Chapter 14

Evolution of Microcomputer-Based Vehicle Routing Software: Case Studies in the United States

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14.1 Introduction

To say that there has been an explosion of microcomputer-based software for the VRP in the last decade is an understatement. The availability and scope of the vehicle routing software packages today exceed expectations of but a few years ago. In their early survey paper, Golden, Bodin, and Goodwin [10], acknowledging that microcomputers were by then commonplace, reviewed 13 commercially available packages and noted that several other packages were under development. By contrast, the 1997 edition of Logistics Software [12], compiled by Andersen Consulting for the Council of Logistics Management, lists 559 microcomputer logistics software packages available from 263 vendors. Within this group, 133 packages, offered by 80 vendors, feature a traffic routing and scheduling component.

This explosion was perhaps inevitable. As the various components of the logistics supply chain, facility location, production scheduling, inventory management, and vehicle routing, yielded to microcomputer modeling methods, early papers, such as those by Geoffrion [7] and Geoffrion and Powers [8], called for the use of comprehensive optimization models in the analysis of distribution systems. With the advent of microcomputer-based geographic information systems and reasonably priced 100 MHz processors and gigabyte hard drives, the fuse was lit. Today, the vast majority of vendors offering vehicle routing and scheduling packages maintain internet websites that discuss their products in detail and allow either an online or a downloadable demonstration.

We do not attempt to review and compare individual vehicle routing software packages or to provide a mechanism by which to choose a package for a specific application. Rather, our purpose is to provide some perspective on the evolution of the currently available microcomputer-based packages for vehicle routing and to give some insight into the direction of their future development. To accomplish this, the 1986 survey of Golden, Bodin, and Goodwin is used as a starting point. We follow the earlier authors' call for a wider scope of problem definition and application of the vehicle routing problem. We discuss the evolution of program capabilities with particular focus on the increased use of GIS and Graphic User Interface (GUI), and we discuss the optimization algorithms in use in several leading packages. Additionally, a summary of conversations with several software developers and current customers contributes to the discussion of how the state of the art evolved to its current position and to where it may proceed.

Given these objectives, this chapter focuses on the microcomputer-based packages for the VRP available from four vendors: CAPS Logistics (now part of Baan Supply Chain Solutions), RouteSmart Technologies, Roadnet, and MicroAnalytics. These four vendors were selected for several reasons. First, each vendor has some longevity in the market. The last three are mentioned in the 1986 survey paper. The CAPS vehicle routing package dates from 1984. Second, the four vendors operate on a national scale and boast client lists of national prominence. Third, each vendor features a specific product designed primarily for and around the VRP. Finally, each vendor offers substantial user support in the form of training center courses or user group support or both. Details of each vendor are given in Table 14.1

CAPS Logistics was incorporated in 1979 in Atlanta, Georgia, with faculty from the Georgia Institute of Technology among its principals. In 1989, CAPS Logistics introduced the basic routing, shipment planning, and supply chain platforms as part of its CAPS LOGIS-

Table 14.1. *Vendors and vehicle routing packages reviewed.*

Vendor	Package
CAPS (now SSAGlobal) 500 West Madison Suite 1600 Chicago, Illinois 60661 (312) 258-6000 www.ssaglobal.com	RoutePro
RouteSmart Technologies 8850 Stanford Boulevard Columbia, MD 21045 (301) 596-7444 www.routesmart.com	RouteSmart
Roadnet Technologies 2311 York Road Timonium, MD 21093 (410) 560-4298 www.roadnet.com	Roadnet 5000
MicroAnalytics 2200 Clarendon Blvd Suite 1002 Arlington, VA 22201-3364 (703)841-0414 www.bestroutes.com	Truckstops

TICS TOOLKIT. With this foundation, clients could build software solutions customized to their logistics and transportation needs. In 1997, CAPS Logistics expanded and enhanced its product line with the introduction of five new products and upgrades of four existing products, including the TOOLKIT. In September 1998, CAPS Logistics was acquired by Baan Company, a leading international supplier of enterprise applications.

RouteSmart Technologies had it origins in Distinct Management Consultants, a transportation and distribution consulting company founded in 1980 by several faculty members from the School of Business at the University of Maryland. As its client base and application needs grew, Distinct formed a partnership with Bowne Consulting to become Bowne Distinct in 1985. The new company's routing software product was named RouteSmart. In 1997, Bowne Distinct became a business partner with ESRI, the leading company in GIS applications. In 1999, to be more clearly identified with its primary product, Bowne Distinct became RouteSmart Technologies.

Roadnet Technologies was founded in 1983 by a group of computer technology entrepreneurs. The initial Roadnet Vehicle Routing and Scheduling System was an early success, and in 1986 Roadnet was purchased by the United Parcel Service (UPS). In 1995, Roadnet Technologies became part of the UPS Logistics Group. Although now a subsidiary of a major corporation, UPS, Roadnet Technologies operates as an independent company in meeting its customer's software needs and requirements.

MicroAnalytics was founded in 1984. The company, based in Arlington, Virginia, found early acceptance and success with its vehicle routing product, TruckStops. One of its earliest successes was with the Canadian Postal System in Toronto, where the company maintains offices. The company has remained true to its focus on personal computer–based routing systems and offers the lowest-priced systems among those considered here. In addition to the TruckStops product, MicroAnalytics offers the OptiSite Distribution Management Systems, the GeoNet location system, and the BUSTOPS Student Transportation System.

This selection of vehicle routing software products reflects the biases of the author. In the initial step in this investigation, the author tried the telephone numbers of all 13 software products listed in the 1986 survey article. To its credit, and perhaps to the credit of Bell Atlantic, only MicroAnalytics had the same number. The author had known of the Truckstops package since 1986, when he was a consultant to Ryder Truck Rental in Miami, Florida. Additionally the author has been an Academic Link partner with CAPS Logistics since 1996. He has visited the CAPS headquarters and training center in Atlanta, Georgia, and has taken the CAPS training courses using both the Supply Chain Designer and the RoutePro modules of the CAPS toolkit. The Roadnet package was mentioned in the 1986 survey paper and has since been acquired by UPS. This vertical integration allows Roadnet entry to a global customer base. Finally, RouteSmart Technologies combines the vehicle routing expertise of Bowne Distinct together with the unique GIS capabilities of ESRI. These associations made it easier to talk with the software designers and engineers and to be able to identify customers who recently made a selection decision.

For readers interested in guidance in selecting a software package, the 1999 edition of Logistics Software CD-ROM is available from the Council of Logistics Management, Publications Department, 2805 Butterfield Road, Suite 200, Oak Brook, IL 60523, or from their website, http://clm1.org. Additionally, the survey by Hall and Partyka [11] reviewed the program capabilities and features, including price and required computing platforms, of

20 available packages. A comprehensive checklist for selecting a logistics network design software is available from Insight, Inc. at www.insight-mss.com. An article comparing a number of supply chain management software packages appeared in the January 2004 issue of Logistics Today. The article may be found at www.logisticstoday.com.

14.2 Definition of the VRP

The formal graph theoretic definitions of the CVRP and its variants with distance and time window constraints, backhauls, and combined pickups and deliveries are given in Chapter 1. These more formally defined problems tend to have concise mathematical formulations based on a number of crucial assumptions that streamline the model. Generally, these problems and their variants have received a great deal of attention from academic researchers. For an excellent survey of classic vehicle routing formulations and solution methods, see Bodin et al. [3].

Although consistent sets of test problems are limited, some recent studies offered computational comparisons of vehicle routing algorithms. Chapters 2 through 9 of this book describe state-of-the-art exact and heuristic algorithms, along with the discussion of their computational performance, for the CVRP (Chapters 2–6) and its main variants: the VRPTW (Chapter 7), the VRPB (Chapter 8), and the VRPPD (Chapter 9).

The types and definitions of the VRP addressed by the various software packages considered in this study are typically much more general. For example, one vendor says that its software can be used “to determine which vehicle should serve each customer location and the best stop sequence to accommodate your customer’s time windows while minimizing your travel time" [12].

Regardless of how formally the VRP is defined, three components must be specified: the customers, the products, and the vehicles. Once these components are specified, the software package, through a sequence of algorithms, produces a set of vehicle routes.

14.2.1 Customer Specification

The customers to be serviced typically are the stops to be visited by the vehicles in the vehicle routing application. The customer typically is specified by its name or by an internal identification number. The customer location generally includes the street address and the latitude and longitude of the location. With the prevalence of geocoding software and the need for a visual map display of the customer locations and vehicle routes, a major portion of commercially available software packages is devoted to file manipulation and geocoding. The Truckstops package, for example, allows the creation of a “data specification file” that allows data to be read from existing customer files into a truckstops customer file. Similarly, data may be exported from Truckstops to other files to allow customary reports to be generated.

The demands of each customer location may be specified simply as a number of units or may be composed of a sequence of orders of multiple products specified in various dimensions. The customer orders may be either pickups or deliveries that may be interspersed on the route or identified as a backhaul that may be loaded only on the return portion of the route.

Time window constraints are now so commonplace that all the packages surveyed allowed for their incorporation. The specification of the time windows allows for multiple windows to exist on multiple days through the week. The windows are specified with open and close times, and some packages, RoutePro, for example, allow cost penalties to be assessed for deviations from specified window openings.

Capacities or other limitations may sometimes exist at a customer site or loading dock. These restrictions may limit the amount of product delivered at any one time due to storage constraints or may limit the height or length of a truck that may be used to service that customer location. These "mateability" constraints are also addressed in the vehicle specifications.

14.2.2 Product Specification

Products are usually described by name and dimensionality. The typical dimensions of products are size (cubic feet), weight, and floor space. The floor space is how much square footage of the trailer floor space each unit of product requires. This type of dimensionality may also be measured in terms of pallets that can be loaded in the trailer.

Occasionally, products must be considered for their compatibility with one another or for the requirement of a special service, such as refrigeration. Additionally, a trailer may have to be cleaned if a particular product is transported. This requirement often is necessary when transporting various chemicals.

14.2.3 Vehicle Specification

The world of vehicle routing software allows various types and descriptions of vehicles to be specified. The vehicles must be identified by number and capacity so that amounts of product to be transported may be determined. In some cases, special features of the vehicle's capacity may be of interest. For example, the number of separate storage compartments in a tanker truck may allow various products to be delivered by the same vehicle. In another case, the presence of access doors in the midsection of a trailer may allow pickups and deliveries to be interspersed without requiring the trailer to be unloaded. Additionally, if loading dock mateability is an issue, vehicle length and height may also be required.

The operational cost of the vehicle typically depends on the time or distance over which the vehicle is operated. The time and distance each vehicle operates is a function of vehicle speed and highway conditions. Speeds at rush hour, for example, are usually less than at off-peak times on city streets. Additionally the drop, service, or dwell times of a vehicle may be dependent on the type and amount of product delivered and on the customer to whom the delivery is made.

Finally, the starting and ending positions of each vehicle each day may be distinct. Additionally, as routing information becomes available throughout the day, the customer stops may be dynamically routed as the uncertainty of the customer demand is realized.

If driver scheduling and costs are a consideration, driver pay rates, work rules, relief or break requirements, and other capabilities must be considered. In the case of trips covering multiple days, the consequences of single man over the road or driving teams must be considered. In a local delivery situation, the operation of more than one route in a day or redispatch may be considered.

14.3 Algorithms

The construction of vehicle routes in vehicle routing software packages generally is a multistep process. This multistep process usually involves an initial route construction procedure and a route improvement procedure. Both procedures may involve a combination of manual and automatic operations that are repeated until the user is satisfied with the resulting solution.

In the case of initial route construction, it is often the case that the user has a set of feasible routes that are being operated that may be used as a starting point or as an initial routing template. All packages considered here provide the user with the capability to create routes manually through a point-and-click construction process. The route under construction may be made to appear graphically on a map of the customer service area, allowing the user to get a sense of the spatial configuration of the routes.

The automatic selection of customer stops for each route is available on all packages. Depending on the type of algorithm used, however, the user may require some experience or expertise in the use of the automatic procedure before a desirable set of routes can be produced automatically.

The algorithms used by most packages are a combination of heuristics and local improvement procedures (see Chapters 5 through 9). RoutePro allows the user to select from among insertion and nearest-neighbor methods to build initial routes. Truckstops uses a method based on the generalized assignment heuristic of Fisher and Jaikumar [6] to seed routes and completes the route structure with a variant of the method of Clarke and Wright [4].

Once an initial set of vehicle routes is available, the routes may be edited by various means. All packages allow the user to manually edit the routes. This type of editing generally is done on a map showing customers and routes in a spatial perspective. By using the mouse, customers may be dropped from or added to routes or moved from one route to another. The packages check all the constraints of the proposed move and report or disallow any infeasibilities.

All packages considered also include a set of local improvement procedures along the lines of the 2-opt and 3-opt methods of Lin and Kernighan [14] and the method of Or [16]. The user may specify the routes on which the procedures are to operate and may specify the amount of time or computing effort to be expended.

The efficacy of the optimization procedures employed by the state-of-the-art vehicle routing packages is validated by their widespread implementation; however, little in the way of comparison testing has been done. MicroAnalytics does report solving three of Fisher's [5] problems to within 1.9% of optimality with the Truckstops package within an elapsed time of 15 minutes.

14.4 Future Trends in Vehicle Routing Software

To get a sense of the future direction of the vehicle routing software industry, materials of each of the products and companies were reviewed and telephone interviews were conducted with several of the software developers and with some of their major customers. As noted earlier, many companies have academic roots. In talking with the software developers, one is struck by the academic feel of the companies, not only in their personnel but also in their “campuses." The software developers are highly trained, often with advanced degrees, and they have extensive knowledge of both computer hardware and software development. For successful software companies to have exceptional people probably should not be surprising. As Don Ratliff, former chief technology officer at Baan Logistics Solutions, put it, “You can’t afford to hire average software developers, you’ve got to get the best” [17].

With a view toward the future, software developers must keep one eye on the latest hardware and software developments and the other on their everchanging customer needs. Adapting to changes in computer hardware is something that all the surveyed companies have done very well. Each has a well-documented list of press releases extolling how its latest product releases have adapted to the changing architectural landscape of the computer world. Several developers mentioned the importance of keeping watch on what Microsoft is doing and the direction that the software giant’s operating systems and support software developments are taking.

Interviews with software developers revealed several areas in which the companies are working to respond to customer needs. Larry Levy of RouteSmart Technologies mentioned two problems related to workloads [13]. The first problem involves the so-called Period Routing Problem, where workloads need to be balanced over days of the week or over several weeks. In a related area, Levy mentioned the importance of matching skill level of crews to the tasks that are to be performed at the customer location. The skill-matching problem raises issues such as, How should routing interact with skill set constraints, and, What is it worth to a customer to have this capability?

Mike Micco, director of product development for Routing Applications at Baan Logistics Solutions, identified the decisions of when and how to use common carriers as part of the routing solution as an area for future investigation [15]. This nuance augments the client defined routing problem with the availability of third-party carriers to form a more general transportation problem. The problem is further complicated by the possible existence of contractual agreements between the client and specific third-party carriers.

Several software developers mentioned “collaborative dispatching” as an area for future work. Collaborative dispatching would allow several users to view the routing solution as a dynamic model where changes to the vehicle routes could be made in real time. Such operations would assume the existence of two-way communication links between the dispatcher and each vehicle, as well as a client-server network configuration among the dispatchers. The two-way communication and data links between dispatchers and vehicles are current technology and are in use in many routing applications today. The collaborative aspects of dispatching and the protocols necessary for the system and vehicle response to real-time changes is an area in which further research must be conducted.

On the client side, trucking companies now recognize that using a computing system for their vehicle routing is essential [1]. The skepticism of early users has, in most cases, been replaced by acceptance and trust. Although at first clients wanted to see their routes mapped out and to take a major role in interactively building routes, clients now wish to take advantage of the second level of savings that comes with implementation of a vehicle routing package, that is, the reduction of onerous manual labor. This fact was reaffirmed by Miller Distributing of Fort Worth, Texas [2].

The level of user trust has developed in some cases to the point where the user wants minimal interaction with the routing system. The desired user scenario is to allow orders to be received and processed electronically and to have the vehicle routes generated without user intervention. Dispatch sheets would then be sent automatically to each vehicle at the beginning of the work period. This type of hands-off solution requires a new level of robustness in the routing system and its algorithms that heretofore had been provided by the human component. Data errors and anomalies under this scenario must be analyzed within the routing system so that appropriate action may be taken so that a workable solution is produced within the scheduling time frame.

Although the clients of vehicle routing software are becoming much more accepting and sophisticated in their use of the products, their focus remains clearly on the bottom line. This focus is not lost on the software development companies. They are acutely attuned to the fact that each of their customers is interested in saving money. The overall theme of the future directions of vehicle routing from clients is, "How can we use this technology to obtain a solution with more value?" and the response of each software developer is, "How can we work with you to accomplish this?"

A recent article [9] states, "To be done right, e-commerce logistics requires integration of systems from the Web front end to the customer's signing for the package." Within this larger context of e-logistics, vehicle routing and scheduling has become an integral part of the customer fulfillment system. Complete fulfillment of customer service requirements must provide for the tracking of individual customer deliveries through the vehicle routing and scheduling process from the customer's website access to the system. As vendors of enterprise resource planning systems add these capabilities to their suites, the scope of vehicle routing and scheduling will expand to become a vital component in the optimal structuring of e-logistics systems.

14.5 Summary and Conclusions

As the power and speed of microcomputers have increased dramatically in recent years, so have the capabilities of vehicle routing packages. Early packages that could be had for less than a thousand dollars solved TSPs. Today, packages costing more than a hundred times as much can be used to optimize the entire logistics supply chain from purchase of materials, through manufacturing, to the final delivery of the product to the customer.

In retrospect, the conclusions of Golden, Bodin, and Goodwin have held true. The explosion of microcomputer vehicle routing software packages has continued. The modern packages are more powerful and more flexible, handling larger and more complex problems than their predecessors. Additionally, the number of implementations producing important cost savings has grown significantly. Perhaps only the cost of the packages, which has increased substantially, does not fulfill earlier expectations. But considering the power and capability of the current systems, there has been a significant increase in the value of the product.

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