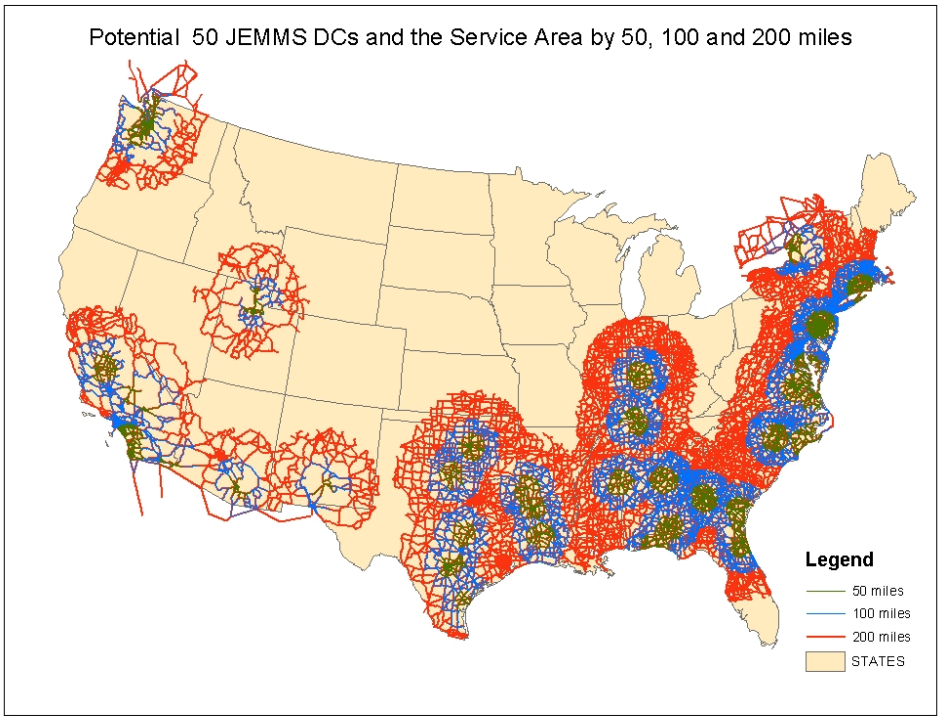

Figure 2

The study area that has 50 DCs with a distance of 200 miles covers 916,733 shipments and $29.5 million revenue in total. About one half of these shipments are considered in the Revenue Model. The other half of the DODAACs are OCONUS, fleets, or outside the study area. Table 2 shows the shipments and revenue with different delivery distance areas. These are the upper bound objective values for the Revenue Model. For example, if all 50 DCs with a 200-mile service range are chosen, it covers 82.7 % of the revenue and 79.7 % of the shipments in CONUS.

Table 2: DODAACs HAZMAT shipments and revenue by delivery distance

	Zip code zones	Shipments		Revenue	
Total HAZMAT (CONUS & OCONUS)	NA		2,143,511		$49M
CONUS	2746	100.0%	1,149,245	100.0%	$29.5M
50 facilities with 200 miles service distance (the red area)	1721	79.7%	916,733	82.7%	$24.4M
50 facilities with 100 miles service distance (the blue area)	930	56.7%	756,426	72.2%	$21.3M
50 facilities with 50 miles service distance (the green area)	401	46.4%	619,246	62.7%	$18.5M

Results of the Analysis

Number of JEMMS DCs

The Revenue Model was run for distances of 50, 100, and 200 miles and the number of facilities was set as 1, 2, …, 20. Figures 3, 4, and 5 show the distribution of the potential JEMMS DCs for delivery distances of 50, 100, and 200 miles. The ideal situation is to have DC delivery regions not overlapping. When delivery regions overlap, this decreases the potential delivery area for the DCs. This in turn results in lower revenue earnings for DCs that have overlapping regions. This also indicates that there are too many DCs in a specific region. For delivery distances of 100 and 200 miles, there are a number of overlapping areas.

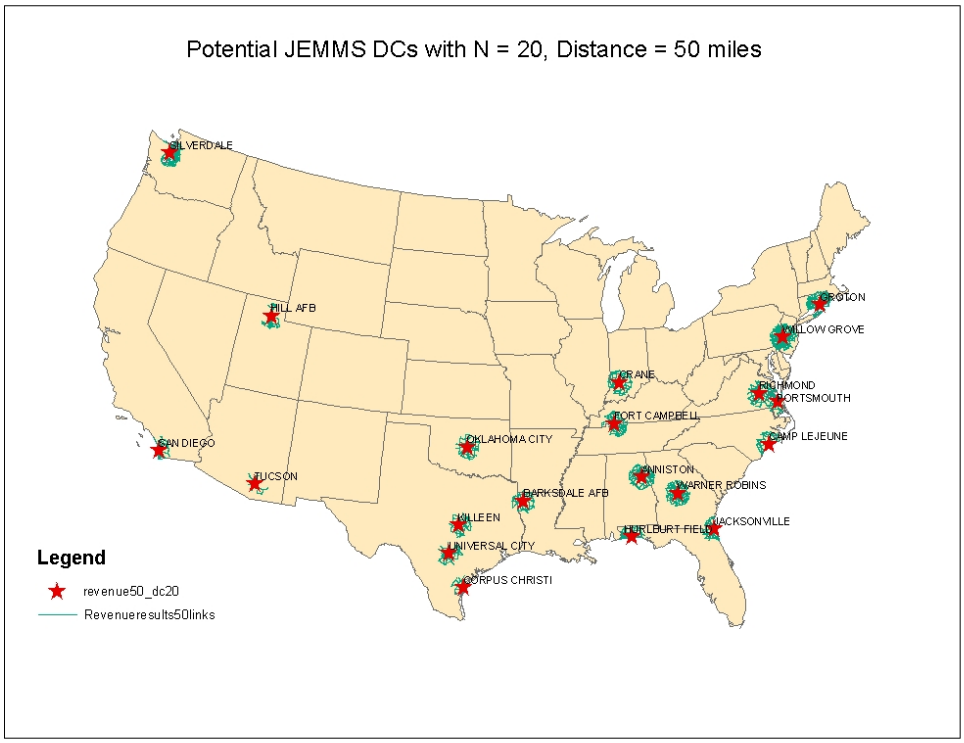

Figure 3

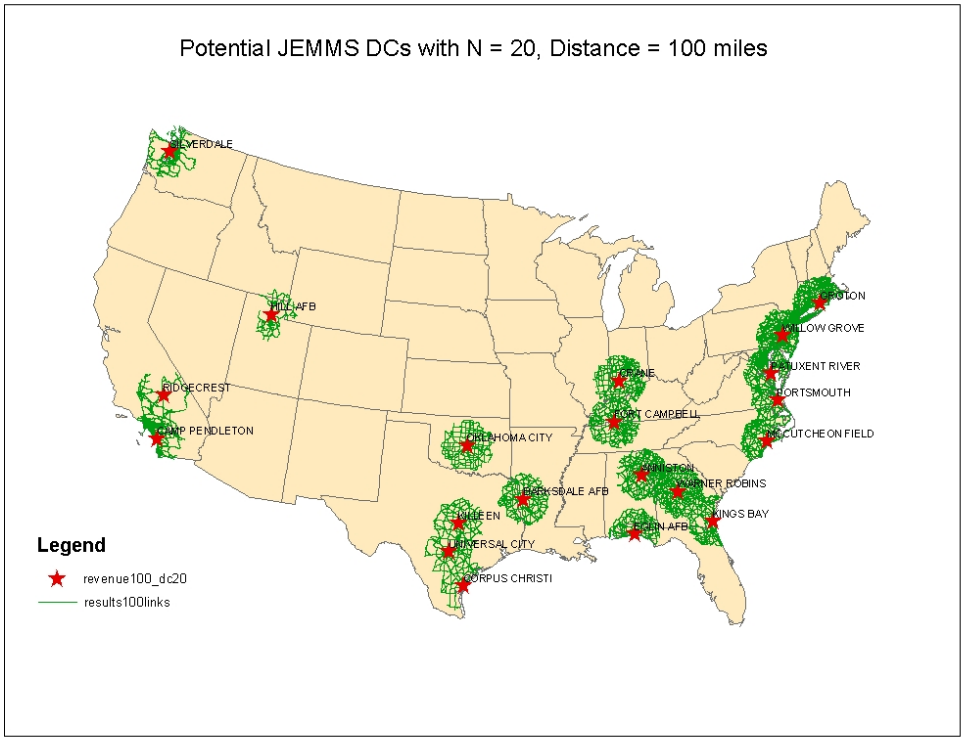

Figure 4

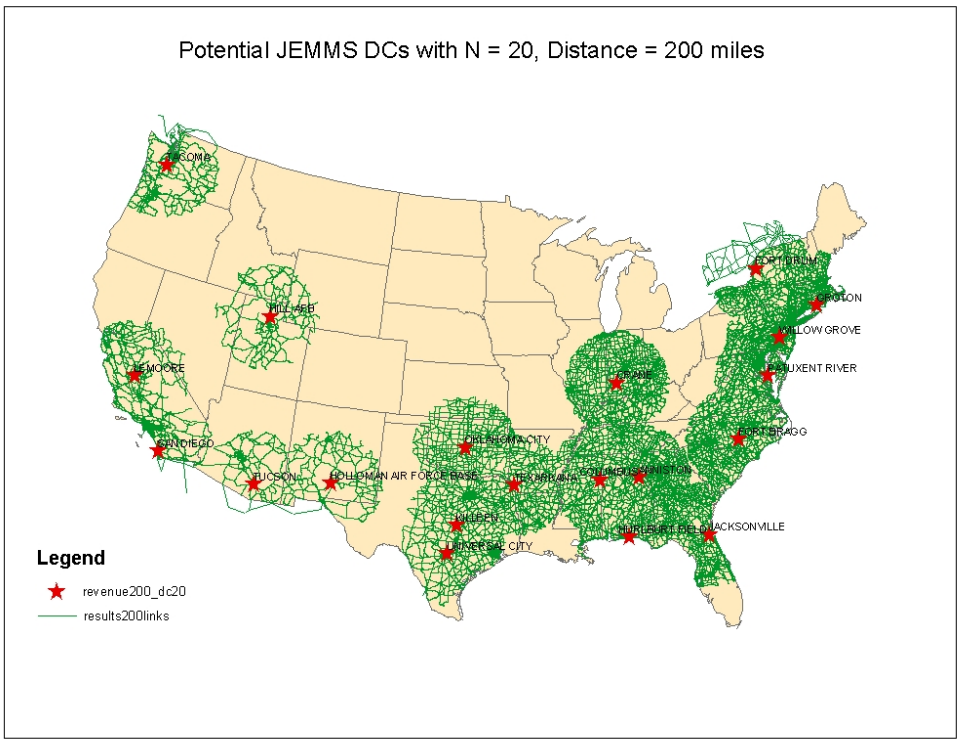

Figure 5

The delivery distance affects the optimal locations of DCs. For instant, many customer locations (like the region around Norfolk) have high revenue but require long delivery distances. For example, there are two JEMMS DCs near Norfolk, VA, when delivery distances are 50 miles, while there is only one JEMMS DC when the delivery distances are 100 and 200 miles (Figure 6).

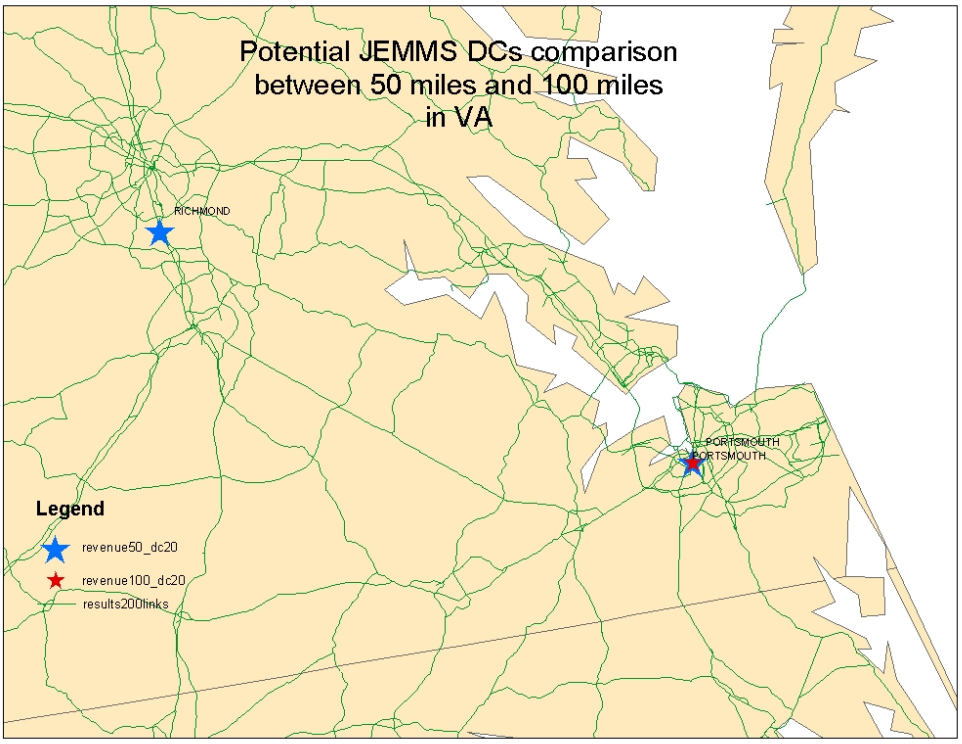

Figure 6

Figure 7 shows the accumulated revenue as each JEMMS DC is added. The Y-axis is the accumulated revenue in dollars and the X-axis is the number of DCs. It shows that as more JEMMS DCs are added, revenue increases, but at a diminishing rate.

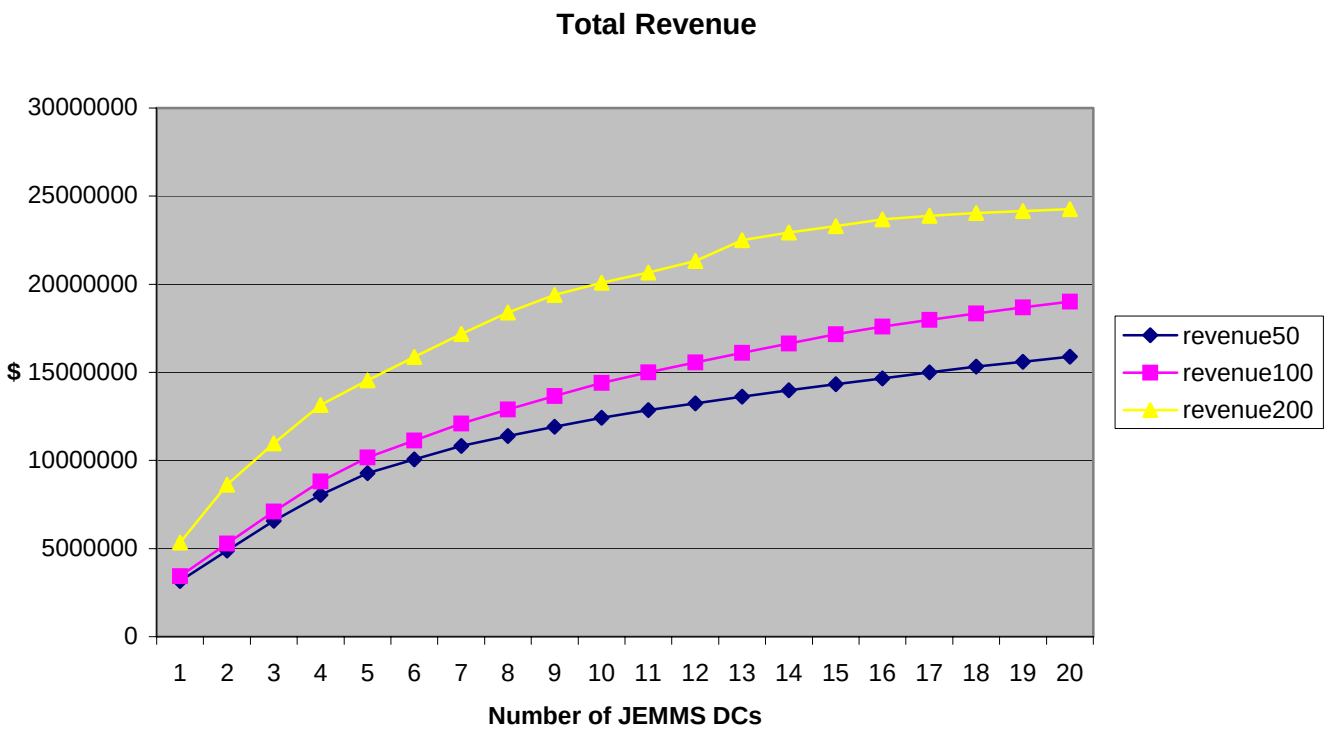

Figure 7

The results of the Revenue Model analysis found that as delivery distances expand (i.e. 50, 100, 200 miles), more revenue is generated by the JEMMS DCs (Figure 7), and revenue increases, but at a decreasing rate of return (Figure 8).

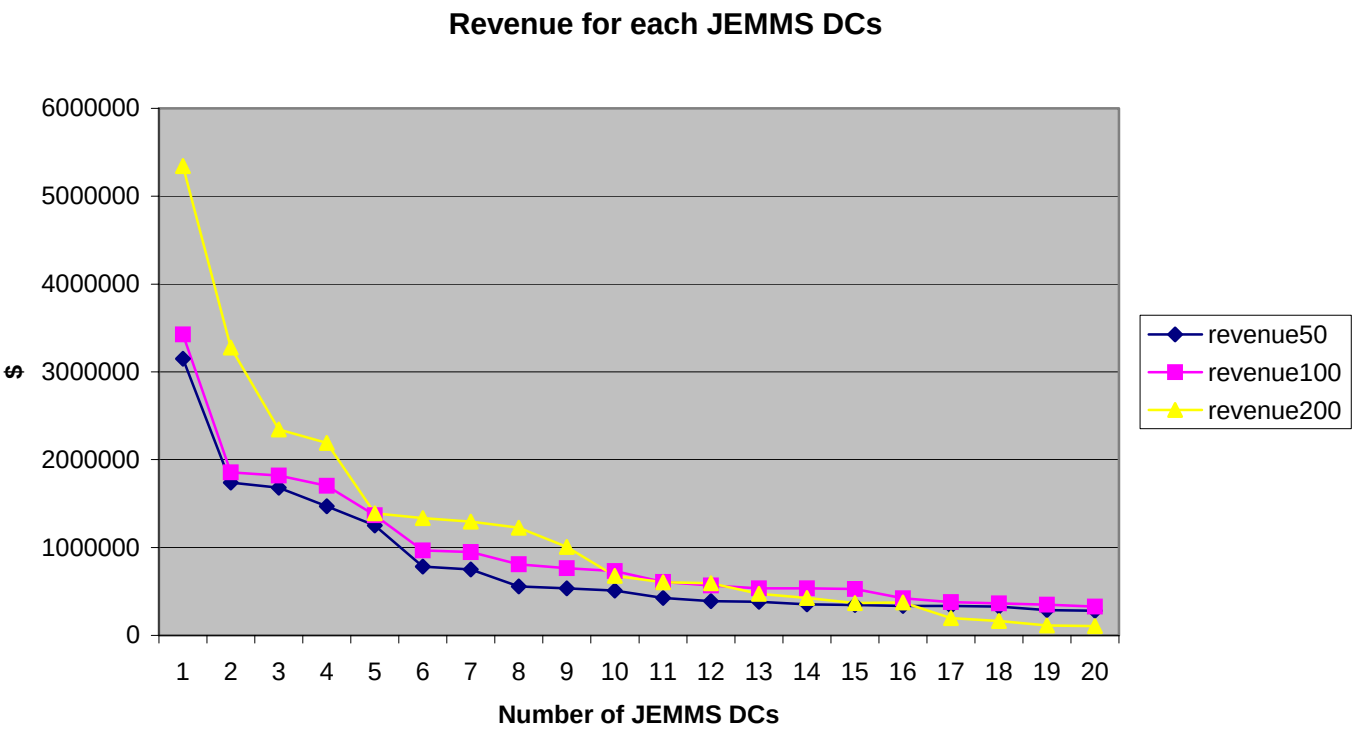

Figure 8

As the customer delivery distance expands (50, 100, 200 miles), some of the DC site locations will change. This result will impact the implementation strategy for the JEMMS DCs. The delivery distance and the number of DCs to be established need to be determined at the beginning of the process to gain the greatest efficiencies from the planning process. As the number of JEMMS DCs increase, especially for the larger delivery distance configuration, there will be overlapping delivery zones. This will result in decreased efficiencies.

Figure 8 illustrates this point. In the case of the 200 mile limit, since there are so many overlapping areas, the marginal returns are lower than they are for 50- and 100-mile limits when the number of DCs is larger than nine. After the ninth JEMMS DC, the revenue decreases to under $1M.

The Revenue Model maximizes revenue, not the number of shipments. Figure 9 shows the total shipments summary. The total shipments increase as each DC is added, but the curve for increasing numbers of shipments is not as smooth as the revenue curve.

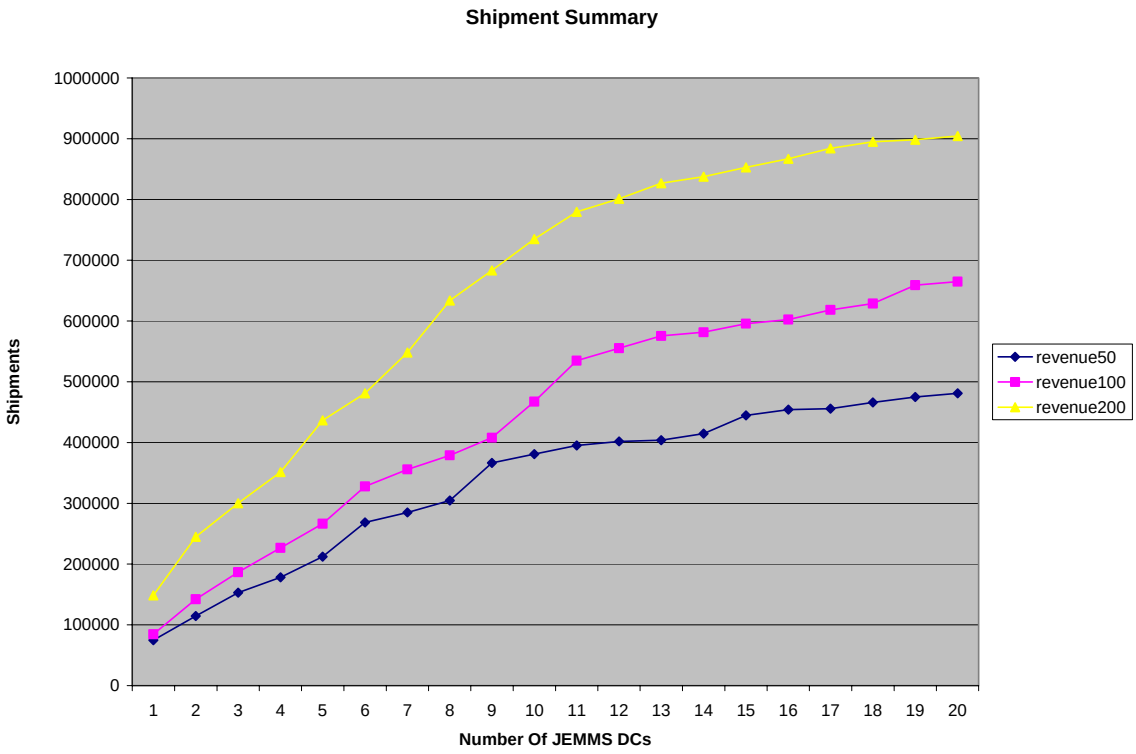

Figure 9

Figure 10 shows the cumulative mileage traveled for shipment deliveries as each DC is added. Each shipment is calculated as a separate transaction without any consolidation. The rapid expansion of the mileage for the 200-mile delivery distance is due to the greater distance of the service area and the increased customer base size.

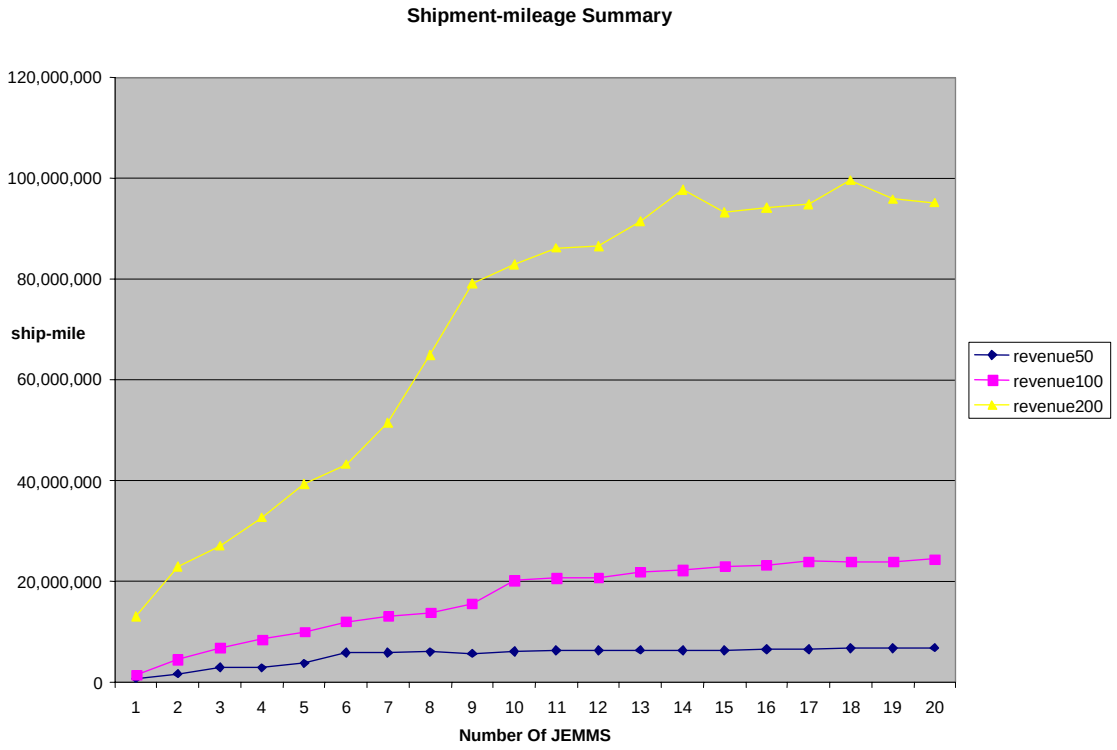

Figure 10

Site Analysis

The previous section discussed the optimal number of DCs for JEMMS. It showed that too many DCs results in territorial competition between the DCs. The solutions are skewed if the number of JEMMS DCs is too great. To avoid this territorial overlap and to ensure operational viability, the number of sites actually implemented should be less than 10. Thus, for the site analysis, the number of JEMMS DCs is set as 10. This number of DCs was chosen because the results for N = 1, 2, …20 showed that the solution set for the first 10 DCs is stable and their territories do not greatly overlap. The solution for the models is a simple algorithm that chooses the zip code zone with highest revenue within its service range, and then chooses the next highest zip code zone, and so on, until it locates 10 DCs.

Tables 3 and 4 complement Figure 11 by providing the details on the revenue and amount of HAZMAT shipped from each of 10 potential JEMMS DCs, and the percent for each military service customer for a delivery distance of 50 miles.

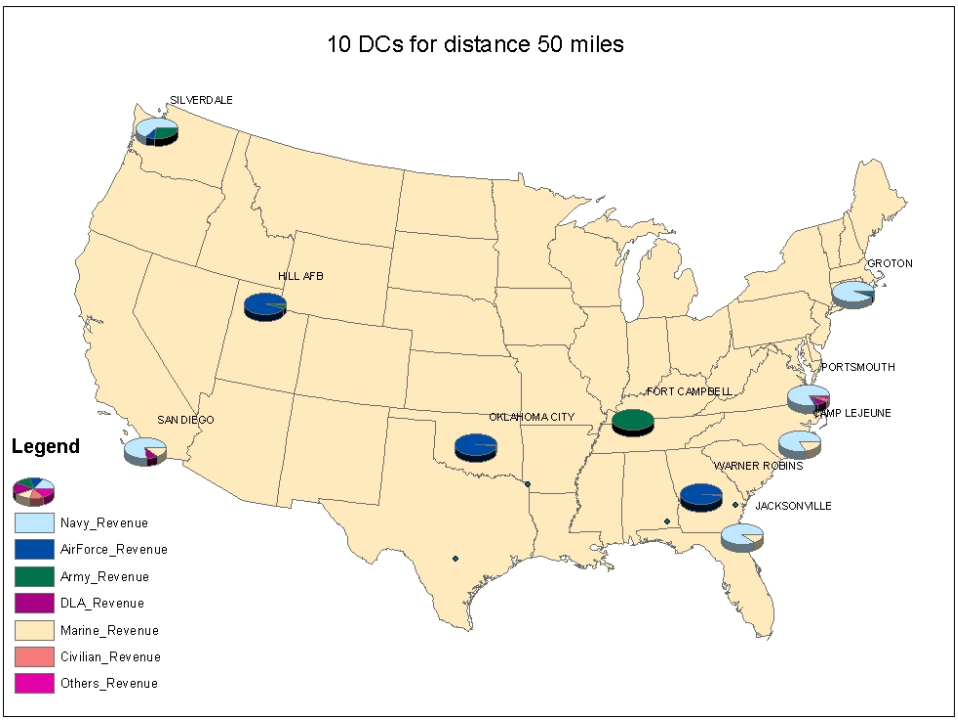

Figure 11

Table 3: Revenue when n = 10 distance = 50

	DC Site	State	Revenue	Accumulated Revenue	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	PORTSMOUTH	VA	3,150,767	3,150,767	1%	3%	83%	0%	9%	3%	1%
2	SAN DIEGO	CA	1,737,615	4,888,382	0%	0%	71%	12%	10%	0%	7%
3	JACKSONVILLE	FL	1,679,159	6,567,541	0%	1%	82%	11%	0%	0%	6%
4	OKLAHOMA CITY	OK	1,469,295	8,036,836	2%	97%	0%	0%	0%	0%	1%
5	CAMP LEJEUNE	NC	1,249,148	9,285,984	0%	0%	81%	18%	1%	0%	0%
6	SILVERDALE	WA	783,357	10,069,341	26%	8%	60%	0%	1%	0%	5%
7	WARNER ROBINS	GA	749,469	10,818,810	0%	98%	0%	0%	2%	0%	0%
8	HILL AFB	UT	558,769	11,377,579	4%	94%	0%	0%	2%	0%	0%
9	GROTON	CT	509,528	11,887,107	3%	4%	93%	0%	0%	0%	0%
10	FORT CAMPBELL	KY	269,596	12,156,703	100%	0%	0%	0%	0%	0%	0%

Table 4: Shipments when n = 10 distance = 50

	DC Site	State	Shipments from DCs	Accumulated shipments from DCs	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	PORTSMOUTH	VA	74798	74,798	2%	2%	68%	0%	18%	3%	8%
2	SAN DIEGO	CA	39737	114,535	0%	0%	34%	18%	37%	1%	11%
3	JACKSONVILLE	FL	38598	153,133	0%	2%	72%	19%	0%	0%	7%
4	OKLAHOMA CITY	OK	25038	178,171	23%	68%	0%	0%	0%	0%	9%
5	CAMP LEJEUNE	NC	34229	212,400	0%	0%	57%	42%	0%	1%	0%
6	SILVERDALE	WA	56089	268,489	57%	2%	34%	0%	4%	0%	3%
7	WARNER ROBINS	GA	16421	284,910	2%	97%	0%	0%	0%	0%	0%
8	HILL AFB	UT	19835	304,745	6%	93%	0%	0%	1%	0%	0%
9	GROTON	CT	14363	319,108	12%	4%	84%	0%	0%	0%	0%
10	FORT CAMPBELL	KY	31121	350,229	100%	0%	0%	0%	0%	0%	0%

Tables 5 and 6 complement Figure 12 by providing the details on the revenue and amount of HAZMAT shipped from each of 10 potential JEMMS DCs, and the percent for each military service customer for a delivery distance of 100 miles.

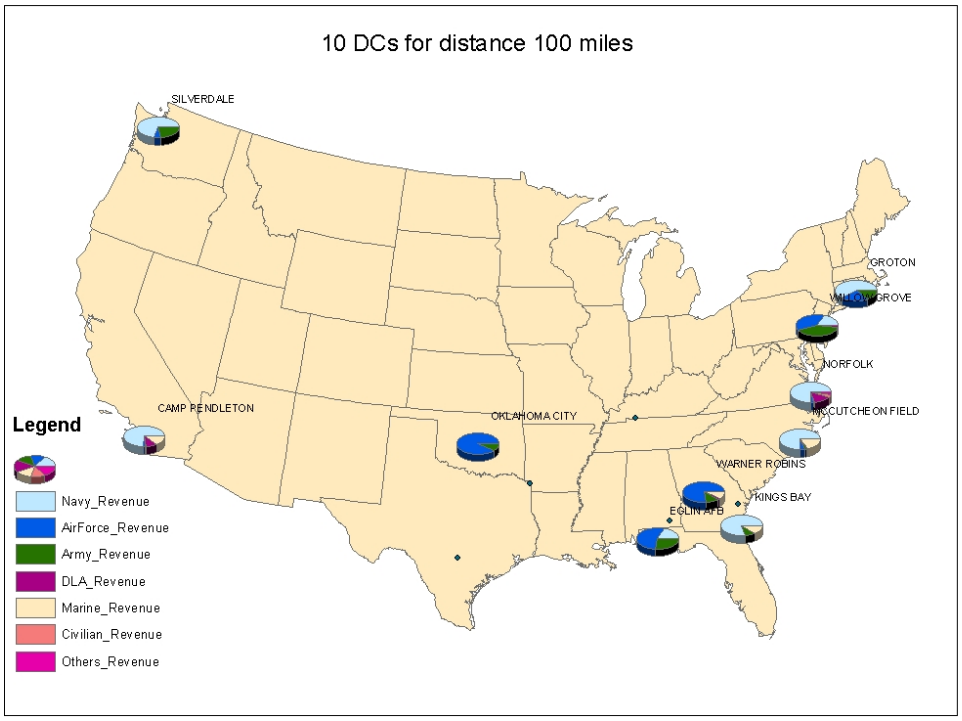

Figure 12

Table 5: Revenue when n = 10 distance = 100

	DC Site	State	Revenue	Accumulated Revenue	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	NORFOLK	VA	3,434,039	3,434,039	2%	3%	77%	0%	15%	3%	1%
2	KINGS BAY	CA	1,857,182	5,291,221	10%	1%	74%	10%	0%	0%	5%
3	CAMP PENDLETON	CA	1,817,253	7,108,474	1%	2%	68%	11%	10%	0%	7%
4	OKLAHOMA CITY	OK	1,703,237	8,811,711	8%	90%	0%	0%	0%	0%	1%
5	MCCUTCHEON FIELD	NC	1,368,358	10,180,069	2%	6%	74%	16%	1%	1%	0%
6	SILVERDALE	WA	965,413	11,145,482	21%	7%	67%	0%	1%	0%	4%
7	WARNER ROBINS	GA	947,747	12,093,229	12%	77%	0%	9%	2%	0%	0%
8	GROTON	CT	808,720	12,901,949	13%	26%	59%	1%	0%	1%	0%
9	WILLOW GROVE	PA	764,729	13,666,678	37%	34%	14%	1%	2%	1%	12%
10	EGLIN AFB	FL	734,311	14,400,989	27%	55%	18%	0%	0%	0%	0%

Table 6: Shipments when n = 10 distance = 100

	DC Site	State	Shipments from DCs	Accumulated shipments from DCs	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	NORFOLK	VA	86,286	86,286	4%	2%	59%	0%	25%	2%	7%
2	KINGS BAY	GA	57,735	144,021	33%	1%	48%	12%	0%	0%	5%
3	CAMP PENDLETON	CA	44,443	188,464	4%	6%	30%	16%	33%	1%	10%
4	OKLAHOMA CITY	OK	40,113	228,577	49%	45%	0%	0%	0%	0%	6%
5	MCCUTCHEON FIELD	NC	39,786	268,363	8%	5%	49%	36%	0%	1%	0%
6	SILVERDALE	WA	61,281	329,644	52%	2%	39%	0%	4%	0%	2%
7	WARNER ROBINS	GA	28,060	357,704	36%	57%	0%	6%	0%	0%	0%
8	GROTON	CT	23,380	381,084	28%	16%	53%	1%	0%	1%	1%
9	WILLOW GROVE	PA	28,908	409,992	46%	26%	13%	0%	0%	1%	14%
10	EGLIN AFB	FL	59,329	469,321	69%	21%	10%	0%	0%	0%	0%

Tables 7 and 8 complement Figure 13 by providing the details on the revenue and amount of HAZMAT shipped from each of 10 potential JEMMS DCs, and the percent for each military service customer for a delivery distance of 200 miles.

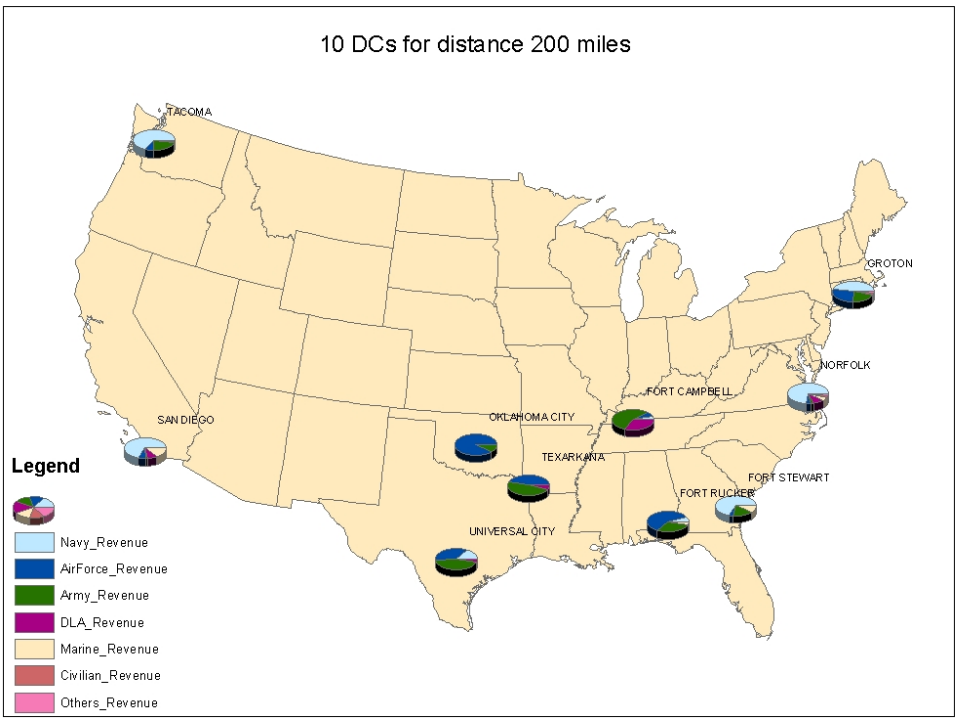

Figure 13

Table 7: Revenue when n = 10 distance = 200

	DC Site	State	Revenue	Accumulated Revenue	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	NORFOLK	VA	5,348,704	5,348,704	3%	6%	73%	4%	10%	2%	2%
2	FORT STEWART	GA	2,392,942	7,741,645	18%	4%	64%	8%	1%	0%	5%
3	SAN DIEGO	CA	2,332,145	10,073,790	2%	8%	62%	12%	8%	0%	8%
4	FORT RUCKER	AL	2,272,967	12,346,757	33%	57%	6%	4%	0%	1%	0%
5	OKLAHOMA CITY	OK	2,063,286	14,410,042	9%	89%	0%	0%	0%	0%	2%
6	GROTON	CT	1,333,648	15,743,690	21%	26%	46%	1%	1%	2%	3%
7	UNIVERSAL CITY	TX	1,296,829	17,040,519	45%	35%	14%	0%	3%	0%	2%
8	TACOMA	WA	1,017,614	18,058,133	22%	9%	64%	0%	1%	1%	4%
9	TEXARKANA	TX	984,953	19,043,086	45%	43%	0%	0%	5%	0%	7%
10	FORT CAMPBELL	TN	887,898	19,930,984	56%	7%	3%	0%	33%	0%	1%

Table 8: Shipments when n = 10 distance = 200

	DC Site	State	Shipments from DCs	Accumulated shipments fro DCs	% Army	% Air Force	% Navy	% Marine	% DLA	% Civilian	% Others
1	NORFOLK	VA	150,596	150,596	7%	7%	52%	11%	14%	2%	7%
2	FORT STEWART	GA	77,889	228,485	39%	5%	38%	9%	0%	1%	8%
3	SAN DIEGO	CA	56,325	284,810	6%	11%	33%	14%	26%	1%	9%
4	FORT RUCKER	AL	103,747	388,557	60%	32%	6%	2%	0%	1%	0%
5	OKLAHOMA CITY	OK	51,407	439,964	44%	50%	0%	0%	0%	0%	6%
6	GROTON	CT	44,680	484,644	37%	18%	36%	1%	0%	2%	6%
7	UNIVERSAL CITY	TX	67,303	551,947	64%	24%	9%	0%	0%	0%	3%
8	TACOMA	WA	64,737	616,684	53%	3%	37%	0%	3%	1%	2%
9	TEXARKANA	TX	32,565	649,249	83%	9%	0%	0%	1%	0%	6%
10	FORT CAMPBELL	TN	56,466	705,715	94%	2%	1%	0%	1%	0%	2%

Tables 9 and 10 give a comparison between the 10 DC's solution and the study area with a potential of 50 DCs (Figure 2). It shows that with 10 DCs and a delivery distance of 200 miles, it covers 82% of the revenue and 77% of the shipments in the study area with a potential of 50 DCs. With a delivery distance of 50 miles it covers 50% of the revenue and 38% of the shipments.

Table 9: **Comparison with study area**

		50 mile		100 mile		200 mile	
	Total	Value	%	Value	%	Value	%
Revenue	$24.4M	$12.2M	50%	$14.4M	58%	$19.9M	82%

Table 10: **Comparison with study area**

		50 mile		100 mile		200 mile	
	Total	Value	%	Value	%	Value	%
Shipment	916,733	350,229	38%	469,321	51%	705,715	77%

Tables 11 and 12 provide a comparison with all shipments and revenue in CONUS. It shows that the 10 DC solution at a 200-mile delivery distance covers 68% of total revenue and 61% of shipments. With a delivery distance of 50 miles it covers 41% of the revenue and 30% of the shipments.

Table 11: **Comparison with CONUS**

		50 mile		100 mile		200 mile	
	Total	Value	%	Value	%	Value	%
Revenue	$29.5M	$12.2M	41%	$14.4M	49%	$19.9M	68%

Table 12: **Comparison with CONUS**

		50 mile		100 mile		200 mile	
	Total	Value	%	Value	%	Value	%
Shipment	1,149,245	350,229	30%	469,321	41%	705,715	61%

Conclusions

The above analysis shows that no more than 10 JEMMS DCs should be established in order to ensure sustainable operations. The number of shipments that this would provide depends on the delivery distance set for the DCs. With 10 JEMMS DC, it could cover a maximum of 68% of revenue and 61% of shipments in the CONUS if we use the 200-mile limit or 41% of revenue and 30% shipments if we use the 50-mile limit. If there is a budget constraint, then 5 – 8 JEMMS should be more efficient.

The analysis also shows that the greater delivery distances result in a more diversified military customer base. A delivery distance of 100 miles would gain a reasonably diversified customer military base.

Further Research for JEMMS Implementation

This research provides a preliminary estimate for the best possible locations for CONUS JEMMS DCs. To actually locate the facilities, additional analysis would need to be performed. First, the actual customer locations would need to be geocoded for identification on a transportation network. Geocoding is the process of finding the geographic location (latitude and longitude) of a site as used in GIS analysis. An estimated transportation cost would then need to be calculated. Then, an actual delivery network could be calculated. This could include the number of shipments between potential DC sites and customer locations and the potential for consolidation of customer shipments.

For the implementation at OCNOUS locations, additional work also needs to be performed, using the OCONUS database to determine the location of some of the actual customer sites. Then, the customer sites would need to be geocoded for identification on a transportation network. The actual transportation networks would need to be obtained and tested for accuracy. The research would also need to understand any HAZMAT delivery restrictions within or between countries. These would need to be implemented on the network or in the algorithms. At that point, the same process of transportation cost, delivery networks, and consolidation that was used in CONUS analysis could be applied for the OCONUS analysis.

APPENDIX A
REVENUE MODEL DETAILS

$$Maximize \quad \sum_{i \in I} \sum_{j \in J} \delta_{ij} x_{ij} r_j$$

subject to

$$\sum_{i \in I} x_{ij} \le D_j \qquad \forall j \qquad (1)$$

$$\sum_{j \in J} x_{ij} - My_i \le 0 \quad \forall i \qquad (2)$$

$$\sum_{i \in I} y_i = N \qquad (3)$$

where

I : *potential DCs*

i : *DC at i*

J : *customers*

j : *customer at location j*

r_j : *revenue at customer j per shipment*

x_{ij} : *shipments from DC i to customer j*

y_i : $\{0,1\}$

$y_i = 1$ *if* y_i *DC is open, otherwise* $y_i = 0$

D_j : *Demand at customer j*

d_{ij} : *distance between DC i to Customer j*

δ_{ij} : $\{0,1\}$

$\delta_{ij} = 1$ *if* $d_{ij} <$ *Distance, otherwise* $\delta_{ij} = 0$

Distance : *maximum serving distance*

M : *a large number*

N : *Number of DCs*

The objective function maximizes the total revenue.
Constraint 1 ensures that each customer will not be over supplied.
Constraint 2 ensures that customer *j* will be supplied by DC *i* only if DC *i* is open.
Constraint 3 sets a limit on the number of DCs.
The capacity for each DC is unlimited (a large number M).