

# Computerized Vehicle Routing for Home Delivery Operations

J. AUGUSTINE HSU, T. P. KIM, AND KEVIN BOTT

Vehicle routing models have been widely used for LTL (less than truckload) trucking operations on interurban highways. These models take into consideration various operational as well as contractual constraints and attempt to minimize the total costs (or maximize the total profit, if that is the goal of the operation). To make these models useful for home delivery services, at least two additional capabilities are needed. The first is the ability to locate (or assign coordinates to) any given address in the service area. The second is the ability to accurately estimate the distance between any given pair of points. In other words, estimated distances have to reflect local traffic conditions, such as one-way streets, locations of freeway interchanges, locations of bridges, and so on. In addition to these two abilities, an interactive graphic capability is useful to ease the task of manually refining results. In this paper, the development of such a vehicle-routing model for the home delivery operations of a major trucking company is presented.

Computerized routing and scheduling systems have been used in less than truckload (LTL) trucking operations on interurban highways for many years. Successful practices reported in the early 1980s (1, 2) helped to convince many trucking operators of the feasibility of computerized truck dispatching. Meanwhile, the capabilities of microcomputers are continuously being enhanced, and their costs are continuously being reduced. The emergence of many microcomputer-based vehicle-routing systems in the mid-1980s (3) makes this kind of application cost-effective, even for a small trucking operation.

Applications of these vehicle-routing systems to a truck operation within a metropolitan area, however, is much more difficult. The primary reason for this difficulty is the accuracy required in estimating the location of any given stop and the distance between any given pair of stops. In a store delivery operation, in which there are only a limited number of customers, each customer's location can be predefined. Distance between any two customers can be preestimated and built into a data base. Estimation of distances thus becomes a routine table lookup procedure. In a home delivery operation, however, the number of potential customers is so large that it becomes impractical to precode the customer locations or to prebuild a distance data base. In this case, accurate estimation of stop loca-

tions and distances becomes the key issue in the successful operation of a home delivery operation.

In this paper, the development of such a system for the home delivery operations of a major trucking company is described. A brief discussion on the vehicle-routing problem is presented first. This is followed by the description of a vehicle-routing system called RouteAssist (developed by the same trucking company) on which the development of the home delivery routing system is based. Finally, the development and implementation of the home delivery routing system are described.

## VEHICLE-ROUTING PROBLEM

In this paper, only a brief and general description of the vehicle-routing problem will be given. An excellent review of this problem can be found in a paper by Bodin et al. (4), and future research perspectives have been discussed in several recent publications (5, 6).

As an operations research problem, a vehicle-routing problem can be described as follows. Given

- A set of delivery or pickup orders,
- A set of available vehicles,
- All relevant cost information, and
- Various operational constraints,

find solutions for

- Assigning orders to vehicles, and
- Sequencing orders on each route

to achieve the objective of

- Minimization of total costs.

Solution strategies to this problem can be classified into the following approaches (7):

1. Cluster first, route second;
2. Route first, cluster second;
3. Savings and insertion;
4. Improvement and exchange;
5. Mathematical programming;
6. Interactive optimization; and
7. Exact procedures.

The first five strategies represent various heuristic procedures to achieve good (but not necessarily optimal) solutions efficiently. The sixth strategy takes advantage of interactions between human knowledge and modeling procedures. The last strategy attempts to solve the problem by various optimization algorithms.

Because of the complexity of the operational environment, most of the vehicle-routing systems are developed on the basis of one or more heuristic methods. In the next section, a vehicle-routing system will be described to illustrate the implementation of these solution strategies. This vehicle-routing system is the basic framework on which the home delivery-routing system is developed.

## DESCRIPTIONS OF A VEHICLE-ROUTING SYSTEM

The previously mentioned vehicle-routing system is designed to assist a fleet dispatcher in the daily routing and scheduling of deliveries and pickups from a central depot, routed over interurban highways. It can also be used as a decision-support tool for management in planning controlled transportation systems. In a multistop environment in which a private or contract carrier is being used, it is used to

- Design routes and schedules that minimize fleet costs,
- Select the demand points that can be most economically served by the private or contract fleet,
- Select the points whose deliveries should be shipped via common carrier, and
- Determine the minimum number of tractors, trailers, and drivers required.

The system is capable of analyzing different transportation conditions, such as a single driver or sleeper team, with realistic constraints about operation, equipment, and union agreements. It can be used to design pickup routes, delivery routes, and backhaul (pickup and delivery) routes. Savings can accrue in many ways, including

- Reduction of the number of miles driven, which results in lower fuel costs, lower maintenance costs, and reduced driver costs;
- Possibility of more stops per route;
- Reduction of the number of vehicles used;
- Assignment of backhauls to the most appropriate route;
- Reduction of the labor force;
- Improved assignment of equipment and drivers to routes; and
- Determination of the best mix of private and common carriers.

The system prepares three basic reports. The first is a schedule that tells drivers what time to leave the depot, the scheduled arrival time at each stop, total route timing, and even their lunch break schedules. The second is a summary

route report that provides the dispatchers with an overview of the entire fleet operation. Timing, performance, and costs for every route are presented in a clear, easily understandable format. The third report, which is the driver and equipment scheduling report, identifies the minimum number of tractors, trailers, and drivers needed to serve the scheduled routes throughout the planning horizon.

The development of this vehicle-routing system, along with one of its earliest implementations, was described by Bott (8). The system was based on the savings approach developed by Clarke and Wright (9). Then, through one of its early installations, a greedy insertion algorithm based on a knapsack-type approach was designed (10). Later, a limited fleet version of the system was developed in which the problem was solved by using a heuristic that was based on a column generation procedure (11).

Currently, the system has been implemented at 28 sites and is used to dispatch some 330 tractors every day. The average savings of the fleet operating cost range from 5 to 15 percent. In one case, an increase of 28 percent in total revenue per mile was reported (12).

## APPLICATIONS TO HOME DELIVERY OPERATIONS

So that the previously described system could be applied to home delivery operations, much effort was put into the development of an accurate address locator and an accurate distance estimator. The graphics capability of the original routing system was also enhanced so that detailed street maps could be interactively displayed to help the dispatcher refine the routing results. The design concept of this system is presented in Figure 1.

### Address Locator

Given an address written by a sales clerk on a sales slip and typed into the system by a data entry clerk, a good address locator has to be able to recognize the various components of an address and assign the accurate coordinates accordingly (Figure 2). The first part of the address-locating process is an address recognizer, which breaks down a given

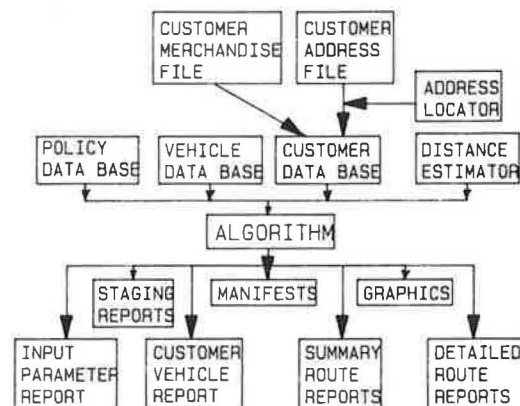


FIGURE 1 Overview schematic of home delivery-routing system.

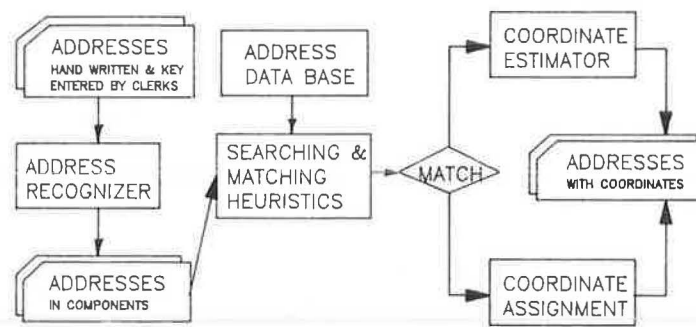


FIGURE 2 Address locator.

address into the following components: street number, directional prefix, street name, street type or street type abbreviation, directional suffix, supplemental street number information (e.g., apartment number), city name, state name or state name abbreviation, and zip code. After an address is broken down into these components, it is ready to be matched against the address data file. In the home delivery system under discussion, the address data file is composed of two types of data files, DIME files and street index files.

GBF/DIME stands for Geographically Based Files created through the Dual Independent Map Encoding technique. A DIME file is basically a collection of street segment records, as well as records of nonstreet features such as railroads, rivers, and boundaries of political units. Each street segment record contains identifiers (e.g., coordinates) for the end points (nodes) of the segment, the low and high address numbers, and other information, such as census blocks, tracts, zip code, and so on. Each DIME file was processed so that only the desired fields and the desired records were retained.

Because these DIME files generally reflect the street conditions in the late 1970s, they have to be updated by a supplemental source of data: street index files produced by map publishers. These street index files usually include the fields of street name, street type, and map index information (such as grid number and page number), as well as directional prefix and suffix. Through digitization, each grid number can be converted to a coordinate consistent with the coordinates used in the DIME files. New residential streets, which tend to be short in length, can be located accurately by using these street index files.

To match a given address to the address data base, two devices are essential: an efficient searching heuristic and a smart spelling checker. It is also important to be able to assign the coordinates for a new street address that is not found in the data base and to update the data base accordingly. When a given address has been matched against a record in the data base, the system estimates the coordinates for the address.

### Distance Estimator

In general, there are three different approaches to estimating distances in a vehicle-routing system: distance ma-

trix, shortest path within a network data base, and coordinates and circuitries. The first approach is most accurate but is only applicable in cases for which the number of stops is fixed and small. The second approach requires a network data base and an algorithm to find the shortest path between two nodes. The network could be a complete street network, a major highway network, or even just a skim tree network in which each link does not necessarily represent a physical road facility. The third approach uses the coordinates of the two points to calculate the direct line distance and then adjusts it by a circuitry factor. The key in a successful application of this last approach is the accuracy of the circuitry factors.

During the development of this home delivery-routing system, both the first and second approaches were determined to be impractical because of the effort required to prepare and maintain the necessary data files. Efforts were then concentrated on developing an accurate circuitry file. The original vehicle-routing system uses a circuitry file at the three-digit zip code level. Even though these circuitries yield a satisfactory result for routing along interurban highways, this file was not found to be precise enough for routing within a metropolitan area.

Traffic zone data was used to develop a more accurate five-digit zip code circuitry file. Because traffic zones are the basic geographical units used in the urban transportation planning process, there is a great deal of zone-based data available from various metropolitan planning organizations (MPOs). To develop this circuitry file, the following information is required: zone to zone distance, travel time matrices, or both; zone to zip code correspondence table; and zone centroid coordinates. Each zone centroid is treated as a sample origin or destination, and a five-digit zip code-based circuitry file is developed accordingly.

Further refinements are usually required to accommodate local traffic conditions, which are not reflected in the zone to zone distance matrices. Circuitry files can also be revised so that "barriers" can be built in to reflect operational or other requirements.

### Interactive Graphics Capabilities

The original vehicle-routing system had many graphics capabilities that were found to be helpful in reviewing and refining the routing solutions. Some of these capabilities

include adding or deleting a stop from a route, requesting stop or route information, joining two routes into one, splitting one route into two, resequencing stops on a route, and overlaying various geographical information, such as roads, water, zip code boundaries, and so on.

For the home delivery-routing system, an additional capability was developed so that streets could be displayed on the screen. This ability was found to be extremely useful in reviewing the sequencing of a cluster of stops close together. By combining these graphics capabilities and an editing screen, stops can be easily swapped between routes or resequenced within the same route.

## RESULTS AND BENEFITS

The home delivery-routing system was implemented at two sites in 1987. The two implementations had different degrees of sophistication in their data base design. The first implementation has a detailed data base for the address locator and distance estimator. This system is used solely for assisting dispatchers in routing and scheduling. The second implementation is part of a home delivery system that includes comprehensive vehicle routing, warehousing, and accounting features. The first phase of this second implementation employed a more aggregated data base for its address locator and distance estimator. The detailed data base will be included in the second phase of implementation. Some results of the parallel processing for the first implementation are presented in Table 1. The three solutions used in the parallel processing are as follow:

- Manual solutions by dispatchers or routers,
- System solutions by resequencing orders that were previously grouped as just described, and
- System solutions consisting of both grouping the orders into routes and sequencing the orders on each route.

It was found that system solutions are better than manual solutions by 16 to 26 percent in total mileages. Even the more primitive system solutions are better than manual solutions by 11 to 20 percent.

To make system-generated routes acceptable to dispatchers, route feasibility is as important as mileage reduction. Again, the system solution was judged by drivers and dispatchers as good as, if not better than, the manual solution. In addition, the implementation of the system provides management with standards for measuring the

performance of dispatchers and drivers. As a result, management efficiency has improved, and performance has become much more consistent.

Finally, it was found that service to customers was also improved because of the availability of better information and the consistency of performance.

## IMPLEMENTATION ISSUES

Successful implementation of any decision support system takes more than just a good computerized system (6, 8, 13). Several important issues emerged through the implementation of this home delivery-routing system. First of all, not all home delivery operations are the same, and the local data bases are not the only difference. Each delivery system client may have different requirements for serving customers and delivering their goods. Furthermore, local management and local labor often have their own requirements. It is most important to make sure that all the operational details are understood and correctly implemented.

Second, use of a computerized dispatching system inevitably involves changes in operating procedures. Each home delivery operation has its own procedural "traditions." Many of these are valid and are necessary to cope with unique local conditions. Some of the others, however, are in reality superficial, and these should be reviewed and changed as needed.

Third, operators, especially dispatchers, should be involved in the implementation from the beginning. Dispatchers are usually the people who are most knowledgeable about local conditions. If they realize that the system is there to free them from routine tasks rather than to replace their jobs, then they will be motivated to use the system effectively.

Fourth, local conditions will keep changing, and so will the operating requirements. The system has to be adaptive so that new requirements can be taken into consideration easily. Local data bases have to be updated on a regular basis, and ideally this task should be performed by the dispatching staff.

## SUMMARY AND CONCLUSIONS

The development of a home delivery-routing system for the home delivery operations of a major trucking company is described in this paper. In addition to reducing operating costs and providing better management controls, many other benefits can be realized by implementing a computer vehicle-routing system for home delivery operations. For example, the address locator helps the dispatcher make early detection of any problems that may have been caused by incorrect addresses and provides sufficient time for corrective actions to be taken. Consequently, the computer-generated manifests provide easy-to-read, error-free addresses that reduce driver guesswork. The schedule generated by the system also provides a much more precise estimate of delivery windows. As a result, retailers are able

TABLE 1 RESULTS OF PARALLEL PROCESSING, BY SOLUTION

Case	No. of Stops	No. of Routes			Total Miles		
		A	B	C	A	B	C
1	144	9	9	8	570	445	421
2	157	8	8	8	1214	1078	1013
3	130	7	7	7	695	586	532

NOTE: Solutions were as follows: A, manual routing; B, resequencing of manual routes; and C, computerized routing.

to give their customers a delivery window of ~1–2 hours rather than half a day. The routing system can also be easily tied into an automated warehousing system and can become an integrated part of a complete home delivery operation.

Given the continuing improvement of microcomputer technology, it is expected that the application of computerized routing systems for home delivery operations will become much more cost-effective. It is hoped that this paper provides some insight into understanding the problems of these systems and supplies at least a partial framework for further development in this area.

## REFERENCES

1. M. Fisher, A. Greenfield, R. Jaikumar, and J. Lester. A Computerized Vehicle Routing Application. *Interface*, Vol. 12, 1982, pp. 42–52.
2. M. Bell, B. Golden, A. Assad, and L. Bodin. Planning for Truck Fleet Size in the Presence of Common-Carrier Option. *Decision Science*, Vol. 14, 1983, pp. 103–120.
3. B. Golden, L. Bodin, and T. Goodwin. Microcomputer-Based Vehicle Routing and Scheduling Software. *Computers and Operations Research*, Vol. 13, 1986, pp. 277–285.
4. L. Bodin, B. Golden, A. Assad, and M. Bell. Routing and Scheduling of Vehicles and Crews: The State of the Art. *Computers and Operations Research*, Vol. 10, 1983, pp. 162–212.
5. K. Bott and R. H. Ballou. Research Perspectives in Vehicle Routing and Scheduling. *Transportation Research*, Vol. 20A, 1986, pp. 239–243.
6. B. L. Golden and A. A. Assad. Perspectives on Vehicle Routing: Exciting New Developments. *Operations Research*, Vol. 34, 1987, pp. 803–810.
7. L. Bodin and B. Golden. Classification in Vehicle Routing and Scheduling. *Networks*, Vol. 11, 1981, pp. 97–108.
8. K. Bott. The Ins and Outs of Implementing a CARS Package. *Proc., Council of Logistics Management Annual Meeting, Vol. 11*. Anaheim, Calif., Oct. 5–8, 1986, pp. 129–139.
9. G. Clarke and J. Wright. Scheduling of Vehicles from a Central Depot to a Number of Delivery Points. *Operations Research*, Vol. 12, 1964, pp. 568–581.
10. S. Javad and V. Venkateswara. Computer Implementation of a Vehicle Routing Model. Presented at the 1984 Joint National Meeting of the Operations Research Society of America/The Institute for Management Sciences (ORSA/TIMS), San Francisco, Calif., May 14–16, 1984.
11. Y. K. Agarwal. Set Partitioning Approach to Vehicle Routing. Presented at the 1985 Joint National Meeting of TIMS/ORSA, Boston, April 29–May 1, 1985.
12. Profitable Tracking at LADD Furniture. *Handling and Shipping Management*, March 1985.
13. J. Fripp. How Effective are Models? *Omega*, Vol. 13, 1985, pp. 19–28.

---

*Publication of this paper sponsored by Committee on Urban Goods Movement.*