A COST EFFECTIVE APPROACH FOR SOLVING LARGE VARIABLE DEMAND VEHICLE ROUTING AND SCHEDULING PROBLEMS

by

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Comparing the quality and cost of vehicle routing and scheduling analyses using actual customer locations and three different grid scales.

INTRODUCTION

The control of costs associated with the shipment of raw materials and finished products is a constant concern of transportation management. High fuel prices, escalating wage rates, and increasing expenses associated with acquiring and maintaining vehicles make efficient fleet operation a necessity if transport costs are to be controlled.

Technology has been available for many years to assist management in the design, evaluation, and improvement of transportation networks. This is particularly true of techniques related to solving vehicle routing and scheduling problems. Procedures presented by Clarke and Wright in 1964 and extensions given by others have served as the basis for many successful analyses (Hallberg and Kriebel, 1979 and 1972; Hardy; Russell and Igo; Turner, et. al). Many applications of these procedures indicate that transportation cost savings of 10 to 20 percent could easily be expected (Murphy and Hardy; Schruben and Clifton).

THE PROBLEM

The major data requirement necessary for all routing analyses is a cost matrix. This matrix relates all stops to each other and to the distribution center. Travel distance is normally used as the unit of measure for this matrix. Various methods have been proposed to assist in the development of these data and even though some are very efficient, the task is still very time consuming and costly. With most procedures, calculation time expands exponentially as the size of the problem increases (Hardy; Hu).

The effort and expense required for deriving the distance matrix make many route managers reluctant to use computer-assisted route analysis. This aversion is particularly strong if the route network being considered has a highly variable or dynamic list of customers to be served; i.e., a service area in which new customers are constantly added, while others are deleted. For analyses to be valid, new distance matrices would have to be constructed for each new set of customers. Any transportation cost reductions realized from the routing analyses could easily be lost through the expense of the analyses themselves.

THE PROCEDURE

The case study analysis presented in this paper illustrates a procedure for generating the distance matrix which should conserve time and be cost effective for even the most highly variable transportation network. The basic concept used is to overlay maps of the total service area with a grid. Use of a grid system is not new to anyone who works with maps. It is, however, somewhat unusual for it to be used in vehicle routing and scheduling problems. Many researchers and practitioners working in the area tend to feel that a grid system is not sufficiently precise to provide efficient routes. Research results presented later in this paper indicate that their judgements of grid based analysis are not always valid.

The basic procedure followed in establishing the foundation for calculating the distance matrix is as follows. First, a map or set of maps is obtained which covers the entire service area for the transportation system under study. The analysis is made a great deal easier if all maps have the same scale. Next, a grid size must be established. Obviously as the grid size is decreased, the grid distance network will more accurately represent the actual distance matrix. Also, with smaller grid sizes, the number of grid cells for a given service area is larger. As the number of cells increases, computation time for generating the distance matrix and for utilizing the matrix for actual analyses also increases. As pointed out earlier, this rate of increase is usually exponential.

The next step in the formulation of the distance matrix is to remove all grid cells that do not contain either a current or potential customer or relevant roadway. The shaded map cells illustrated in Figure 1 indicate which grid cells would be kept for use in establishing the distance matrix.

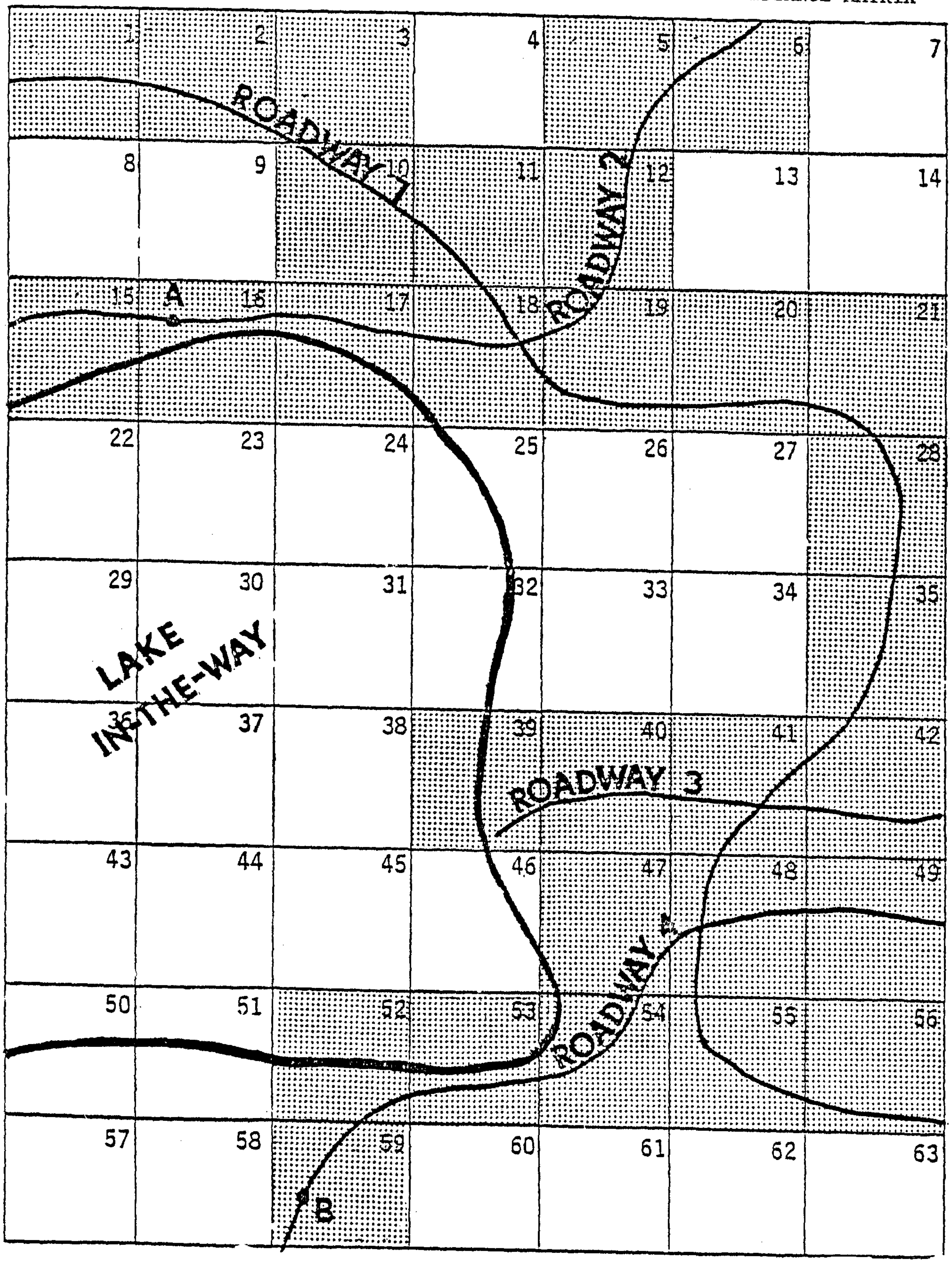
Elimination of unnecessary grid cells accomplishes two purposes. First, the distance matrix developed from the grid network more accurately follows the actual road network. For example, if all cells were left in the map illustrated in Figure 1, then the distance between points A and B, using a one mile grid, would be 7 miles. (This would give results similar to those obtained from using rectangular coordinates to calculate travel distances). The actual distance; however, since travel around the lake is required, is 15 miles.

The second advantage of removing cells is that the total number used for the analysis is reduced. For the example illustration in Figure 1, the 63 grid cells for the total map have been reduced to 30, thus reducing computational time and computer storage requirements.

After the total service area has been mapped and identified with a grid network, including all current and potential customer sites as well as relevant travel paths, the distance matrix may be generated. This dataset should be stored on the computer in an easy-to-access, permanent form so that it may be utilized for each individual routing analysis.

Each routing analysis would be initiated by a preprocessing computer program which would establish the relevant distance matrix for the customers being analyzed. Each customer record would identify the map cell location for that customer. The preprocessing program would identify all map cells that were needed and construct the appropriate distance matrix for the routing analysis. Construction of this matrix requires a simple search of the total distance matrix for the service area. This process is significantly less costly and time consuming than

FIGURE 1. EXAMPLE MAP ILLUSTRATING USE OF GRID NETWORK TO CONSTRUCT DISTANCE MATRIX



generation of a completely new matrix for each analysis.

RESULTS

The distribution system of a bottled water distributor located in a major city was chosen for analysis to compare routing results obtained by using actual customer locations and several different size grid systems. Management of the case study firm indicated that their customer list was very dynamic. In addition to their work load constantly increasing, they might experience a 30 percent turnover in customers during the year. With such extensive changes expected, it would not be feasible from both time and cost viewpoints to use computer-assisted routing if a new distance matrix had to be calculated for each new set of customers. The use of a grid system to calculate a master distance file appeared to be the most viable alternative.

It was also felt that the delivery system of the water distributor would be a good test on the value of the grid system because of the relatively dense customer population. With customers located close together, the likelihood for error in the specification of travel distance with a grid system is greater than if the customers are widely dispersed over a large geographic area.

A list of 564 customers served out of one distribution center of the company was plotted on a map of the service area. Both residential and business customers are served, with demand ranging from one bottle of water for many individual homes to 29 bottles for the largest commercial customer. Water is delivered on a vehicle with a maximum capacity of 150 bottles.

Data describing the current delivery system and several improved systems developed through computer-assisted routing are presented in Table 1. The current delivery network requires nine routes which cover a total of 435.7 miles in a little over 68 total service hours. Total cost for this delivery service is $1,707.74. This total is based upon driver base pay and fringe benefits of $17.12 per hour, overtime of $15.95 per hour, daily fixed cost of each truck at $15.22, and a cost per mile of $0.51. A total of 1,069 bottles was delivered, giving a cost per bottle of $1.60.

As indicated previously, the normal procedure for route analysis is to pinpoint the actual location of each customer and generate a distance matrix which accurately represents the true distances connecting each customer to all other customers and to the distribution center. This was accomplished for the 564 customers for use in establishing the best possible delivery system. The initial reroute reduced the number of routes to eight, in addition to decreasing total mileage traveled and service time. Most importantly, total cost was reduced about 8 percent and the cost per unit delivered from $1.60 to $1.47. One additional reroute (with some manual adjustment as is required in most analyses) was run which generated additional minor improvements in mileage, time, and cost.

A somewhat disappointing feature of the results using actual locations was the cost of the analysis itself. First, the distance matrix, which represented the 564 stops, had to be generated. Using very conservative computer rates, this expense was $77.60. It should be remembered that this distance matrix is only good for the particular set of 564 customers used in the analysis. In addition, the cost for the initial route analysis was $983.40 and the manual reroute was $35.40. Nearly 90 percent of the cost of the initial route analysis was devoted to the actual design of routes.

TABLE 1. DATA DESCRIBING THE CURRENT DELIVERY SYSTEM AND IMPROVED SYSTEMS USING ACTUAL CUSTOMER LOCATIONS AND GRIDS BASED ON QUARTER-MILE, HALF-MILE, AND MILE SCALES FOR CASE STUDY FIRM

		Actual Locations		Quarter-Mile Grid		Half-Mile Grid		One-Mile Grid	
	Current Routes	Initial Reroute	Improved Reroutes[2]	Initial Reroute	Improved Reroutes[3]	Initial Reroute	Improved Reroutes[3]	Initial Reroute	Improved Reroutes[3]
Number of Routes	9	8	8	8	8	8	8	8	8
Total Distance (miles)	435.7	336.27	334.82	400.7	358.2	431.35	358.4	416.4	372.4
Total Service Time (hours)	68:36	66:23	66:22	67:39	66:55	68:30	67:04	67:59	67:12
Total Cost (dollars)	1707.74	1575.82	1553.54	1682.04	1574.23	1692.09	1576.73	1681.22	1586.03
Cost/Unit Delivered (dollars)	1.60	1.47	1.45	1.57	1.47	1.58	1.47	1.57	1.48
Total Number of Grid Cells		564		2447		826		244	
Setup Cost[1]		77.60		2402.50		150.40		17.70	
Grid Cells for Analysis		564		173		102		55	
Run Cost[1]		983.40	35.40	882.90	46.81	95.20	32.70	17.10	19.70

[1]Figured at a rate of $10.00/CPU minute on an IBM 3031.

[2]One additional reroute was run.

[3]Three additional reroutes were run.

With 564 cells to consider, the number of possible route alternatives was extensive. A total investment of over $1,000 to reduce costs by only $150 is certainly not a good investment.

The delivery system was analyzed using three different grid scales--quarter-mile, half-mile, and mile. In all cases, the number of routes was reduced to eight. Also, total delivery costs were reduced significantly with results (after three manual reroutes of each) nearly as good as were obtained when actual locations were used.

Major differences, however, are seen when the costs of the analyses are compared. First, a look at the setup costs shows that with the quarter-mile grid scale, nearly $2,500 of computer time was required to generate the distance matrix. This distance matrix, with 2,447 cells, covered the entire service area and represented all current and potential customer locations and travel alternatives. It would not have to be generated again and would be available for all subsequent analyses of that service area.

The total number of cells required to cover the total service area was a great deal smaller when the grid size was increased to half-mile. A total of 826 map cells required a computer cost of $150.40 to generate. The 244 cells needed for the one-mile scale cost only $17.70 to construct.

Costs for the routing analyses also declined significantly as the size of the grid cells was increased. A major portion of the time required for the initial quarter-mile reroute was spent in searching the large distance data matrix to find the appropriate elements for the 173 cells in which the customers were located. The portion of the cost for actual route design was relatively small. Again, as with the analysis using actual locations, the total cost of analysis surpassed the potential benefit received.

With the half-mile grid, the cost of the analysis for the 102 cells containing customers was a little less than the projected benefit. Significant potential savings appeared to be possible, however, when the one-mile grid was used. The total cost of the analysis, $36.80, was only about one-third of the projected savings of $121.71.

SUMMARY AND CONCLUSIONS

The costs (both time and computer expense) associated with routing analyses of transportation systems having a variable set of customers are likely to be high since a new distance matrix would be required for each customer list. Also, if the service area is densely populated with a large number of customers, the cost of the individual analysis could possibly exceed the benefit to be realized from the route reorganization.

One approach for solving the problem of having to recompute the distance matrix each time the list of customers changes would be to use a grid system. A distance matrix of this type would have to be calculated only once and could be utilized repeatedly for additional routing analyses. Access to this database would significantly reduce the time and cost for each routing analysis.

This paper compares route statistics for improved delivery systems that were developed using actual customer locations and three different grid scales. Routes (after minor manual adjustments) were similar with all procedures.

Significant differences were seen, however, in the costs for the analysis. Solutions using actual customer locations and a quarter-mile grid had costs which far exceeded the projected benefits from the analysis. With the half-mile grid, the cost of the analysis was nearly the same as the projected savings. The return on the analysis expenditures was a great deal better with the one-mile scale grid. With the one-mile scale, projected savings were more than three times the amount of the analysis cost.

Research results presented by others have stressed that the clustering or grouping of the customers that will be included on a route is as important as the actual sequence of services on the route when minimizing cost (Hwang; Krolak and Nelson). Results of the routing analyses presented in this paper tend to verify that premise. The use of a grid network for establishing the distance matrix does some of the clustering before actual route analysis begins. The resultant smaller number of cells greatly reduces the expense of analysis with little loss in improved routing efficiency.

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