

**COMPUTERISED ROUTING:  
ITS TIME HAS COME**

**J. MILLER\*\* & L. DE VRIES\*\***

\*Senior Lecturer, UCT Graduate School of Business, Rondebosch, 7700

\*\*Partners, Distribution Management Services, P O Box 4733, Cape Town, 8000

**ABSTRACT**

The costs of commercial fleet management in South Africa continue to rise ahead of the inflation rate. Computerised routing and scheduling promises to alleviate the situation provided it is judiciously applied. This article describes the nature of the routing problem and ways to cope with its complexity. Some results of research into South African firms are presented and this leads to a discussion of computer-based routing and scheduling. The authors offer a framework for assessing routing situations and apply it to cases in South Africa. The relative benefits of the application of computer solutions are discussed and recommendations are made.

## 1 INTRODUCTION

Years of persistent inflation and continuing erosion of the international value of the South African currency have taken their toll on the costs of doing business. This is particularly so in the area termed "logistics management." Logistics management encompasses the movement of raw materials and supplies to the firm, movement of work in progress and finished goods within the firm, and onward delivery to the eventual client.

This article concerns itself with a particular aspect of logistics—physical distribution, and more specifically road transportation of goods to the client. Physical distribution accounts for a sizeable and growing proportion of product costs. In turn transportation costs are an important part of the total cost of distribution. A recent study puts distribution at 30% of retail product costs and transport at 50% of the cost of distribution (Walker 1988). Firms have made much progress in controlling and minimising distribution costs such as warehousing, order processing and inventory holding. This is not true for the transportation component, especially the costs of routing and scheduling of truck fleets.

The topic is an important one for firms in South Africa because of:

- ▶ especially rapid escalation in South African truck ownership costs due to local content programmes and the high cost of capital.
- ▶ growing competitive pressures to reduce costs in a highly inflationary environment.
- ▶ government relaxation of road transport constraints in South Africa. This is resulting in greater flexibility in distribution and consequent cost and service opportunities.
- ▶ the growing availability of computer packages claiming to cope with the many practical constraints governing commercial routing and scheduling operations, and assertions that substantial cost savings can be achieved.

Road transportation problems vary widely in complexity. At one extreme are firms delivering full truck loads to customers at regular preplanned intervals, with few constraints to hamper the firm's freedom to route and schedule. At the other are firms delivering variable quantities of disparate products to small subsets of their total customer base on a given day, with orders flowing in continuously and a service policy that stresses promptness, priority attention, etc.

This article commences with a discussion of the nature and complexity of road distribution. It then summarises research into methods local firms use to cope with complexity. This leads to a discussion of the features of computer-based routing and scheduling packages. A framework for assessing routing situations is then offered and applied to several cases in South Africa. The relative benefits of the application of computer solutions are discussed and guidelines for managerial action are offered.

## **2 NATURE AND COMPLEXITY OF ROAD DISTRIBUTION**

Many elements influence daily routing and scheduling decisions. The nature and variability of each of these elements dictate the complexity of the distribution problem, influencing truck fleet characteristics and strategies for handling delivery. These elements can be categorised as follows:

**Place** - the general size of the service area; whether it is local, regional or long-haul; land-use patterns (CBD, industrial, residential, rural); road network characteristics, and the total number of customers and their dispersion (clustered, transport corridors, random).

**Load** - the frequency, size and variability of orders placed, limitations on mixing different classes of product, product/truck restrictions, loading/unloading characteristics, weight and/or volume constraints, backhauls, returns of pallets or empties, and the opportunity to deviate from the order placed (e.g., to make up to full load).

**Time** - length and flexibility of lead time from receipt of order (e.g., "within twenty-four hours" vs. "anytime next week"), customer time-windows (e.g., "mornings only"), variability in unloading time, policy regarding uneconomical, priority and rush orders, and initiation of orders by the client as opposed to the company.

Considering these characteristics, individual firms define the characteristics of their truck fleets (no. of vehicles, variety, compartmentalisation etc.) and devise procedures to control their costs and levels of service. The greater the complexity of place, load and time factors, ~~the more variable and difficult to plan will be the daily schedules and the more likely it is~~ that total fleet usage will be suboptimal.

### 3 COPING WITH COMPLEXITY

Firms cope with complex decision making and the associated information overload in various ways (Galbraith, 1974). First, *slack resources can be created*, e.g., considering vehicle routing and scheduling: increase the fleet-size, have drivers and trucks standing by, send trucks out half-empty, increase promised lead times, add shifts. Second, *the routing/scheduling decision can be simplified*: standardise routes, fix delivery days, eliminate priority service. Third, *the distribution problem can be partitioned*: isolate subregions, separate productlines, differentiate between customer categories. Fourth, *information processing can be improved*. This may involve on-line data capture of orders, on-board data capture of trip details, in-house exception reporting, integrated fleet management systems and application of routing and scheduling optimisation programmes.

What is most significant is that the first three coping strategies described above *all lead to increased operational costs and/or poorer service*. The fourth strategy, improved information processing, *is the only approach that promises better utilisation of company resources*. Firms make an initial investment and incur the operational costs of hardware and software in return for lower distribution costs and improved service in the future.

A research study of nine firms delivering food, consumer goods, pharmaceutical products, petroleum products and bread and confectioneries provides useful insights (Miller & de Vries 1986).

All of the firms in that study allocate daily loads to customers, sequence the deliveries for each truck and select desired routes. The most common coping strategy is *partitioning*— the "pigeonhole" method. Operators assign invoices to pigeonholes representing geographic regions. They then group orders in truckloads, where necessary combining adjacent pigeonholes to enable fuller loads.

*Simplification* is also used. Some firms fix delivery dates for particular regions or types of customer, others eliminate priority service and yet others operate fixed daily routes.

*Slack resource utilisation* is clear. Large numbers of trucks go out underloaded, there is unplanned use of overtime, and different leadtimes are applied to different customer categories.

Few of the firms in this sample employed *improved information processing* as a coping strategy. One uses a fleet management system, also electronic truck monitoring and a routing and scheduling package. Another conducts computer analysis of distribution grid data.

In many cases studied in the research, drivers are responsible for the sequence of drops on a route. In all cases they choose the roads used. Dependence on drivers is very common and can result in problems. This is shown in two recent studies conducted by the authors, one of a major carrier of small parcels and the other of a bakery. Drivers developed their own routes over time and switched regular customers from one route to another. There are now no accurate or even usable records of customer locations or route sequences in either case.

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*"It's taken me years to train my drivers and gain their loyalty. Now they work out their own routes. I know I'm underutilising my fleet, but if I impose a computer solution, my drivers will walk out and I'll have to start all over!"*

The bakery mentioned brings the complexity of the distribution problem to the fore. That firm is conscious of increasing competition in the marketplace and wants to reduce its transport costs "as long as our customers aren't antagonised." Since all their customers are used to receiving deliveries at particular times in the day, a severe constraint on new routes is imposed!

There is no doubt that many South African firms with complex vehicle routing and scheduling problems are currently employing suboptimal strategies for daily fleet operations. To a degree this is not surprising. Routing and scheduling complexity is a "creeping" phenomenon. As firms grow and diversify, so does the size and spread of their customer base. Special needs have to be serviced, growing competitive pressures require possibly uneconomic schedules, and additional depots may have to be opened.

If a firm has not consciously planned its distribution strategy, then steadily it will respond to changes such as those described above by creating slack resources. There may be "too many" vehicles for a particular task, or poor utilisation of the available fleet. Because firms associate growth in business activity with growth in resources required, typically operational management will not recognise the existence of slack resources. Higher level management will accept annual increases in truck fleets, drivers and other distribution facilities as part of corporate growth.

Of course sophisticated computer-based information processing is not the only solution in complex distribution situations. Routing and scheduling packages can be very expensive

and require substantial ongoing maintenance and operational costs, possibly including additional staff. Furthermore, quantitative assessment of potential savings is often extremely difficult if not impossible. The real savings may be limited by the extent to which the firm is willing and able to adapt to the requirements of the chosen computer package. Often the *simplification* and *partitioning* approaches referred to above are logical and straightforward and may be the most cost-effective alternatives. Nevertheless, the growing availability of PC-based, lower cost, user-friendly computer systems is shifting interest very much towards *improved information processing* as the coping strategy of choice.

## 5 COMPUTERISED ROUTING AND SCHEDULING PACKAGES

Section 2 suggests that routing and scheduling can consist of many variables related in complex ways. The field offers a natural opportunity for mathematical modeling and computer-based solutions. Many minds have applied themselves to the problem and influential journals such as Management Science contain many theoretical papers on the topic (e.g., Fisher, 1981). There are various specialist journals devoted to the topic as well, including Transport Reviews, Transportation Journal and Transportation Research.

A route optimisation package should decide routes and schedules for a given number of vehicles to serve a set of customers with known locations and known demands at minimum cost, subject to:

- ▶ meeting customer requirements
- ▶ not exceeding the capacity of the vehicles
- ▶ not violating travel time available
- ▶ preserving time-windows stipulated by the customers
- ▶ meeting whatever other practical constraints exist.

Since the 1970s computer packages have been available to tackle this problem. The earliest of these is probably IBM's VSPX originating in the United States. Routemaster is a pioneering package to come out of the United Kingdom. Today there are very many alternatives, developed in North America, Europe and the UK, and differing widely in price and functionality.

To date no package can claim to give an exact solution to the routing and scheduling problem, although those based on the work of Fisher & Jaikumar (1981) come closest to this ideal. Generally a variety of heuristics are used, some of which are briefly described in the Appendix. The Appendix also discusses data collection issues and different approaches to pinpointing customer locations.

As computer hardware and software have improved, there has been a steady progression in the capabilities and cost-benefits of routing packages. Following are some aspects of this progression:

- ▶ Incorporation of more and more practical constraints such as varying road conditions, natural barriers, priority orders and time-windows.
- ▶ Dramatic increases in the speed of computer processing. Schedulers can solve practical problems in minutes and not hours and conduct real-time routing and scenario testing.
- ▶ A shift from mainframe to microcomputer-based packages, enabling decentralisation and local control of routing.
- ▶ Provision of "pull-down" menus, mouse-driven controls and other user-friendly features that enable schedulers rather than computer personnel to apply the procedures (see Figure 1).
- ▶ Full colour graphics interfaces for displaying road networks, landmarks and recommended routes. Schedulers can analyse routes and make manual adjustments (see Figure 2).
- ▶ Specialised packages to handle multiple depot optimisation.
- ▶ Substantial reductions in package prices.
- ▶ Linkages to public data bases of road networks.
- ▶ Simple interfaces with front-end (e.g., order entry) and back-end (e.g., dispatching) systems and standard reports for monitoring driver and fleet efficiency.
- ▶ Facilities to superimpose computer solutions on video images of town and city maps.



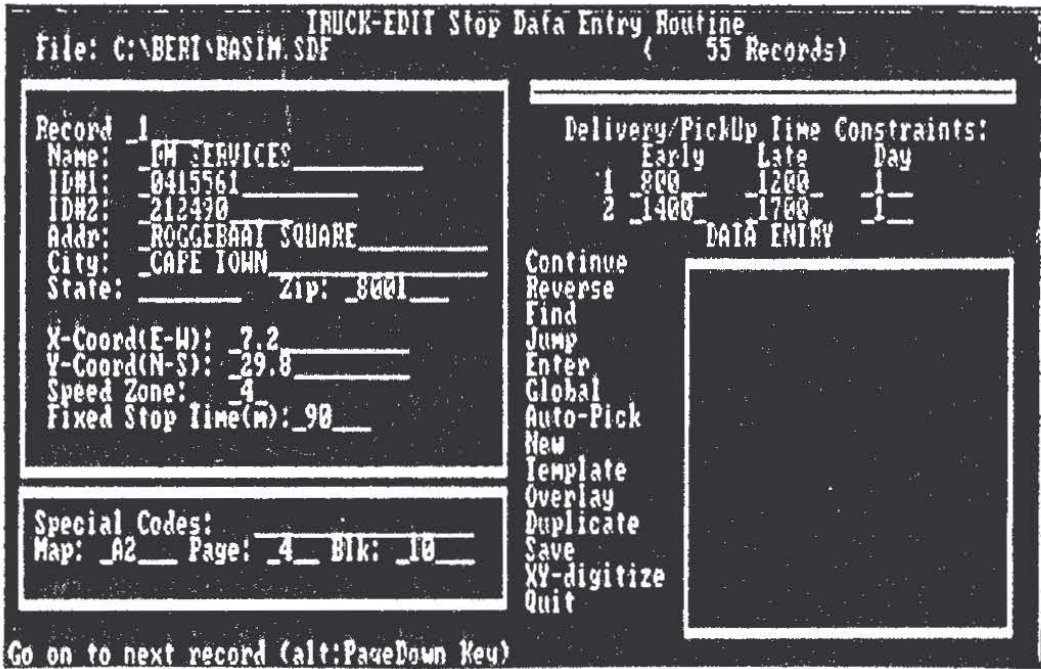


Figure 1 An Example of a Point & Go Menu with On-Screen Help from the TRUCKSTOPS System (Source TruckStops 2 Manual).

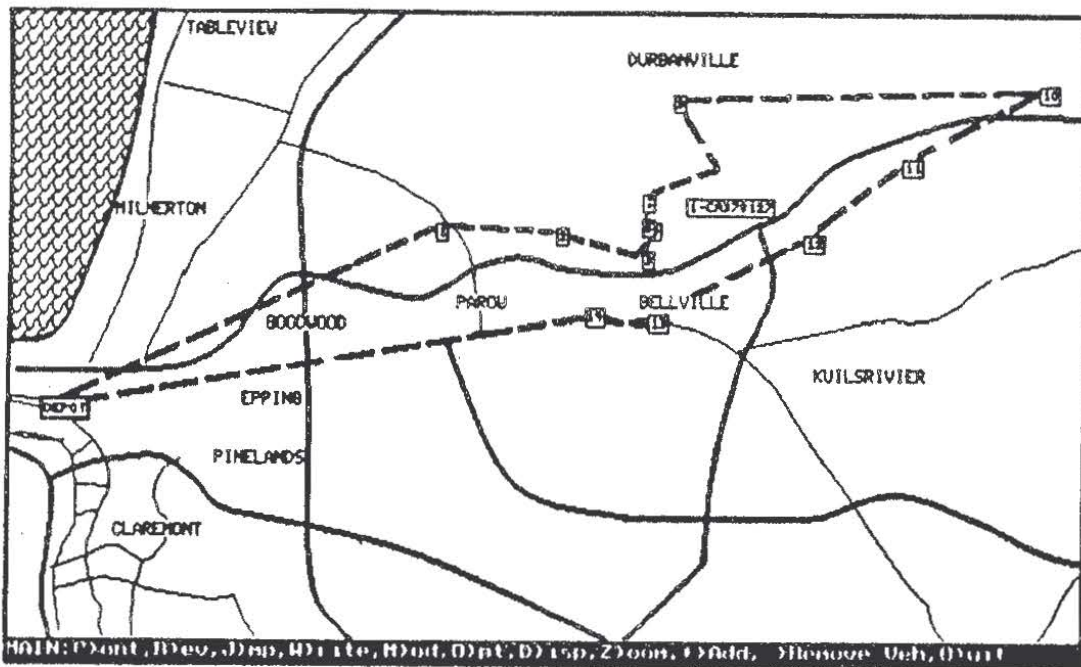


Figure 2 A Typical Route Map (Source: TruckStops 2 Manual)

Further features can be expected in the future, including higher resolution graphics images, interfacing with Geographic Information Systems, continued improvements in price-performance, incorporation of further constraints, and abilities to tailor-make routines and reports.

The above comments show that systems developers have placed increasing emphasis on the practical and human issues in routing and scheduling of truck fleets. This, coupled with the great improvement in price-performance ratios, now makes a computer-based solution realistic for very many firms.

## **6 DEFINING THE ROUTING AND SCHEDULING PROFILE**

It has already been said that the decision to adopt a computer solution to tackle routing problems is difficult and sometimes expensive. Exhibit 1 brings together a variety of items that make up a *routing and scheduling profile* (Miller & de Vries 1986). Completion of this profile using a simple scoring procedure will give a strong indication of the potential for day-to-day operational savings and reductions in total truck fleet size. This is an important first step in evaluating the potential of improved information processing and especially computerisation as a strategy for coping with the complexity of a given transportation situation. After describing the nature of the profile, examples of its application will be given.

The profile is such that responses on the left imply more complex routing and scheduling (e.g., many, widely dispersed customers, irregular ordering patterns). Managers can expect greater benefits from the use of computer-based systems if the profile tends to the left. Certain responses on the right, however, reflect greater flexibility in fleet management (freedom to deliver any time, freedom to adjust ordered quantities to suit the truck schedule). This affords special opportunities for an optimisation routine to find the best routes and schedules.

Inspection of the elements in the routing and scheduling profile reveals varying degrees of control that the firm can exert.

- ▶ The first six elements relate to the customer base (essentially "place" referred to in Section 2). The nature of the profile that exists here is out of the hands of the supplying firm, assuming that radical changes to the nature of the business are not made. These elements are a function of the business environment and are classified as *uncontrollable*.
  
- ▶ the next eight elements relate to the truck fleet, its delivery pattern and customer and product constraints given the existing fleet composition (the "load" elements referred to in Section 2). *In the short term* the profile here is largely uncontrollable and responses on the left make for greater complexity. However, in the longer term, decisions to change truck type and characteristics, fleet sizes and composition, etc., can be taken to reduce complexity and cost and enhance service. These elements are thus *short term uncontrollable* and *long term controllable* aspects of fleet operations. An attractive opportunity here is the use of an optimisation package for day-to-day routing and scheduling and "what if" analyses to make strategic fleet decisions.
  
- ▶ the final seven elements are *controllable to the extent that they reflect existing* policies (e.g., use of outside contractors, same day delivery) or where change may be effected via negotiation (e.g., flexible order quantities might be negotiated in return for improved service or price breaks).

An analysis of the routing and scheduling profile of a particular firm thus reveals the degree of *environmental complexity* in the operations (the uncontrollable elements), the added *operational complexities* that have to be addressed in the short term (the short term uncontrollable elements), and those *company policy elements* that, if warranted, could immediately be dealt with to reduce complexity or increase the firm's degrees of freedom (the controllable elements).

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**Exhibit One: Routing and Scheduling Profile**

Our customers lie all over a wide area	----- -----	Most of our customers are bunched or lie on transport corridors
We have to handle urban, industrial and rural areas	----- -----	Generally our travel conditions are uniform
Our customer base exceeds 2000	----- -----	We have less than 200 active customers
Our customer base changes constantly	----- -----	We have a very stable set of customers
On any given day we serve less than 10% of our customers	----- -----	We visit each customer every day
Our typical customer usage pattern is very lumpy	----- -----	Most customer usage is smooth and predictable
<hr/>		
At least one of our depots has more than 15 trucks	----- -----	Our largest fleet has less than six trucks
We have different trucks for different product types and customers	----- -----	Any truck can take any product and visit all customers
We have physical <i>and</i> legal limits on weight <i>and</i> volume	----- -----	Maximum load is based only on weight <i>or</i> volume limits
Some products can't go with others on the same truck	----- -----	We can mix any products on our trucks
We always pick up pallets and empties	----- -----	We have no recollections
Our trucks make 20+ drops per round trip	----- -----	Each truck makes one drop at a single destination
Most trucks make two or more round trips per day	----- -----	Each trip is planned to take about a day
Some trips take two days or more	----- -----	All trucks are back on the same day
<hr/>		
We often use outside contractors to supplement our own fleet	----- -----	All deliveries are made with our own fleet
We only know quantities once the customer has phoned	----- -----	Either we forecast customer needs, or they get regular loads
Each customer specifies when we can deliver	----- -----	We drop off at our convenience
We promise same day delivery	----- -----	We've got a week to play with
We try to meet any special orders or emergency needs	----- -----	We only deliver when it suits us
We have to deliver the exact order quantity	----- -----	We can adjust quantities to suit our available capacity
We plan to use overtime	----- -----	Our operation is strictly normal time

## **7 APPLICATIONS OF COMPUTERISED ROUTING**

Possibly for competitive reasons, there are few published articles on successes (or failures) in the application of computerised routing and scheduling. A prizewinning article on the Air Products and Chemicals case in the US is however available (Bell et al, 1983) as are other examples in the US and UK (Cassidy 1990, Davis 1990, Walker 1988, Shepard 1984).

In South Africa, SA Breweries acquired the TruckStops package from the present authors. Press commentary shortly after implementation at the Waltloo depot near Pretoria was very positive. The depot manager claimed realised savings of 15-20% in otherwise wasted kilometers and annualised cost savings of some R200000. He also credited the routing package with improved working conditions for drivers and better customer service (Logistics News 1991).

The authors have conducted several projects using the TruckStops package (MicroAnalytics Inc.). Previously they also used the ROVER system on a mainframe (Rover Technology Inc., now a subsidiary of STSC Inc.), and PARAGON on PCs (PA Consultants plc). The following are examples of particular situations in South Africa that have been subjected to detailed computer analysis using one or other of these packages. These examples cover a broad spectrum of routing and scheduling environments.

### **1 An Explosives Distributor**

This firm operates five trucks, delivering to about ten customers a day out of a total customer base of sixty. Each trip has one to three deliveries and there are legal constraints that limit flexibility. The routing and scheduling profile can thus be defined as "simple." Processing typical sets of daily orders through a routing package showed no significant savings and revealed no surprises compared with manual solutions.

## 2 Milk Collections

Fifteen tankers visit 270 farms to collect fresh milk. All farms are visited every day and fixed routes are followed. There is a predictable seasonal pattern in milk production through the year.

While this is a relatively simple application, the larger number of tankers and customers visited per trip make it more complex than the explosives distributor. Computer analysis revealed the potential to meet typical demands with twelve to thirteen tankers and yield savings of 10 percent in operational costs. Use of a package also allows frequent reevaluation of the fixed routes to cope with the changing seasons. Previously staff hardly ever carried out this exercise because of the "number crunching" involved.

## 3 Bread Deliveries

Twenty-seven trucks supply 670 customers. All customers are visited every day, some of them twice. The larger chain stores demand strict adherence to time-windows.

While this is also a fixed route application, the time-window constraint, waiting time problem, daily changes in order quantities and other factors make this a more complex profile. Computer analysis suggested 10 percent potential savings in operational costs, made up as follows:

### First Round Deliveries

No of Routes	27	→	24	11% reduction
Km Travelled	1541	→	1323	14% "
Hrs Taken	110	→	102	7% "
Rands Cost	3823	→	3477	9% "

### Second Round Deliveries

No of Routes	7	→	2	71% "
Km Travelled	132	→	86	35% "
Hrs Taken	7	→	5	29% "
Rands Cost	252	→	182	28% "

Additional benefits include the opportunity to test out various strategic options such as different methods of handling overtime, cash collections and "second round" deliveries. Analysis also reveals that traditional patterns of delivery will change significantly, requiring special effort to make the new routes acceptable to some customers.

An important issue is the changing nature of particular industries. Now deregulation is throwing the whole arena of bread sales open to more competition and the use of computer-based scenario-planning represents a major opportunity for competitive positioning.

#### **4 A Liquor Distributor**

This firm uses fourteen trucks to deliver to about 130 customers a day—a third of the total client base. There are legal constraints on the amounts delivered. Variable routes are made up every day and a 48-hour delivery policy is followed. Although this is a fairly small problem, the dynamic routing undertaken, number of drops per trip and collection of empties make this a profile of "medium" complexity.

An example of the results obtained in simulating actual deliveries is as follows:

	Actual	Simulated
Calls Made	128	128
Weight delivered kg.	71000	71000
No. of Trucks Required	14	9
Weight Utilisation	59%	81%
Time Utilisation	60%	90%
Km. Travelled	666	510

Inspection of these results showed that they were feasible in practice, but would demand very tight control. Manual adjustment led to the conclusion that application of a computer package could lead to realistic operational savings of 15 percent. It would be possible to achieve these savings and simultaneously institute a 24-hour delivery policy.

## **5 Building Materials**

This firm uses twenty-four trucks to deliver to 300-400 customers a week. New customers (e.g., building sites) arise continually. Routes are made up each day and cover both urban and rural terrain. Information is such that schedulers can plan a week's deliveries in advance. There are three major product classes, some trucks able to handle all, and others only some. All types of truck cannot visit all customers because of unloading restrictions. A balance is sought between the use of outside contractors and own fleet. Computerised routing and scheduling of this very complex fleet operation suggests a 30 percent reduction in operational and ownership costs and a rational basis for sharing deliveries between outside contractors and company vehicles.

## **6 Summary**

This section has briefly described computer analysis of situations reflecting many Routing and Scheduling Profiles in South Africa. The potential savings increase with increasing complexity in the transportation environment.

Apart from the "simple" case of the explosives distributor, all these firms are candidates for routing and scheduling packages. In practice one decided not to proceed, feeling that the risk of disrupting their customer relations outweighed the potential savings from improved fleet control. The remaining three are at various stages of setting up routing packages, but details of the outcomes of these projects are unfortunately not available.

## **8 CONCLUSIONS AND RECOMMENDATIONS**

In the face of increased competition, deregulation and the escalating costs of trucking, the need to control and reduce the costs of transportation is growing constantly. This article presents a simple starting point for finding the potential benefits of computer-based solutions. By defining the Routing and Scheduling Profile for a given transport situation its complexity can be assessed. Analysts can then explore various solutions including provision of slack resources, partitioning or simplifying the problem, and application of computers.



The more complex the environment the more potential there is for the cost-effective application of a routing and scheduling package.

The management science community understands the mathematics of routing and scheduling of truck fleets well, but it is only in recent times that software developers have incorporated these principles into useful computer systems. There has been a steady progression towards more cost-effective and user-friendly packages. At last distribution managers in many firms can look realistically to computer solutions for the routing problem.

The references and examples in Section 7 suggest that savings of up to 37 percent in transport costs may be achieved and that the potential savings do increase with increasing complexity of the distribution environment.

In the light of this, the following approach is offered to evaluate a given transport situation and decide action to be taken:

- ▶ Develop the Routing and Scheduling Profile for the firm.
- ▶ Make an objective assessment of the profile. Consider the criticalness of distribution to the firm and the quality of existing data collection, planning and control procedures.
- ▶ Where indicated, follow up with a detailed analysis: depending on the complexity of the profile, assume potential savings of 10-30% in operational and fleet ownership costs.
- ▶ Examine available packages in terms of cost, track record, technical compatibility, ability to meet practical constraints, user-friendliness, local support.
- ▶ Conduct a pilot test, processing real historical data and comparing with the computer simulations.
- ▶ Establish appropriate data collection procedures and implement jointly with data processing and transportation personnel.

## APPENDIX

### MATHEMATICAL AND DATA PROCESSING ASPECTS OF ROUTING AND SCHEDULING

Some routing and scheduling programmes are based on a look-ahead procedure. In this procedure a starting point is selected, i.e. the first customer to be visited from the depot, and the program "looks-ahead" to select that customer for which the inclusion "cost" in the tour is small. This process continues till a tour is built that fulfils the constraints. The whole procedure is repeated until all orders are dealt with or until the available vehicle capacity is used.

Other programmes break the routing problem in two distinct phases: the loading problems are solved first with the aid of a mathematical method, *the general assignment method*, in which available fleet capacity is loaded in an optimal way. In this procedure each customer is assigned to a vehicle (the "Knapsack" problem, Eilon et al. (1971)). The routing of this vehicle along the assigned customer call points is solved in the second phase with the aid of a "Travelling Salesman" heuristic (Eilon et al. (1971)). The general assignment method is an advanced linear programming heuristic that has achieved impressive computational results. In a set of standard tests it has outperformed several of the best existing heuristics (Fisher & Jaikumar 1981).

One package loads vehicles according to transport corridors into which the service area has been divided. If not enough orders are available in one corridor, orders from adjacent corridors are used. In the second phase the vehicles are sequenced along the assigned customer call points. The program is heavily oriented towards traffic characteristics which form the basis for the selection of transport corridors.

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The information and data handling requirements for typical routing and scheduling programs can be broken down into:

Order Information  
Customer Information  
Vehicle Information  
Transport Environment Information

The received orders should be captured in an order file, which can produce the orders that have to be included in the planning period under consideration. Sorting facilities might be required to select this planning base. All firms studied in the research by de Vries (1984) had their orders processed by computer, but this process usually stopped after invoice preparation.

Customer information is stored in a customer file. This file should contain the customer characteristics such as waiting and unloading time, vehicle and time constraints and the location of the customer in relation to the road system of the service area. Most firms collect operational time and distance data with the aid of log sheets or with "in-vehicle" electronic monitoring devices. However, in most cases no further analyses are undertaken to link these data to individual customers. Furthermore, with one exception, none of the interviewed firms had useful customer location data.

Fleet and vehicle characteristics are made accessible through a vehicle file in which all the available vehicles are classified according to type, capacity and unloading equipment.

Transportation environment information can be captured in two ways, first by means of a grid system and second by means of a road network system. In the grid system the customers are located in the service area by specifying X—Y coordinates. Straight line distances are then calculated between customers. To simulate road transportation conditions the following options are available:

- a distance adjustment factor can be applied
- transport barriers can be specified
- differing travel speeds can be assigned to sections of the service area.

Networks are based on an approximation of the road system. Major roads are segmented into links, which are the road sections between intersections. These intersections form the nodes of the network. Extensive description of each road link in terms of road width, number of lanes, road capacity and land use of the area traversed is captured. Based on road classification and area classification, travel times are assigned to the road links by the network building program either by inserting nodes in the network or by locating customers to network zones. The actual transportation characteristics of the delivery environment can be simulated in this way by the network. Furthermore, any alteration of the road system can be incorporated in the delivery system.

The grid system has the advantage that it is simple and easily maintained. Road networks can produce more accurate transport data but they require substantial effort in keeping them up to date. Furthermore, obsolete networks will produce non-optimum routes that might not be noticed due to absolute "trust" in the computer results.

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