AN INTERACTIVE APPROACH TO LOCATE BREAKBULK TERMINALS FOR LTL TRUCKING OPERATIONS

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ABSTRACT

In this report, the authors introduce an interactive approach for constructing or improving Less-than-Truckload (LTL) distribution networks. The primary consideration for the interactive design process is that of determining breakbulk locations to minimize total transportation and handling costs, based on freight density and transshipment volume analysis. An interactive software decision analysis tool, called BBNET, is introduced as a means of achieving near optimal design without the use of complicated math programming alternatives. The software system is made transportable by using a DOS platform on a personal computer. It is validated using freight density and breakbulk location data supplied by ABF Freight System, Inc. A detailed user‟s, manual is provided to enhance technology transfer.

1. INTRODUCTION

The less-than-truckload (LTL) industry has been able to gain tremendous competitive advantages through the use of hubbing for load consolidation. These hubs are in the form of breakbulk terminals which are used to consolidate LTL shipments moving between end-of-line (EOL) terminals at origin and destination points. The primary function of breakbulk activity is to consolidate loads with common destinations so that LTL trucking companies can benefit from the economies of scale enjoyed by truckload truckers.

With appropriately located terminals in sufficient quantities, total costs can be drastically reduced. Even so, the task of determining the optimal number of breakbulk terminals and the optimal location for each terminal to support LTL operations is extremely difficult. A small number of terminals means higher circuity but fewer freight transfers. A large number of terminals means less circuity but more freight transfers. Furthermore it is difficult to locate terminals such that they are optimally located from a global standpoint relative to freight demand and transshipment density.

The consolidation of loads with common destinations greatly reduces the transportation costs, yet the amount of cost savings depends heavily upon the number of hubs, the location of each hub, and the determination of service areas in terms of EOL terminals and geographical regions that are served by each hub. The remainder of this report addresses the issue of breakbulk location. The interactive approach for breakbulk location determination described herein focuses on operational costs associated primarily with transportation and handling. Freight density and transshipment volume play a huge role in this process. It is assumed that adequate labor and real estate exists within suggested regions and that the capital requirements associated with a particular site are not drastically different from that of other sites.

Discrete hub location problems involve locating a set of fully interconnected hubs that serve as transshipment and switching points for traffic between specified origins and destinations. Hub location problems can be classified by the way in which demand points are assigned to hubs. In the single allocation option, each demand point can send and receive through a single hub only. This problem has been studied by O'Kelly [8] and Klicewicz [7]. Both studies make use of mathematical programming formulations for dicrete hub location problems. Multiple allocation problems, in which a demand point may send and receive through more than one hub, have been studied by O'Kelly and Lao [10], and by Campbell [3].

A heuristic-based approach to evaluate the networks and hub locations to find locally optimal designs has been proposed by O'Kelly [8]. This research includes the hub usage or activity level and assesses the trade-off between costs and congestion for a four-hub network. The congestion aspect of the model involves solving a quadratic expression. The author concludes that in an undiscounted network that promotes wide spacing of hubs, assignment of nodes to a non-nearest hub may result in minimizing transportation costs.

Campbell [5] presents integer programming formulations for discrete hub location problems where the objective is to minimize transportation costs over all origin-destination pairs. The formulations also include threshold values for flow between the origin or the destination and a hub, and fixed costs for the spoke links. This results in controlling the spokes or allocations in a system. A discount factor for flows between hubs is also allowed.

Campbell [5] has presented IP formulations for four types of discrete hub location problems: The p-hub median problem, the uncapacitated hub location problem, the p-hub center problem and the hub covering problem. In the uncapacitated hub location problem, the constraint involving the number of hubs is replaced in the objective function with a fixed cost of establishing a hub. The p-hub center problem is deemed important because of its application in locating hubs that are subject to a time limit on continuous driving. One important feature is that the objective function maximizes flow only between a single origin-destination pair but not the sum of all flows as in the p-hub median problem. Hub covering problems are important for solving hub center problems where the objective is to locate hubs to cover all demand points such that the cost for the hubs is minimized.

Plane hub location problems, where hubs may be located anywhere on a plane has been addressed by Aykin and Brown [1] and by Campbell [2]. The research focus presented herein is on operational costs associated with breakbulk terminal location. Other researchers have examined fixed and capital costs associated with location.

Locating transportation terminals to serve an expanding demand has been addressed by Campbell [2], using terminal, transportation, and relocation costs. A myopic strategy with limited capability of relocation is shown to be nearly optimal unless terminal relocation costs are large. This conclusion has been made under three assumptions:

1. The demand density is uniform for a region.
2. Shipment handling costs are not considered.
3. Terminal location is a function of discounted terminal, transportation, and relocation costs.

Campbell [2] concludes that a simple myopic strategy without relocations is preferred over a strategy with relocations whose cost exceeds 25% of the fixed terminal costs.

According to Powell and Sheffi [11], major considerations for optimization of network design in the motor carrier industry are terminal locations and the assignment of direct service between pairs of terminals. The network design formulation develops a decomposition strategy based on a range of important real world issues and constraints.

Campbell [3] determines the optimal terminal locations analytically based on three assumptions:

1. Continuous uniform distribution of demand.
2. Rectilinear travel.
3. Equal flows between origins and destinations.

He then concludes that the solution is dependent on the efficiency of the linehaul transportation between terminals. He also analyzes three schemes for routing freight shipments via consolidation terminals. The effectiveness of each routing scheme is shown to depend on the number of consolidation terminals and the efficiency of the linehaul transportation.

Basically there are two approaches to determine optimal solutions with respect to transportation costs and hub locations for large hub network problems: (1) The transportation oriented continuous approximation approach develops models of transportation costs for idealized networks with a continuous demand density, rectilinear travel, and equal flows. (2) The location oriented discrete demand approach finds optimal, or near optimal hub locations for specific cases with relatively few demand points (< 60), euclidean travel, and unequal flows.

Campbell [4] links these two research streams by analyzing how well the solution for idealized hub networks approximates the actual optimal transportation costs. The analytic expression from Campbell [3] is reformulated and the predicted transportation costs are compared to the actual costs for 48 discrete demand problems (4 discount factors X 4 discrete demand patterns X 3 hub locations) using rectilinear travel. The author concludes that the approximation formula performs well for problems with even demand distribution. But the approximation becomes less reliable for problems with a large number of hubs and high inter-hub discounts.

O'Kelly [9] proposes a distance-based heuristic that allocates non-hub nodes to the nearest hub. The data used in this research are based on the airline passenger interaction among 25 major US cities during 1970.

Klincewicz [7] proposes an allocation criterion based on the weighted sum of 'distance-based' and 'flow-based' rules. This criterion uses a heuristic that evaluates all possible exchanges for each non-hub node to determine the best improvement in the transportation costs. Taylor et al [13] make use of IP formulations to determine hub locations. They conclude that the hub location problem is best solved by a hybrid method that includes flow-based, density-based, and distance-based hubbing. Although their area of emphasis is truckload trucking, their results are similar to those presented in Klincewicz [7].

Darko and Jadranko [6] have proposed a heuristic method based on Tabu search for locating interacting hub facilities among interacting nodes in a network. For uncapacitated hubs, equal importance has been given to the locational as well as allocational part of the problem. They use the neighborhood solution approach with a single location exchange in which a non-hub replaces a hub. A similar approach is also used with a single allocation exchange that differs in the allocation of exactly one non-hub node. The Tabu search strategy is superimposed on both location and allocation levels in search of the local optimum. The authors demonstrate the superiority of their heuristic to that developed by O'Kelly [9] by showing that for problems with 20 or more nodes and 3 or more hubs, the Tabu search method yields a better solution using comparatively less CPU time. They, like Kliecivwcz [7] and Taylor [13], discuss the importance of allocating non-hub nodes based on distances and flows among nodes.

2. SOLUTION APPROACH

In the LTL trucking industry, load consolidation plays an important role in determining the location and the number of breakbulk terminals. Therefore, an analysis of freight density is a logical first step in the determination of an optimal number and optimal locations for breakbulk terminals.

The problem presented in this report can be considered a formulation of the p-hub location problem as addressed by O'Kelly [8,9], Klincewicz [7] and Campbell [5]. Basically, the operational cost of delivering a shipment to its destination from an origin has two cost components, transportation cost and handling cost. The transportation cost constitutes the EOL (origin or the destination) to breakbulk cost and breakbulk to breakbulk cost. The calculation of transportation cost c_{ij}, between two points i and j is

$$c_{ij} = tr \times d_{ij} \times wt$$

where

tr = transportation rate in $/lb/mile.

d_{ij} = distance from point i to point j (including circuity to breakbulk).

wt = shipment weight in lbs.

The EOL terminal to breakbulk cost can be minimized only by assigning the originating or destinating shipment to the nearest in-line breakbulk terminal that is located in a region with high freight density and transshipment volume. Once a shipment reaches a breakbulk, depending upon its destination, it may need to be consolidated with other shipments that have the same breakbulk or EOL destination. The total transportation cost for a shipment would be the sum of the individual costs along the segments of the route from origin to destination. In some cases shipment volume is sufficient to assemble full truckload shipments directly to the destination EOL terminal, bypassing all interim breakbulks and thus eliminating handling cost.

The handling cost, hc, is accrued each time freight is handled at a breakbulk terminal. In order to achieve load consolidation, a shipment may undergo a freight transfer at each intermediate breakbulk terminal on the route. This is inevitable in a LTL trucking industry since consolidation is the primary objective. We can compute the handling cost as,

hc = hr x wt x number of freight transfers.

where

hr = handling rate for a shipment in $/lb.

wt = weight of shipment in lbs.

Certainly, any solution approach taken to the breakbulk location problem would necessarily include both transportation and handling costs. In the introduction to this report, the investigators name several examples of researchers seeking math programming approaches to the hub location problem. As a result of the examination of such approaches, the investigators gained insight into the restrictive and impractical nature of such approaches relative to LTL industry concerns and practical constraints. The goal of this project is to provide an useful tool for hub location analysis in a realistic setting, without restrictive assumptions or the use of methods that simplify the problem to the extent that results are not useable. A more pragmatic approach is deemed to be an interactive approach with human users, making use of the same mathematical formulation principles used in more difficult and restrictive math programming solutions. An interactive decision support system could easily be used to practically and completely solve such an unwieldy problem.

INTERACTIVE APPROACH

It is extremely difficult to use a mathematical approach to determine the optimal number of breakbulk terminals and their locations. A computer-based decision support system with interactive capability is less cumbersome and much faster in determining the near optimal number of terminals and their locations for a given freight density. The approach permits rapid user assisted examination of many potential alternative breakbulk network designs. It is driven by actual company provided freight density profiles and is unrestricted by simplifications.

Breakb**u**lk **NET**work Software (BBNET), a decision support system software was developed in Turbo C to determine the optimum number of breakbulk terminals and their locations. It builds upon a user friendly graphical network tool called HUBNET, which was developed and tested for use in the truckload industry. See Taha, Taylor, and Taha [13] for more regarding HUBNET development. The transformation to the LTL environment involved detailed freight and transshipment analysis and required the development of a new decision support engine. Even so, the HUBNET platform proved robust to the LTL design.

BBNET OVERVIEW

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Figure 1 shows a schematic representation of the BBNET layout. Although a detailed user's manual appears in the Appendix to this document, a brief overview of the capabilities of BBNET are explained below.

Figure 1. Layout of the BBNET Software

Data Preparation Any freight density data file can serve as input to BBNET. The investigators were fortunate in obtaining characteristic data files from ABF Freight System, Inc., for testing and validation. The input file should include the location of the origin and the destination (latitude and longitude) for each shipment and also the weight of the shipment in pounds.

Graphical Network Builder The user can enter several parameters by using the interactive graphics screens. The parameters that can be entered by the user include:

1. *Breakbulk Location and Freight Lanes.*

The graphical user interface presents a map of the U.S.A, southern parts of Canada, and northern parts of Mexico. On this screen the user can build a distribution network including the selection of the locations of breakbulk terminals and freight lanes. The freight lanes are the connection between breakbulk terminals only. This input completes the network consisting of breakbulk terminals and the freight lanes that connect them.

2. *Selection of Service Areas for a Breakbulk Terminal.*

One option is to define a service area by assigning 2^{o} x 2^{o} latitude/longitude squares to be served by a particular breakbulk terminal. A second option is to assign the origin or the destination to the nearest breakbulk terminal. The latitude/longitude option is useful when used in conjunction with load analysis that indicates clustering of loads in some regions. If the loads are evenly distributed, the nearest breakbulk option would be ideal for the system. Generally the nearest breakbulk option can be used to obtain a quick bench- mark performance with little effort.

3. *Number of Freight Changes.*

In LTL industries, load consolidation permits savings that far exceed the increase in cost associated with hub management. In order to achieve load consolidation in multiple breakbulks, a shipment may have to go through a circuitous route. This may result not only in higher transportation costs, but also in higher handling costs due to increase in the number of freight changes. Obviously, the larger the actual origin to destination distance the larger the probability that a large number of freight transfers or handling costs would be incurred, especially for low density origin/destination pairs.

BBNET permits the user to input the maximum number of breakbulks where a given shipment will be handled for each 500 mile increment between the origin and destination. In this way, BBNET permits the user to specify the expected number of freight transfers for shipments of various distances. BBNET enhancements in the near future will aggregate truckload shipments directly. Even so, the interactive approach will likely be retained as an option to enable "what-if" analysis regarding the determination of benefits from less handlings.

4. *Rates and Speed.*

The cost parameters, including the transportation rate in $/lb/mile, the handling time in mins/lb, the handling cost in $/lb, and the speed of transportation in miles/hour are entered by the user.

<u>Network Operation</u> Once the user has input all parameters and the shipment data are available, the network is evaluated. The output from the graphical interface serves as an input for the operations module. The network is evaluated in terms of the following measures of performance:

1. Total transportation cost for all the shipments.
2. Total time required for all the shipments to reach their destination.
3. Total distance travelled for all the shipments.
4. Total handling time for all the shipments.
5. Total handling cost for all the shipments.
6. Total number of shipments that either originated or were delivered from each breakbulk terminal.

Once the network has been established, the origin and destination for a shipment is assigned to a breakbulk terminal, according to the service area assignment option that has been selected. The transportation cost and time are then calculated by determining the shortestpossible distance for a shipment on the network using Floyd"s algorithm (Dreyfus, 1969) for the shortest route between all nodes. The establishment of the shortest euclidean network travel distance for a given shipment defines an upper bound on the number of freight changes. This upper bound is then compared with the user specified number of freight changes for that distance range in which the shipment falls. If the user specified number of allowable freight transfers is exceeded by the upper bound, the user specified limit is used in computing the handling cost and time.

3. FREIGHT DENSITY AND TRANSSHIPMENT ANALYSIS

METHODOLOGY

It is important to analyze the freight density before trying to determine the optimal location of breakbulk terminals. Freight density analysis achieves two objectives; it helps to determine those areas in which freight originates or is delivered, and it helps to determine locations with high transshipment volume. Freight origins and destinations with high volume supports EOL location while breakbulk location is affected by transshipment volume. Even so, pick-up and delivery density also drive breakbulk locations.

Using two data sets supplied by ABF Freight Systems, Inc., an analysis of freight density has been performed. Each data set represents one month of operation with one data set characteristic of an average month and the other characteristic of a heavy month. In this analysis, the United States is divided into sixty-five 4^o X 4^o latitude/longitude regions (see figure 2). A Turbo C program has been written to keep record of the number of loads entering and leaving each region. Even if this freight volume level is high, it does not necessarily mean that the region will have a high transshipment volume. Hence an analysis of the transshipment of loads is also required. This analysis is also supported by a Turbo C program.

By placing breakbulk terminals in high freight density regions which also have high transshipment frequencies, we achieve two things:

1. The transportation cost is low because the terminal is on the shortest distance path in the network.

(Insert figure 2 from the file \docfigs**)**

2. The chance of load consolidation is very high and the savings achieved by consolidation may be greater than the increase in handling costs.

AN EXAMPLE OF BBNET OPERATION

Obviously, freight density is considered to be highly proprietary. Therefore, we cannot show actual density information in this report. An uncharacteristic sample has been selected for demonstration purposes. Figure 3 shows a graphical representation of freight density and transshipment load analysis for this sample data set.

The freight density analysis for loads in and out of each region reveals that regions 26, 37 and 50 have high freight densities. The transshipment analysis reveals that regions 24,25,26,36,37,38 and 50 have high transshipment volumes. For illustrative purposes, consider an example network with only three breakbulk terminals.

Considering the transshipment analysis, the good regions to have the breakbulk terminals would be 24, 37 and 50. Following are the results obtained for the network that includes breakbulk terminals in the regions 24, 37 and 50 with the "nearest breakbulk" service area determination rule in effect.

Total distance	913412 miles.
Traveling time	16607 hours.
Handling cost	$ 130774
Transportation cost	$ 152274
Total cost	**$ 283048**

An analysis of both the freight density and the transshipment loads reveals that breakbulk terminals in the regions numbered 26, 37 and 50 may lead to improved performance. The results below are for the network that includes breakbulk terminals in the regions 26, 37 and 50.

Total distance	949730 miles.
Traveling time	17267 hours.
Handling cost	$ 121277
Transportation cost	$ 137914
Total cost	**$ 259191**

Clearly the transportation cost and the handling cost are less when the breakbulk terminals are located in regions of high freight density and high transshipment of loads. Even though the distance travelled is higher, the total cost is less because of the load consolidation at the breakbulk terminals, which effectively reduces the per mile rate for inter-breakbulk shipments.

(Insert figure 3 from the file \docfigs)

CURRENT OPERATIONS NETWORK REPORT

Following is a presentation of the results obtained using the current locations for 10 ABF Freight Systems, Inc. breakbulk terminals. As mentioned preciously, two sets of data are utilized to represent peak and average freight density periods. Figures 4 and 5 show the results of BBNET network operations using the data for the months of September and June 1994, respectively. The data below has been disguised to protect proprietary data. The nearest breakbulk service area determination rule is in effect. For the two data sets, Figures 6 and 7 show graphically the total number of loads entering and exiting each region and also the transshipment volume for each 4^o x 4^o latitude/longitude region.

Improved Operations Network Report

To further demonstrate the efficacy of the interactive breakbulk location determination technique using BBNET, the investigators now present results indicating improvement for the two disguised data sets.

The freight density analysis (see Figures 6 and 7) reveals that a better breakbulk location scenario might be developed by adding a breakbulk terminal in region #27 (see Figures 2 and 3). The results of the improved network for the September 94 and June 94 data set are shown in figures 8 and 9. As shown in these figures the total cost has decreased by 5.05%, in September 94 and by 4.95% in June 94.

Figures 8 and 9 reveal that this saving is achieved by a decrease in the transportation and handling cost. The freight density and transshipment analysis reveals that region #27 has a high freight density and also a relatively high transshipment volume. Furthermore, the current operations network results (see figures 4 and 5) reveal that the activity level of

NUMBER OF BREAK BULKS: 10
TRANSPORTATION RATE: 0.2200 $/lb/mile
TRANSPORTATION SPEED: 55 mph
HANDLING RATE: 0.0050 $/lb
HANDLING TIME: 0.5000 mins/lb
NUMBER OF SHIPMENTS: 487961
TOTAL WEIGHT: 680606886 lbs
TRANSPORTATION COST: $64728884.00
TOTAL DISTANCE: 798246848.00 miles
TRAVELING TIME: 14513579.00 hours
TOTAL HANDLING COST: $6421668.00
TOTAL HANDLING TIME: 10706481.00 hours

ORIGIN	# OF SHIPMENTS	%SHIPMENT	TOTAL WEIGHT
1	45024	9.23	63294923
2	99588	20.41	123834934
3	67883	13.91	93975746
4	30696	6.29	45867826
5	21350	4.38	32166646
6	46122	9.45	67645627
7	69164	14.17	97901692
8	51488	10.55	70694769
9	22313	4.57	33320242
10	34333	7.04	51904481
TOTAL	**487961**	**100.00**	**680606886**

ORIGIN	# OF SHIPMENTS	%SHIPMENT	TOTAL WEIGHT
1	28220	5.78	40695625
2	101694	20.84	13948930
3	45452	9.31	70480997
4	43011	8.81	61654119
5	39689	8.13	54604763
6	53615	10.99	71351449
7	63327	12.98	85201772
8	51508	10.56	70747549

9	24620	5.05	34656066
10	36825	7.55	51725237
TOTAL	**487961**	**100.00**	**68060688**

Figure 4. Current Operations Network Results for September 94.

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NUMBER OF BREAK BULKS:  10
TRANSPORTATION RATE:  0.2200 $/lb/mile
TRANSPORTATION SPEED:  55 mph
HANDLING RATE:  0.0050 $/lb
 HANDLING TIME:  0.5000 mins/lb
   NUMBER OF SHIPMENTS:  470404
TOTAL WEIGHT:  657930982 lbs
TRANSPORTATION COST:  $62339472.00
TOTAL DISTANCE:  764312960.00 miles
TRAVELING TIME:  13896599.00 hours
TOTAL HANDLING COST:  $6169089.00
TOTAL HANDLING TIME:  10284973.00 hours
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ORIGIN	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	43164	9.18	63139780
2	96252	20.46	120752699
3	63803	13.56	85470550
4	31291	6.65	46219393
5	21351	4.54	30305147
6	43532	9.25	63380258
7	65682	13.96	91253651
8	49341	10.49	73340732
9	21674	4.61	33498156
10	34314	7.29	50570616
TOTAL	**470404**	**100.00**	**657930982**

DESTINATION	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	27078	5.76	39329674
2	97779	20.79	136893670
3	44321	9.42	67174302
4	41319	8.78	60391450
5	37521	7.98	51897866
6	49829	10.59	65822193
7	62099	13.20	82930098
8	49779	10.58	67289337
9	24805	5.27	34101382
10	35874	7.63	52101010
TOTAL	**470404**	**100.00**	**657930982**

Figure 5. Current Operations Network Results for June 94.

(Insert figure 6 from the file \docfigs**)**

(Insert figure 7 from the file \docfigs**)**

terminal #2 is very high. This terminal is located in one of the regions surrounding region #27. By placing a terminal in region #27, the loads between terminal #2 and #11 are consolidated. This reduces the per mile rate for inter-breakbulk shipments. The results shown in figures 8 and 9 reveal that the activity level of terminal #2 is about 7% for both the data sets with the new breakbulk #11 taking on an activity level of about 13% for both the data set.

NUMBER OF BREAK BULKS: 11

TRANSPORTATION RATE: 0.2200 $/lb/mile

TRANSPORTATION SPEED: 55 mph

HANDLING RATE: 0.0050 $/lb

HANDLING TIME: 0.5000 mins/lb

NUMBER OF SHIPMENTS: 497961

TOTAL WEIGHT: 680606886 lbs

TRANSPORTATION COST: $61279428.00

TOTAL DISTANCE: 807123136.00 miles

TRAVELING TIME: 14674966.00 hours

TOTAL HANDLING COST: $6282241.50

TOTAL HANDLING TIME: 10473999.00 hours

ORIGIN	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	45115	9.25	63295014
2	32772	6.72	44550679
3	67974	13.93	93975837
4	30787	6.31	45867917
5	21441	4.39	32166737
6	46213	9.47	67645718
7	69255	14.19	97901783
8	51579	10.57	70694860
9	22404	4.59	33320333
10	34405	7.05	51870888
11	66017	13.53	79317121

TOTAL 497961 100 680606886

# OF			TOTAL
DESTINATION	SHIPMENTS	%SHIPMENTS	WEIGHT
1	28311	5.80	40695716
2	34176	7.00	47319418
3	45543	9.33	70481088
4	43102	8.83	61654210
5	39780	8.15	54604854
6	53706	11.01	71351540
7	63418	13.00	85201863
8	51599	10.57	70747640
9	24711	5.06	34656157
10	36890	7.56	51681279
11	66726	13.67	92213122
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TOTAL	**487961**	**100.00680606886**	

Figure 8. Improved Operations Network Results for September 94.

	# OF		TOTAL
ORIGIN	SHIPMENTS	%SHIPMENTS	WEIGHT
1	43255	9.20	63139871
2	33092	7.03	45354285
3	63894	13.58	85470641

4	31382	6.67	46219484
5	21442	4.56	30305238
6	43623	9.27	63380349
7	65773	13.98	91253742
8	49432	10.51	73340823
9	21765	4.63	33498247
10	34405	7.31	50570707
11	62342	13.25	75397596
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TOTAL	**470404**	**100.00**	**6579930982**

DESTINATION	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	27169	5.78	39329765
2	32840	6.98	44634933
3	44412	9.44	67174393
4	41410	8.80	60391541
5	37612	8.00	51897957
6	49920	10.61	65822284
7	62190	13.22	82930189
8	49870	10.60	67289428
9	24896	5.29	34101473
10	35965	7.65	52101101

11	64121	13.63	92257919
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TOTAL	**470404**	**100.00**	**6579930982**

Figure 9. Improved Operations Network Results for June 94.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Clearly, BBNET provides an excellent means of designing breakbulk distribution networks in either network construction or network improvement situations. The software is currently installed on site at ABF Freight System, Inc., where it is being validated and verified for continued use. A detailed user's manual is provided as an appendix to this report to ensure that the reader fully understands the unique and complete capabilities of the system. BBNET has been developed on a DOS platform for personal computers to enhance technology transfer and transportability. A Unix version could be easily developed, to provide the user with the opportunity to use larger databases.

Another potential area of future research would be in providing explicit rules or modeling capability to handle load consolidation activity at each breakbulk terminal. This would eliminate the approximation method presently used in computing the breakbulk to breakbulk transportation cost. Therefore, one additional degree of modelling abstraction could be removed, making BBNET more realistic for use in calculating cost savings.

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APPENDIX

BBNET USER'S MANUAL

BBNET USER MANUAL

1. INTRODUCTION

BBNET is a decision support tool for analyzing less than truckload operations in a hub-and-spoke network environment. A graphical interface allows the user to create a network and then run the model using available freight data to evaluate the effectiveness of a hub-and-spoke network.

2. BBNET SYSTEM REQUIREMENTS

IBM PC or compatible

VGA Monitor

Mouse

3. INSTALLATION

BBNET runs primarily on a PC platform. The amount of disk space needed on each system will depend on the amount of historical freight data that you choose to evaluate. Data files will be discussed in more detail in the sections that follow.

3.1 PC Installation

1. Insert BBNET Installation Disk in drive A: and type the following at the DOS prompt:

   C:\>a:install

   A directory called C:\BBNET will be created and software files will be copied into it.

4. STARTING BBNET

To run BBNET, type the following at the DOS prompt:

C:\BBNET>bbnet

5. SYSTEM COMMANDS

All pull-down menus are accessed with the mousen.

FILE

New - opens a new file for editing
Open - opens an existing network
file Close - closes the current
file Save - Saves the current file
Save As - prompts user for a new file name
DOS Shell - accesses DOS prompt
Exit - exits BBNET

MODIFY

Add Breakbulk - place breakbulks with either mouse or keyboard
Remove Breakbulk - remove a breakbulk from the network
B/b area - Nearest - service areas assigned to Nearest breakbulk
B/b area - Lat/Long - select service areas for each breakbulk based on 2^o x 2^o Lat/long grids

Add Freight Lane - connects two breakbulks with a lane
Remove Freight Lane - removes a freight lane between two breakbulks
Number of breakbulks - enter maximum number of breakbulks for each distance range

RUN PROGRAMS

B/b Operations - runs operations model

REPORTS

B/b Operations - generates operations model report

Note: All information describing a particular scenario must be input before selecting the Run Program, option.

6. USING BBNET

6.1 Network Construction

This section gives steps for building a hub-and-spoke network and running a model based on its design. BBNET's opening screen displays a United States map as shown in Figure 1.

(Insert figure 1 from the file \fig1-6)

Figure 1. Opening BBNET Screen.

Step One: Breakbulk Placement

(Insert figure 2 from the file \fig1-6)

Figure 2. Breakbulk Placement.

1.Select Add Breakbulk from the MODIFY menu

2.Choose the Mouse or Keyboard option

Mouse - place breakbulks by clicking the left mouse button at

the desired location

Keyboard - A. Type in latitude
B. Type in longitude

3.Continue until all breakbulks are placed. Press right mouse

button or Esc to exit.

Note: Up to 60 breakbulks can be entered in a network. Breakbulks can be removed using the Remove Breakbulk command.

Comments

When considering locations for breakbulk placement, it is important to place breakbulks in regions of high freight density so as to minimize the travel distance to and from the breakbulk in the form of local pickups and deliveries. Also, it is important to place breakbulks in areas with high transshipment volume to help eliminate excess circuity in transit on the networks. Any number of network breakbulks may be specified by the user (up to 60). However, one possible scenario is to intersperse breakbulks equidistantly across the United States approximately one day driving distance apart. This option satisfies D.O.T regulations which require a river to sleep 8 hours for every 10 hours of driving. Drivers can travel to connecting breakbulks from their home breakbulk in one shift (10 hours) and thus lessen the chance of being required to sleep on the road between breakbulks.

Step Two: Freight Lane Placement

(Insert figure 3 from the file \fig1-6)

Figure 3. Freight Lane Placement.

1. Select Add Freight Lane from the MODIFY menu

2. Select the first breakbulk to be connected by clicking the left mouse button on the breakbulk. Select the second breakbulk in the same manner.

3. Continue until all freight lanes are placed. Press right mouse button or Esc to exit.

Note: Freight Lanes can be removed using the Remove Freight Lane command.

NOTE: Each freight lane designates the path that SHIPMENTS will take when traveling between the two breakbulks. It is required that every breakbulk be connected to at least one other breakbulk in the network.

Step Three: Breakbulk Service Area Designation (See Figure 3)

(Insert figure 4 from the file \fig1-6)

Figure 4. Breakbulk Service Area Designation.

LAT/LONG OPTION

1. Select B/b Areas Lat/long from the MODIFY menu. Only one option for service area allocation can be selected; the lat/long option or the nearest breakbulk option. To change from the nearest breakbulk option to the lat/long option, select the nearest option once again and type N.

2. Select the first breakbulk area to be defined by clicking the left mouse button on the breakbulk. Select breakbulk area squares by clicking those 2o x 2o lat/long regions to be served by the specified breakbulk with the left mouse button .

3. Once the area is fully defined, click the right mouse button to return to the grid screen. Go to Step 2 and continue until all the 2o x 2o lat/long squares are assigned (see Comments). Press right mouse button or Esc to exit.

Note: Squares can be de-selected by clicking on them with the left mouse button

Comments

The purpose of designating breakbulk areas is to define the local pickup and delivery areas for each breakbulk. Any shipments originating or terminating in a breakbulk's area will be handled by that particular breakbulk's local drivers. The following are some tips in selecting breakbulk areas:

Each square is 2^o by 2^o latitude/longitude.

Individual squares are designated on the map by a letter and number code. The following is a list of squares that must be assigned to a breakbulk prior to the execution of the simulation model:

A1 - A30 D1 - D29 G2 - G26 J5 - J23 L22 - L24
B1 - B30 E1 - E29 H3 - H26 K6 - K23 M7 - M15
C1 - C30 F2 - F26 I4 - I25 L6 - L15 M23

All breakbulks must be assigned at least one 2° x 2° region.

As breakbulk areas are assigned, they will appear in different colors on the map to distinguish one breakbulk area from another.

A good method for assigning breakbulk areas is to start at one end of the country and proceed to the other end. In this manner, the likelihood of missing squares in the middle of the map is minimized.

When in doubt, consult the list of assignable squares to make sure they are all assigned. BBNET will not continue to the next step unless all squares are assigned to a breakbulk.

NEAREST BREAKBULK OPTION

1. Select B/b Areas Nearest Option from the modify menu and type Y. To change from the lat/long option to the nearest breakbulk option, select the lat/long option and deselect at

least one square that was that was previously defined for a breakbulk.

Now select the nearest option and type Y.

Step Four: Maximum Number of Breakbulks for Each Shipment

(Insert figure 5 from the file \fig1-6)

Figure 5. Number of Breakbulks

1.Select Number of breakbulks from the MODIFY menu .

2.Enter any number between 0 and 9 for each 500 mile range.

Comments
By specifying the maximum number of breakbulks through which a shipment can be routed, the minimum of the user specified or

the actual number of intermediate assigned by FloydÆs algorithm for the shortest distance between all breakbulks is considered for calculation of handling cost and handling time. In this way, BBNET can account for truckload freight consolidation to EOL terminals that are not handled again at intermediate breakbulks. 6.2 Preparing Data Files Data files can be based on historical or forecast data. To test BBNET, we made use of historical data supplied by ABF Freight System, Inc. These data files are called abf.dat for the test problems.

The following is a list of the fields found in each record type:

Order History (Record Length = 42)

Field	Description	Field Length
1	Origin City ID	3
2	Origin Latitude	6
3	Origin Longitude	6
4	Destination City ID	3
5	Destination Latitude	6
6	Destination Longitude	6
7	Shipment Weight in lbs	6

The following is a sample from abf.dat for one shipment:

```
FSM 035.23 094.24 PHx 033.27 112.04 000018
```

6.3 RUNNING BBNET

(Inser figure 6 from the0 file \fig1-6)

Figure 6. Transportation and Handling Details

The following is the procedure for performing the operational

analysis:

1. Select B/b Operations from the RUN PROGRAMS menu.

2. You are then given the option to enter the following data;
   a. Transportation rate in $/lb/mile.
   b. Transportation speed in mph.
   c. Handling rate in $/lb/handling.
   d. Handling time in mins/lb.

3. When the analysis is finished, the BBNET map screen will reappear. Select B/b Operations from the REPORTS menu.

4. The report will be displayed. When finished viewing the report, press Alt x to return to the BBNET main menu.

Comments

The report is displayed in the SIMNET II Editor format. Use <page up> and <page down> to look at the report. The report can be printed by pressing Alt P. Press F1 for the HELP menu.

For a full description of the breakbulk operations report, see Section 7.

7. BBNET OUTPUT REPORT

7.1 COST AND TIME CALCULATIONS

Following is a presentation of the calculations involved in collecting the various measures of performance.

1. Transportation cost = transportation rate ($/lb/mile) x shipment weight (lbs) x EOL distance (origin to breakbulk miles + breakbulk to destination miles) + transportation rate ($/lb/mile) x shipment weight (lbs) x (breakbulk to breakbulk miles)/17500

2. Traveling time = total distance from origin to destination (miles) x speed (miles/hr).

3. Handling cost = handling rate ($/lb) x shipment weight (lbs) x minimum of actual and user specified number of breakbulk terminals.

4. Handling time = time to transfer (minutes/lb) x shipment weight (lbs) x minimum of actual and user specified number of breakbulk terminals where the shipments are handled.

7.2 EXAMPLE OPERATIONAL REPORT

BBNET Version 1.0. Break bulk Network Evaluation Software (1995).
Industrial Engineering Dept., University of Arkansas, Fayetteville, Arkansas.

****
NETWORK REPORT

***** NEAREST BREAKBULK SERVICE AREA OPTION*****

NUMBER OF BREAK BULKS: 10
TRANSPORTATION RATE: 0.2200 $/lb/mile
TRANSPORTATION SPEED: 55 mph
HANDLING RATE: 0.0050 $/lb
HANDLING TIME: 0.5000 mins/lb
NUMBER OF SHIPMENTS: 470404
TOTAL WEIGHT: 657930982 lbs
TRANSPORTATION COST: $62339472.00
TOTAL DISTANCE: 764312960.00 miles
TRAVELING TIME: 13896599.00 hours
TOTAL HANDLING COST: $6169089.00
TOTAL HANDLING TIME: 10284973.00 hours

ORIGIN	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	43164	9.18	63139780
2	96252	20.46	120752699
3	63803	13.56	85470550
4	31291	6.65	46219393
5	21351	4.54	30305147
6	43532	9.25	63380258
7	65682	13.96	91253651
8	49341	10.49	73340732
9	21674	4.61	33498156
10	34314	7.29	50570616
TOTAL	470404	100.00	657930982

DESTINATION	# OF SHIPMENTS	%SHIPMENTS	TOTAL WEIGHT
1	27078	5.76	39329674
2	97779	20.79	136893670
3	44321	9.42	67174302
4	41319	8.78	60391450
5	37521	7.98	51897866
6	49829	10.59	65822193
7	62099	13.20	82930098
8	49779	10.58	67289337
9	24805	5.27	34101382
10	35874	7.63	52101010
TOTAL	**470404**	**100.00**	**657930982**