OPTIMIZATION SCALE IN ROUTE DESIGNING

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Abstract –The Vehicle Routing Problem can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints. Whenever organizations, in the business of providing mobility, is entrusted with moving goods and people a natural question that arises is how efficiently that organization can provide the services. This basic requirement of efficient mobility of goods and passengers gives rise to, among many other things, the subject areas of optimal routing and scheduling. The problem of designing a good or efficient route set for a system is a difficult optimization problem which does not lend itself readily to and solutions using traditional techniques. The main objectives of this study on Travelling Salesman Routing Problems are to find out how the salesman can minimize travel costs by choosing the right route and the shortest route to the zone or area where he or she is to sell and also the passenger transit problems and optimization.

Keywords— Route, Optimization, Cost Transport, scheduling in transportation and Minimize.

I. INTRODUCTION

The routing and scheduling of vehicles and their crews is an area of importance to both operations researchers and transportation planners. Recent research in this field includes significant breakthroughs in problem formulations and in the construction, analysis, and implementation of solution procedures. These advances have important implications for future research in routing and scheduling, as well as for immediate use in the design of mass transit systems and other applications. From a practical standpoint, the effective routing and scheduling of vehicles and crews can save government and industry many millions of dollars a year by increasing productivity, aiding longrange planning, assisting in contract negotiation, and in controlling the financial impact of adverse weather conditions on vehicle utilization. First, we need to define what we mean by routing and scheduling of vehicles. A vehicle route is a sequence of pickup and/or delivery points which the vehicle must traverse in order, starting and ending at a depot or domicile. A vehicle schedule is a sequence of pickup and/or delivery points together with an associated set of arrival and departure times. The vehicle must traverse the points in the designated order at the specified times. When arrival times at nodes and/or arcs are fixed in advance, we refer to the problem as a scheduling problem. When arrival times are unspecified, the problem is a straightforward routing problem. When time windows and/or precedence relationships exist so that both routing and scheduling functions need to be performed, we view the problem as a combined vehicle routing and scheduling problem. These combined routing and scheduling problems often arise in practice and are representative of many real-world applications.The travelling salesman problem and the vehicle routing problem are among the most widely studied combinatorial optimization problems. Both problems, as well as their numerous extensions, deal with optimally visiting customers from a central depot. A very large number of papers and books deal with these problems. There are usually two characteristics of salesman routine problems. They are: every customer has to be serviced and that, consequently, no value is associated with the service. The redistribution of finished products from the manufacturers is part of the salesman responsibility which drags the salesman into the routing problem. However, some variant problems propose to select customers depending on a profit value that is gained when the visit occurs. This feature gives rise to a number of problems that we gather together under the name of travelling salesman problems with profits, when a single vehicle is involved. When many problems occur in which several vehicles might be in operations, it is called routing problems. In this research we will review the existing literature on the travelling salesman routing problems, with an aim on Traveling Salesman Routing Problems, which have been more widely studied all over the world. Many researchers that are interested in these problems address the problem in single-criterion versions. Thus, either the two objectives are weighted and combined linearly, or one of the objectives is constrained with a specified bound value. To our knowledge, the only attempts to solve the two-criterion problem, who call it the multi-objective vending problem, but their approaches, consist of sequentially solving single-criterion versions of the problem. One should note, however, that many articles deal with other kinds of multi-criteria TSPs. Interested readers are referred to for a recent survey. Whenever an organization, in the business of providing mobility, is entrusted with moving goods and peoples a natural question that arises is how efficiently that organization can provide the services. This basic requirement of efficient mobility of goods and passengers gives rise to, among many other things, the subject areas of optimal routing and scheduling. In the following sections the problems of optimal routing and optimal scheduling are explained. Finally, how these optimization problems, which are often difficult to solve using traditional optimization tools, have been solved.

II. LITERATURE REVIEW

Among the most remarkable works on this matter, it is possible to mention Mandl (1979), who proposed an algorithm that at each step individuates a route on the shortest path that connects a pair of terminals and serves the greatest number of O/D pairs. The pair of terminal nodes is then removed and the procedure is repeated until the pairs of terminal nodes to connect are all examined. Ceder and Wilson (1986) developed a heuristic algorithm concerned with minimizing the difference between the number of users served directly (i.e., by a route coincident to the shortest path) and indirectly (i.e. in the contrary case). Filippi and Gori (1993) developed an integrated model system for solving the transit network design problem, where routes generated are joined at main nodes or transit centers. The most innovative feature of this model concerns the routes design procedure, which is carried out by means of a system of integrated models, facing problems ranging from low demand to high-density areas specific problems, where mass transit rail systems are needed. Ceder and Israeli (1993) proposed a public transport design system based on the mathematical programming approaches. The first step generates a very large set of feasible routes connecting every node to all others. Then, the system creates the minimal subsets of routes solving a Set Covering Problem and, using a multi-objective analysis, it is possible to select the most suitable subset. Baaj and Mahmassani (1995) used an Artificial-Intelligent heuristic algorithm for route generation, which searches the transit demand matrix for highdemand node pairs and selects them as seeds of skeletons. The skeletons are expanded to routes according to a node selection strategy reflecting different trade-off between performance measures, users' and operators' costs. Carrese and Gori (1998) presented a system of models that face transit network design problem in urban areas in a sequential way. The design procedure explicitly involves relationships between transit network design and parking and land use policies. Several authors have recently proposed a genetic approach to the network design problem (among them: Xiong and Schneider, 1993; Pattnaik et al., 1998; Chien et al., 2001). Recently, Agrawal and Mathew (2004) applied a GA approach to a large-scale transit network. However, the travel demand was relatively small, and the search method required multiprocessor parallel processing due to intensive computation involved. Detailed information about various optimization approaches may be found in Fan and Machemehl (2004), which provides an extensive review and comparison of various optimization methods for TN design, and Zhao and Gan (2003), among others. A recent method for analyzing fixed-route bus systems is the out-of-direction technique (Welch et al. 1991). This method improves the accessibility of a bus system by improving passenger accessibility along certain route segments. A survey (Stern 1996) of various transit agencies in U.S. indicated that about 58% of the respondents believed that transit riders were only willing to transfer once per trip. It is widely accepted in the U.S. transit industry that the willingness of riders to transfer has a significant impact on the total ridership of a transit system (Newman et al. 1983). Chien and Schonfeld (1997) optimize a grid transit system in an urban area without oversimplifying the spatial and demand characteristics. They extended the model to jointly optimize the characteristics of a rail transit route and the associated feeder bus routes in an urban corridor (Chien and Schonfeld 1998). Chien and Yang (2000) developed an algorithm to search for the best bus route feeding a major intermodal station while considering the intersection delays and realistic street network. The model optimized the bus route location and operating headway by minimizing the sum of operator and user costs. It considered irregular and discrete demand realistically distributed over the service area. The route and headway were optimized analytically.

III. VEHICLE ROUTING AND SCHEDULING PROBLEMS

The vehicle routing problem refers to all problems where optimal closed loop paths which touch different points of interest are to be determined. There may be one or more vehicles. Generally the points of interest are referred to as nodes; further, the start and end nodes of a route are the same and often referred to as the depot. We first outline a number of characteristics that describe any vehicle routing and scheduling problem. A specific vehicle routing or scheduling problem can then be classified on the basis of these characteristics in rather obvious ways.

A. Time to service a particular node or arc
 1. Time specified and fixed in advance (pure vehicle scheduling problem)
 2. Time windows (combined vehicle routing and scheduling problem)
 3. Time unspecified (in this case, we have a vehicle routing problem unless there are precedence relationships as well, in which case we have a combined vehicle routing and scheduling problem)

B. Number of domiciles
 1. One domicile
 2. More than one domicile

C. Size of vehicle fleet available
 1. One vehicle
 2. More than one vehicle

D. Type of fleet available
 1. Homogeneous case (all vehicles the same)

2. Heterogeneous case (not all vehicles the same)

E. Nature of demands
1. Deterministic
2. Stochastic

F. Location of demands
1. At nodes (not necessarily all)
2. On arcs (not necessarily all)
3. Mixed

E. Nature of demands
1. Undirected
2. Directed
3. Mixed

D. Type of fleet available

G. Underlying network

H. Vehicle capacity constraints
1. Imposed-all the same
2. Imposed-not all the same
3. Not imposed

I. Maximum vehicle route-times
1. Imposed -all the same
2. Imposed -not all the same
3. Not imposed

J. Costs
1. Variable or routing costs
2. Fixed operating or vehicle acquisition costs (capital costs)

K. Operations
1. Pickups only
2. Drop-offs only
3. Mixed

L. Objective
1. Minimize routing costs incurred
2. Minimize sum of fixed and variable costs
3. Minimize number of ehicles required M. Other (problem-dependent) constraints

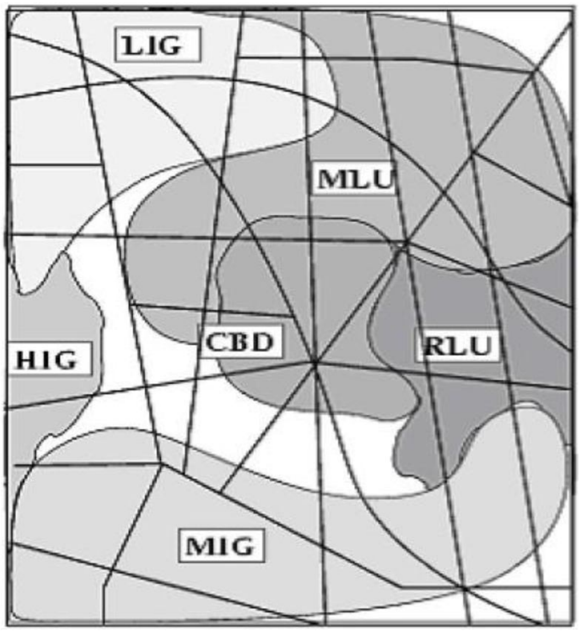

Fig 1- An urban area with land use and roads

LIG- Low Income Group (Residential)
MIG- middle Income Group (Residential)
HIG- High Income Group (Residential)

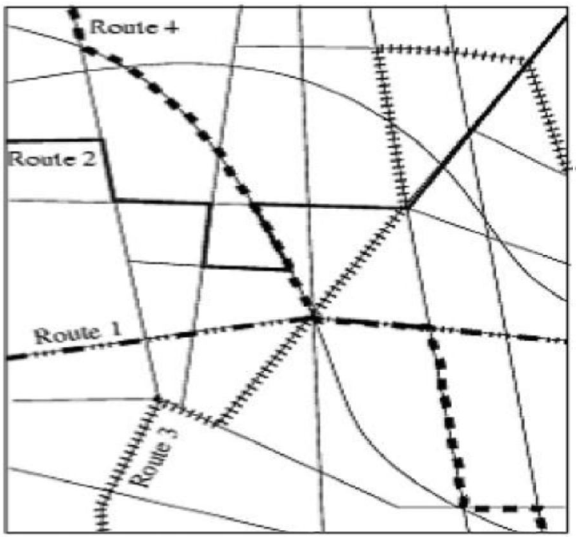

Fig 2- A possible route for the urban area

MLU- Mixed land use (Office, Residual, etc.)
RLU- Recreational land use
CBD- Central business district

IV. COMBINED ROUTING AND SCHEDULING PROBLEMS

Combined routing and scheduling problems are extremely complex. There are, in fact, so many potential, complicating factors that we do not even dare, in this section, to propose a detailed classification scheme or a hierarchy of problems. Instead we focus on specific examples in order to illustrate the myriad of difficulties that can arise when routing and scheduling operations must be performed simultaneously. The three examples that we describe are

1. School bus routing and scheduling,
2. Subscriber dial-a-ride routing and scheduling,
3. Routing and scheduling with full loads and time windows.

School Bus Routing and Scheduling

In the school bus routing and scheduling problem, there are a number of schools and each one has a set of bus stops associated with it. In addition, there are a given number of students associated with each bus stop. Each school has a fixed start and finish time with a time window about each of these for the delivery of students to the school in the morning and the pickup of students from the school in the afternoon. The problem is to minimize the number of buses used or total transportation costs while servicing all the students and satisfying all of the time windows. Much thought has gone into the analysis of this problem although most of the effort has been directed at the routing aspect. A general solution procedure can be sketched as follows:

(i) Determine a reasonable set of routes for each of the schools.

(ii) Schedule the buses, starting from the beginning of

the day.
(iii) Improve routes and/or schedules,

Subscriber Dial-a-Ride Routing and Scheduling
In the subscriber dial-a-ride environment, customers call in advance requesting service. Each customer specifies a pickup point, a delivery point, and a desired time of pickup and/or delivery. The problem is to develop a set of routes and schedules for the vehicles in a fleet of fixed size in order to minimize total customer dissatisfaction or inconvenience. This problem is characterized by a set of precedence relationships (each customer's origin must precede his destination) and time windows at each point (in particular, to pick up a customer too early or deliver him too late is unacceptable).

Routing and Scheduling with Full Loads and Time Windows
In this problem, a set of demands is specified for a number of origin-destination pairs. Each demand is a full trailer which must be loaded onto a tractor at an origin and unloaded at a destination. These stops must satisfy prespecified time window constraints and the goal is to design routes and schedules for the fleet of tractors. In most cases, the objective is to minimize total transportation costs or the number of tractors used. In the real-world instance of this problem described by Ball et al., a "bangfor-buck" objective was specified by management. Three algorithmic approaches were experimented with. In these experiments, a greedy insertion procedure outperformed the other heuristics with respect to the bang-for-buck objective function.

V. ROUTE CONSTRAINTS

(1) Fixed route constraints
A transit route and all its stops/nodes are specified and may not be changed during the optimization process. Examples of such routes include fixed guide way transit lines, bus ways, or any routes specified by transit planners to meet certain planning goals.

(2) Prescribed route starting and ending area constraints (two-area constraints)
The general areas of starting and ending points of a transit route are defined by two sets of nodes. A route with such constraints must start from a node inside the starting area, and end at a node inside the ending area. A route starting from a given node, and/or ending at a given node is a special case of such constraint, where the starting area or ending area has only one node. When there is only one node in a specified area, the constraint in the corresponding end is called a fixed boundary constraint; otherwise, it is called a flexible boundary constraint. This constraint is applied when transit planners wish to specify transit routes between two major activity centers. Examples of such routes are those that serve airports, downtown, government centers, railway terminals, universities, shopping malls, etc.

(3) Prescribed route starting, ending, and an in-between area constraints (three-area constraint)
In addition to the starting and ending areas of a transit route, an intermediate area may also be specified. A route with such constraint must start from a node inside the starting area, and pass a node inside the intermediate area, and end at a node inside the ending area. Depending on the number of nodes in a specified area, this constraint may be also called fixed boundary constraint if there is only one node in the area, or flexible boundary constraint there are more than one node in the area. This constraint allows transit planners to specify transit routes between three major civic activity areas.
The two- and three-area constraints described above may also be used in situations where transit planners specify several transit routes intersecting in certain activity areas. Examples of such areas are transit transfer centers. Connecting several feeder bus lines with a major transit line such as a rail rapid transit line will be a special application of these constraints, where the specified area will be defined by some or all of the nodes on the transit line, and routes will be all the feeder bus lines.

VI. METHODOLOGY FOR SOLUTION

For simplicity, the following assumptions were made in this study:

1. The demand pattern, expressed in a transit origin-destination (OD) matrix, remains the same during the period of study.
2. Passengers' choices of routes are based on the shortest travel time. Terminal times are not included, although may be added easily.
3. Transit vehicles have the same seating capacity.
4. Passengers arrive at transit stops randomly (uniform distribution); therefore, the average waiting time to board a vehicle (twait) is one half of the headway
(h), i.e.,

$t_{wait} = h/2$ …(1)

The following simple (yet widely used) relationships between TN parameters are employed:

$$L \equiv \frac{h \cdot q_{\max}}{V_{Seat}} \leq L_{\max}, \quad \ldots (2)$$

$$h = \frac{2 \cdot R_L}{R_{Fleet}}, \quad \ldots. (3)$$

Where:

L is vehicle load factor
q_{max} represents the critical link passenger flow of a given route

V_{Seat} indicates vehicle seating capacity
L_{max} signifies a user-defined maximum allowable load factor 2_{RL} is the round-trip in-vehicle travel time
R_{Fleet} represents the route vehicle fleet size

VII. ROUTE DESIGNING APPLICATIONS

1. Dedicated Logistics
2. Retail Chains
3. Wholesale Manufacturing
4. Building Products
5. Less Than Truckload Carriers
6. Direct Store Delivery
7. Snack Foods
8. Beverage
9. Long Haul
10. Local
11. Grocery Wholesale
12. Restaurant Supply
13. Automobile Parts
14. Propane
15. Courier Services
16. Janitorial
17. Sales and Field Service

VIII. CLASSIFICATION OF SOLUTION STRATEGIES

Most solution strategies for vehicle routing problems can be classified as one of the following approaches:

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

The first four and last approaches have been used extensively in the past. The other two approaches represent relatively recently developed ideas. A more general framework for heuristic algorithms is given in the article by Ball and Magazine in this issue.

Cluster first-route second procedures group or cluster demand nodes and/or arcs first and then design economical routes over each cluster as a second step. Examples of this idea are given by Gillett and Miller, Gillett and Johnson, and Karp for the standard single depot vehicle routing problem.

Route first-cluster second procedures work in the reverse sequence. First, a large (usually infeasible) route or cycle is constructed which includes all of the demand entities (that is, nodes and/or arcs). Next, the large route is partitioned into a number of smaller, but feasible, routes. Golden et al. provide an algorithm that typifies this approach for a heterogeneous fleet size vehicle routing problem. Newton and Thomas and Bodin and Berman use this approach for routing school buses to and from a single school, and Bodin and Kursh utilize this approach for routing street sweepers. See also the work of Stern and Dror.

Savings or insertion procedures build a solution in such a way that at each step of the procedure (up to and including the penultimate step) a current configuration that is possibly infeasible is compared with an alternative configuration that may also be infeasible. The alternative configuration is one that yields the largest savings in terms of some criterion function, such as, total cost, or that inserts least expensively a demand entity not in the current configuration into the existing route or routes. The procedure eventually concludes with a feasible configuration. Examples of savings insertion procedures for single depot node and arc routing problems are described by Clarke and Wright, Golden et al, Norback and Love, and Golden and Wong. Hinson and Mulherkar use a variant of this procedure for routing airplanes.

Improvement or exchange procedures such as the well-known branch exchange heuristic developed by Lin and Lin and Kernighan and extended by Christofides and Eilon and Russell always maintain feasibility and strive towards optimality. At each step, one feasible solution is altered to yield another feasible solution with a reduced overall cost. This procedure continues until no additional cost reductions are possible. Bodin and Sexton modify this approach in order to schedule minibuses for the subscriber dial-a-ride problem.

Mathematical programming approaches include algorithms that are directly based on a mathematical programming formulation of the underlying routing problem. An excellent example of mathematical-programming-based procedures is given in the Fisher and Jaikumar article “A Generalized Assignment Heuristic For Vehicle Routing” contained in this issue. They formulate the Dantzig-Ramser vehicle routing problem as a mathematical program in which two interrelated components are identified. One component is a traveling salesman (routing) problem and the other is a generalized assignment (packing) problem. Their heuristic attempts to take advantage of the fact that these two problems have been studied extensively and powerful mathematical programming approaches for their solution have already been devised. Christofides et al. and Stewart and Golden discuss Lagrangean relaxation procedures for the routing of vehicles. In addition, the article by Christofides, Mingozzi, and Toth in this issue represents a mathematical-programming-based (in particular, dynamic programming) approach for obtaining lower bounds in a variety of combinatorial optimization problems related to vehicle routing. Further discussion on this topic can be found in the article by Magnanti in this issue.

Interactive optimization is a general-purpose approach in which a high degree of human interaction is incorporated into the problem-solving process. The idea is that the experienced decision-maker should have the capability of setting and revising parameters and injecting subjective assessments based on knowledge and intuition into the optimization model. This almost always increases the likelihood that the model will eventually be implemented and used. Some early adaptations of this approach to vehicle routing problems are presented by Krolak, Felts, and Marble and Krolak, Felts, and Nelson, The paper by Jarvis and Ratliff in this issue introduces several rather novel interactive optimization heuristics.

Exact procedures for solving vehicle routing problems include specialized branch and bound and cutting plane algorithms.

CONCLUSION

In this paper, we have attempted to classify the many vehicle routing and scheduling problems in a reasonable and useful way. A few of these problems have been looked at in some detail while others have been mentioned just briefly. In the remaining portion of this Special Issue, other papers highlight some of the more significant recent developments in this field. It is our hope that the classification scheme and discussion presented in this paper along with the other papers in this issue will lead to new insights and suggest important new research topics in the area of vehicle routing and scheduling.

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