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Algorithm of "vehicle routing scheduling problem" for business managers in the third millennium

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The problem studied in this literature tend to be highly simplified compared to the issues faced by distribution managers due to several reasons: the number of vehicles, customers, difficult real world constraints and the fact that such routes must be constructed in a relatively short period of time. In the past several years, micro computers have become more powerful and less expensive, thus they enhanced their attractiveness to potential users. Not surprisingly, the market place has witnessed rapid growth in the number of vehicle routing packages that are commercially available. This paper is focused on introducing computer programs for planning the vehicle schedules from depots. There are some interesting features in this problem, such as: different time windows for different commodities, loading restriction for different commodities, special multi trips, and an additional depot for some products. In this paper, we present some case studies and software packages, and then, we analyze and describe the reason of designing specific algorithm for vehicle routing scheduling problem (VRSP) instead of using only commercial software packages for real world problems.

Key words: Vehicle routing and scheduling problem (VRSP), computer software packages, Algorithms.

INTRODUCTION

In the world of business, competition is a major concern, and all companies try to lower their costs so they can obtain increasing benefits as they satisfy their customers. For the companies, vehicle routing scheduling is an important and big problem. The costs associated with operating vehicles and crews for delivery purposes form an important part of total distribution costs. By considering the substantial amount of current costs and the anticipated growth in future costs, a small percentage savings could result in substantial dollar savings over years. The significance of detecting these potential savings has become increasingly apparent due to escalating fuel costs, higher capital costs of replacing new vehicles, increase in crews’ salaries, and other related factors (Golden et al., 1984). These factors have caused a larger percentage of an organization’s total operating costs to be devoted to vehicle routing and scheduling activities. The vehicle routing and scheduling problems (VRSP) have been extensively studied, especially in the last decades. The reason of this expanding attention is that, it is very interesting for operational research (OR) scientists and very important for the economy of the firms, simultaneously. Since most firms want to route and schedule their vehicles at near minimal cost, the use of vehicle routing software packages can be instrumental in realizing the importance of cost saving. For OR scientists, the VRSP is fascinating; because, most of its instances had resisted most of various attempts at optimization. The VRSP and its sub problems, like the traveling salesman problem and the generalized assignment problem, play a central role in the field of combinatorial optimization. The VRSP belongs to a category of problems which is called NP-hard in combinatorial optimization, and means that the
resolution time increases exponentially with the size of the problem. In practice, the VRSP is not a unique problem but there are vast classes of problems, each one with its own characteristics and constraints. The VRSP is conceived as a model for the real life distribution problems faced by companies.

The problem

The VRP is a complex combinatorial optimization problem, which can be seen as a merger of two well-known issues: the traveling salesperson (TSP) and the bin packing (BPP). It can be described as follow: given a fleet of vehicles with uniform capacity, a common depot and several customer demands (represented as a collection of geographical scattered points), we find a set of routes with overall minimum route cost which could satisfy all the demands. All the itineraries start and end at the depot and they must be designed in such a way that each costumer is served only once and just by one vehicle (Figure 1). VRP is NP-hard and therefore difficult to solve.

Indeed, VRP constraints are common in many applications including bank deliveries, postal deliveries, grocery distribution, dial-a-ride service, bus routing and repairmen scheduling. VRP has generated significant research interest over years (Br´aysy and Gendreau, 2005). This problem can be considered as an extension of our previous complementary works (Bisnik et al., 2007; Pavone et al., 2007).

The meaning of logistics and its importance

In this section the meaning of logistics and its importance is described. Since the VRP is a subset of logistics, it is necessary to describe it here.

Logistics can be defined as studying “the problems of integrating and optimizing purchase/supply, manufacturing/processing, transportation/distribution and trading of Industrial materials (Br’aysy and Gendreau, 2005). In this definition, it is also necessary to mention the transportation/distribution of people and/or services in order to include the problems studied throughout this paper. Some authors (Christofides and Mingozzi, 1989; Pavone et al., 2007) use distribution and logistics as synonyms. What is important is to notice that the most general logistics system encompasses the following functions: “raw material and component part acquisition, transportation and control; inventories management of raw materials and finished products; physical distribution management of products from factories to depots (trucking) and from depots to customers (delivery)”.

This system is very big and complex; so in practice, it should not be surprising to realize that logistics is totally still as much as an art not a science. Physical distribution, a subsystem of logistics, includes “the series of inter related functions (principal transport, stockholding, storage, goods handling and order processing) involved in the physical transfer of finished goods directly from producer to consumer via intermediaries (Bisnik et al., 2007)”. Either vehicle routing or vehicle scheduling problems are subsystems of the physical distribution system, although in some activities, these problems cannot be in this system, because McKinnon’s definition includes only the transportation of goods. These are more concerned with the transportation of either goods or people or services. The importance of logistics can be seen through the costs related to it. Therefore some statistical information is presented below in order to show its importance. Bodin et al. (1983) state that, only distribution costs add about $400 billion per year to the cost of purchased goods in USA. This figure does not include other very important areas, such as garbage collection and traveling of people to work and to schools. Magee et al. (Christofides and Mingozzi, 1989) said that, over 8% of the gross national product of the USA is due to transportation. They also say that the transportation cost is the most important element of logistics costs.

For some products, transportation costs can account for up to 50% of the product cost. They also assert, in the same book that logistics costs were about 9% of the sales in 1984 and that for many industries, logistics costs are greater than 25% of the sales. Christoifides and Mingozzi (1989) and Pavone et al., (2007) belief that, in a developed manufacturing country, the cost of logistics function is about 10% of gross national product and about 15% of the average sales price of the product. They also mentioned that the supply cost of finished goods from warehouses to customers is about 30 to 40% of the total logistics cost. McKinnon (Bisnik et al., 2007) wrote that physical distribution costs account for approximately 8% of the net sales revenue of British and American firms. He also presented a functional desegregation of physical distribution costs which are shown in Table 1.

Waters (McKinnon, 1989) concluded that, distribution costs are around 20% of the product value but this varies widely according to the types of product. They might range from 1 to 2% for expensive machinery to 60% for building materials. Besides, the distribution costs have been rising faster than general rates of inflation. Transportation is the largest element in distribution costs, typically accounting for 5% of the product value. The information above contains different types of measures, for different countries in different times of years. Therefore, it is complementary information that allows us to reach to the following common conclusions:

i. Undoubtedly in the modern economies, the logistics cost is very important and the transportation cost which mainly supply customers with finished goods represents a large part of it.
ii. There is a tendency to increase the importance of delivery of finished goods. This can be explained by the
fact that delivery is part of the physical distribution that involves traveling long distances. Besides, it is more difficult to improve because the customers are geographically dispersed in places that are sometimes quite far apart. At the same time, the traveling related costs (principally the fuel) have increased substantially more than other costs.

These conclusions justify the attention paid to the vehicle routing and scheduling problems during the past decades.

CASE STUDIES

There have been several comprehensive surveys to establish the state of the art in the resolution of practical VRSP's. Two of them can be found in Bodin et al. (Rijn, 1989) and in a book edited by Golden et al. (Bodin et al., 1983). The objective of this section is not to repeat any of them but give some new good examples in order to show how complex the practical VRSP's can be and how the practitioners have tackled them. Because computer software packages were not able to satisfy all the constraints which appear in the real world vehicle routing problems. Vliet et al. (Magee, 1985) in Netherlands have studied case of bulk sugar delivery. This study was carried out by Foe Suiker Unie, farming cooperative that processes about 60% of the Dutch sugar beet crop. The trucks deliver full loads to each customer and can be reloaded at any of the five factories, but there is a minimum and a maximum daily quantities to be shipped out of them; although, this can be taken as a soft constraint. Loading the trucks is very time consuming (about one hour per a full truck) and at each factory, trucks can only be loaded one at a time. The total number of customers is about 150 and the number of customers served per day is approximately 50. The customer's order

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**Figure 1.** An example of the VRP.

**Table 1.** Physical distribution costs disaggregated.

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<tr>
<td>Transport</td>
<td>48</td>
<td>46</td>
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<tr>
<td>Inventory</td>
<td>20</td>
<td>22</td>
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<td>Storage</td>
<td>25</td>
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<td>Administration/other</td>
<td>7</td>
<td>10</td>
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<td>Total</td>
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contains different types of sugar, the quantity, and the
day and time (or time interval) for the delivery. The
company owns 20 trucks of different types; each of them
has a home base where it should return there at the end
of each working day. Some customers can only be
served by some types of trucks. If on a given day the
number of vehicles is not large enough to serve all the
customers, additional trucks should be hired.

This problem can be classified as a multi-depot vehicle
routing with time windows, but there is some distinctions:
- a truck delivers a full load to each customer;
- the trucks interact at loading facilities because they have to be
  loaded sequentially.

The objective is to satisfy customer’s requirements at a
minimum cost. "Costs" consisted of: distance traveled;
driver’s pay including overtime; and the cost of hired
vehicles. The authors expressed those "costs" in terms of
time. The distance is based on a road network in
Netherlands. Therefore, the distance is the shortest path
between the nodes (customers, factories and truck
parking facilities). The times are calculated through the
distances, defining a speed for each type of vehicle and
type of road (motorways, main roads, etc.). Suiker Unie
bought a package for the multi-depot vehicle routing with
time windows. But the package could not solve their
problem completely. Therefore, they designed an
algorithm just to enhance the performance of the
package, customizing it to the real features of company.
The whole software, an interactive optimization system,
has now been used in the company since September
1991. Before that, the planning of the daily bulk deliveries
was made manually. This new system made a reduction
of about seven percent in operating costs.

Goel and Gruhn (Goel and Gruhn, 2005) studied a
more complicated problem arising in air-cargo transport.
They were concerned with a multiple pickup and delivery
problem with a heterogeneous fleet. A comprehensive
overview of the vehicle routing problem and its stochastic
variant can be found in Toth and Vigo (Waters, 1990) and
Gendreau et al. (Golden and Assad, 1988) works, and
the service time at customer sites (Hadjiconstantinou and
Roberts, 2002; Vliet et al., 1992); by Markov decision
process (Dror and Trudeau, 1986; Dror, 1993; Dror et al.
1989; Secomandi (Lysgaard, 1992) or by robust
optimization methodology (Sungur et al., 2006;
Solomon,1987) on how to solve the model, which heavily
depends on the modeling method, and can be broadly
classified into two categories: exact methods [branch and
cut, integer L-shape method and generalized dynamic
programming and heuristic methods such as saving
algorithms, sweep algorithms, GAs, Tabu search
(Gendreau et al., 1996b) to name a few (Shen et al.,
2006; Semet and Taillard, 1993).

The next case described is a study carried out by
Lysgaard (Waters, 1990) for a Danish company that
delivers approximately 500 per day to customers, using
about 100 trucks. These trucks are of different kinds and
have different capacities. The customers require to be
satisfied during a given time interval. This problem can be
classified as VRSP, in which one of the peculiar
difficulties is the fact that some arcs of the road networks
are dynamic.

The dynamic arcs result from the fact that in order to
satisfy some customers that are located on islands, the
vehicles have to be carried by a ferry that only makes the
trip at certain hours of the day. The distances and times
of travel are based on the Danish digital road network.
The author emphases the time (18 months) that took him
to put that road network in a form ready to be used by
the algorithms. Initially the author solved this problem using
the nearest neighbour heuristic following the work of
Solomon (Waters, 1990), with some changes to take into
account the different types of vehicles. The quality of the
solutions given by this method was almost like the
computer package solution. Since the distances and
times used by this algorithm do not correspond to the
road network of Denmark, he decided to travel according
to the real road network with all the characteristics re-
ferred in the previous paragraph. The author abandoned
the nearest neighbour heuristic and created a new one to
take into account the real features of road network. One
of the steps should be taken to solve it is to calculate the
shortest path (and shortest time) between customers and
them. This is straightforward when a pair of customers is
connected by land, but needs some more consideration
when there are dynamic arcs between them (this is called
dynamic path). According to his assumptions and heu-
ristic, some dynamic paths can be calculated beforehand
while some others have to be calculated during the
execution of the algorithm for the VRSP.

His heuristic for the VRSP combines the formation of
clusters of customers with an insertion type heuristic.
Another case described is a study performed by Semet et
al. (Golden and Assad, 1988) in Switzerland. The
problem involves the transportation of goods from one
depot or warehouse to 45 grocery stores. Each of these
stores can require two different types of orders every day.
Therefore, the number of daily orders is about 70 to 90.
An order cannot be split, but the sum of two orders may
exceed the capacity of some vehicles. Each order must
be delivered during a time window. The company
possesses 21 trucks (not of the same type) and 7 trailers.
The trailers could not go anywhere independently but
must be drawn by trucks. The trailer and the truck
constitute what they call a road train. Some customers
demands can be visited by road trains or trucks (they call
them trailer-stores), others only by trucks, and others only
by some trucks (these two sets are called truck-stores).
The main peculiarity of this problem is that there are two
types of routes. The classical VRP route that consists of
a departure from the depot serve the customers assigned
to the route and return to the depot. Another type of route
that is performed by the road trains is described as
follows: the road train departs from the depot, visits a
trailer-store where the trailer may be uncoupled to be unloaded. Meanwhile, the truck visits other customers (trailer-stores or truck-stores) and comes back to the store where the trailer was left (this is called a subtour). Then after the coupling, the road train may visit another trailer-store and another subtour may be realised, and so on. When the authors began the study, the problem was being solved by computer package. After that, the first approach was to develop an heuristic based on Fisher et al. (Vliet, 1992) method, along with the necessary adaptations for this particular problem. This heuristic gives significantly better solutions than those obtained by computer package. However it does not take time windows into account. The last case described is a study carried out by Sohrabi (Lysgaard, 1992) in England.

A particular distribution problem was studied in his research which is typical of what is faced by companies operating supermarkets and other types of shop. The research is focused on designing an algorithm and also developing a computer programme for planning the vehicle schedules from a regional distribution center. The program has been designed to deal with features and constraints which are important in practice but which are often ignored by academic literature.

These features include:

1) Dealing with both pickup and delivery
2) Delivering different types of commodity
3) Loading constraints depending on the type of commodity
4) Pickup and delivery from a hub depot (Tamworth in his case)
5) Time window constraints, which depend on the type of commodity
6) Multiple trips in one vehicle route
7) Service time, including an additional preparation time

Companies attempts to solve its distribution problem by using the computer software package (PARAGON). Although package was a helpful tool, companies are not satisfied with implementing all the required planning. So instead of using PARAGON, the programmes are used. Conclusions of these four case studies are:

i. There is a tendency to take into account most of the constraints, to use real data, and more realistic objective functions. In all cases real road network was used. None of them considers an objective function that includes all the costs. Nevertheless, the objective functions of all the cases is a little more than just the distance, as the position used to be.

ii. When dealing with practical cases, because they are too complex, generally heuristic methods are used for either the master problem or the sub problems.

iii. Although it is desirable to use general packages, the customization is still unavoidable in most of the companies. Usually, customization is a long process.

The profits of the algorithmic solution over the computer package one, measured in percentage terms are not generally very high. The authors (Bisnik, 2007) studied a similar vehicle routing problem where demands expire. They presented approximation algorithms for the case where vehicles’ motion is restricted to a planar curve. However, in the long run, this represents a very large profit. Besides, there are many other indirect benefits like the increase in the customer service level, reduction in the landing time, etc.

**COMPUTER SOFTWARE PACKAGES**

After the computer program had been written and checked, a series of experiments was carried out using the software. The first sets of experiments were designed to determine the best values of the met heuristic parameters to use. After the values were determining, they used in subsequent experiments in order to determine the effects of various changes in the distribution problem, which was being studied. Since many companies are trying to solve their distribution problems, which some of them are highly complex due to several constraints, there is a big market for the companies engaged in the business of developing routing software. They are keenly aware of these real constraints and are developing user friendly packages employing a blend of heuristic and optimization algorithms to assist dispatchers in routing their fleets. In this section, we focus on the computer software packages.

Golden and Assad (Christofides and Mingozzi, 1989) stated that in the United States, there were 15 micro based systems for VPR. Also they stated that commercial packages can now handle time windows, overtime, crew breaks, backhauls, pick-ups and deliveries, and mixed fleets or multiple commodities. Willinger and Willmott (Solomon, 1987) made an exhaustive survey of all the distribution software packages that have been produced or marketed in Britain. The number of packages sent to transport management for routing and scheduling was 87. However some of these do not perform routing and scheduling at all and some only do very rudimentary functions, such as, calculating shortest path between two points. Only about 15 of them really cope with routing and scheduling.

Most of them are designed for microcomputers (PC) or workstations; some can take into account many constraints, while others only consider the basic problems. Most of packages contain more than one logistics function. Two of them support all the seven functions in which the authors have divided logistics (stock management, fleet management, transport management, etc). However, the authors do not say if these functions are integrated by the software or not. Although, the data can be common, but it appears that several functions act separately.
In order to give a more exact idea of features of software that is being sold in UK, two packages are described in more detail. The first one is called DiPS, is produced by a company with the same name, since 1979. According to the producer, this software is conceived in either strategic planning (depots’ location), or tactical (daily) planning (truckings operations between the factories and the depots, and delivery). Daily route planning is prepared to interface with the customer’s order entry system.

It contains road network, postcode and gazetteer databanks. It must be executed on a PC. In fact it needs two PC’s interconnected: one for drawing the roads and another to make the interface with the user. The user can choose between the real distances given by the road network or the straight line distances. The speeds for each kind of road can be different but they do not vary by the type of the vehicle. Access restrictions as well as time windows are taken into account. Another feature of this software is that it is possible to plan manually.

The interface of this system is rather user-unfriendly. The algorithms for the routing and scheduling are not revealed by the company, but the impression given by reading the manual is that, they are quite elementary. The experience of one of the buyers of Burrton’s company was that this software is not appropriate for daily planning.

The second example is Optrak, produced by Logistics Business. The company classifies it as a decision support system, which in fact is an appropriate name, considering its features. The road network is based on Bartholomew’s 1250000 digital maps. Each road calls may have a different speed. This software can deal with the following types of constraints: multiple time windows (up to three); different types of vehicles and products, including products that cannot be mixed, so they have to be carried in different compartments of the vehicles; loading and unloading times; restrictions on the type of vehicles that can visit the customers albeit the driver’s hours regulations are respected; multiple driver’s per vehicle (more than one shift); multiple depots; priorities for the orders; deliveries or collections; multi-day planning fixed routes. This software runs within Microsoft Windows and the user interface is based on menus similar to those of Windows. This interface includes the following functions: editing of the trips to make changes if desired; displaying of the trips, shortest paths and maps of more or lesser details; execution of reports; selection, updating, and reporting of data.

The automatic planning is based on two phase algorithm (Semet and Taillard, 1993). Besides, the user can establish the trips (all or only part of them) manually. A trip that is made by the computer can be changed by the user, and afterwards, the software can be verified if it is feasible or not.

The package is divided into several modules in order that the buyer can choose according to his needs. The whole package, that includes all the functions above, costs about £ 30,000.

Two important features that are missing in this software are the capability of a driver to make several trips per day, and the possibility of implementing part of a route manually and then allowing the software to complete the route with other orders and/or improving it. On the other hand, the company gives no details about the quality of the solutions or the resolution time. It is known that the two-phase algorithm performs quite well with the basic VRP but the behavior in the presence of many other side constraints is not known.

This section finishes with a description of two other pieces of software that are slightly different from the previous ones, because they were created by academics and they are not ready for being commercialized. Although, it is the author’s opinion that they have not been very successful yet, they represent an evolutionary trend in distribution software.

Duchessi et al. (Fisher and Jaikumar, 1981) create software that combines a decision support system (DSS) with a knowledge base expert system (KBES). The DSS has the following functions: enabling the user to enter delivery requirements and routes, changing the routes, obtaining reports and view the routes on a map, generating routes automatically, and providing sensitivity analyses. The routes were generated with savings criterion, but with some modifications. The formula used is

\[ S_{ij} = d_{0i} + d_{ij} - \delta d_{ij} \]

Where \( S_{ij} \) is the savings resulting from inserting the customers \( i \) and \( j \) in the same route, \( d_{0i} \) is the distance between 0 (the depot) and \( i \), \( d_{ij} \) the distance between 0 and \( j \), \( \delta \) is a parameter, and \( d_{ij} \) is the distance between \( i \) and \( j \). The parameter \( \delta \) is inspired in the work of Gaskell (Sohrabi, 2000) and is related to the shape of the route (Willinger and Willmott, 1988). A similar formula to this was used by Mole and Jameson (Mole and Jameson, 1976) but it is more generic and has better results. Heuristic reasoning is used to reduce the routing problem through the formation of logic clusters. Their implementation enables it to handle time windows constraints.

The KBES is used to make recommendations to improve a set of routes. The whole system is very ambitious but at present, the only function that contains and performs is related to outlying stores, that is, stores that do not comply with the constraints of the problem. This function consists of: a) identifying an outlier; b) finding another route for an outlier; c) changing delivery day (recommendation); d) changing delivery time (recommendation).

Potvin et al. (Potvin et al., 2002; Christofides, 1979) developed an interactive-graphic computer system designated by ALTO that "integrates artificial intelligence
The kind of problem that can be solved is the basic VPR, but without a priori restriction on the number of vehicles, and it may have the following additional constraints:

1. Maximal capacity for each vehicle;
2. Maximal travel distance (or time) for each vehicle;
3. A single time window at each client.

Another interesting feature of ALTO is that the user has the possibility to work with soft constraints relative to the capacity, travel distance or time, and time windows. This is done through parameters like, for example, for the maximum travel time allowed to each vehicle $T_k$, Travel time $k \leq \text{Lambda}$ Time $T_k$; where Travel time $k$ is the effective travel time of vehicle $k$, and Lambda Time is a constant. So, if Lambda Time is more than one, then Travel time comes greater that $T_k$, what that means is that, the initial constraint $T_k$ is overtaken. This facility makes it possible to attain some goals like balancing the working time of the drivers or balancing the vehicles load, etc.

The authors have applied this software to a real problem of mail pick-up in Canada. The total time of each route is constrained and there are time windows for pick-up. The total length of the routes that constitute the solution was reduced by 10% as compared to a solution produced by a specialized algorithm, which was already better than the one produced by an expert scheduler. This algorithm takes 90 s to find the solution while ALTO, once correctly instantiated, takes 360 s. It must be said that the size of this problem, is very small –37 posts – boxes and 4 routes.

The authors are the first to recognize that more tests have to be done to assess its robustness and computing time for problems of larger dimension and with more constraints. The idea behind the development of ALTO is very interesting, but at present the results are not so good. The main shortcoming is the fact that, to create the specific heuristic from the generic one is far from simple (Sungur et al, 2006). Only an expert user who has studied ALTO very well can do it. Besides, the user needs to know a lot about the specific algorithms for routing, in order that he can do the instantiation. Another problem is computing time, which according to the example given, is very long. This is due to the computing language in which it is implemented and the fact that the heuristic is generic. So, there are many operations which are not needed in a specific heuristic.

The three main driving forces of the distribution software evolution are: economic is importance of the distribution, improvements in both information technologies and algorithms for the distribution. The high economic of the distribution was already proven in previously.

This is the reason of so many researches in this field, and why it will continue. In some areas of the information technologies progress have been so high that they are nearly unbelievable. Bodin et al. (Rijn and Van, 1989) stated 11 years ago: “One may currently purchase a 64 k micro – computer with 5 to 10 megabytes of hard disk storage, printer terminal and all systems software for under $20,000. “Now there is no such computer for sale, but if it were, the computer itself would cost cheaper than then. The improvements in all areas of information technologies communications, microprocessors, or even information storage and software have been astonishing.

The progress on computer side is very important for the distribution software, because it allows more and more complex algorithms to be created, that takes into account more realistic constraints and gives better solutions. Besides, if computers are more powerful, more compatible, better integrated and cheaper, they will be widely available in every company.

The actual trends of the VRSP computer packages are:

i. To be more and more based in microcomputers (or
workstations), although, with easy communications with other computers in order to exchange information with them, to receive orders of the customers, to “know” the inventories levels, to access large geographic databases, to send the reports, etc. This also means that the tendency is towards integrated systems in order to handle complete logistics system:

i. Use of road networks and to display the routes on the screen and printers;

ii. Creating new heuristics eventually, based on the existing ones and using mathematical techniques or using only an analogue human – like reasoning;

iii. Indicating the consequences of determined actions, this being done interactively in order to answer the questions of the user.

This last trend is probably the “last frontier” and actually it is only at beginning of its infancy. The objective of AI is to complement the techniques of OR but to complement them through:

i. Suggesting to the user which are the best heuristics and/or parameters for a specific problem;

ii. Creating new heuristics eventually, based on the existing ones and using mathematical techniques or using only an analogue human – like reasoning;

iii. Indicating the consequences of determined actions, this being done interactively in order to answer the questions of the user.

CONCLUSION

A particular distribution problem has been studied in this research which is typical example of what is faced by companies operating factories and other places. The research has focused on introducing computer programs for planning the vehicle schedules from a distribution centre.

The programs introduced in this paper have been designed to deal with features and constraints which are important in practice but which are often ignored in the academic literature. These features include:

1. Dealing with both pickup and delivery
2. Delivering different types of products
3. Loading constraints depending on types of products
4. Pickup and delivery from a hub depot
5. Time window constraints, which depend on the types of products
6. Multiple trips in one vehicle route
7. Service time, which includes an additional preparation time.

The program runs quickly enough, so that it can be used on a daily basis using the most recent demand figures, instead of planners having to update a base schedule manually.

The production of the computer program has involved development of algorithms. The program is designed to be user friendly so it can be used by a scheduler and is very flexible in terms of being able to change time windows, demands and other inputs. The program is not just specified to particular firms, but it is general to the extent that, it could be used for any distribution problem including the features listed earlier.

Further computational experiments in chapter 6 illustrated the flexibility of the computer program and demonstrate how it can be used to address broader management issues (such as the capacity of the vehicles to be used), as well as the daily scheduling.

Considering what has been written in this paper, the following conclusions can be drawn:

A. The best software for the VRSP and the one for which the authors advocate big savings, is the one which is tailored to a specific problem. This is due to the fact that the VRSPs are very complicated, and in general, each one is different from the others, at least in some important points.

B. In general, the best saving reported, is relative to methods that were being used which are about 10 to 15% frequently the greatest benefits (Rousseau (Rousseau, 1988; Duchessi et al., 1988) and Hoolan (hoolan, 1988; Gaskell, 1967) do not result directly from a better solution to the VRSP but from many other related management problems, for which VRSP solutions give data:

i. Strategic planning of the goods distribution;

ii. Planning the maintenance of the vehicles and numbers to be hired;

iii. Planning the acquisition of vehicles;

iv. Control of inventories;

v. Analysis (cost- benefit) of whether it is worth saving a given customer.

C. The computer packages do not have enough generality yet to fit any specific problem. This is the principal reason why in spite of all development, only 1 to 5% of the companies use computer – based routing (McKinnon, 1989).

For these reasons we should design specific algorithm for real-world vehicle routing problem rather than using only general package.

REFERENCES


