

Multiple-Criteria Decision-Making Combined with VRP: A Categorized Bibliographic Study

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Abstract

In this research, author reviews references related to the topic of multi-criterion (goal programming, multiple objective linear and nonlinear programming, bi-criterion programming, Multi-Attribute Decision-Making, Compromise Programming, Surrogate Worth Trade-off Method) and various versions of vehicle routing problem (VRP), Multi-Depot VRP (MDVRP), VRP with time windows (VRPWTW), Stochastic VRP (SVRP), Capacitated VRP (CVRP), Fuzzy VRP (FVRP), Location VRP (LVRP), Backhauling VRP (BHVRP), Facility Location VRP (FLVRP), and Inventory control VRP (ICVRP). Although VRP is a research area with rich research works and powerful researchers, only 81 articles are found that relate various vehicle routing type problems with various multiple objectives techniques. This author found that there is no research done in some areas of VRP (i.e., FVRP, ICVRP, LRP and CVRP). It is interesting to see that this research area was completely unattractive to master students (with zero research reported) and somewhat attractive to doctoral students (with 6 researches reported). Among the many multi-criterion programming techniques available, only three of them (goal programming, bi-criterion programming, linear and nonlinear multi-objective programming) are being employed to solve the problem.

Keywords: Vehicle Routing Problem; Goal Programming; Bicriterion Programming; Multiple objective programming; Multi-Attribute Decision-Making; Heuristics; Meta-heuristic; Decision-Making.

1. Introduction

Vehicle Routing Problem (VRP) is a challenging logistics management problem with variations that range from school bus routing to the dispatching of delivery trucks for customer goods. Regardless of the variations, the basic components of the problem are a fleet of vehicles with fixed capacities and a set of demands for transporting passengers or certain objects (customer goods) between specified depots and delivery points. The problem is complicated because managers must also take into consideration a variety of constraints such as fixed vehicle capacity and the duration of the route. The prospective and prospects on VRP is discussed by Magnanti (1981). The concept of VRP has been addressed within the framework of other management science techniques. For instance, Federgruen (1984) discusses a combined knowledge of VRP and inventory problem and Ball (1983) discusses planning for truck fleet size in the presence of common-carrier option. Zare Mehrjerdi and Nadizadeh (2013) discuss the modeling of the problem within the location routing problem and in fuzzy environment. The purpose of this article is to review works published on the VRP combined with the Multi-Criteria Decision-Making. This review provides all types of researches published on this attractive combinatorial field,

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Including the Ph.D. dissertations, Master Thesis, Conference articles, Journal articles, and technical reports. To provide a meaningful survey, the following criteria are considered in this paper:

1. Only works published in OR/MS literature.
2. Work done in the United States as well as abroad
3. Application areas as well as theoretical works related to the subject
4. Special articles thought to be important to the field of VRP.

A total of 81 published references on Multi-Criteria Decision-Making (MCDM) combined with Vehicle Routing Problem have been compiled in this research.

For those articles that were on the border line, this author decided to use the following characteristics for determining the paper whether it is eligible or not:

1. The title contains both VRP and multi-criteria decision-making language
2. The abstract relies on the concepts of VRP and MCDM
3. The paper addresses both topics theoretically, practically, or in the form of a case study
4. The list of references used in the article directs us to this reality that MCDM and VRP are dominating the content of the whole article.

To make the foregoing criteria operational, a survey was made using the following sources:

- www.Sciencedirect.com
- Web Directory such as Yahoo and Google
- This author personal knowledge on the topic.

Before digging truly into the topic of this article, I was wondering why there are not too many publications on the multi-criteria decision-making and VRP. Once I completed my research I came to this conclusion that there are people there who are interested on the topic and working hard to make the VRP more operational and manageable. Knowing that VRP is a subset of the combinatorial and an NP-hard type problem, we will appreciate the level of efforts that one needs to implement in model development and programming in a way that is manageable and suitable to an organization’s profit-making.

2. Research Background

2.1 Travelling Salesman Problem

Some of the problems classified under the generic name are the traveling salesman problem (TSP) and its variants Multiple TSP and Time Constrained (MTSPT); Single depot, Multiple Vehicle Node Routing (SMVNR), Multiple depot, multiple Vehicle Node Routing (MVMNR); and single depot, Multiple Vehicle Node routing problem (SMVNR) with stochastic demands. These problems are of discrete type with combinatorial structure and hence are known as “combinatorial Optimization”. The TSP, a combinatorial optimization problem with some real life applications, is the substructure of all VRP problems (1995) and has been studied extensively in the literature. Dantzig and Ramser (1959) described the TSP as follows: “Find the shortest route (tour) for a salesman, starting from a given city, visiting each of a specified group of cities, and returning to the original point of departure”. Mathematically, this problem can be formulated as:

$$\text{Minimize } \sum_{i=1}^N \sum_{j=1}^N C_{ij} X_{ij} \tag{1}$$

S.t.

$$\sum_{i=1}^N X_{ij} = 1 \quad j \in S = \{1, \dots, N\} \tag{2}$$

$$\sum_{j=1}^N X_{ij} = 1 \quad i \in S \tag{3}$$

$$X_{ij} = \begin{cases} 0 \\ 1 \end{cases} \quad i, j \in S \tag{4}$$

$$X_{ij} = \{\text{form a tour}\} \tag{5}$$

where C_{ij} is the cost of traveling from node i to node j , $C_{ij} = \infty$, where $i=1,2,\dots,N$. Constraint (5) can thus be written in the form of

$$Z_i - Z_j + NX_{ij} \leq N - 1 \quad 2 \leq i \neq j \leq N \tag{6}$$

And for some nonnegative real numbers Z_i .

2.2 Vehicle Routing Problem

Since 1959 when Dantzig and Ramser (1959) first introduced the VRP and proposed a linear programming-based heuristic for its solution, the heuristic method has been widely researched. Christofieds and Eilon (1972, 1979) indicated that the largest VRP of any complexity solved to date by exact methods and reported in the open literature contains only 31 demand points. Before considering model development for this research, a formulation of the VRP problem as a 0-1 integer program is given below. The problem that is known as “pure delivery” can be formulated as (2006):

$$P3: \quad \text{Minimize} \quad \sum_{i=1}^N \sum_{j=1}^N \sum_{\substack{k=1 \\ i \neq j}}^{NV} d_{ij} X_{ijk} \quad (7)$$

S.t.

S= {

$$\sum_{i=1}^N \sum_{k=1}^{NV} X_{ijk} = 0 \quad j=2, 3, \dots, N \quad (8)$$

$$\sum_{i=1}^N x_{ipk} \sum_{\substack{j=1 \\ i \neq j}}^N X_{pjk} = 0 \quad k=1, 2, \dots, NV, \quad p=1, 2, \dots, N \quad (9)$$

$$\sum_{j=2}^N X_{ijk} \leq 1 \quad k=1, 2, \dots, NV \quad (10)$$

$$Z_i - Z_j + N \sum_{k=1}^{NV} X_{ijk} \leq N - 1 \quad i \neq j = 1, 2, \dots, N \quad (11)$$

}

$$\sum_{i=1}^N d_i \left(\sum_{\substack{j=1 \\ i \neq j}}^N X_{ijk} \right) \leq Q_k \quad k=1, 2, \dots, NV \quad (12)$$

$$\sum_{i=1}^N t_{ijk} \sum_{\substack{j=1 \\ i \neq j}}^N X_{ijk} + \sum_{i=1}^N \sum_{\substack{j=1 \\ i \neq j}}^N t_{ijk} X_{ijk} \leq T_k \quad k=1, 2, \dots, NV \quad (13)$$

$$X_{ijk} = \begin{cases} 0 \\ 1 \end{cases} \quad i, j, k \text{ and } i \neq j \quad (14)$$

Where;

N= Number of nodes

NV= Number of Vehicles

Q_k = Capacity of Vehicle k

T_k = Maximum time allowed for vehicle k on a route

d_i = Demand at node i (assuming that $d_1=0$)

t_{ik} = Time required for vehicle k to deliver or collect at node i ($t_{1k} = 0$)

t_{ijk} = Travel time for vehicle k from node i to node j

d_{ij} = Distance from node i to j

$$X_{ijk} = \begin{cases} 1 & \text{if arc (i, j) is traversed by vehicle k} \\ 0 & \text{Otherwise} \end{cases}$$

Z_i = Arbitrary real numbers, $i=1, 2, \dots, N$.

The objective function (7) represents minimization of total distance traveled by NV vehicles. Alternatively, costs could be minimized by replacing d_{ij} with C_{ij} , depending on the vehicle type. Equation (8) ensures that each demand node is served by exactly one vehicle; equation (9) ensures that if a vehicle enters a demand node it must exit from that node; and (10) guarantees that vehicle availability is not exceeded; equation (11) prohibits sub-tours generation, equation (12) is vehicle capacity constraint, and finally, (13) is the total elapsed route time constraint. Decision variables X_{ijk} that is of 0 and 1 type is represented by equation 14.

The set of constraints (8), (9), (10), and (11) produce a space that we will refer to as S in the remainder of this article. All feasible decision variables of the problem belong to this space. For having any decision variable from set S as an acceptable solution of the problem it must satisfy constraints (12), (13), and (14) as well.

Golden and Stewart (1977) formulated the single depot SVRP via the concept of CCP. The verbal nature of their formulation is as shown below:

Minimize {Expected total cost}

S.t.

- $$\left\{ \begin{array}{l} 1. \text{ A fixed set of routes} \\ 2. \text{ Satisfaction of customers} \\ 3. \text{ Vehicle capacity is obeyed} \\ 4. \text{ P (total demand} \geq \text{ truck capacity) } \geq (1 - \alpha) \end{array} \right\}$$

where $0 \leq \alpha \leq 1$.

Tillman (1969, 1972) is credited for realizing the probabilistic nature of the customer demand in the scheduling of the multi-depot delivery and collection problems. This is a valuable problem and has been adapted by many industries dealing with the distribution and/or collection of products from one/many location(s) into many/one locations. Bodin (1979) used a survey by Kearney (1980) to show that about 16 percent of the sales value of an item is based upon the physical distribution costs of that item, and about one-fourth of that is due to the downstream distribution of the final product from distribution centers to customers. Turner and Vu (1979) further reported that in 1974 about 10 percent of the average community budget was spent on refusal collection and disposal, a total of 7.8 billion dollars in USA alone. Factors such as these attracted a great deal of attention to the VRP and SVRP.

Three excellent volumes have been published on the subject of the traveling salesman problem (Lawler et al., 1985), on routing and scheduling (Bodin et al., 1983) and on vehicle routing problem (Golden and Assad 1984). Each publication offers hundreds of references to the subject of routing and scheduling. Vehicle routing with stochastic elements has received attention as well. Stewart, and Golden (1984), Stewart (1981), Golden and Yee (1979), Dror and Trudeau (1986), Laporte and Louveau (1992) have employed stochastic optimization techniques to solve small size problems.

Park (1984) proposed a multiple objective analysis of the deterministic vehicle routing problem. Interactive VRP is studied by Waters (1984), while computational modifications of the savings method for VRP are studied by Yellow (1970). In 2004, Bianchi et al(2004) have studied vehicle routing problem with stochastic demand using meta-Heuristic approaches. In 2006, Bianchi et al (2006) have considered five meta-heuristics of Simulated Annealing; Tabu Search; Iterated Local Search; Ant Colony Optimization and Evolutionary Algorithms to study VRP with stochastic demand. In 2005, Haugland, Ho and Laporte (2005) studied the delivery districts for the VRP with stochastic demands. A two-stage hybrid algorithm for pickup and delivery vehicle routing problems with time windows and multiple vehicles is studied by Bent et al (2006). In the first stage, a simple simulated annealing algorithm is used for decreasing the number of routes while the second stage uses large neighborhood search for decreasing total travel cost. Zheng and Liu (2006) studied the vehicle

routing problem in which the travel times are assumed to be fuzzy variables. Many other researchers have conducted studies on VRP to find an exact or approximate solution of the problem: Bertsimas et al. (1990), Golden et al. (1977), Holmes and Parker (1976), Magnanti (1981), Nagy and Salhi (2007), Salhi and Rand (1987), Stacy (1983), and Wassan and Osman (2002).

A brief discussion on MCDM problem is given in section 2. That is followed by the discussion on various types of VRP that is outlined in section 3. A brief review of solution methodologies for MCDM combined with VRP is given in section 4. Next, a discussion on Meta-heuristics Techniques and VRP is given in section 5. Data classification is the topic of section 6. The analysis of data and tables are given in section 7. The discussion on tables is given in section 8. Section 9 indicates the future research areas for VRP and author's conclusion on this topic.

3. Multiple-Criteria Methodologies

Perhaps the single most important decision faced by management when dealing with multiple objectives is the selection of an appropriate solution, which optimizes the proposed criteria simultaneously. Therefore, it is hardly surprising that much of the literature in operations research focuses on the Multiple Objective Programming Problems. Today, there are many multi-criteria solution techniques available that can be used to model this problem of vehicle routing problem. Some of the techniques that are most suitable for addressing the problem are: multiple objective linear programming, goal programming, surrogate worth trade-off method, the step method, bi-criterion programming, and multi-attribute decision-making. The review of 81 articles presented in this research with regard to MCDM indicates that the main tools used for solving various classes of VRP are those listed below: (1) Goal Programming; (2) Interactive Goal Programming; (3) Bi-criterion Programming; and (4) Multiple Objective Programming.

Goal programming was originally introduced by Charnes and Cooper in early 1961 for a linear model. It has been extended into many areas including the facility location analysis (Current et al., 1990), public project selection (Colin, 1985), government planning and budgeting (Joiner and Drakke), office management (Bres et al. 1980), insurance industry (Gleason, 1977), and stochastic vehicle routing programming (Zare Mehrjerdi, 1986), transportation network and location (Current et al., 1984), transportation network and routing (Current et al., 1993), transportation location (Current, et al., 1984) VRP with time windows (Calvete et al., 2007), to mention a few. Goal programming is a useful tool for planning because many planning criteria can be expressed in terms of goals. A goal programming model can be solved using one of the many techniques available in the literature as are listed below (Flavell 1976; Ijiri 1965; Lee 1972; Romero 1991; SchneiderJans 1995; Zare Mehrjerdi 1995; Zeleny 1982; Tamiz 1998; Ateuer 1999): (1) Archimedean Goal Programming; (2) Preemptive (Lexicographical) Goal Programming; (3) Partitioning Goal Programming; (4) Multiple Criterion Function Goal Programming; (5) Iterative Goal Programming; (6) Dual Simplex method for Goal Programming; and (7) Revised Simplex method of Goal Programming.

Additionally, one can solve a GP model either regularly or interactively. To solve a GP model interactively, one needs to develop a computer program that can allow the decision-maker as a part of the solution process. Goal programming and interactive goal programming are chosen to solve multi-criterion vehicle routing problem for the following primary reasons: (1) Computationally efficient (Park 1984) and ease of modeling; (2) Concepts can be easily communicated with the decision-makers (Park 1984); and (3) It is flexible enough to address problems in a MCDM format.

In many cases it is necessary to have the decision-maker as a part of the solution process to obtain an end result that is consistent with his/her needs. The fact that any analytic tool is comprised of many iterations therefore having DM as a part of solution process and feeding his/her feedbacks into the process in a straight manner is of primary concern. The original works done in the area of VRP by Park (1984) and Zare Mehrjerdi (1986, 1993, 2013, 2014) are of interactive goal programming type.

As indicated by Jones et al. (2002), the recent decades have seen an increase in the awareness of multiple objectives and the design of multi-objective programming techniques to handle situations where it also is true about the vehicle routing problem. A multi-objective programming problem can be formulated as:

$$\text{Maximize } f_1(x_j) = \sum_{j=1}^n C_{1j} X_j$$

$$\text{Maximize } f_m(x_j) = \sum_{j=1}^n C_{mj} X_j$$

S.t.

$$X \in S$$

In multiple objective programming, we solve the problem and identify a set of non-dominated solutions and then represent those to the decision-maker for final decisions to be made. A good review of multiple objective programming is presented in (Cohon 1979; Deb, 2001, Zeleny 1974). There are few methods available for generating the set of non-dominated solutions in multi-objective programming area. These methods are: (1) Weighting method; (2) ε - constrained method; (3) Phillip's linear multi objective method; and (4) Zeleny's linear multi-objective method. The areas of VRP combined with multi-objectives are studied by Min (1991), Fonseca. (1995), Keller (1985), Lacomme (2003), Daskin(1985), Hall (1994), Kim (2006), Lin(2006), Josefowicz (2007), Baran (2003), Boffey (1995), Bowerman (1995), Corberan(2002), Ehrgott (2000), El-Sherbeng (2001), Josefoweiz (2004, 2005), and Ribeiro (2001) as are listed in the references.

As it was discussed above, there are many other Multi-Criterion solution techniques that can be used to solve a version of a VRP. What is important in problem solving is the result that can be obtained at the end and the level of the effort that must be put into that in order to reach the final solution. A method known as surrogate worth trade-off can also be used to solve a VRP combined with MCDM. Compromise programming (Romero 1998, Yu 1973) which has a common mathematical root with goal programming Zeleny (1974, 1982) can also be used for solving multi-objective VRP.

4. Vehicle Routing Problem by Types

The problem of VRP can be classified into ten categories of: (1) deterministic Vehicle Routing Problem (DVRP), (2) Multi-depot VRP (MDVRP), (3) VRP with time windows (VRPWTW), (4) Stochastic VRP (SVRP), (5) Capacitated VRP (CVRP), (6) Fuzzy VRP (FVRP), (7) Location VRP (LVRP), (8) Facility Location VRP (FLVRP), (9) Backhauling VRP (BHVRP), and (10) Inventory Control VRP (ICVRP). In the sections that follow each of these subcategories are very briefly discussed.

4.1. Deterministic VRP

The basic components of the VRP are a fleet of vehicles with fixed capacities and a set of demands for transporting passengers or certain objects (customer goods, etc.) between specified depot and delivery points. The problem is complicated because managers must also take into consideration a variety of constraints such as fixed vehicle capacity and the duration of the route. The prospective and prospects on VRP are discussed by Magnanti (1981). The concept of VRP has been addressed within the framework of other management science techniques. For instance, Federgruen (1984) discusses a combined knowledge of VRP and inventory problem and Ball et al (1983) discusses planning for truck fleet size in the presence of common-carrier option.

4.2. Vehicle Routing Problems with Time Windows

Vehicle routing problem with time windows are divided into two categories of VRP with hard time windows (VRPHTW) and VRP with soft time windows (VRPSTW). The goal of VRPHTW is to determine the optimal set of routes and the optimal sequence of customers visited by each vehicle, taking into account vehicle capacities, service times and time windows. These time windows are hard constraints when a route is not feasible if the service of any customer does not start within the limits established by the time window. These are Vehicle Routing Problems with Hard Time Windows (VRPHTW) (Calvete, 2007). Comprehensive reviews of these problems are presented in (Tan et al. 2003; Tan et al. 2006; Tan et al., 2003; Van Landeghem 1988). There are cases that both lower and upper bounds of the time window can be violated at a price, for a penalty. These are Vehicle Routing Problems with Soft Time Windows (VRPSTW) (Calvete, 2007). The number of references in VRPSTW is relatively small. Sexton and Choi (Sexton et al. 1986) consider a single-vehicle pickup-and-delivery routing problem where each load has its own origin and its own destination.

4.3. Stochastic VRP

Stochastic Vehicle Routing Problems (SVRP) can be classified into four categories as listed below:

1. Stochastic Customers (Jaillet and Odoni 1988; Jaillet 1987),
2. Stochastic Demands (Bianchi et al. 2004; Bianchi et al. 2006; Dror et al. 1993; Golden and Stewart 1977; Golden and Yee 1979; Haugland 2005; Tan 2007; Tillmand 1969; Tillman et al, 1972; Yee and Golden 1980; Zare Mehrjerdi 1986),
3. Stochastic travel and unload times (Zare Mehrjerdi 1993; Zare Mehrjerdi 1986),
4. Stochastic demands and stochastic travel and unload times (Zare Mehrjerdi, 1986, 2013, and 2014).

In 2004, Bianchi et al (2004) studied vehicle routing problem with stochastic demand using meta-heuristic approaches. In 2006, Bianchi et al (2006) have considered five meta-heuristics of Simulated Annealing; Tabu Search; Iterated Local Search; Ant Colony Optimization and Evolutionary Algorithms to study VRP with stochastic demand. In 2005, Haugland, Ho, and Laporte (2005) studied the delivery districts for the VRP with stochastic demands. Demands are assumed to be uncertain at the time when districts are made, and these are revealed only after the districting decisions are determined.

4.4. The VRP with Backhauls

The VRP with backhauls is an extension of the VRP that includes both a set of customer to whom they should deliver goods and a set of vendors from whom they need to pick up the goods for transporting back to the distribution center. In addition to that, on each route all deliveries have to be made before any goods can be picked to avoid rearranging of the loads on the truck. This is a problem of some concerns to some distribution centers that need to be studied clearly and timely (Jacobs Blecha, 1998).

4.5. Multi Depot VRP

In the MDVRP, each customer may be serviced by a vehicle originating at any of the available depots. Tillman (1969 and 1972) is credited for realizing the probabilistic nature of the customer demand in the scheduling of the multi-depot delivery and collection problems. This is a valuable problem and has been adapted by many industries dealing with the distribution and/or collection of products from one/many location(s) into many/one locations.

4.6. Location Routing Problem

Location routing problem (Negi and Salhi, 2007) is a new research area that has gained the attention of some researchers recently. The LRP is comprised of a research area in the framework of the local analysis while having deep and specific looks at the vehicle routing problem. There are few works done in this area and none is related to the combined topics of location routing problem and multi-objective programming. To obtain a better understanding of the topic one may consult the work of Balakrishnan (1993), Laporte (1992), Berman (1995), and Min (1991).

4.7. Capacitated VRP

Capacitated Vehicle Routing Problem (CVRP) is another subset of the VRP that has attracted the attention of many researchers. In this problem, one has to deliver goods to a set of customers with known demands on minimum cost vehicle routes originating and terminating at a depot. The vehicles are assumed to be homogeneous and having a certain capacity. In some versions of the CVRP, one also has to obey a route duration constraint that limits the lengths of the feasible routes (Tavakkoli-Moghaddam et al.2006 and Tavakkoli Moghaddam et al. 2007).

4.8. Inventory Control/Periodic VRP

The inventory routing problem arises when inventory replenishment considerations are added to the vehicle routing problem. Considering this problem, the timing of deliveries to customers must be determined based on their inventory positions, the replenishment policy, and the routing costs. In problems such as delivery of liquids, gases or fuels to distributors, it is necessary to consider a planning horizon of, say, one week, and then plan to visit that place, for instance, 3 times per week (Sunday, Tuesday and Thursday or Monday, Wednesday, and Friday). This problem is called assignment routing problem or period routing problem. Algorithms for solving the Period Routing problem are suggested by Russell and Igo (1979), and Tan and Beasley (1984).

4.9. Fuzzy VRP

A fuzzy vehicle routing problem is assumed to have the following characteristics (Zhenyu et al. 2003):

1. Each vehicle has a container with a physical capacity limitation and the total loading of each vehicle cannot exceed its capacity;
2. A vehicle will be assigned for only one route on which there may be more than one customer;
3. A customer will be visited by only and only one vehicle.
4. Each route begins and ends at the company site (depot);
5. Each customer specifies its time window within which the delivery is permitted or preferred to start;
6. Travel times between customers are assumed to be fuzzy variables.

Zheng and Liu (2006) studied vehicle routing problem in which the travel times are assumed to be fuzzy variables.

4.10. Facility Location VRP

Due to budget limitation and growths of population and demand, developing countries usually face the

determination of cost effective public facilities taking people most important requirements into consideration. In most of these countries, distance is the most influential factor. This means that distance and transporting mean play an important role in this type of problem development. Taking at least two criteria into consideration, we need to design, develop, and solve a multi-objective facility location vehicle routing problem into consideration. A simple example of this case is the development of a healthcare center in a city or urban area. Doerner (2006) has proposed such a problem for a mobile center using multi-objective routing problem.

5. Solution Methodologies for Combined MCDM and VRP

Solution techniques for the VRP fall into two categories: those which solve the problem heuristically and those which solve the problem optimally. Basically, heuristics techniques have proved to be an attractive alternative to exact methods because they are easy to understand, readily accepted by managers, easy to program and maintain for computerized planning, and effective in solving a wide range of practical problems which provide solutions that are usually accepted as “reasonable”.

The VRP formulation as an integer program is actually the one presented originally by Golden et al. (1997). Balinski and Quandt (1964) formulated the VRP as integer program where it is a representative of a cluster-first, route-second approach to the VRP in which demand points are first assigned to the vehicle clusters and then each vehicle is routed over the demand points assigned to it to determine a delivery sequence. Foster and Ryan (1976) proposed an integer programming formulation of the VRP which is solved using the revised SIMPLEX Method. This method is strictly primal in that both feasibility and integrality are withheld at all stages. An integer programming formulation of the VRP with a planning horizon of more than one day is extended to incorporate the linear constraints.

The solution process for VRP can be divided into (1) one-phase method; and (2) two-phase method. In one-phase method which is usually used in exact solution techniques one can solve the problem by a general mathematical programming model. The model proposed by Dantzig and Ramser (1959) are of this type. Other methodologies belonging to this category involve the use of branch and bound methods (Bard 2002), column generation (Mourgaya et al. 2007; Skitt 1985; and Talliard 1999), and Lagrangian relaxation (Kohl 1997; and Stewart and Golden 1984). For larger problems, researchers usually focus on heuristic and meta-heuristic (tabu search, genetic algorithms, simulated annealing) methods to derive a solution of an acceptable quality in a reasonable computation time (Gendreau 1994; Greistorfer 2003; Hertz 2000; Pacheco 2006; Taillard 1997; Wassan 2002; Tavakkoli-Moghaddam ----; Park 2001; Potvin 1996; Rahoual 2001; and Zhou 2003)

In two-phase method, customers are first assigned to vehicles without specifying the sequence in which customers are visited. In the second phase, routes are obtained for each vehicle using a TSP heuristic. The procedures introduced by Gillett and Miller (1974) and Christofieds and Eilon (1979) are two-phase methods that use a modified Lin-Kernighan heuristic in phase-two. The two-phase method is comprised of two stages of (1) the route construction stage and (2) the route improvement stage as are discussed below. The solution methodology proposed in (Zare Mehrjerdi 1986) for solving the stochastic vehicle routing problem is also of a two-phase method.

5.1. The Route Construction Stage

The RCS of the VRP consists of the problem of partitioning a set of stations into feasible sets of vehicle routes. To deal with the NP-hard type problems and solving those in a manner acceptable to managers only heuristic methods are considered. The RCS of the VRP consists of following steps:

1. Problem formulation in which objective functions and constraints are identified.
2. Transformation of the defined problem into an equivalent deterministic form when demand or time constraints are of probabilistic type, and
3. Partitioning of a set of stations into feasible subsets using an appropriate heuristic approach.

5.2. The Route Improvement Stage

When the arrangement of stations on one route does not exactly or even partially meet the decision maker’s needs, then the route improvement technique needs to be taken into consideration. This stage of the problem is required for sequencing stations on each route for the purpose of meeting customer’s requirements and decision maker’s obligations. Stations on each route are sequenced using an appropriate management science technique. Prior to the utilization of this technique, decision-maker should acknowledge the following information from the route construction stage of the problem.

- Construction routes

- Total demand of each route
- Total expected cost, time or distance for whole delivery system
- Unload and travel times for each route, and
- Number of required vehicles.

6. Meta-heuristics Techniques and VRP

Meta-heuristics have become prominent approaches in tackling complex and multi-objective problems (Jones et al. 2002). Recent examples include a bus driver scheduling problem (Lourenco 2001) and a resource-constrained project scheduling problem (Viana et al. 2000). What are known as meta-heuristics techniques are tabu search, simulated annealing, genetic algorithm, evolutionary algorithm, and Ant Colony Optimization. In the sections that follow, each of these techniques are discussed briefly.

6.1 Tabu search

Tabu Search is a direct searching algorithm for optimizing very complicate problems. This method that is based upon the human memory process generates a list of the latest points that are being investigated. The purpose of this list preparation is the prevention of transformation to the points that have been investigated previously. The tabu search implementations of Taillard (1999) has obtained the best known results to benchmark VRPs. Similar results were reported by various authors using tabu search (Gendreau 1994; Greistorfer 2003; Hertz 2000; Pacheco 2006; Taillard et al. 1997; Wassan 2002), or simulated annealing (Tavakkoli-Moghaddam 2006). Taillard et al. (1997) recognized possible savings allowing multiple uses of vehicles in VR modeling and scheduling. These researchers applied tabu search in a 3-step procedure to design routes with multiple vehicle uses to minimize the total cost of routes. Golden et al (1997) reported on the use of a tabu search based upon the “adaptive memory procedure” for solving a VRP with a Minmax objective.

6.2 Simulated Annealing

A methodology known as simulated annealing has its origin in statistical mechanics (Tavakkoli Moghaddam 2006 and 2007) which draws its concept from the annealing process of solids. The annealing process can be described as heating a solid to high temperature and then cooling that gradually to lower it to crystallize. The process of heating allows the atoms to move randomly. A rapid cooling process gives atoms sufficient time to align themselves to reach a minimum energy state known as “equilibrium” or “stability”. As described in (Czyzak et al. 1998, Tavakkoli Moghaddam 2006 and 2007), this methodology can be used in combinatorial optimizations in which the state of solid corresponds to feasible solution and the energy at each state corresponds to an improvement in the objective function and the minimum energy state will be the optimal solution. Simulated annealing was applied to improve the solution.

6.3 Genetic Algorithms (GA)

Genetic Algorithm is a new optimization technique used mostly for solving nonlinear and very complicated programming problems. This method is based upon the evolution process which has an evolutionary path as a biological path would own. In a simple term, this method by generating various generations (solution sets) of feasible solutions try to move toward the optimal solution point of the problem. Among the modern meta-heuristics, GA is used wide with several applications reported in the area of VRP (Park 2001; Potvin 1996; Rahoual 2001; Zhou 2003) . GA is used for solving the VRP with backhauls, multi-depot routing problem (Tillman 1969, 1972), and school bus driving (Bowerman 1995; Corberan 2002). Baker and Ayechev (2003) put forward a conceptually straightforward genetic algorithm for the basic VRP, which is competitive with other modern heuristics in terms of computing time and solution quality.

6.4 Evolutionary Algorithms

Under the most frequent classification, Evolutionary Algorithms, together with Fuzzy Logic and Neural Networks, is part of the so-called Soft Computing. Evolutionary Algorithms is comprised of Genetic Algorithms, Evolutionary Programming, Evolutionary Strategies and Genetic Programming and some similar techniques. Evolutionary Algorithm may have the following structure (Coello Coello 2002; Tan et al. 2003; Tan et al. 2006; Tan et al. 2007 and Tan and Cheong 2007):

- Search space – space of all possible solutions.
- Population – set of actual candidates for solution; elements of population are called individuals or items, or search nodes, or points in search space.
- String space – space that contains string representations of individuals in population.
- Functions for conversion between points in search space and points in string space (coding and decoding).
- Set of genetic operators for generating new strings (and new individuals).

- Fitness function – it evaluates fitness (degree of adaptation) for each individual in population.
- Stochastic control of genetic operators.

Basic steps in Evolutionary Algorithms are:

1. Initialization (using random sampling to generate initial population).
2. Evaluation (to calculate fitness for all individuals in population).
3. Selection (to choose surviving individuals in population in accordance with the values of fitness function).
4. Recombination (includes crossover and mutation) – to change individual's representation.
5. Repeating steps 1 to 4 until fulfilling finishing criteria.

In multi-objective vehicle routing problems, the Pareto concept is frequently used within an evolutionary framework. Many authors (Coello Coello 2002; Deb 1999; Deb et al. 2002; Jaskiewicz 2003; Jozefowicz 2004; Lacomme 2003; Li 2005; Murata 2005; Paqurte 2003; Sarker 2002; Tan 2003; Tan et al. 2003; Tan and Cheong and Goh 2007; Tan and Chew and Lee 2006; Tan, Lee, Chew and Lee 2003; Tan, Chew and Lee 2006; Van Veldhuizen 1998; Zhenyu 2003; Zitzler 2000; and Deb 2001) have used evolutionary algorithms methods to solve multi-objective routing problems. Some have used evolutionary algorithms with Pareto methods (Li, 2005; and Skitt 1985) to solve the MOVRP as well. Others have employed hybrids based on evolutionary algorithms and local searches, heuristics, and/or exact methods for the considered problem (Bodin 1983; Doerner et al. 2006; Ehrgott 2000; Jozefowicz et al. 2005; Jozefowicz et al. 2006; Lacomme 2003; Sessomboon et al. 1998; Tan et al. 2003). Pareto dominance has also been used by El-Sherbeny (El-sherbeny 2001) in a simulated annealing technique called Multi-Objective Simulated Annealing (MOSA) while Paquete et al. (2003, and 2004) have called upon Pareto Local Search techniques. These techniques are based on the principle that the next current solution is chosen from the non-dominated solutions of the neighborhood.

6.5 Ant Colony Optimization

There are some researches that report the application of Ant Colony (AC) in the combinatorial optimization (Bell and McMullen 2004; Baran 2003; Chitty et al. 2004; Donati 2007; Gambardella et al. 1999; and Martinez et al. 2007)

These published works have reported successful applications. Baker and Ayechev (2003) pointed that with a 2-opt heuristic applied to improve individual routes produced by artificial ants this approach provided results which are only slightly inferior to those from tabu search. Baran and Schaerer (2003) do not use a standard multi-objective approach for solving multi-objective VRP. They had considered the reality of dealing with the problem of multiple objective nature using appropriate mechanisms in the ant colony system being proposed. Chitty and Hernandez (2004) reported an ant colony system adapting bi-objective situation considering total mean transit time and the variance in the transit time. Pareto Ant Colony Optimization (PACO) is a multi-objective meta-heuristic approach used by Doerner et al (2006) for solving the location-routing problem with several objective functions.

6.6. Hybrid Algorithm

A techniques that is known as hybrid algorithm combines one or more of meta-heuristics techniques along with an optimization or heuristic technique that can solve the problem accurate, fast and easy. A two-stage hybrid algorithm for pickup and delivery vehicle routing problems with time windows and multiple vehicles is studied by Bent et al (2006). In the first stage, a simple simulated annealing algorithm is used for decreasing the number of routes while the second stage uses large neighborhood search for decreasing total travel cost. Studies on VRP and LRP (Bres et al. 1980) suggests that building hybrid meta-heuristics, like tabu search and simulated annealing, helps to combine their best features to gain the best results possible. A hybrid approach to vehicle routing using neural networks and GA has also been reported (Potvin 1996). A hybrid heuristic which incorporates neighborhood search into GA is also considered.

7. Data Classification and Analysis

In the following sections we will classify the data into nine tables as listed below:

Table 1- Presents the list of works published on the VRP combined with MCDM methodology by solution methodologies

Table 2- Presents the list of works published on the VRP combined with MCDM methodology by solution methodologies

Table 3- Presents the list of works published on the VRP combined with MCDM methodology by VRP classifications

Table 4- Presents the list of works published on the VRP combined with MCDM methodology for important

cases

Table 5- Presents sample objective functions used in VRP areas by researchers

Table 6- Presents the sample objective functions used by practitioners

Table 7- Presents publications classifications by type of research

Table 8- Presents publications classifications by publications Journal

Table 9- Presents publications classifications by MCDM.

Table 1 presents the list of 81 articles by the names of authors and the years of publications starting from 1984. This class of researches was started by the work of Park (1984) in the department of Industrial Engineering and Management at Oklahoma State University and then followed by the work of Keller (1985 and 1988), Current (1985), Daskin (1985), Zare Mehrjerdi (1986, 1993, 2013 2014) and Park and Keolling (1986 and 1989) . Most of these researchers started their works with the interactive goal programming as a tool for solving VRP with more than one objective functions. For the first time, a VRP with more than one objective functions was solved by Zare Mehrjerdi where demand, travel time and unload time were assumed to be random variable with known distribution functions.

Table 2 shows the list of works published on the VRP combined with the MCDM methods and by solution methodologies. Generally speaking, multiple objective vehicle routing problems are solved using one or more of the techniques of tabu search, genetic algorithm, simulated annealing, evolutionary algorithm, heuristic methods, Pareto method, meta-heuristics, and hybrid heuristics. Table 3 shows the list of works published by the names of the authors combined with the MCDM methodologies and by VRP classified into ten categories of VRP, SVRP, FVRP, VRPWTW, CVRP, LRP, FLVRP, BHVRP, MDVRP, and ICVRP.

Table 4 shows the list of works published on the VRP combined with the MCDM methodologies for important cases such as Library Distribution System, Control Engineering Problem, Truck and Trailer VRP, School Bus routing problem, Bus Driver Scheduling Problem, Waste Collection VRP with Time Windows, Location Routing Problem, Transit Vehicle Scheduling, Traffic Light Network, Urban School Bus Routing, Rural School Bus Routing, Mobile Health Care Facility Tour Planning, and Belgian Transportation Company as reported in the literature of Operations Research and VRP. Tables 5 and 6 list the most important objective functions taken into consideration in the problem formulation of the multiple objective vehicle routing problems.

According to table 7, of 81 articles researched, only 6 are Ph.D. dissertations, 11 are conference articles, 13 are published as a chapter of a book and 50 are published as research articles in scientific journals. Table 8 shows the publications classification by publications Journals. This author has found that about 29 percent of these research articles are published by the European Journal of Operational Research, 5 percent by the Computers and Operations Research Journal and 4 percent by the Transportation Science Part A journal. Table 9 shows that in most of the published articles, heuristics and genetic algorithms have been chosen for solving multi-criterion problems of VRP types. The same table also shows the distribution of published works by multi-criteria tools.

Table 1. List of works published on the VRP combined with MCDM methodology

Year	Author	Characteristics of the Problem
1984	Park, Y.B.	VRP, single depot, deterministic, interactive goal programming.
1985	Keller, C.P.	VRP with time window, Multiple objective programming.
1985	Current, J.R., et al.	General Transportation, Network, Multiple Criteria programming.
1985	Daskin, M.	VRP, multiple Objective, Stochastic, Multiple Modes.
1986	Zare Mehrjerdi, Y.	SVRP review, single depot, stochastic programming, goal programming.
1986	Park, Y.B. and Keolling, C.P.	VRP, single depot, deterministic, interactive goal programming.
1987	Solommon	VRP with time windows
1988	Van-Landeghen	VRP with time windows, Bicriterion programming.
1988	Ronen, D.	VRP, Truck Routing and Scheduling, Multiple Objective Programming, Genetic Algorithm, Software design.
1988	Keller, C.P.	TSP, Lexicographical Method, Heuristics.
1989	Park, Y.B., et al.	VRP with Time Windows, single depot, deterministic, interactive goal programming
1990	Sutchiffe and Board	VRP, Bicriterion programming.
1991	Min, H.	VRPTW, deterministic, goal programming, a case study of Library distribution system in Franklin County Ohio.
1992	None	None
1993	Zare Mehrjerdi	SVRP, single depot, stochastic demand, stochastic load and unload times, Multiple Objective goal programming, chance constraint programming
1994	None	None
1995	Fonseca, C.M.	VRP, Multiple Objective Programming, Control Engineering Problem.
1995	Fonseca, C.M.	VRP, Multiple Objective Programming, Control Engineering Problem.
1995	Bowerman, R.	Rural School Bus Touting, Multiple Objectives, Aggregation, Heuristics.

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1995	Boffey, B.	VRP, Multiple objective programming.
1995	Ulungu...	VRP, Combinatorial Optimizations, Bicriterion programming, Two phase methods.
1996	Shang, J.S., Cuff,C.	VRP, Multiple Objective programming, minimizing Vehicle expenses, Minimizing Tardiness and travel times.
1997	Golden, B., et al.	VRP, Minmax Objectives, Capacitated VRP, Tabu Search.
1998	Sessomboon, W.,	VRP with time windows, Pareto Approach, Bicriterion programming.
1998	Czyzak, P.	VRP, multiple objective programming, Simulated Annealing
1998	Van-Veldhuizen	VRP, Multiple objective programming, Evolutionary Algorithm.
1998	Gainnikor, ...	Location Routing Problem, Goal Programming, Hazardous Management.
1998	Lee and Ueng...	VRP, Aggregation, Minimize the traveled distance.
1999	(Hong, S.C.)	VRP with time windows, Bicriterion Programming
2000	Viana, A.	VRP, Multiple objective programming, metaheuristics
2000	Talbi, E.G	VRP, Multiple objective, Sample problems.
2000	Ehrgott,...	VRP, Approximation Algorithms, Multiple objectives.
2001	Rahoual, M.	VRP with time windows, Multi-Criterion Genetic Algorithm
2001	Lourenco,	VRP, Bus driver scheduling problems, multiple objective Metaheuristics
2001	Jaszkiwicz	VRP, Multiple objective and Genetic Algorithm.
2001	El-Sherbeny,	VRP, Simulated Annealing, Pareto Approach, Multiple objective Programming.
2001	Geiger...	VRP with time windows, Multiple Objective Programming, Pareto Approach.
2001	Ribeiro,	VRP, Multi-Period VRP, Aggregation, Multiple Objective Programming.
2002	Corberan, A.	VRP, School bus scheduling, Multiple objective programming, Heuristic
2002	Sarker, R.	VRP, Multiple objective programming, Evolutionary algorithm.
2002	Borges, P.C.	TSP, Multiple Objectives.
2002	Corberan,	Rural School Bus routing, Multiple Objectives, \mathcal{E} - Constraint approach.
2002	Jaszkiwicz	VRP with route Balancing, Goal programming, Tabu Search.
2002	Jozefowies,	VRP, parallel modeling, Hybrid modeling, Multiple objectives.
2003	Lacomme, P.	VRP, Multiple objective programming
2003	Tan, K.C.,	Truck and Trailer VRP, hybrid multiple objective evolutionary algorithms
2003	Tan, K.C.	VRP with time window, deterministic, Multiple Objective Evolutionary Algorithm.
2003	Lau, H.C., et al.	VRP with Time Windows, Tabu Search, Multiple Objectives, Heuristics.
2003	Chen, Y., et al.	Shortest path with time windows, Traffic Light, bi-criterion.
2003	Zhuo, G., et al.	VRP, Allocation, Genetic Algorithms, Bi-Criterion.
2003	Baran, B.	VRP with time windows, Ant Colony Systems, Multiple Objectives.
2003	Geiger...	VRP, Genetic Algorithm, Goal programming.
2003	Paquete...	TSP, Aggregation, Multiple Objective Programming.
2003	Zhenyu,...	TSP, Genetic Algorithms, Pareto Approach, Multiple Objective Programming.
2004	Angel E. et al	TSP, Multiple Objective Programming, Local Search.
2004	Jozefowicz ..	VRP modeling, Evolutionary Algorithms, Multiple Objective.
2004	Zografos,	VRP with time windows, Heuristics, Aggregation, Multiple Objective Programming.
2004	Chitty, et al	VRP, dynamic VRP, Ant Colony optimization, bi-objective modeling.
2004	Mourgaya	VRP, Multiple Period, Heuristics, Multiple objectives.
2004	Jozefowicz ...	VRP, evolutionary algorithms, Applications, Multiple objectives.
2004	Paquete	TSP, Pareto Local Optimum, Bicriterion programming.
2005	Jozefowicz .	VRP, tour balancing, Applications demonstrations.
2005	Li, ...	TSP, Heuristics, Bicriterion programming.
2005	Murata,	VRP, Genetic Algorithms, Multiple Objective Programming, Pareto Search.
2005	Riera-Ledesma ,	TSP, Aggregation
2006	Lacomme, P.	VRP with time windows, bicriterion Genetic algorithms.
2006	Kim, B., et al.	VRP with time windows, Waste Collection, Capacitated VRP, Multiple Objective, Arc routing, Clustering.
2006	Lin, C.K.Y., et al.	VRP, Logistics, Multiple Objectives, Metaheuristics.
2006	Doerner,	Mobile health care facilities tour planning, Multiple objectives Programming, Ant Colony Optimization.
2006	Jozefowicz .	VRP, route balancing, Pareto search.
2006	Ombuki,	VRP with time windows, Genetic Algorithms, Multiple objective programming, Weighted sum.
2006	Pacheco,	Rural School Bus routing, \mathcal{E} - constrained Method, Multiple Objectives Programming.
2006	La Commet et al	VRP, Capacitated VRP, Genetic Algorithms, Multiple Objectives.
2007	Herminia, I.	VRP with soft time windows, Goal programming
2007	Zare Mehrjerdi	VRP, Chance Constrained Programming, goal programming,
2007	Zare Mehrjerdi	VRP, Chance Constrained Programming, goal programming, theory and developments for approximations
2007	Calvete, H.I., et al.	VRP with soft time windows, Multiple Objective, Goal programming, Logistics.
2007	DaSilva, C.G., et al	VRP, Bi-criteria, Exact Methods, Metaheuristics, Combinatorial Optimization.
2007	Martinez, C.G., et al	TSP, Ant Colony, multiple Objective Optimization, Evolutionary Algorithms.
2007	Donati, A.V., et al.	VRP, Multi-objective, Ant Colony System , Hierarchical objectives.
2007	Josefowicz, N., et al	VRP, Multiple Objective programming.
2007	Mourgaya, M., et al	VRP, Combinatorial Optimization, Bi-Objectives.
2007	Murata,	VRP, Genetic Algorithms, Multiple Objective Programming, Pareto Search.

Table 2. List of works published on the VRP combined with MCDM methodology by Solution Methodologies

Solution Methodologies	Authors
Goal Programming & VRP	Zare-Mehrjerdi, Y.(2007), Zare-Mehrjerdi, Y.(2007), Herminia (2007), Calvete, .I., et.al.(2007), Geiger (2003), Giannikor(1998), Jaskiewicz(2002).
Interactive-Goal Programming & VRP	Park, Y.B. (1984), Park, Y.B. and Keolling(1985), Zare Mehrjerdi (1986).
Bi-Criterion Programming & VRP	Van-Landeghen (1988), Lacomme, P.(2006), Sessomboon, W.(1998), Chen, Y., et. Al. (2003), Mourgaya, M., et al. (2007), Ulungu (1995), Sutcliffe et al.(1990), Hong, S.C. and Park, Y.B.(1999), Zhou, G, et.al.(2003), DaSilva, C.G, et.al.(2007), Josefoweiz (2007).
Multiple-Objective Programming	Min, H.(1991), Fonseca, C.M.(1995), Keller, C.P.(1985), Lacomme, P.(2003), Daskin, M.(1985), Hall, G.B. et al. (1994), Kim, B., et al.(2006), Lin, C.K.Y., et.al(2006), Josefowicz, N., et.al.(2007), Baran, B.(2003), Boffey, B.(1995), Bowerman, R.(1995), Corberan(2002), Ehrgott(2000), El-Sherbeng(2001), Josefoweiz (2004), Josefoweiz (2005), Ribeiro(2001).
Multiple Objective Programming (Simulated Annealing) & VRP	Czyzak, P.(1998), El-Sherbeny(2001).
Multiple Objective Programming (Evolutionary Algorithms) & VRP	Tan, K.C.(2003), Tan, K.C.(2006), Tan, K.C.(2006), Sarker, R.(2002), Van-Veldhuizen(1998), Martinez, C.G., et.al.(2007), Josefoweiz (2004).
Multiple Objective Programming (Genetic Algorithms) & VR	Ombuki(2006), Lacomme, P.(2006), Jaskiewicz(2001), Rahoual, M.(2001), Fonseca, V\ C.M.(1995), Ronen, D. (1988), Zhou, G, et.al.(2003), geiger (2003), Murata(2005, 2007), Ombuki(2006), Seasomboon(1998), Zhenyu (2003), LaCommet et.al.(2006).
Multiple Objective Programming (Tabu Search) & VRP	Jaskiewicz (2002), Golden, B. et al.(1997), Lau, H.C., et.al.(2003), Pacheco(2006).
Multiple Objective Programming (Heuristics) & VRP	Park, Y.B. and Kelloing(1986), Zare Mehrjerdi (1993), Lau, H.C. et al.(2003), Zografos(2004), Mourgaya(2004), Corberan, A.(2002), Ronen, D.(1988), Min, H.(1989), Hall, G.B., et al.(1994), Bowerman, R.(1995), Keller (1985), Keller(1988), Li(2005).
Multiple objective Programming (Hybrid Heuristics) & VRP	Josefoweiz (2002), Tan, K.C.(2003), Seasomboon(1988).
Multiple Objective Programming (Pareto) & VRP	Geiger(2001), Josefoweiz (2006), Murata(2005, 2007), Paquete(2004), Seasomboon(1987), La Commet, et.al(2006).
Multiple Objective Programming (Metaheuristics) & VRP	Lin, C.K.Y.(2006), Lourenco(2001), Viana, A.(2000), DaSilva, C.G(2007).
Other Multi-Criterion Techniques & VRP	Golden, B. et al.(1997), Donati, A.V.et.al.(2007)

Table 3. List of works published on the VRP combined with MCDM methodology by VRP Classifications

Solution Methodologies	Authors
MOP and deterministic VRP	Park, Y.B.(1984), Park, Y.B. and Keolling, P.C.(1986, 1989)
MOP and Stochastic Demand VRP	Zare Mehrjerdi (1986), Tan, K.C.(2007),
MOP and Stochastic Time and demand VRP	Zare Mehrjerdi (1986, 1993, 2007),
MOP and Multi-Period VRP	Mourgaya (2004)
MOP and Backhauling VRP	Min, H.(1989), Shange, J.et.al.(1996)
MOP and VRP with Time Window	Tan, K.C.(2003), Van-Landeghen(1988), Hong, S.C., and Park, Y.B. (1999), Sessomboon, W.(1998), Herminia, I. (2007), Rahoual, M.(2001), Lau, H.C. et.al.(2003), Kim, B. et.al.(2006), Calvete, H.I., et.al.(2007), Chen, Y., et al. (2003), Baran, B.(2003), Geiger (2001, 2003), Ombuki (2006), Rahoual(2001), Solomon(1987),
MOP with Capacitated Vehicle Routing Problem	Golden, B. et.al.(1997), La Comment et.al.(2006), Kim, B. et al.(2006)
MOP and Location VRP	Lin, C.K.Y.(1965), Giannikor (1998)
MOP and Facility Location VRP	Doerner (2006)
Others (MOP and Fuzzy VRP, MOP and Multi-depot VRP, and MOP and Inventory control VRP)	None

Table 4. List of works published on the VRP combined with MCDM methodology for important cases

Important Cases/ Problems Solved	Authors
Library Distribution System	Min, H.(19910)
Control Engineering Problem	Fonseca, C.M.(1995)
Truck and Trailer VRP	Tan, K.C.(2003)
School Bus routing	Corberan, A.(2002)
Bus Driver Scheduling Problems	Lourenco(2001)
Waste Collection VRP with Time Windows	Kim, B. et.al(2006)
Location Routing Problem	Lin, C.K.Y.(2006)
Transit Vehicle Scheduling	Wanh, H.(2007)
Traffic Light Network	Chen, Y.et.al(2003)
Urban School Bus Routing	Bowerman R.(1995)
Rural School Bus Routing	Corberan (2002)
Mobile Health care Facility Tour Planning	Doerner(2006)
Belgian Transportation Company	El-sherbeny
Rural School Bus Roating	Pacheco (2006)

Table 5. Sample of objective functions used in VRP

Minimize the traveled distance	Maximize the realization of the urgent queries
Minimize the merchandise deterioration	Maximize the capacity utilization
Maximize the equalization of the vehicle travel times	Optimize the balance of the load
Maximize the customer satisfaction	Minimize the number of vehicles
Optimize the balancing (numbers of visited customers)	Minimize the total mean transit time
Minimize the total variance in transit time	Maximize profit
Minimize the total customer waiting times	Minimize the total travel times
Minimize the total deviations from the time windows violations	

Table 6. Sample of objective functions used by Practitioners

Minimize the total length	Minimize the student walking distance
Optimize the balance of the load	Minimize the total cost
Minimize the total perceived risk	Minimize the individual perceived risk
Minimize the individual disutility	Minimize the total time
Minimize the waiting times	Minimize the number of trucks
Minimize the number of covered trucks	Maximize the flexibility
Minimize the number of unused working hours	Optimize the regionalization (clustering) of the customers
Minimize the ineffectiveness of the personnel	Minimize the average distance for an inhabitant to walk
Maximize the size of the population covered	

Table 7. Publications Classifications by type of research

Journal or Type of Distribution	Number of Works	% of Total
Ph.D. Dissertation	6	7.4%
Master of Science Thesis	0	0
Conference Articles	13	16.0
Journal Articles	50	61.7
Technical Report – University level	1	1.2
Published as a Chapter of a Book	11	13.6
Total	81	100%

Table 8. Publications Classifications by publications Journal

Name of Journals carried such publications	Number of Works	% of Total
1) European Journal of Operational Research	23	28.4%
2) Computers and Operations Research	4	4.9
3) Transportation Science Part A	3	3.7
4) Operations Research Society	2	2.5
5) International Journal of Production Economics	2	2.5
6) Computers and Industrial Engineering	2	2.5
7) Transactions of the Japan Society of Mechanical Engineering	2	2.5
8) Theoretical Computer Science	1	1.2
9) TOP	1	1.2
10) Multi-Criteria Decision-Making	1	1.2
11) International Journal of Operations Research	1	1.2
12) Journal of Heuristics	1	1.2
13) Environmental and Planning B: Planning and Design	1	1.2
14) Socio-Economic Planning Science	1	1.2
15) Applied Intelligence	1	1.2
16) Engineering Costs and production Economics	1	1.2
17) Foundations of Computing and Decision Sciences	1	1.2
18) Journal of Industrial Engineering International	1	1.2
19) Discrete Optimization	1	1.2
20) Others	31	38.3
Total	81	100%

Table 9. Publications Classifications by Multi-Criterion Techniques

Rows	Multi-Criteria Tools	Number of Works Published
1	Bicriterion Programming	11
2	Goal Programming	7
3	Interactive Goal Programming	4
4	Multi-Objective Programming	18
5	Multi-Objective Heuristics	13
6	Multi-Objective Meta-heuristics	4
7	Multi-Objective & Genetic Algorithm	13
8	Multi-Objective and Tabu search	4
9	Multi-Objective & Simulated Annealing	2
10	Multi-Objective & Evolutionary Algorithm	7
11	Hybrid Multi Objective & Heuristic Algorithm	3
12	Multiple Objective and Pareto	6
13	Other Multiple objective methods	2

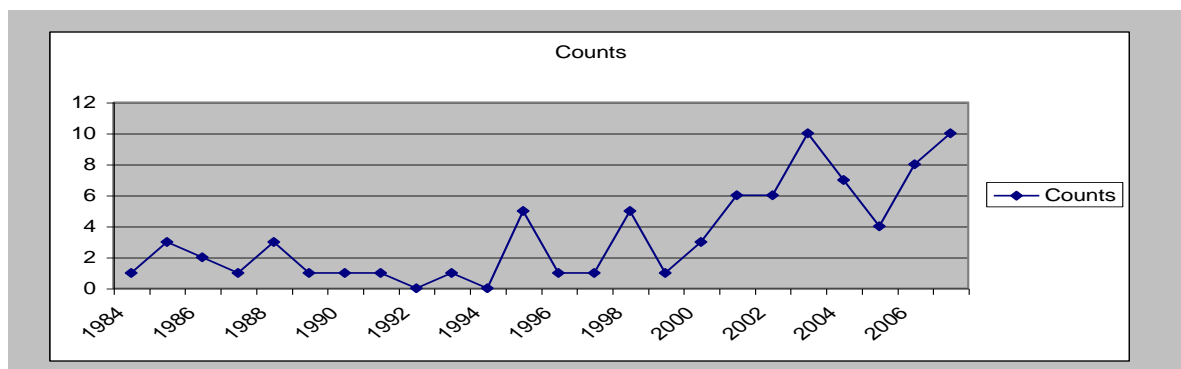


Figure 1. Distribution of publications by years of publications

8. Future Research and Conclusion

Figure 1 shows that although up to year 2000 there were not too many researches reported in the multiple objective VRP, since that time the trend is upward and hopefully it will continue likewise. The area that is relatively rich with research in multi-criterion technique is VRP with time windows. Another area that has received more attention is multi-objective programming VRP using genetic algorithms and heuristics to solve the problem. With the present research, I have come to this conclusion that there are many untapped areas in various subsets of VRP that require the attention of researchers. The most important areas that need more attention are:

1. Fuzzy vehicle routing problem
2. Location routing problem
3. Capacitated vehicle routing problem
4. Facility location vehicle routing problem
5. Multi-period vehicle routing problem
6. Backhauling vehicle routing problem
7. Stochastic vehicle routing problem

Each of these VRP subsets can be considered in the mathematical modeling of the problem and then by proposing an appropriate exact or heuristic solution technique the problem can be solved.

Due to the fact that we are looking at eleven different types of VRP and all multi-criterion decision-making tools, in this research we expect to see more than 77 cases that are of interest to us. These cases are shown in table 10. The cross sign of X is used to show where there exist untapped areas that need more attention from researchers. From table 10 it can be seen that of these 77 areas of research, only 17 areas are being fully or to some degree taken into consideration. Other areas are either untapped or barely touched by researchers.

Table 10. Problem Classification by VRP types and Multi-Criterion Techniques

Types of VRP Problems	Goal Program.	Interactive Goal Program.	Bi-Criterion Program.	Multi-Objective Program.	Compromise Program.	Surrogate Worth Trade-off Method	Other Multiple Objective Methods
VRP					*	*	*
SDVRP (1)			*		*	*	*
SOTVRP (2)			*		*	*	*
VRPWTW					*	*	*
FVRP	*	*	*	*	*	*	*
CVRP	*	*	*	*	*	*	*
LRP	*	*	*	*	*	*	*
FLVRP	*	*	*	*	*	*	*
BHVRP	*	*	*	*	*	*	*
MDVRP	*	*	*	*	*	*	*
ICVRP	*	*	*	*	*	*	*

(1) Stochastic Demand VRP (SDVRP)

(2) Stochastic Demand and Travel and unload times VRP (SOTVRP)

In this article author viewed all references related to the topics of multi-criterion (goal programming, multiple objective linear and nonlinear programming, bi-criterion programming, multi-attribute decision-making, compromise programming, etc.) and various branches of vehicle routing problem such as deterministic VRP (DVRP), MDVRP, VRPWTW, VRP with stochastic demand (SDVRP), VRP with stochastic travel and unload times (STVRP), CVRP, FVRP, LRP, FLVRP, and ICVRP. Although VRP is a research area with powerful

researcher hands on, only 81 articles are found that relate various vehicle routing problems with various multiple objectives techniques. This author has found that no research was done in some of the areas of VRP such as FVRP, ICVRP, LRP, and CVRP. It was interesting to notice that this research area has not been able to attract one researcher at the Master of Science level to do a master thesis (zero research reported in the literature.) On the other hand, it was attractive to the Doctoral Students to some level only (6 researches reported in this case.) Among the many multi-criterion programming techniques available, only three of them (i.e., goal programming, bi-criterion programming, linear, and nonlinear multi-objective programming) are being employed to solve the problem.

In conclusion, with this research we will be able to dig into all untapped areas of VRP combined with MCDM that are of many values to both researchers and practitioners. This review indicates that VRP combined with MCDM is still a developing area of combinatorial optimization. We hope that the challenges posed here will arouse the interest of some researchers and readers and direct them in working on this challenging research area. In addition to all those discussed above a combination of Radio Frequency Identification technology (RFID) with various types of routing and inventory problems and supply chain management can be of the demand in the future. More on RFID topics can be seen from the work of Zare Mehrjerdi (2008; 2009; 2010; 2011a; 2011b; 2011c; 2012; 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2014) and Ruta et al. (2010). Moubed and Zare Mehrjerdi (2015) have modeled a reverse supply chain problem as an inventory-routing problem.

References

- Angel, E., E. Bampis and L. Gourvès, 2004, "Approximating the Pareto curve with local search for the bi-criteria TSP (1, 2) problem", *Theoretical Computer Science* 310 (2004), pp. 135–146.
- Bacopulas, A., and I.Singer, "On Convex Vectorial optimization in Linear Spaces" *Journal of Optimization Theory and Applications*, Vol. 21, (1977) pp.175-188.
- Baker, B.M., Ayechev, M.A., 2003 "A Genetic Algorithm for the Vehicle Routing Problem", *Computers and Operations Research* 30, PP.787-800.
- Balakrishnan, N., 1993, "Simple Heuristics for the Vehicle Routing Problem with Soft Time Windows", *Journal of the Operational Research Society* 44, PP. 279–287.
- Balinski, M.L. and R.E. Quandt, 1964, "On an Integer Operations Program for a Delivery Program," *Operations Research* 12, PP.300-304.
- Ball, M., B., Golden, A., Assad, and L. Bodin "1983, Planning for Truck Fleet Size in the Presence of a Common-Carrier Option", *Decision Science* 14, 103-120.
- Bard, J.F., G. Kontoravdis and G. Yu, 2002, "A branch-and-cut procedure for the vehicle routing problem with time windows", *Transportation Science* 36, pp. 250–269.
- Bell, J. and McMullen, R., 2004, "Ant Colony Optimization Techniques for the Vehicle Routing Problem", *Advanced Engineering Informatics* 18, PP.41-48.
- Barán, B., M. Schaefer, 2003, "A multi-objective ant colony system for vehicle routing problem with time windows", in: *Proceedings of the Twenty-first IASTED International Conference on Applied Informatics*, pp. 97–102, 2003.
- Bent, R., Hentenrych, P.V., 2006, "A two-Stage hybrid for Pickup and Delivery Vehicle Routing Problems with Time Windows", *Computers and Operations Research* 33, PP.875-893.
- Berman, O., Jaillet, P., Simchi-Levi, D., 1995, "Location-Routing Problems with uncertainty" In: Drezner, Z. (Ed.), *Facility Location: A Survey of Applications and Methods*, Springer, New York, pp.427-452.
- Bianchi, L., et al., 2004, "Meta-heuristics for the Vehicle Routing Problem with Stochastic Demands", *PPSN, VIII, LNCS* 3242, PP.450-460.
- Bianchi, L., et al., 2006, "Hybrid Meta-Heuristics for the Vehicle Routing Problem with Stochastic Demands", *Journal of Mathematical Modeling and Algorithms*, PP.91-110.
- Bodin, L.D., 1979, "A Taxonomic Structure for Vehicle Routing and Scheduling problems," *Computers Urban Society* 1, PP.11-29.
- Bodin, L., Golden, B., Assad, A., and Ball, M., 1983, "Vehicle Routing and Scheduling", *Computer and Operations Research*, 10, 1983, PP. 67-211.
- Boffey, B., 1995, "Multi-objective routing problems", *Top* 3 (1995), pp. 167–220.
- Borges, P.C., and M.P. Hansen, 2002, "Essays and surveys in metaheuristics, chapter A study of Global Convexity for a Multiple Objective Traveling Salesman Problem", *Kluwer Academic Publishers, Norwell* (2002) pp. 129–150.
- Bowerman, R., B. Hall and P. Calamai, 1995, "A multi-objective optimization approach to urban school bus routing: Formulation and solution method", *Transportation Research Part A* 29 (1995), pp. 123–197.
- Bres, E.S., D., Burnes, A. Charnes, and W.W.Cooper, "A Goal Programming Model for Planning Office Accessions", *management Science* 26, 1980, pp.773-783.
- Buxery, G., 1979, "The Vehicle Scheduling Problem and Monte-Carlo Simulation" *Journal Of Operations Research*

Society 30, PP.563-573

Calvete, H.I., Carmen Galé, María-José Oliveros, and Belén Sánchez-Valverde, 2007, "A Goal programming approach to vehicle routing problems with soft time windows", *European Journal of Operational Research* 177, PP.1720-1733.

Chaing, W.C., R. Russell, "Simulated Annealing Meta-Heuristics for the Vehicle Routing Problem with Time Windows", *An Operations Research*, 93, PP.3-27.

Charnes, A., and Cooper, W.W. "Management Models and Industrial Applications of Linear Programming", Wiley, New York, 1961.

Chitty, D.M., and M.L. Hernandez, A hybrid ant colony optimisation technique for dynamic vehicle routing. In: K. Deb et al., Editors, GECCO 2004, Lecture Notes in Computer Science vol. 3102, Springer-Verlag (2004), pp. 48–59.

Chen, Y., and Yang, H., 2003, "Minimization of Travel time and weighted number of steps in a Traffic Light Network", *European Journal Of Operational Research* 144, PP.565-580.

Christofides, N. and Eilon, S., 1979, "The Vehicle Routing Problem", *Combinatorial Optimization*, New York: Wiley.

Christofides, N., Eilon, S., 1972, "Algorithms for Large Scale TSP", *Operational Research Quarterly*, 23, PP.511-518.

Clarke, G., Wright, J. W., 1964, "Scheduling of Vehicle from a Central Depot to a Number of Delivery Points", *Operations Research*, 12, PP. 568-581.

C.A. Coello Coello, D.A. Van Veldhuizen and G.B. Lamont, "Evolutionary algorithms for solving multi-objective problems", Kluwer, New York (2002).

C.A. Coello Coello, "An updated survey of GA-based multiobjective optimization techniques", *ACM Computing Surveys* 32 (2000) (2), pp. 109–143.

Corberan, A., Fernandez, E., Laguna M., Marti, R., 2002, "Heuristic Solutions to the Problems of Routing School Buses with Multiple Objectives", *Journal of Operational Research Society* 53, PP.427-435.

Cook, M. T., and Russell, R. A., 1978, "A Simulation and Statistical Analysis of Stochastic Vehicle Routing with Timing Constraints", *Decision Science*, 9, PP. 673-687.

Cordeau, J.F., G. Laporte and A. Mercier, 2001, "A Unified Tabu Search Heuristic for Vehicle Routing problems with Time Windows", *Journal of the Operational Research Society* 52, PP. 928–936

Current, J.R., and D.A. Schilling, The median tour and maximal covering tour problems: Formulations and heuristics, *European Journal of Operational Research* 73 (1994), pp. 114–126.

Current, J.R., Velle, C.S.Re, and Cohon, J.L., 1985, "The Maximum Covering/Shortest Path Problem: A Multi objective Network Design and Routing Formulation", *European Journal of Operational Research* 21, PP.189-199.

J. Current and M. Marsh, Multi objective transportation network design and routing problems: Taxonomy and annotation. *European Journal of Operational Research* 65 (1993), pp. 4–19.

J. Current and H. Min, Multi objective design of transportation networks: Taxonomy and annotation. *European Journal of Operational Research* 26 (1986), pp. 187–201.

J. Current, H. Min and D.A. Schilling, Multi objective analysis of facility location decisions. *European Journal of Operational Research* 49 (1990), pp. 295–307.

J. Current, C. ReVelle and I. Cohon, The application of location models to the multi objective design of transportation networks. *Regional Science Review* 14 (1984), pp. 1–23.

Czyżak, P., and A. Jaskiewicz, 1998, "Pareto simulated annealing—a Metaheuristic Technique for Multiple-objective combinatorial optimization", *Journal of Multi-Criteria Decision Analysis* 7, pp. 34–37.

Dantzig, G.P., J.H. Ramser, 1959, "The Truck Dispatching Problem", *Management Science* 6, PP.80-91.

Da Silva, G.C., Figueira, J., Climaco, J., 2007, "Integrating Pareto Optimization with Scatter Search for Solving Bi-Criteria {0, 1} Knapsack problems", *European Journal of Operational Research* 177, PP: 1656-1677.

Daskin, M., 1985, "Logistics: An Overview of the State of the Art and Perspectives on Future Research", *Transportation Research Part A* 19, PP: 383-398.

K. Deb, Multi-objective genetic algorithms: problem difficulties and construction of test problems, *Evolutionary Computation* 7 (1999) (3), pp. 205–230.

K. Deb, A. Pratap, S. Agarwal and T. Meyarivan, A fast and elitist multi-objective genetic algorithm NSGA-II, *IEEE Transactions on Evolutionary Computation* 6 (2002) (2), pp. 182–197.

Desrochers, M., J. Desrosiers and M. Solomon, 1992, "A New Optimization Algorithm for the Vehicle Routing Problem with Time Windows", *Operations Research* 40, PP. 342–354.

Desrosiers, J., F. Somis and M. Desrochers, 1984, "Routing with Time Windows by Column Generation", *Network* 14, PP.545-565.

Doerner, K., A. Focke and W.J. Gutjahr, 2006, "Multicriteria tour planning for mobile healthcare facilities in a developing country", *European Journal of Operational Research* (2006).

Donati, A.V., Montemanni, R., Norman, C., Rizzoli, A.E., Gambardella, L.C., 2007, "Time Dependent Vehicle Routing Problem with a Multi Ant Colony system", *European Journal of Operational Research* 2007 (in press)

Dror, M., Laporte, G., 1993, "Vehicle Routing with Stochastic Demands and Restricted Failures", *Zeitschrift Fur Operations Research*, 37, PP.273-283.

Dror, M., Trudeauau, P., 1986, "Stochastic Vehicle Routing with Modified Savings Algorithms", *European Journal of*

Operational research 23, PP. 228-235.

M. Ehrgott and X. Gandibleux, Multiobjective combinatorial optimization. In: M. Ehrgott and X. Gandibleux, Editors, International series in operations research and management science vol. 52, Kluwer, Dordrecht (2002), pp. 369–444.

Ehrgott, M., 2000, “Approximation algorithms for combinatorial multi-criteria problems”, International Transactions in Operations Research 7 (2000), pp. 5–31.

El-Sherbeny, N., 2001, “Resolution of a vehicle routing problem with multi-objective simulated annealing method”. Ph.D. thesis, Faculté Polytechnique de Mons, Mons, Belgique, 2001.

Federgruen, A., and P., Zipkin, 1984, “A combined Vehicle Routing and Inventory Allocation Problem”, Operations Research 32, 1019-1037.

Fisher, M.L., 1987, “Lagrangian Optimization Algorithms for Vehicle Routing Problems” Operational Research, PP. 635-649

Flavell, R.B., “A New Goal programming formulation”, Omega 4, 1976, 731-732.

Foster, B.A., and Ryan, D. M., 1976, “An Integer Programming Approach to the Vehicle Scheduling Problem”, Operational Research Quarterly, 27, PP.3367-3384.

Fonseca, C.M., 1995, “Multi-objective Genetic Algorithms with Application to Control Engineering Problems”, Ph.D. Thesis, Department of Automatic Control and Systems Engineering, University of Sheffield, Sheffield, UK.

Fonseca, C.M., Fleming, P.J., 1995, “Multiple Objective Genetic Algorithms Made Easy: Selection, Sharing and Mating Restrictions”, In IEEE Int. Conference on Genetic Algorithms in Engineering Systems: Innovations and Applications, Page 45, Sheffield, U.K.

Gambardella L.M, Taillard E., Agazzi G., 1999, MACS-VRPTW: “A Multiple Ant Colony System for Vehicle Routing Problems with Time Windows” , In D. Corne, M. Dorigo and F. Glover, editors, New Ideas in Optimization. McGraw-Hill, London, UK, PP. 63-76.

Gearhart, W.B., “On the Characterization of Pareto Optimal Solutions in Bicriterion Optimization”, Journal of Optimization Theory and Applications, Vol. 27, No.2, April 1979, PP.301-307.

Gendreau, M., A. Hertz, G. Laporte, 1994, “Tabu Search Heuristic for the Vehicle Routing Problem”, Management Science 40, PP. 1276-1290.

Geoffrion, A. “Solving Bicriterion Mathematical Programming”, ORSA, 1967.

Geoffrion, A., Proper efficiency and theory of vector maximization, Journal of Mathematical Analysis and Applications 22 (1968), pp. 618–630.

Geiger, M.J., 2001, “Genetic algorithms for multiple objective vehicle routing”, in: metaheuristic International Conference 2001 (MIC'2001), pp. 348–353, 2001.

Geiger, M.J., 2003, “Multi-Criteria und Fuzzy System in Theory und Praxis chapter A Computational Study of Genetic Crossover Operators for Multi-objective Vehicle Routing Problem with Soft Time Windows”, Deutscher Universitäts-Verlag (2003) pp. 191–207.

Giannikos, I., 1998, “A multi objective goal programming model for locating treatment sites and routing hazardous wastes”, European Journal of Operational Research 104 (1998), pp. 333–342.

Gillet, B.E., L. R. Miller, 1974, "A Heuristic Algorithm for the Vehicle Dispatch Problem", Operations Research, 22, PP.340-349.

Golden, B., Laporte, G., and Tailard, E.D., 1997, “An Adaptive Memory Heuristic for a Class of VRP with MinMax objectives”, Computers and Operations Research 24, PP: 445-452.

Golden, B. L., Stewart, R. A., 1977, “Vehicle Routing with Probabilistic Demands”, Proceedings of the Tenth Annual Symposium on the Interface of Computer Science and Statistics, Gaithersburg, Maryland.

Golden, B. L., and Yee, J. R. 1979, A Framework for Probabilistic Vehicle Routing. AIIE, 11, pp.109-112.

Greistorfer, P., A tabu-scatter search metaheuristic for the arc routing problem, Computers and Industrial Engineering 44 (2003) (2), pp. 249–266.

Haimes, Y.Y., L.S.Lasdon, and D.A. Wismer, “On a Bicriterion Formulation of the Problems of Integrated System Identification and System Optimization” IEEE Transaction on Systems, Man and Cybernetics, (1971) pp.296-297.

Haugland, D., Ho, S.C., and Laporte, G., 2005, Designing Delivery Districts for Vehicle Routing Problem with Stochastic Demand.

A. Hertz, G. Laporte and M. Mittaz, A tabu search heuristic for the capacitated arc routing problem, Operations Research 48 (2000) (1), pp. 129–135.

Hong S.C., Park, Y.B., “A Heuristic for Bi-Objective Vehicle Routing Problem with Time Windows Constraints”, International Journal of Production Economics, 1999, 62, PP. 249-258.

Jacobs-Blecha, C., and Goetschalcky, M., (1998) “The Vehicle Routing Problem with Backhauls: Properties and Solution Algorithms”, School of Industrial Engineering and System Engineering, Georgia Institute of Technology.

Jaillet, P., Odoni, A.R., 1988, “The Probabilistic Vehicle Routing Problem”, In Golden, B.L., and Assad, A.A. (Eds.), Vehicle Routing: Methods and Studies, North-Holland, Amsterdam.

Jaillet, P., 1987, “Stochastic Routing Problems”, In: Andretta, G., Mason, F., Serafini, P. (Eds.), Stochastic in Combinatorial Optimization, World Scientific, New Jersey.

Jaszkiwicz, A., 2001, “Genetic Local Search for Multiple objective Combinatorial Optimization”, European Journal of

Operational Research 137, PP.50-71

Jaszkiwicz, A., Do multiple objective metaheuristics deliver on their promises? a computational experiment on the set covering problem, *IEEE Transactions on Evolutionary Computation* 7 (2003) (2), pp. 133–143.

Jones, D.F., S.K. Mirrazavi and M. Tamiz, 2002, “Multi-objective meta-heuristics: An overview of the current state-of-the-art”, *European Journal of Operational Research* 137, pp. 1–9.

Jozefowicz, N., 2004, “Modélisation et résolution Approchées de Problèmes de tournées multi-objectif”, Ph.D. thesis, Laboratoire d’Informatique Fondamentale de Lille, Université des Sciences et Technologies de Lille, Villeneuve d’Ascq, France, December 2004.

Jozefowicz, N., F. Semet and E-G. Talbi, 2002, “Parallel and hybrid models for multi-objective optimization: Application to the vehicle routing problem”, In: J.J. Merelo Guervos et al., Editors, *Parallel Problem Solving from Nature VII*, Lecture Notes in Computer Science vol. 2439, Springer-Verlag (2002), pp. 271–280.

Jozefowicz, N., F. Semet and E-G. Talbi, 2007, “Multi Objective Vehicle Routing Problem”, *European Journal of Operational Research*, (in press).

Jozefowicz, N., F. Semet, and E-G. Talbi, 2004, “Applications of multi-objective evolutionary algorithm, *Advance in Natural Computation*”, chapter A multi-objective evolutionary algorithm for the covering tour problem, vol. 1, World Scientific, 2004, (pp. 247–267).

Jozefowicz, N., F. Semet and E-G. Talbi, 2007, “The bi-objective covering tour problem”, *Computers and Operations Research* 34 (2007), pp. 1929–1942

Jozefowicz, N., F. Semet and E-G. Talbi, 2005, “Enhancements of NSGA II and its application to the vehicle routing problem with route balancing”, In: E-G. Talbi, P. Liardet, P. Collet, E. Lutton and M. Schoenauer, Editors, *Artificial Evolution 2005*, 7th International Conference (EA’2005), Lecture Notes in Computer Science vol. 3871, Springer (2006), pp. 131–142.

Jozefowicz, N., F. Semet and E-G. Talbi, 2006, “Target Aiming Pareto Search and its application to the vehicle routing problem with route balancing”, *Journal of Heuristics* (2006).

Keller, C.P., 1985, “Routing to cover time dependent demand: A Multiple Objective Approach, Sixteen Annual Pittsburgh Conference on Modeling and Simulation 16, PP: 651-655.

Keller, C.P., 1985, “Multi-objective routing through space and time: The MVP and TDVRP problems”, Ph.D. thesis, Department of Geography, University of Western Ontario, London, Ontario, Canada, 1985.

Keller, C.P., and M. Goodchild, 1988, “The multi objective vending problem: A generalization of the traveling salesman problem”, *Environment and Planning B: Planning and Design* 15 (1988), pp. 447–460.

Kim, B., Kim, S., Sahoo, S., 2006, “Waste Collection Vehicle Routing Problems with Time Windows”, *Computers and Operations Research* 33, PP: 3624-3642.

Kohl, N., O.B.G. Madsen, 1997, “An Optimization Algorithm for the Vehicle Routing Problem with time Windows based upon Lagrangian Relaxation”, *Operations Research* 45, PP. 395–406.

Kolen, A.W.J., A.H.G. Rinnooy Kan and H.W.J.M. Trienekens, 1987, “Vehicle Routing with Time Windows”, *Operations Research* 35, PP. 266–273.

Koskosidis, Y.A., W.B. Powell and M.M. Solomon, 1992, “An optimization-based heuristic for vehicle routing and scheduling with soft time window constraints”, *Transportation Science* 26, PP. 69–85.

Lacomme, P., Prins, C., Sevaux, M. 2006, “A Genetic Algorithm for a Bi-Objective Capacitated Arc Routing Problem”, *Computers and Operations Research* 33, PP.3473-3493.

Lacomme, P., Prins, C., Sevaux, M. 2003, “Multi-Objective Capacitated Arc Routing Problem”, In: Fonseca CM., et al. editor, *Evolutionary multi-criterion Optimization (Proceeding of EMO 2003, Faro, Portugal)*. Lecture Notes in Computer Science, Vol. 2632. Berlin: Springer; 2003, PP.550-564.

Lai, K.K., B. Liu, J. Peng, 2003, “Vehicle Routing Problem with Fuzzy Travel Times and its Genetic Algorithms”, Technical Report.

Laporte, G., 1992, “The Vehicle Routing Problem: An Overview of Exact and Approximate Algorithms”, *European Journal of Operational Research*, 59, PP.345-358.

Lau H.C., Sim, M., Toe, K.M., 2003, “Vehicle Routing Problem with Time Windows and a Limited Number of Vehicles”, *European Journal of Operational Research* 148, PP: 559-569.

Lee, T-R, and J-H. Ueng, 1998, “A Study of Vehicle Routing Problem with Load Balancing”, *International Journal of Physical Distribution and Logistics Management* 29 (1998), pp. 646–648.

Lee, Y., Kim, S., Lee, S., Kang, K., 2003, “A Location-Routing Problem in Designing Optical Internet with WDM Systems”, *Photonic Network Communications* 6, 151-160.

Levy, L., Bodin, L., 1989, “The Arc Oriented Location Routing Problem”, *INFOR* 27, PP.74-94.

Li, W., 2005, “Finding pareto-optimal set by merging attractors for a Bi-objective traveling salesman problem”, In: C.A. Coello Coello, A.H. Aguirre and E. Zitzler, Editors, *Evolutionary Multi-Criterion Optimization*, Third International Conference, EMO 2005, Lecture Notes in Computer Science vol. 3410, Springer, Guanajanto, Mexico (2005), pp. 797–810.

Lin, C.K.Y., and R.C.W. Kwok, 2006, “Multi Objective Metaheuristics for a Location-Routing Problem with Multiple use

- of Vehicles on real data and simulated data” *European journal of Operational Research* 175, PP.1833-1849.
- Lin, S., 1965, “Computer Solutions of the Traveling Salesman Problem”, *Bell System Technical Journal*,44, PP.2245-2269.
- Lin, S. and B.W. Kernighan, 1973, “An Effective Heuristic Algorithms for the Traveling Salesman Problem”, *Operations Research* 21, PP.498-512.
- Liu, B., K. Iwamura, 1998, “Chance Constrained Programming with Fuzzy Parameters”, *Fuzzy Sets and Systems* 94, PP.227-237.
- Lourenço, Paixão and Portugal, 2001, “Multi Objective Metaheuristics for the Bus Driver Scheduling problem”, *Transportation Science* 35, pp. 331–343.
- Magnanti, T.L., “Combinatorial Optimization and Vehicle Fleet Planning: Prospectives and prospects.” *Network* 7 9(1981), pp. 179-213.
- Martinez, C.G., Cordon, O., Herrera, F., 2007, “A Taxonomy and an Empirical Analysis of Multiple Objective Ant Colony Optimization Algorithms for the bi-Criteria TSP”, *European Journal of Operational Research* 180, PP: 116-148.
- Min, H., 1991, “A Multi-Objective Vehicle Routing Problem with Soft Time Windows: The Case of a Public Library Distribution System”, *Socio-Economic Planning Science* 25, PP. 179–188.
- P. Moscato, *Memetic Algorithms a Short Introduction*. In: D. Corne, M. Dorigo and F. Glover, Editors, *New ideas in optimization*, McGraw-Hill, Maidenhead, UK (1999), pp. 219–234.
- Mourgaya, M., Vanderbeck, F., 2007, “Column Generation Based Heuristic for Tactical Planning Multi-Period Vehicle Routing Problem”, *European Journal of Operational Research* 183, PP: 1028-1041.
- Murata, T., and R. Itai, 2007, “Local Search in two-fold EMO algorithm to enhance solution similarity for multi-objective vehicle routing problems”, In: S. Obayashi, K. Deb, C. Poloni, T. Hiroyasu and T. Murata, Editors, *EMO 2007* vol. 4403, Springer (2007), pp. 201–215.
- Nagy, G. and Salhi, S., 2007, “Location-Routing: Issues, Models and Methods”, *European Journal of Operational Research*, 177, PP.649-672.
- Murata, T., and R. Itai, 2005, “Multi-objective vehicle routing problems using two-fold EMO algorithm to enhance solution similarity on non-dominated set”, In: C.A. Coello Coello, A.H. Aguirre and E. Zitzler, Editors, *Evolutionary Multi-Criterion Optimization. Third International Conference, EMO 2005, Lecture Notes in Computer Science* vol. 3410, Springer, Guanajanto, Mexico (2005), pp. 885–896.
- Mirchandani, P., An integrated network/planar multi objective model for routing and siting for hazardous materials and wastes. *Transportation Science* 25 2 (1991), pp. 146–156.
- Ombuki, B., B.J. Ross and F. Hanshar, 2006, “Multi-objective genetic algorithm for vehicle routing problem with time windows”, *Applied Intelligence* 24 (2006), pp. 17–30.
- Onieva, L., I.Garcia-Zarza, Larraneta, J. 1986, “Interactive Generation of Vehicle Schedules for an Urban Bus System on a Microcomputer”, *OR Models in Microcomputers*, PP. 67-64.
- Pacheco, J., and R. Marti, 2006, “Tabu search for a Multi-objective routing problem”, *Journal of the Operational Research Society* 57 (2006), pp. 29–37.
- Paquete, L., L. Chiarandini and T. Stützle, 2004, “Pareto local optimum sets in the bi-objective traveling salesman problem: An experimental study”, In: X. Gandibleux, M. Sevaux, K. Sörensen and V. T’Kindt, Editors, *Metaheuristics for Multiobjective Optimization, Lecture Notes in Economics and Mathematical Systems* vol. 535, Springer (2004), pp. 177–199.
- Paquete, L., and T. Stützle, 2003, “A two-phase local search for the bi-objective traveling salesman problem”, In: C.M. Fonseca et al., Editors, *Evolutionary Multi-criterion Optimization, Lecture Notes in Computer Science* vol. 2632, Springer-Verlag (2003), pp. 479–493.
- Park, Y.B., Keolling, C.P. “An Interactive Computerized Algorithm for Multi-Criteria Vehicle Routing Problems”, *Computers and Industrial Engineering*, 1989, 16, PP.477-490.
- Park, Y. B., 1984, “The Solution of Vehicle Routing Problems in a Multiple Objective Environment”, Ph.D. Dissertation, Oklahoma State University, Stillwater Oklahoma, USA.
- Park, Y.B., and Keolling, C.P., 1986, ‘A Solution of Vehicle routing problem in Multiple objective environment”, *Engineering Costs and Production Economics* 10, PP.121-132.
- Y. Park, A hybrid genetic algorithm for the vehicle scheduling problem with due times and time deadlines. *International Journal of Production Economics* 73 (2001), pp. 175–188.
- J. Potvin, D. Dube and C. Robillard, A hybrid approach to vehicle routing using neural networks and genetic algorithms. *Artificial Intelligence* 6 (1996), pp. 241–252.
- Ronen, D. 1988, “Perspectives on Practical Aspects of Truck Routing and Scheduling” *European Journal of Operational Research* 35, PP:137-145.
- Rahoual, M., Kitoun, B., Mabed, M.H., Bachelet, V., and Benameur, F., 2001, “Multicriteria Genetic Algorithms for the Vehicle Routing Problem with Time Windows”, *MIC 2001 – 4th Metaheuristics International Conference*, PP.527-532.
- Rahoual, M., B. Kitoun, M. Mabed, V. Bachelet, F. Benameur, 2001, “Multicriteria genetic algorithms for the vehicle routing problem with time windows”, in: *Metaheuristic International Conference (MIC’2001)*, pp. 527–532, 2001.
- Ribeiro, R., and H.R. Lourenço, 2001, “A multi-objective model for a multi-period distribution management problem”, in:

- Metaheuristic International Conference 2001 (MIC'2001), pp. 91–102, 2001.
- Riera-Ledesma, J., and J.J. Salazar-González, 2005, "The bi-objective traveling purchaser problem", *European Journal of Operational Research* 160 (2005), pp. 599–613.
- Russell, R., and Igo, W., 1979, "An Assignment Routing Problem", *Network* 9, 1-17.
- Sarker, R., and C.A.C. Coello, 2002, "Assessment methodologies for multiobjective evolutionary algorithms". In: R. Sarker, M. Mohammadian and X. Yao, Editors, *Evolutionary Optimization*, Kluwer Academic Publishers, Massachusetts (2002), pp. 177–195.
- Sessomboon, W., Watanabe, K. Irohara, K. "A Study on Multi-Objective Vehicle Routing Problem Considering Customer Satisfaction with due-time (The creation of Pareto Optimal solutions by hybrid genetic algorithm). *Transactions of the Japan Society of Mechanical Engineering*, 1998.
- Schaffer, J.D., 1985, "Multiple objective optimization with vector evaluated genetic algorithms", *Genetic Algorithms and their Applications*, Proceedings of the First International Conference on Genetic Algorithms, vch (1985), pp. 93–100.
- Shang, J.S., Cuff, C., 1996, "Multi Criteria Pick-up and Delivery Problem with Transfer Opportunity ", *computers and Industrial Engineering* 30, PP: 631-645.
- Sessomboon, W. .K. Watanabe, T. Irohara and K. Yoshimoto, 1998, "A study on multi-objective vehicle routing problem considering customer satisfaction with due-time (the creation of Pareto optimal solutions by hybrid genetic algorithm)", *Transaction of the Japan Society of Mechanical Engineering* (1998).
- Skitt, R.A. and Levary, R.R., 1985, "Vehicle Routing via Column Generation" *European Journal of Operational Research*, Vol. 21, PP.65-75.
- Solomon, M.M., 1987, "Algorithms for the vehicle routing and scheduling problem with time windows constraints", *Operations Research* 35, PP. 254–265.
- Solomon, M.M., J. Desrosiers, 1988, "Time window constrained routing and scheduling problems", *Transportation Science* 22, PP. 1–13
- Solomon, M.M., 1987, "Algorithms for the Vehicle Routing and Scheduling Problem with Time Window Constraints", *Operations Research* 35, PP.254-265.
- Stewart, W. R. 1981, "New Algorithms for Deterministic and Stochastic Vehicle Routing Problems", Ph.D. Dissertation, University of Maryland.
- Stewart, W. R., and Golden B.L., 1984, "A Lagrangian Relaxation Heuristic for Vehicle Routing", *European Journal of Operational Research*, 17, PP.84-88.
- Sutcliffe, C., and J. Board, 1990, "Optimal solution of a vehicle routing problem: Transporting mentally handicapped adults to an adult training centre", *Journal of the Operational Research Society* 41 (1990), pp. 61–67.
- Sexton, T.R., Y.M. Choi, 1986, "Pickup and delivery of partial loads with soft time windows", *American Journal of Mathematical and Management Sciences* 6, PP. 369–398.
- Taillard, E., P. Badezu, M. Gendreau, F. Guertin and J.Y. Potvin, 1997, "A Tabu Search Heuristic for the Vehicle Routing Problem with Soft Time Windows", *Transportation Science* 31, PP. 170–186.
- Talliard, E.D., 1999, "A Heuristic Column Generation Method for the Heterogeneous Fleet", *VRP, RAIRO* 33, PP.1-14.
- [147] Talbi, E.G., 2000, "Meta-heuristics pour l'optimisation combinatoire multi-objectif: Etat de l'art, Submitted to RAIRO 2000.
- Tan, K.C., T.H., Chew, Y.H., Lee, L.H., 2003, "A Hybrid Multi-objective Evolutionary Algorithm for Solving Truck and Trailer Vehicle Routing Problems" In: *Proceedings of the 2003 Congress on Evolutionary Computation*, Canberra, Australia, 8-12 December, Vol. 3. PP. 2134-2141.
- Tan, K.C., T.H., Chew, Y.H., Lee, L.H., 2003, "A Multi-objective Evolutionary Algorithm for Solving Vehicle Routing Problem with Time Windows" In: *Proceedings of the IEEE International Congress on Systems, Man and Cybernetics*, Washington, DC, USA, 5-8 October 2003, Vol.1, PP.361-366.
- Tan, K.C., Cheong, C.Y., Goh, C.K., "Solving Multi-objective Vehicle Routing Problem with Stochastic Demand via Evolutionary Computation", *European Journal of Operational Research* 177, 2007, PP. 813-839.
- Tan, K.C., Y.H. Chew and L.H. Lee, 2006, "A hybrid multi-objective evolutionary algorithm for solving vehicle routing problem with time windows", *European Journal of Operational Research* 34 (2006), pp. 115–151.
- Tan, K.C., T.H. Lee, Y.H. Chew and L.H. Lee, "A Multi objective evolutionary algorithm for solving vehicle routing problem with time windows", *IEEE International Conference on Systems, Man, and Cybernetics*, IEEE Service Center (2003), pp. 361–366.
- Tan, K.C., Y.H. Chew and L.H. Lee, "A hybrid multi-objective evolutionary algorithm for solving truck and trailer vehicle routing problems", *European Journal of Operational Research* 172 (2006), pp. 855–885
- Tan, C. and J., Beasley, 1984, "A Heuristic Algorithm for the Period Vehicle Routing Problem", *Omega* 12, PP.497-504.
- Tavakkoli-Moghaddam, R., N. Safaei, Y. Gholipour, (2006) "A Hybrid Simulated Annealing for Capacitated Vehicle Routing Problems with the Independent Route Length" *Applied mathematics and Modeling*.
- Tavakkoli-Moghaddam, R., N. Safaei, M.M.O. Kah, and M. Rabbani "A New Capacitated Vehicle Routing Problem with Split Service for Minimizing Fleet Cost by Simulated Annealing", *Journal of the Franklin Institute Journal of Faraklin* 2007.

- D. Teodorovic, G. Pavkovic, 1996, "The Fuzzy set Theory Approach to the Vehicle Routing Problem when Deman at nodes are uncertain", *Fuzzy Sets and Systems* 82, PP.307-317.
- [158] Tillman, F. A., 1969, "The Multiple Terminal Delivery Problem with Probabilistic Demands", *Transportation Science*, 3, PP.192-204.
- Tillman, F. A., and Gain T. M., 1972, "An Upper Bound Algorithm for the Single and Multiple Terminal Delivery problem", *Management Science*, 18, PP.664-682.
- Turner, W.C., and Vu, V.T., 1979, "Systems Design for Rural Refuse Collections", *AIEE*, 11, PP.84-85.
- Ulungu, E., and J. Teghem, "The two-phase method: An efficient procedure to solve bi-objective combinatorial optimization problems", *Foundations of Computing and Decision Sciences* 20 (1995), pp. 149–165.
- Van Landeghem, H.R.G., 1988, "A Bi-Criteria Heuristics for the Vehicle Routing Problem with Time Windows", *European Journal of Operational Research* 36, PP.217-226.
- Van Veldhuizen, D., Lamont, G.B., 1998, "Multiple Objective Evolutionary Algorithms Research: A history and Analysis", Technical Report TR-98-03, Department of Electrical and Computer Engineering, Air Force institute of Technology, Ohio.
- Viana, A., and J. Pinho de Sousa, 2000, "Using metaheuristics in Multi-objective resource constrained project scheduling", *European Journal of Operational Research* 120, PP: 359–374.
- Wassan, N.A. & Osman, I.H., 2002, "Tabu Search Variants for the Mix Fleet Vehicle Routing Problem", *Journal of the Operational Research Society*, 53, PP768-782
- Waters, C.D., 1984, *Interactive Vehicle Routing*, "Operational Research Society", 35, PP.821-826.
- Yee, J.R., and Golden, B.L., 1980, "A Note on Determining Strategies for Probabilistic Vehicle Routing", *Naval Research Logistics Quarterly* 27, PP.159-163.
- Yellow, P.C. 1970, "A Computational Modification of the Savings Method of Vehicle Scheduling", *Operational Research Quarterly*, 21, PP.281-283.
- Zare Mehrjerdi, Y., 1993, "A Multiple Objective Stochastic Approach to Vehicle Routing Problem", Conference on Applied Probability in Engineering, Computer and Communication Sciences INRIA/ORS/TIMS/SMIAI, Paris, June 16-23, 1993.
- Zare Mehrjerdi, Y., 1986, *A Goal Programming Model of the Stochastic Vehicle Routing Problem*, Ph.D. Dissertation, Oklahoma State University, Stillwater, Oklahoma. USA.
- Zare Mehrjerdi Y., 2014, "A Multiple Objective Stochastic Approach to Vehicle Routing Problem", *The International Journal of Advanced Manufacturing Technology* Vol. 74,
- Zare Mehrjerdi Y., 2013, "Stochastic Approach to Vehicle Routing Problem: Development and Theories", *International Journal of Industrial Engineering* 24 (4), 285-295.
- Zhenyu, Y., L. Zhang, K. Lishan and L. Guangming, "A new MOEA for multi-objective TSP and its convergence property analysis", In: C.M. Fonseca et al., Editors, *Evolutionary multi-criterion optimization*, Lecture Notes in Computer Science vol. 2632, Springer-Verlag (2003), pp. 342–354.
- Zheng, Y., and Liu, B., 2006, "Fuzzy Vehicle Routing Model with Credibility Measure and its hybrid intelligent Algorithm", *Applied Mathematics and Computations*, 176, PP. 673-683.
- Zhou, G., Hokey, M., Mitsuo, G., 2003, "A Genetic Algorithm Approach to the Bi-Criteria Allocation of Customers to Warehouse", *International Journal Of Production Economics* 86, PP: 35-45.
- E. Zitzler, K. Deb and L. Thiele, Comparison of multiobjective evolutionary algorithms empirical results, *Evolutionary Computation* 8 (2000) (2), pp. 173–195.
- Zografos, K.G., and K.N. Androustopoulos, "A heuristic algorithm for solving hazardous material distribution problems", *European Journal of Operational Research* 152 (2004), pp. 507–519.
- Books, Surveys and others**
- Cohon, J., *Multi Objective Programming and Planning*, Academic Press, New York (1978).
- Deb, K., "Multi-objective Optimization using Evolutionary Algorithms", John Wiley and Sons (2001).
- Hwang, C., and K. Yoon. "Multiple Attribute Decision Making: Methods and Applications", Springer, Berlin (1981).
- Ijiri, Y., "Management Goals and Accounting for Control", Rand McNally, Chicago, 1965,
- Lee, Sang, M , "Goal Programming for Decision Making Analysis", Auerbach Publishers, Philadelphia, 1972.
- Romero, C., 1991, "Handbook of Critical Issues in Goal Programming", Pergamon Press, Oxford.
- Schniederjans, M., 1995, "Goal Programming Methodology and Applications", Kluwer Publishers, Boston.
- Zare Mehrjerdi, Yahia, (2015), "Vehicle Routing Problem", Mehrjerd Press, Tehran, Iran.
- Zeleny, M., 1982, "Multiple Criteria Decision Making", McGraw-Hill, New York.
- Zeleny, M., "Linear Multiple Objective Programming", Springer-Verlag, New York, 1974.
- Tamiz, M., D.F. Jones and C. Romero, 1998, "Goal programming for decision making: An overview of the current state-of-the-art", *European Journal of Operational Research* 111, pp. 569–581.
- Steuer, R., Na, P. "Multiple Criterion Decision Making Combined with Finance: A Categorized Bibliographical Study", *European Journal of Operational Research* 150, 496-515.
- Madsen, 1981. O.B.G. Madsen, A survey of methods for solving combined location-routing methods. In: N.K. Jaiswal, Ed., *Scientific Management of Transport Systems*, North-Holland, Amsterdam, Holland (1981), pp.194–201.
- Yahia Zare Mehrjerdi, (2013d) *Operations Research a Profit Making Tool*, LAP publishing Co. Germany.

- Yahia Zare Mehrjerdi, (2013e), Multi-Criteria Risk-Benefit Analysis of Healthcare Management, *International Journal of Industrial Engineering* 24 (3), 151-167
- Yahia Zare Mehrjerdi, (2013f) Group decision making process for RFID-based system selection using fuzzy TOPSIS approach, *Artificial Intelligence Research* 2 (3).
- Colin, O.B., "A Linear Goal Programming Model for Public Sector Project Selection", *Journal of Operational Research Society* 36, 1985, PP.13-23.
- Joiner, C., and Drakke, A.E., "Government Planning and Budgeting with Multiple Objective Models", *Omega* 11, PP. 57-66.
- Gleason, J.M., and Lilly, C.C. (1977), "A Goal Programming Model for Insurance Agency Management", *Decision Sciences* 8, 180-190.
- W.R. Stewart, B.L. Golden and F. Gheysens, "A survey of stochastic vehicle routing". In: *Proceedings of 1982 IEEE International Large Scale Systems Symposium* (1982), pp. 229–232.
- D. F. Jones, D.F., S. K. Mirrazavi and M. Tamiz, "Multi-objective meta-heuristics: An overview of the current state-of-the-Art", *European Journal of Operational Research* 137, 2002, PP.1-9.
- Romero, C., D.F. Jones and M. Tamiz, "Goal programming, compromise programming, and reference-point method formulations: Linkages and utility theorems". *Journal of the Operational Research Society* 49 (1998), pp. 986–991.
- Yu, P.L., "A class of solutions for group decision problems". *Management Science* 19 (1973), pp. 936–946.
- Bell, J.E., McMullen, P.R., "Ant Colony Optimization techniques for the Vehicle Routing Problem", *Advanced Engineering Informatics* 18, 2004, PP.41-48.
- Yoshiike, N., Takefuji, Y., "Solving Vehicle Routing Problems by Maximum Neuron Model", *Advanced Engineering Informatics* 16, 2002, PP.99-105.
- Gebresenbet, G., Ljungberg, D., "Coordination and Route Optimization of Agricultural Goods Transport to Attenuate Environmental Impacts", *Journal of Agricultural Engineering Research* 80, 2001, pp.329-342.
- DPS, *Distribution Planning Software* (1996), *Route LogiX*.
- Gebresenbet, G., Oostra, H., "Environmental Impact of goods transport with special emphasis on agricultural and related products: Part 1: A Simulation Model for Goods Transport and Environmental Research, MODTRANS. Department of Agricultural Engineering, Swedish University of Agricultural Sciences, Report 219, Uppsala, Sweden.
- Zare Mehrjerdi, Yahia, (2008) RFID-enabled systems: a brief review, *Assembly Automation*, Vol.28, No.3, 235–245
- Zare Mehrjerdi, Yahia (2009), RFID-enabled supply chain systems with computer Simulation, *Assembly Automation* 29/2, 174–183
- Zare Mehrjerdi, Yahia, (2011a), RFID Adoption: A Systems Thinking Perspective through Profitability Engagement, *Assembly Automation*.
- Zare Mehrjerdi, Yahia, (2011b), RFID and its benefits: A Multiple case analysis, *Assembly Automation*.
- Zare Mehrjerdi, Yahia, (2010) Coupling RFID with supply chain to enhance productivity, *Business Strategy Series*, VOL. 11 NO. 2, pp. 107-123.
- Zare Mehrjerdi, Y. (2013c) A Framework for Six-Sigma Driven RFID-Enabled Supply Chain Systems, *International Journal of Quality and Reliability Management*.
- Zare Mehrjerdi, Y. (2012) Vehicle routing problem: meta-heuristic approaches, *International Journal of Applied Operational Research* 2 (3), 55-68
- Zare Mehrjerdi, Y. and Nadizadeh, A. (2013a), using greedy clustering method to solve capacitated location-routing problem with fuzzy demands, *European Journal of Operational Research*, Vol. 229, 2013.
- Moubed, Mitra, Zare Mehrjerdi, Y. (2015), A Robust Modeling Of Inventory Routing In Collaborative Reverse Supply Chains, Vol. 5, No.2.
- M. Ruta, F. Scioscia, E. Di Sciascio, F. Gramegna, S. Ieva and G. Loseto, (2010) RFID-assisted Product Delivery in Sustainable Supply Chains: A Knowledge-based Approach, <http://www.researchgate.net/publication/221311824>.
- Zare Mehrjerdi, Y. (2011c) RFID the big role player in the Libraries of the Future, *The Electronic Library*, Vol 29, No.1 pp.36-51
- Zare Mehrjerdi, Y. (2014) RFID: A Bibliographical Literature Review with Future Research Directions, *International Journal of Industrial Engineering* 25 (2), 151-190
- Yahia Zare Mehrjerdi, (2013b) Hierarchical multi-criteria risk-benefit analysis in fuzzy environment, *Applied Soft Computing* 13 (1), 590-599