DECISION SUPPORT SYSTEMS FOR PHYSICAL DISTRIBUTION

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Introduction

The Vehicle Scheduling Problem (VSP) is one of the classical problems of Operations Research (OR). It is a simplification of many practical distribution scenarios in which a planner must schedule the delivery or collection of goods or services for a number of customer points, from a central depot, in an efficient fashion. In the VSP it is assumed that the distribution will take place via a number of vehicles, each with a known capacity to carry the goods or to perform the services. Further, each customer has a known output or demand for the goods or services. Also the travel cost, in terms of time, distance, or some other criterion, is known between all pairs of locations. The VSP involves clustering the customers into groups, each group to be visited in sequence by a vehicle which begins and ends its route at the central depot. In later refinements of the VSP, a few extra practical considerations are allowed, such as time windows which allow vehicles to visit customers only during certain time intervals.

The traditional OR approach to this problem is to formulate it as a mathematical model and to attempt to solve it by applying various mathematical programming techniques. Despite the intricacy of some of the VSP models, and the innovative nature of their solution techniques, their resulting solutions are often criticised by experienced schedulers who attempt their implementation.

The purposes of this article are to discuss what the authors believe are pitfalls with the above approach when it is applied in practice, and to suggest an alternate procedure that combines the skills and specialised knowledge of an experienced scheduler with a microcomputer-based interactive scheduling decision support system (DSS). A later paper by the authors (Butler and Foulds[1989]) describes the implementation of such an approach in the milk collection department of an Irish dairy cooperative. We now review the literature on the VSP and discuss the commercial vehicle scheduling packages that arose from it.

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VSP Literature and Packages

One of the first studies of the VSP was reported by Dantzig and Ramser (1959) who formulated it as a linear programming model. Since then many others, including Clarke and Wright (1964), Gillet and Miller (1974), Foulds et al. (1974, 1977a, 1977b), Christofides et al. (1981, 1984), Mingozzi and Toth (1981), and Fisher and Jaikumar (1981) have contributed to the area. The VSP literature has been surveyed by Golden, Magnanti and Nguyen (1977), and by Foulds and Watson-Gandy (1981).

Increased commercial interest in practical vehicle scheduling has motivated various groups to commercialise the academic findings in the form of marketable vehicle scheduling computer packages. The first was developed by IBM. It is termed VSPX and is based on the VSP procedure developed by Clarke and Wright (1964). Since the early 1970s, several other packages have been marketed, including: ROUTEMASTER, TRANSIT, PARAGON, IRG, and MOVER. We now discuss what the authors perceive to be serious drawbacks to these packages when they are applied to practical routing problems.

Practical Problems with VSP Computer Packages

VSP computer packages attempt to find a feasible solution to a mathematically defined model. In the mathematical model, the objective function is usually concerned with optimising a single criterion, such as the cost of calling on all customers, or the total distance driven to service all customers. Several types of constraints are also sometimes included such as: vehicle capacities, maximum route lengths, route start times, route finish times, time windows, the sequence in which suppliers are visited, and the ability of different vehicle types of gain access to suppliers. When they are included, these constraints are invariably expressed as inequalities which cannot be violated in any feasible solution.

It appears, however, that the models which underpin these VSP packages are invariably very poor approximations of practical vehicle routing scenarios. This is because these scenarios cannot be represented by a single well-defined optimality criterion together with families of well-defined constraints, expressed in mathematical form.

In practice, the total cost of the servicing of all customers is only one of many considerations in the comparison of possible scheduling options. Often it is only a secondary consideration of the busy planner who is under pressure to produce a satisfactory schedule. Combinations of other factors such as the level of customer service, equity of route duration —

including driving and visiting times, rostering arrangements for drivers, efficient vehicle and driver utilisation, the total schedule time, company financial strategies, and political considerations are often given precedence.

Also, in practice, the majority of constraints, especially of the time or capacity variety, are indicators of desired operation, and minor violations are usually tolerated. For example, a schedule with a single route marginally over eight hours is often accepted, not withstanding the fact that a work practice arrangement dictates that all routes should be less than eight hours in duration.

The majority of practical vehicle routing problems involve a multitude of considerations which are sometimes difficult to quantify. Examples include driver preference for customers, routes, and vehicles, access problems involving certain vehicle — customer combinations, road inclinations in winter snow, queueing at the depot, accidents and breakdowns, geographical obstacles which complicate distance and time estimation, vehicle cleaning and maintenance, union rules, labour and traffic codes, company and customer policies, political considerations, and unpredictable human behaviour. Thus, the scheduler is typically faced with a multitude of ill-defined objectives and constraints, the relative priorities of which may change markedly in a short space of time. These factors are seldom captured in the VSP computer package models.

VSP computer packages require sophisticated computer systems which are expensive to purchase and to maintain. These packages require the input of a very large amount of detailed data in order to produce meaningful results on practical problems. They are also inflexible in the sense that they provide a single response for each senario, with little opportunity for human interaction or sensitivity analysis. In contrast, a DSS of the type of described later in this article, requires only a standard personal computer with colour graphics capability, far less data input, and is menu-driven, user-friendly, and interactive. For an informative introduction to the concepts underlying the DSS and its uses see Davis (1988).

The most significant failing of the VSP computer packages is that they do not attempt to utilise the knowledge and intuition of the experienced scheduler. The aim and philosophy behind the majority of packages is to replace the scheduler by a computer system. However, the scheduler has an intimate knowledge and understanding of the problem that is completely ignored by the computer packages.

To summarise, the authors suggest that the currently available computer systems suffer from major deficiencies. First, they attempt to optimise an unrealistic objective function. Second, they impose constraints which cannot be violated, and ignore many other vital consideratins, some of which are nonquantifiable. Third, they require sophisticated computer systems, large-scale data input, and are inflexible. Most importantly, however, they ignore the talents of the experienced scheduler.

In 1984 the EEC investigated several computer packages for vehicle routing, including: VSPX, PARAGON, ROUTEMASTER, IRG, and TRANSIT. This study was concerned with quantifying the potential savings within Europe's dairy sector if computer packages were used to generate routes to be used by bulk milk tankers. The study findings, reported by Herligh, Butler and Pitts (1984), concluded that, because of the complexity of the practical vehicle routing problems, the human scheduler is capable of producing routes as good, if not better, than any of the currently available VSP computer packages.

Vehicle Scheduling Decision Support Systems: Motivation

Because of the problems associated with the currently available VSP computer packages, we now review the role of the computer in the area of practical vehicle route generation.

We start from the premise that a vehicle scheduling computer system should be developed in order to aid, rather than to replace, the scheduler. This is because it is difficult to see how any automatic VSP computer system, designed to produce, unaided, a complete schedule, could cope as well as an experienced scheduler, with the practical considerations discussed in the previous section. Hence we believe that the current computer packages are too optimistic in what they attempt to achieve, and that a more realistic goal is to develop an interactive computer system that will support the scheduler in carrying out the day-to-day decision-making activities.

Traditionally, a large map of the customers' area, together with coloured pins displaying customers and routes, have been of high utility to many schedulers. Using the map and pins the scheduler can tell, at a glance, what route services each customer, and in the event of a customer having to switch routes, the map will indicate other routes closest to that customer and what options are available. In order to construct the required routes the scheduler, using a detailed knowledge of customers, terrain, drivers, and other relevant factors, will then decide upon which option to select.

This map-and-pin procedure serves the scheduler well in some ways, but suffers from deficiencies. First, each pin does not usually provide any inkling of the characteristics of the customer it represents, such as supply level. Thus, for example, in the event of the over-capacity of a route, the scheduler may have to remove a customer from a particular route. The map and pins will indicate which customers are closest to other routes, and therefore candidates to be removed from the existing route. However, before the scheduler can decide which customer to remove, the service level of each customer on the overloaded route must be ascertained. This information is usually not available from the map and a detailed search through invoices or dockets may be required.

Second, over time, the map may become overloaded with pins, many representing locations whose customers are no longer serviced. This problem of map overloading can be avoided by having pins tied to an invoice or delivery system, with only customers requiring immediate service being displayed.

Because of the reliance of the majority of schedulers on the map-and-pin approach, the authors believe that a computerised scheduler's aid can be fruitfully based on a computer-generated map of the customers' area displayed on a high resolution graphics screen. Geographical features, and all relevant locations can be represented on that screen as a result of digitising their coordinates. Once the "map" and "pins" are computer driven, it is then possible to control what customers are displayed. Relevant customer information can be represented by using a colour graphics display system.

The authors believe that the computerisation of the map will allow a complementary combination of the skills of the scheduler with the power of the computer. The scheduler has ability, superior to that of the digital computer, to recognise patterns in the location of customers and routes. These patterns will suggest possible clusters for new routes, and options when routes have to modified. Before these patterns can be translated into new routes, the scheduler needs, among other things, information on individual customer service requirements, and these service levels totalled for any cluster. The generation of this information is a task to which the digital computer is better suited than most, if not all, schedulers. Such a scheduler-computer combination marries the pattern recognition skills, local knowledge, and experience of the scheduler with the numerical and recall ability of the computer. We now discuss the development of a DSS which is based on these considerations.

Vehicle Scheduling Decision Support System: Design

The previous section outlined the motivation behind the development of a microcomputer-based DSS for practical vehicle scheduling problems. The kernel of this system is a high resolution graphics screen which enables a computer map, showing customer locations, to be displayed.

One of the keys to the design of a vehicle scheduling DSS is to first discover the behaviour and strategies of a typcal, experienced scheduler. One must then devise ways in which a DSS can make this person more efficient. The task faced by a vehicle scheduler is typically one of two types. The first, "local" type involves the modification of an existing schedule. This is appropriate when there is relatively little change in the conditions or data. The second, "global" type involves the generation of a complete set of new routes, without reference to an existing schedule. This is appropriate in a start-up situation, or when there are significant changes in conditions or data which trigger a rationalisation of resources.

The local task often involves the clustering or re-clustering of the customers on one route or a limited number of neighbouring routes. The global task can usually be accomplished by carrying out systematically the clustering of customers' regions into which the whole area has been divided. As this is akin to carrying out the local task repeatedly, in one region after another, we deal only with the local task throughout the rest of this article.

Suppose a scheduler wishes to carry out a local task by modifying an existing schedule in order to generate the new schedule. Two key questions should be asked:

i. What are the requirements of the new schedule which differ from the previous schedule? and,
ii. How should the previous schedule be modified in order to create a satisfactory new schedule?

The first question usually involves constraints governing the feasibility of any new schedule. The second question involves not only these constraints, but also the measurement of how satisfactory the new schedule is, in terms of various objectives. We now list some possible main-menu options of a DSS designed to aid the scheduler in the search for answers to these questions.

The Schedule List Option

In order to begin the process of new schedule generation, based on the previous schedule, the scheduler must first be able to access the previous schedule. The DSS should thus have a listing of all the routes for any previous schedule, along with various of its summary statistics which will be used in the generation of a new schedule. Examples of such statistics are, for each route: total customer service level, excess vehicle capacity, distance traveled, and time taken.

The Parameter Comparison Option

There should be some means whereby the scheduler can ascertain how the previous schedule will not meet the requirements of the forthcoming schedule. Thus a mechanism for the comparison of the parameters of the previous schedule with the new parameters is desirable. This may require the comparison of parameters such as: customer service levels, changes in customer location, and vehicle capacity.

The Schedule Modification Option

Having pinpointed where the previous schedule is deficient, the scheduler must then devise modifications to it which produce a satisfactory new schedule. Thus in answering question (ii), the system must provide for existing schedule modification by such means as:

(a) Adding a new customer to a route,
(b) Deleting a customer from route,
(c) Transferring a customer from one route to another,
(d) Interchanging customers between different routes, and
(e) Creating a new route.

The selection of these options should be guided by the provision of relevant statistics associated with them, such as: vehicle capacity utilisation, and route duration or time. Naturally there must be a mechanism whereby the new schedule can be recorded, usually by overwriting the previous schedule which is being modified.

The logical consequences of adopting any of the above options must be incorporated, in the sense that all relevant parameters and statistics must be automatically updated. Further, the system must not only be able to deal with options inputted by the user, but it is desirable that it displays an intelligence by suggesting relevant options. The system should enable the scheduler analyse the consequence of these options. Routines based on the above options should enable a scheduler to behave as usual when carrying out the scheduling task, but in a more systematic and efficient manner.

Conclusion and Summary

We have discussed the classical OR problem of vehicle scheduling and the computer packages available for its solution which are based on mathematical programming methodology. It is asserted that these approaches are deficient when used to solve practical vehicle scheduling scenarios, for the following reasons, among others. The models upon which the packages are based assume mathematically defined optimality criteria and constraints. In our experience, such models are largely irrelevant in the practical scheduling scene and more importantly, the computer packages based upon them cannot compete with an experienced human scheduler who has an intimate knowledge of the specific situation. It appears unwise to attempt to replace the scheduler and thus ignore this valuable inspiration and experience, which cannot be emulated by today's packages.

Rather, we suggest a more constructive approach, in the form of a decision support system to enhance the scheduler's unique powers. This allows both human and machine to combine to form a powerful scheduling team, each of the two complementing each other's abilities. This approach has been used in the dairy industry with significant success in a number of countries, in situations where vehicle scheduling packages foundered. A later paper will describe the successful implementation of a DSS for milk tanker route generation in an Irish dairy cooperative.

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