Soft Computing Methods in Transport and Logistics

Julio Brito, Dagoberto Castellanos-Nieves, Airam Expósito and José. A. Moreno

Abstract The current economic context generates in supply chain management greater demands for flexibility and dynamism. In addition, there is an increase in uncertainty that adds more complexity to the problems associated with planning and management. Soft Computing offers a set of methodologies capable of responding to these challenges. This work provides an overview of transport and logistics problems, as well as the most representative combinatorial optimization models. Specifically, it focuses on the treatment of uncertainty through fuzzy optimization and metaheuristics methodologies. Promising results from the use of this approach suggest emerging areas of application, which are presented and described.

1 Introduction

Logistical, transport and distribution planning have adapted to the evolution of new business organization models. Distribution strategies and transportation decisions are some of the main subjects in supply chain management and play an important role in its success because they improve service quality, reduce costs and optimize resources [20]. Supply chain management (SCM) involves all activities related to integration, planning and control of product and information flows that are generated between suppliers and clients. The supply chain can be broken down into three

J. Brito (✉) · D. Castellanos-Nieves · A. Expósito · J.A. Moreno
Grupo de Computación Inteligente, Instituto Universitario de Desarrollo Regional, Universidad de La Laguna, La Laguna, Spain
e-mail: jbrito@ull.edu.es

D. Castellanos-Nieves
e-mail: dcastell@ull.edu.es

A. Expósito
e-mail: aexposim@ull.edu.es

J.A. Moreno
e-mail: jamoreno@ull.edu.es

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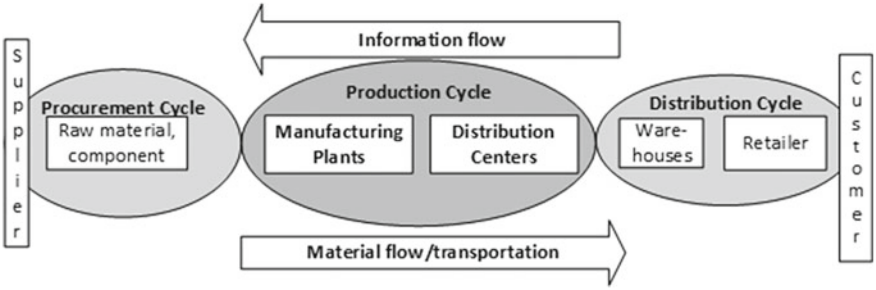

Fig. 1 Cycles of the supply chain procurement, production and distribution

cycles, procurement, production and distribution (Fig. 1). The distribution cycle refers to the activities and processes associated with storage and distribution [21].

One of the basic activities in the integral management of the supply chain is implied planning and decision making. Three levels of planning are apparent: strategic, tactical and operational [33]. Each one of these three levels is associated with different time horizons and creates a distinct set of important problems which usually correspond to optimization problems. Thus long term strategic problems include decisions on the number, size, location and capacity of the storage units and transport; tactical decisions in the medium term are the design of the distribution network, location and assignment of distribution zones/areas and the supply rate; and finally, operational aspects, studied in the short term, such as the establishment of pickup and delivery routes, and/or the organization of vehicle loading/unloading [67].

Methods/methodologies found in Soft Computing offer a useful alternative to solve problems with this type of complexity [6, 58]. The design of Intelligent Systems to aid in decision making in real settings, such as transport and logistics planning, needs to take advantage of Soft Computing methodologies [37]. The design of Intelligent Systems to aid in decision making in real settings, such as transport and logistics planning, needs to take advantage of Soft Computing methodologies. The quality of information is the most common scenario, especially in real-world applications, and this incomplete or imprecise information is reflected in the parameters and variables. Fuzzy set theory offers an appropriate methodological framework to approach this class of uncertainty, which is not the product of absence of information, nor of a random nature, but instead of the imprecise nature of the expression. Some solution techniques employ exact methods but in real-world problems, these methods do not guarantee that an optimal solution will be found. Heuristic and metaheuristics techniques are important tools constituent of Soft Computing [81] to tackle complex optimization problems. They are capable of evaluating possible alternatives and determine the preferred solution in efficient time, by means of strategies that integrate problem knowledge.

Our discussion is centered on problems and application of the levels of tactical and operational transportation planning. Transportation planning concerns the short-term planning of the distribution operations and mostly deals with the planning of deliveries to different customers. Typical considerations at this decision level are the details of delivery routes: that is, at what exact times, by which vehicle, and in what sequence customers will get their products delivered. In addition, location decision problems may have to be made on these levels.

The aim of this chapter is to analyze some relevant and emerging problems and application in transport and distribution. The application of fuzzy optimization in this field can be significant. In addition to providing an overview of transport and distribution problems and their models, the purpose is to give an overview of the fuzzy optimization and metaheuristic approach for the treatment of uncertainty in these models, to review their use and to propose new areas of application in real practical problems.

The remainder of this chapter is organized as follows. Section 2 introduces the Soft Computing based approach. Section 3 then presents a review of some problems that we have considered emerging, which are of interest for the application of Soft Computing methodologies, fuzzy optimization and metaheuristics. The chapter ends with some conclusions in Sect. 4.

2 Soft Computing Based Solution Approach

This section describes the use of an approximation that integrates specific techniques from Soft Computing, such as fuzzy optimization and metaheuristics. An outline of how these techniques are applied in the resolution of classic transport and logistics problems is also given.

2.1 Fuzzy Optimization

Fuzzy sets and systems are used to build computing systems to solve decision and optimization problems whose modeling is difficult to define accurately, managing the uncertainty and the imprecision of the available information, as well as of the formulation of preferences, restrictions and objectives expressed by decision makers. If there is imprecision in some of the formulation components of the optimization problem and we can express it with fuzzy terms then we are faced with fuzzy optimization problem. Discussions concerning solutions do not focus on their feasibility, nor if they are optimal solutions. We, in turn, have chosen to discuss the degree of feasibility and optimality of the solution. Bellman and Zadeh [10] are the authors who introduced the fundamentals for fuzzy optimization problems, where objectives and constraints can be defined in an imprecise way and characterized using membership function such as fuzzy sets. This approximation requires that the formulation and problem solutions be dealt with adequately by making use of fuzzy number representations and their operations.

An optimization problem is described as the search for the value of specific decision variables x so that identified objective functions $f(x)$ attain their optimum values. The value of the variables is subject to stated constraints $g(x)$. In these problems the objective functions are defined on a set of solutions that we will denote by X. Thus, an optimization problem can be represented by: $\max\{f(x) : g(x) \geq 0\},\ \forall x \in X$. When some of its components are considered fuzzy, we are facing a problem of fuzzy optimization. Among all optimization problems, Linear Programming are those whose objective function and constraints are linear. The general model of Linear Programming is formulated as $\max\{f(x_j, c_j) : g(x_j, a_{ij}) \geq b_i,\ i = 1, ..., m, j = 1, ..., n, x_j \geq 0\}$. In the formulation $a_{ij} \in \mathfrak{R}^{m\times n}$ is the technological matrix, $b_i \in \mathfrak{R}^m$ the resources, $c_j \in \mathfrak{R}^n$ the costs and $x_j \in \mathfrak{R}^n$ the variables. Fuzzy Linear Programming (FLP) constitutes the basis for solving fuzzy optimization problems and their solution methods have been the subject of many studies in the fuzzy context. Different FLP models can be considered according to the fuzzy components [80]. These models can be solved in a direct and simple way, obtaining solutions that are coherent with their fuzzy nature.

(a) *Models with fuzzy constraints*. In this case there is a certain tolerance in the fulfilment constraints and consequently the feasible region can be defined as a fuzzy set. This is $\max\{f(x_j, c_j) : g(x_j, a_{ij}) \geq_f b_i,\ i = 1, ..., m, j = 1, ..., n, x_j \geq 0\}$. In particular, Verdegay [79], using the representation theorem for fuzzy sets, proves a solution which can be obtained from the auxiliary model: $\max\{f(x_j, c_j) : g(x_j, a_{ij}) \geq_f b_i + \tau_i(1 - \alpha),\ i = 1, ..., m, j = 1, ..., n, x_j \geq 0\}$, where $\alpha \in [0, 1]$ and $\tau = (\tau_1, ..., \tau_m)$ is referred to as a violation tolerance level.

(b) *Models with fuzzy cost*. In this case the model is represented by $\max\{f(x_j, c_j^f) : g(x_j, a_{ij}) \geq b_i,\ i = 1, ..., m, j = 1, ...n, x_j \geq 0\}$, where c_j^f is a fuzzy number described by its corresponding membership function $\mu_j(x)$. [23] prove that the solution can be obtained with the multi-objective auxiliary model. We can also used a simple method considering fuzzy solutions that are solved with the application of an ordered function h for the constraints [35], i.e. $\max\{f(x_j, h(c_j)) : g(x_j, a_{ij}) \geq b_i,\ i = 1, ..., m, j = 1, ...n, x_j \geq 0\}$.

(c) *Models with fuzzy coefficients in constraints*. This model considers a problem of the type $\max\{f(x_j, c_j) : g(x_j, a_{ij}^f) \geq_f b_i^f,\ i = 1, ..., m, j = 1, ...n, x_j \geq 0\}$ where the values of the technological matrix and the coefficients are fuzzy numbers and are described by its corresponding membership function. Delgado et al. [22] also include imprecision in the constraints. They propose considering fuzzy solutions that are solved with the application of an ordered function h for the constraints. The new formulation is expressed by the auxiliary problem: $\max\{f(x_j, c_j) : g(x_j, a_{ij}^f) \geq_h b_i^f + \tau_i^f(1 - \alpha),\ i = 1, ..., m, j = 1, ...n, x_j \geq 0\}$ where the symbol $\geq_h$ stands for a comparison relation between fuzzy numbers, $\alpha \in [0, 1]$ and τ_i^f is a tolerance of fuzzy nature set by the decision maker.

2.2 Evolutionary Heuristic and Metaheuristics

In Artificial Intelligence (AI), the qualifier *Heuristic* is usually applied to all those aspects related with the use of knowledge in the dynamic realization of tasks. Heuristics are used to refer to any intelligent technique, method or procedure of performing a task that is not the product of a rigorous formal analysis, but of expert knowledge about the task. In particular, the term heuristic is used to refer to a procedure that tries to provide solutions of a problem with a good performance, as regards the quality of the solutions and the resources used. Successful heuristic procedures have emerged in solving specific problems or performing difficult tasks. It has been tried to extract from them what was essential in their success in order to apply it to other problems or tasks, or in larger contexts. As has clearly occurred in various fields of AI, especially with expert systems, this line of research has contributed to the scientific development of the field of heuristics and to extend the application of its results. In this way, both specific computational techniques and resources have been obtained, as well as general design strategies for problem resolution heuristic procedures. These general strategies for constructing algorithms, which go beyond heuristics, and go further, are called Metaheuristics. Specific and elaborated heuristics for solving a simple problem in a narrow context have usually better performance than any algorithm based on metaheuristics. However, the metaheuristics tries to exploits other kind of advantages. They can improve while are used, are flexible and adaptable. They get good performance with low level of knowledge. Some recent reviews and survey show the relevance of the methods [7, 11, 68, 90].

2.3 Fuzzy Optimization in Transport and Logistics Problems

Vehicle routing, scheduling, locations and relations between them are the most important processes and decisions in transport and logistics. From a mathematical point of view, they can usually be modeled as a combinatorial optimization problem. The numerous applications of these problems include, among others, movement of goods, public transport, fresh and perishable food distributions, courier services, solid waste collection and caterers. Each problem has its own objectives, associated with cost, available resources or quality of service which in general is expressed in terms of time or distance. They also have their own specific constraints that may reflect vehicle capacity, fleet size, warehouse number and capacity, collection and/or delivery, points of loading/unloading, distances traveled and specific time windows. Most of the transportation and logistics models reviewed in this work are based on well-known problems.

Routing problems have been widely addressed in the literature and among them the Vehicle Routing Problem (VRP) is one of the most widely studied [75]. VRP is commonly defined as the problem of designing optimal delivery or collection routes for a vehicle fleet from one or several depots to a set of geographically scattered demand points, under an extensive variety of conditions. Some real-life examples, which are variants of the classic VRP with different constraints, are presented in [1]. Location problems (LP) deal with the optimal choice of a set of points for establishing certain facilities that take into account different criteria and constraints. Several models have been proposed to address these problems such as that of the P-median, P-center or covering [56]. A literature review of facility location models in the context of supply chain management is given in [49]. The Location routing problem (LRP) models and solves the facility location problem by taking into account simultaneous route planning which implies an integrated solution. Two recent surveys have been presented that describe models and variants investigated [25, 61].

In practical real-world problems decision makers use subjective knowledge or linguistic information when making decisions, measuring parameters, objectives and constraints and even when modeling the problem. In this context, a Soft Computing approach, specifically fuzzy optimization and metaheuristics, is useful for solving routing and location problems because they are flexible enough to deal with complex systems, provide acceptable approximate solutions and therefore add value. Our specific interest is in problems where various components are imprecise, treated as fuzzy and addressed with fuzzy optimization and metaheuristics.

In the literature we can find several approaches, models and solutions of the VRP considering some fuzzy component. The most widely discussed models are the ones that have imprecision demand, time travel and time services. The fuzzy optimization approach described in previous subsection are applied to VRP and some of its variants [13, 14, 74].

Several authors formulate and solve fuzzy LP, on networks [51], on networks using p-center [53], using p-median [15] or with covering [34]. Models of the fuzzy LRP problem have also been presented such as the capacitated model with fuzzy demands in [48] or a realistic version with more fuzzy components [31].

3 Applications and Emergent Problems

This section analyzes some relevant and emergent problems and application in transport and logistics, in which the application of fuzzy optimization can be significant. In addition to providing a synthesis of the existing literature on the subject, we give an overview of the problem in the context of the field to help researchers better understand the practical motivations where to apply methodologies. Thus it identifies the challenges and the direction in which future researches could be conducted in this field. The relevant and emergent problems and applications selected to realize an overview in the remainder of this section are Disaster Emergency Humanitarian Logistics, City Logistics, Green Logistics, and Tourist Trip Logistics.

3.1 Disaster Emergency Humanitarian Logistics

The International Federation of Red Cross and Red Crescent Societies defines a disaster as a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community‘s or society‘s ability to cope using its own resources. Though often caused by nature, disasters can have human origins. Disaster impacts more than 200 million people and produce around 75,000 fatalities every year [87].

The authors in [64] define emergency logistics as a process of planning, managing and controlling the efficient flows of relief, information, and services from the points of origin to the points of destination to meet the urgent needs of the affected people under emergency conditions. In this context, there are many challenges in logistics that differ from those encountered in commercial supply chains. Some of these challenges that introduce complexity and uncertainty are listed by [9] as:

- High level of uncertainty of demands in terms of capacities, travel times, locations, etc.
- Limited resources in large scale disasters, lack of supplies, people, technology, transportation capacity and money.
- Sudden changes in terms of demand, large resource demands in short time frames.
- Difficulties in achieving efficient and timely delivery.

In [17], an analysis of the literature is presented, showing the main optimization models used in emergency logistics. Facility location, location-evacuation, location with relief distribution and pre-positioning, relief distribution and casualty transportation, resource allocation, commodity flow, resource allocation and commodity flow, and other models are others just some of the cited models.

A survey of recent advances in bio-inspired meta-heuristics, including genetic algorithms, particle swarm optimization, ant colony optimization, etc., for solving emergency transportation problems is also presented in [92].

Optimization problems of emergency logistic involve complex systems introducing fuzzy sets and systems. In the literature there are several papers related to fuzzy location and routing problem, for instance, in [66], a hybrid fuzzy optimization methodology to solve the large-scale disaster relief distribution problem is presented. The solution approach is made up of three steps. In the first step fuzzy clustering techniques are used to classify the damaged areas, while the second and third steps use FLP to deal with lack of resources. The authors in [65] provide a hybrid fuzzy clustering optimization approach to the operation of an emergency logistics co-distribution center responding to the urgent relief demands in the crucial rescue period.

The fuzzy LRP is a research area with several papers in emergency logistics. In [84] a model considering fuzzy demands of relief materials, timeliness and limited resources is proposed. The objective function of the model minimizes the total cost and the relief time of the system.

Other papers focus on emergency logistics transportation path optimization using fuzzy approaches. In [89] a multi-objective optimization model for emergency logistics transportation path is proposed. Factors such as transportation time, safety factor and transportation costs are described using trapezoidal fuzzy numbers in order to deal with the uncertainty of these factors.

3.2 City Logistics

Urban mobility plays a key role in the promotion of the sustainable urban development of a city. In particular, an efficient freight transport system is required as it plays a significant role in its competitiveness and represents an important element for the local economy regarding the employment and income that it generates [63]. Logistics activities and operations, especially transportation and distribution of goods, now receive a specific treatment which is known as urban logistics or city logistics. This concept has its origins in the 1980s, it has become in the last decades more relevant by the development of cities, the growing demands for supply that is more efficient and concern about the negative impacts of it. Taniguchi et al. [73] defined city logistics as the process for totally optimizing the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy [73].

Urban distribution and transport of goods is an important part of urban logistics. In cities complicated problems arise related to urban freight transport: demand of higher levels of service in terms of time, need for better services with lower costs for customers, use of fewer vehicles, better utilization of vehicle capacity, reduction of negative environmental impacts, lower energy consumption, reduction of noise, contribution to traffic congestion, the use of alternative energies and improving safety [26]. In the next coming years, changes from increased e-commerce and home delivery will be apparent. This growth reinforces the general trend in logistics towards smaller consignments, single orders and thus higher delivery frequency and an increase in vehicle movements within cities [83].

In urban areas, goods distribution services are the most important transportation and logistics activities and are usually called the last mile. Clear examples of these are courier express and parcel services food delivery, perishable products, milk and newspaper, urban solid waste collection and emergency transport. Surveys about these problems are available in [16, 41].

Important areas in urban freight routes are concerned with reduction of fuel consumption and emissions [70], and the use of night delivery schemes [18]. In contemporary living the travel speed between locations varies throughout the day according to traffic conditions, especially in urban areas. Therefore, it is necessary to adapt the models with time-dependence for routing planning [27]. The effects of e-commerce on the urban freight transport using vehicle routing and scheduling problem model are studied in [36, 72].

The design and development of city logistics systems requires the availability of the models for the location of the logistics centers. The location of warehouse, distribution centers and/or consolidation centers should be appropriately determined for optimal operations [54]. On the other hand, depot location and vehicle routing are two interdependent decisions and there are many authors who consider the integrated problem of locating distribution centers in urban areas and the corresponding freight distribution [52]. Recently, the authors in [38] investigate the combined impact of depot location, fleet composition and routing decisions on vehicle emissions in city logistics. When real-time information is available, dynamic models can support the developed systems. For example, in [29] on-line re-optimization based on current traffic information and soft time constraints are proposed.

All of these problems are subject to the uncertainty of the environment. In some situations logistic problems cannot exactly specify attributes as either deterministic numbers or probabilistic random variables and it is natural and realistic to express vagueness and ambiguity in fuzzy terms and to solve the problem with a fuzzy approach [88]. In the literature, Soft Computing methodologies have been considered in routing, scheduling and location. But integrating such methods into city logistics has not been fully considered and needs to be addressed. Only a few references are found in the literature. In [45] a postal delivery in agglomerations with a large number of customers modelled as a street routing problem is solved using fuzzy clustering. Customer clustering is also used for VRP and is solved in the framework of urban freight transport [85]. Another paper studies the dynamic operational environment of courier service with fuzzy time windows [44]. Location models [86] and specifically the design of e-commerce distribution systems [40] complete the papers found in the literature.

3.3 Green Logistics

For decades, the main goal of logistics has been to improve its objectives from a purely economic point of view. Through this period logistics professionals have perpetuated this economic and commercial paradigm by allowing organization and management logistics to focus on maximizing economic profitability. Economic performance did not include costs such as environmental and social impact, instead it only considered operational economic costs.

Nowadays there is a growing demand for multi-objective metrics associated with logistical processes, where reduced operational costs and the negative impact of the environment are some of the most common. As regards the last objective, logistic stakeholders are pressured from public administrations and government to reduce the environmental impact of their logistics operations. The environmental impact of logistics companies can be measured in different ways such as generation of noise and vibrations, air quality and the contribution to global warming.

Mckinnon et al. [47] present a classification of the main pillars that compose what we call green logistics:

- Reducing Freight transport externalities. The largest part of the research on the environmental impact of logistics is due to growth of freight traffic volumes. As a consequence, the search for ways of reducing freight-related externalities is a priority.
- City Logistics. The study of transport efficiency and environmental impact of logistics in urban areas. This topic will be further developed in later sections.
- Reverse Logistics. The logistic associated with waste product and packaging for reuse, is a promising area of green logistics. The logistics of waste management help to increase the proportion of waste material that is recycled and reused.
- Corporate environmental strategies. Companies have adopted and improved strategies to reduce environmental impact and manage a balanced relationship with nature. These strategies generate a wide range of actions on logistics operations of the company.
- Green Supply Chain Management. This pillar can be defined as the alignment and integration of environmental management within supply chain management. This is based on that part of the environmental impact that is extended beyond their own structure.

It is possible to find several surveys and literature reviews related to green logistics. In [93] a review of combinatorial optimization problems related with green logistics and meta-heuristics in the swarm intelligence field is proposed. A review of Green Logistic Vehicle Routing Problems (GVRP) and a discussion of the next wave of research into GVRP is presented in [43].

In general, the complex infrastructure of logistics and working in a dynamic business environment imposes a high degree of uncertainty in the logistics process that affects its overall performance. More specifically, there is a complex system present in green logistics with highly imprecise parameters and environmental factors with a complexity that requires fuzzy sets to be represented.

In the literature, it has been proven that green logistics belong to a wide range of practical application areas. In most cases, these optimization problems involve complex systems introducing fuzzy sets and systems. A literature review and a discussion of the applications of fuzzy green logistics focus on fuzzy optimization in green transport are provided in the remaining part of this section.

There are several papers in literature related with green logistics and fuzzy approaches, specifically in green routing problems. A transport spatial decision support model for the optimization of green routes for city logistics centers is presented in [57], where the solution integrates a multi-criteria method of Weighted Linear Combination and the modified Dijkstra algorithm with a geographic information system for processing spatial data in order to minimize the environmental impact of the routes. In freight transportation activities, [28] puts forward the use of green logistics in order to reduce the negative impact on the environment considering demand and travel time uncertainty.

Other papers focus on aspects such as reverse logistics and green scheduling. In [62], a bi-objective mathematical model in the distribution of perishable products with specified expiration date in inventory routing problem is presented. In order to solve the model the Torabi-Hassini method based on a fuzzy approach is applied. A green train scheduling model with a fuzzy multi-objective optimization algorithm is presented in [42]. In order to solve the problem and obtain non-dominated solutions which has an equally satisfactory degree on both objectives, a fuzzy mathematical programming approach is proposed.

3.4 Tourist Trip Logistics

The Tourist Trip Design Problem, (TTDP) [78] arises when a tourist visiting a tourist area, for one or more days, and is interested in visiting a number of points of interest (POI). The problem more specifically deals with the choice of the POIÂt's of the trip and the order to follow each day. Each one of these POIs is associated with several features that are taken into account in the selection. The main features are the minimum time required for the visit, the days and hours of operation, the cost of the activities within the visit and some indicators of profit or degree of satisfaction that could be perceived by the tourist for the visit. Information regarding distance, travel time and cost between the POIs, and between these points and the hotel or stay residence of the tourist (start and end point of the trips), must also be taken into account. This information together with some information about the tourist, such as his/her preferences, budget and time limitations must be used to decide the trip selected for each day of the stay at destination. The corresponding optimization problems have received increasing interest in the tourist management and service in order to be incorporated to recommenders, tourist planning tools and electronic guides. Since most of the features that have to be used are subjective or subject to some level of imprecision and vagueness, the fuzzy techniques and points of view have been used.

The problems may be complicated and made more realistic by considering additional features and constraints. Some of them are maximum budget (daily or complete stay at destination), specific requirements on the minimum and/or maximum number of days that the tourist visits to the POIs within a certain category (restaurants, beaches, historic sites, nature facilities, etc.), or on the number of visits to POIs of a category some days. Travel times that depend on traffic congestion, weather conditions, or the time of the day when traveling. Other realistic variants arise when some of the POIs have time window constraints and the time used to visit them have to be taken into account in the cost or profit of the visit. Finally, in realistic cases evaluation of the profits or interest of the POIs depend on the already visited POIs or some additional information [5].

The literature firstly distinguishes between problems with only one tour and with several tours. Most research considers two opposed features or criteria: the profit and the cost. In the single tour problem, the main variants are the Profitable Tour Problem (PTP) where the objective is to maximize the difference between the profit and the total cost that has been considered in [24], the Prize Collecting Travelling Salesman Problem (PCTSP) where the objective is to minimize the travel cost subject to a minimum profit [2], and the Orienteering Problem (OP) where the objective is to maximize the total profit subject to a limit on the travel costs that was introduced by [77].

Problems with multiple tours are usually known as Vehicle Routing Problems with Profit (VRPP), and the simplest version is the well-known Team Orienteering Problem (TOP), which is an extension of the OP in which there is a fixed number m of routes and m also corresponds to the number of days available to tourists.

There are other problems using different objective functions, such as the Prize-Collecting VRP (PCVRP) [71] and the Capacitated Profitable Tour Problem (CPTP) [3]. In PCVRP, the objective function is given by the combination of three different objectives: minimizing the travel distance, minimizing the number of vehicles used and maximizing profits collected, while in CPTP the goal is to minimize the difference between the total harvest profit and the total trip cost.

The Team Orienteering Problem has been extensively studied in the literature [4] and several versions, such as the Team Orienteering Problem with Time Windows (TOPTW) [76] and Time Dependent Team Orienteering Problem with Time Windows [30].

The use of metaheuristics and fuzzy approaches are quite common in wide range of recent TTDP and other routing problems. The early work [46] considers a fuzzy routing problem for sightseeing. A Genetic Algorithm for the VRPTW with fuzzy demand is applied in [91]. In [55] a supplier selection model using fuzzy logic is developed. Several multi-objective metaheuristics are used in [69] to solve VRP with fuzzy demands. Several authors [19, 59, 60] apply a Particle Swarm Optimization for a VRP with fuzzy demands and [8] use Genetic Algorithm. The paper [94] deal with the CVRPTW with fuzzy travel time and demand using a hybrid between Ant Colony and Genetic Algorithm. A fuzzy capacitated location routing problem is solved in [32] by applying a Simulating Annealing with a mutation operator. Recently [82] apply fuzzy optimization to the orienteering problem, [39] apply a fuzzy Ant Colony system to solve the dynamic vehicle routing problem with uncertain service time, and [50] uses fuzzy number comparisons to deal with VRPTW with fuzzy scores. Finally, [12] apply a GRASP for solving the TOP with fuzzy scores and constraints.

4 Conclusions

This review has focused on two major areas of Soft Computing applied to optimization: metaheuristics and fuzzy optimization. Works in metaheuristics are numerous and often applied in emerging logistics areas. Relevant works with metaheuristics outperform other methods, such as exact algorithms. Fuzzy optimization methods are less frequent in the literature, providing additional research opportunities for Soft Computing in a very open and promising field.

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References

1. Anbuudayasankar, S.P., Ganesh, K., Mohapatra, S.: Models for Practical Routing Problems in Logistics. Springer International Publishing (2014)
2. Archetti, C., Bianchessi, N., Speranza, M.G.: Optimal solutions for routing problems with profits. Discrete Appl. Math. **161**(4), 547–557 (2013)
3. Archetti, C., Feillet, D., Hertz, A., Speranza, M.G.: The capacitated team orienteering and profitable tour problems. J. Oper. Res. Soc. **60**(6), 831–842 (2009)
4. Archetti, C., Hertz, A., Speranza, M.G.: Metaheuristics for the team orienteering problem. J. Heuristics **13**(1), 49–76 (2007)
5. Archetti, C., Speranza, M.G., Vigo, D.: Vehicle routing: problems, methods, and applications, vol. 18, chapter Vehicle Routing Problem with Profits, pp. 273. SIAM (2014)
6. Avineri, E.: Soft computing applications in traffic and transport systems: a review. In: Hoffmann, F., Kappen, M., Klawonn, F., Roy, R. (eds.) Soft Computing: Methodologies and Applications. Advances in Soft Computing, vol. 32, pp. 17–25. Springer, Berlin (2005)
7. Baghel, M., Agrawal, S., Silakari, S.: Survey of metaheuristic algorithms for combinatorial optimization. Int J Comput Appl **58**(19) (2012)
8. Bahri, O., Amor, N.B., El-Ghazali, T.: Optimization algorithms for multi-objective problems with fuzzy data. In: 2014 IEEE Symposium on Computational Intelligence in Multi-Criteria Decision-Making (MCDM), pp. 194–201. IEEE (2014)
9. Balcik, B., Beamon, B.M.: Facility location in humanitarian relief. Int. J. Logistics Res. Appl. **11**(2), 101–121 (2008)
10. Bellman, R.E., Zadeh, L.A.: Decision-making in a fuzzy environment. Manage. Sci. **17**(4), B–141 (1970)
11. BoussaïD, I., Lepagnot, J., Siarry, P.: A survey on optimization metaheuristics. Inf. Sci. **237**, 82–117 (2013)
12. Brito, J., Expósito, A., Moreno, J.A.: Solving the team orienteering problem with fuzzy scores and constraints. In: 2016 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), pp. 1614–1620. IEEE (2016)
13. Brito, J., Moreno, J.A., Verdegay, J.L.: Fuzzy optimization in vehicle routing problems. In: IFSA/EUSFLAT Conference, pp. 1547–1552 (2009)
14. Brito, J., Moreno, J.A., Verdegay, J.L.: Transport route planning models based on fuzzy approach. Iran. J. Fuzzy Syst. **9**(1), 141–158 (2012)
15. Cadenas, J., Canas, M., Garrido, M., Ivorra, C., Liern, V.: Soft-computing based heuristics for location on networks: the p-median problem. Appl. Soft Comput. **11**(2), 1540–1547 (2011). The Impact of Soft Computing for the Progress of Artificial Intelligence
16. Cattaruzza, D., Absi, N., Feillet, D., González-Feliu, J.: Vehicle routing problems for city logistics. EURO J. Transp. Logistics 1–29 (2015)
17. Caunhye, A.M., Nie, X., Pokharel, S.: Optimization models in emergency logistics: a literature review. Socio-Econ. Plann. Sci. **46**(1), 4–13 (2012). Special Issue: Disaster Planning and Logistics: Part 1
18. Cavar, I., Kavran, Z., Jolic, N.: Intelligent transportation system and night delivery schemes for city logistics. Comput. Technol. Appl. **2**(9), 782–787 (2011)
19. Chen, J.-Q., Li, W.-L., Murata, T.: Particle swarm optimization for vehicle routing problem with uncertain demand. In: 2013 4th IEEE International Conference on Software Engineering and Service Science (ICSESS), pp. 857–860. IEEE (2013)

20. Cooper, M.C., Lambert, D.M., Pagh, J.D.: Supply chain management: more than a new name for logistics. Int. J. Logistics Manag. **8**(1), 1–14 (1997)
21. Croom, S., Romano, P., Giannakis, M.: Supply chain management: an analytical framework for critical literature review. Eur. J. Purchasing Supply Manag. **6**(1), 67–83 (2000)
22. Delgado, M., Verdegay, J., Vila, M.: A general model for fuzzy linear programming. Fuzzy Sets Syst. **29**, 21–29 (1989)
23. Delgado, M., Verdegay, J.L., Vila, M.A.: Imprecise costs in mathematical programming problems. Control Cybernet **16**(2), 113–121 (1987)
24. Dell'Amico, M., Maffioli, F., Värbrand, P.: On prize-collecting tours and the asymmetric travelling salesman problem. Int. Trans. Oper. Res. **2**(3), 297–308 (1995)
25. Drexl, M., Schneider, M.: A survey of variants and extensions of the location-routing problem. Eur. J. Oper. Res. **241**(2), 283–308 (2015)
26. Ehmke, J.: Integration of information and optimization models for routing in city logistics, vol. 177. Springer Science & Business Media (2012)
27. Ehmke, J.F., Steinert, A., Mattfeld, D.C.: Advanced routing for city logistics service providers based on time-dependent travel times. J. Comput. Sci. **3**(4), 193–205 (2012). City Logistics
28. Eshtehadi, R., Fathian, M., Demir, E.: Robust solutions to the pollution-routing problem with demand and travel time uncertainty. Transp. Res. Part D: Transp. Environ. **51**, 351–363 (2017)
29. Flamini, M., Nigro, M., Pacciarelli, D.: The value of real-time traffic information in urban freight distribution. J. Intell. Transp. Syst. (2017). In press
30. Gavalas, D., Konstantopoulos, C., Mastakas, K., Pantziou, G., Vathis, N.: Heuristics for the time dependent team orienteering problem: application to tourist route planning. Comput. Oper. Res. **62**, 36–50 (2015)
31. Ghaffari-Nasab, N., Ahari, S.G., Ghazanfari, M.: A hybrid simulated annealing based heuristic for solving the location-routing problem with fuzzy demands. Scientia Iranica **20**(3), 919–930 (2013)
32. Golozari, F., Jafari, A., Amiri, M.: Application of a hybrid simulated annealing-mutation operator to solve fuzzy capacitated location-routing problem. Int. J. Adv. Manuf. Technol. **67**(5–8), 1791–1807 (2013)
33. Gunasekaran, A., Kobu, B.: Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications. Int. J. Prod. Res. **45**(12), 2819–2840 (2007)
34. Guzmán, V.C., Masegosa, A.D., Pelta, D.A., Verdegay, J.L.: Fuzzy models and resolution methods for covering location problems: an annotated bibliography. Int. J. Uncertainty Fuzziness Knowl. Based Syst. **24**(04), 561–591 (2016)
35. Herrera, F., Verdegay, J.: Three models of fuzzy integer linear programming. Eur. J. Oper. Res. **83**(3), 581–593 (1995)
36. Hong, X., Jingjing, Q., Xingli, T.: B2c e-commerce vehicle delivery model and simulation. Inf. Technol. J. **12**(20), 5891 (2013)
37. Ko, M., Tiwari, A., Mehnen, J.: A review of soft computing applications in supply chain management. Appl. Soft Comput. **10**(3), 661–674 (2010)
38. Koc, C., Bekta, T., Jabali, O., Laporte, G.: The impact of depot location, fleet composition and routing on emissions in city logistics. Transp. Res. Part B: Methodol. **84**, 81–102 (2016)
39. Kuo, R., Wibowo, B., Zulvia, F.: Application of a fuzzy ant colony system to solve the dynamic vehicle routing problem with uncertain service time. Appl. Math. Modell. **40**(23), 9990–10001 (2016)
40. Lau, H.C.W., Jiang, Z.Z., Ip, W.H., Wang, D.W.: A credibility-based fuzzy location model with hurwicz criteria for the design of distribution systems in b2c e-commerce. Comput. Ind. Eng. **59**(4), 873–886 (2010)
41. Lewczuk, K., Żak, J., Pyza, D., Jacyna-Gołda, I.: Vehicle routing in an urban area: environmental and technological determinants. WIT Trans. Built Environ. **130**, 373–384 (2013)
42. Li, X., Wang, D., Li, K., Gao, Z.: A green train scheduling model and fuzzy multi-objective optimization algorithm. Appl. Math. Modell. **37**(4), 2063–2073 (2013)

43. Lin, C., Choy, K., Ho, G., Chung, S., Lam, H.: Survey of green vehicle routing problem: past and future trends. Expert Syst. Appl. **41**(4, Part 1), 1118–1138 (2014)
44. Lin, C., Choy, K., Ho, G., Lam, H., Pang, G.K., Chin, K.: A decision support system for optimizing dynamic courier routing operations. Expert Syst. Appl. **41**(15), 6917–6933 (2014)
45. Matis, P., Koháni, M.: Very large street routing problem with mixed transportation mode. CEJOR **19**(3), 359–369 (2011)
46. Matsuda, Y., Nakamura, M., Kang, D., Miyagi, H.: A fuzzy optimal routing problem for sightseeing. IEEJ Trans. Electron. Inf. Syst. **125**, 1350–1357 (2005)
47. McKinnon, P., Cullinane, S., Whiteing, A., Browne, P.: Green Logistics: Improving the Environmental Sustainability of Logistics. Kogan Page (2010)
48. Mehrjerdi, Y.Z., Nadizadeh, A.: Using greedy clustering method to solve capacitated location-routing problem with fuzzy demands. Eur. J. Oper. Res. **229**(1), 75–84 (2013)
49. Melo, M., Nickel, S., da Gama, F.S.: Facility location and supply chain management: a review. Eur. J. Oper. Res. **196**(2), 401–412 (2009)
50. Mendez, C.E.C.: Team Orienteering Problem with Time Windows and Fuzzy Scores. PhD thesis, National Taiwan University of Science and Technology (2016)
51. Moreno, J.A., Vega, J.M., Verdegay, J.L.: Fuzzy location problems on networks. Fuzzy Sets Syst. **142**(3), 393–405 (2004)
52. Muñoz-Villamizar, A., Montoya-Torres, J.R., Juan, A.A., Cáceres-Cruz, J.: A simulation-based algorithm for the integrated location and routing problem in urban logistics. In: 2013 Winter Simulations Conference (WSC), pp. 2032–2041 (2013)
53. Nayeem, S.M.A., Pal, M.: The p-center problem on fuzzy networks and reduction of cost. Iran. J. Fuzzy Syst. **5**(1), 1–26 (2008)
54. Olsson, J., Woxenius, J.: Localisation of freight consolidation centres serving small road hauliers in a wider urban area: barriers for more efficient freight deliveries in gothenburg. J. Transp. Geogr. **34**, 25–33 (2014)
55. Ordoobadi, S.M.: Development of a supplier selection model using fuzzy logic. Supply Chain Manage. Int. J. **14**(4), 314–327 (2009)
56. Owen, S.H., Daskin, M.S.: Strategic facility location: a review. Eur. J. Oper. Res. **111**(3), 423–447 (1998)
57. Pamučar, D., Gigović, L., Ćirović, G., Regodić, M.: Transport spatial model for the definition of green routes for city logistics centers. Environ. Impact Assess. Rev. **56**, 72–87 (2016)
58. Peidro, D., Mula, J., Poler, R., Verdegay, J.-L.: Fuzzy optimization for supply chain planning under supply, demand and process uncertainties. Fuzzy Sets Syst. **160**(18), 2640–2657 (2009)
59. Peng, Y., Chen, J.: Vehicle routing problem with fuzzy demands and the particle swarm optimization solution. In: 2010 International Conference on Management and Service Science (MASS), pp. 1–4. IEEE (2010)
60. Peng, Y., Qian, Y.-M.: A particle swarm optimization to vehicle routing problem with fuzzy demands. J. Convergence Inf. Technol. **5**(6), 112–119 (2010)
61. Prodhon, C., Prins, C.: A survey of recent research on location-routing problems. Eur. J. Oper. Res. **238**(1), 1–17 (2014)
62. Rahimi, M., Baboli, A., Rekik, Y.: Sustainable inventory routing problem for perishable products by considering reverse logistic. IFAC-PapersOnLine **49**(12), 949–954 (2016)
63. Russo, F., Comi, A.: A classification of city logistics measures and connected impacts. Procedia—Soc. Behav. Sci. **2**(3), 6355–6365 (2010)
64. Sheu, J.-B.: Challenges of emergency logistics management. In: Transportation Research Part E: Logistics and Transportation Review, vol. 43, no. 6, pp. 655–659 (2007). Challenges of Emergency Logistics Management
65. Sheu, J.-B.: An emergency logistics distribution approach for quick response to urgent relief demand in disasters. In: Transportation Research Part E: Logistics and Transportation Review, vol. 43, no. 6, pp. 687–709 (2007). Challenges of Emergency Logistics Management
66. Sheu, J.-B., Chen, Y.-H., Lan, L.W., et al.: A novel model for quick response to disaster relief distribution. Proc. Eastern Asia Soc. Transp. Stud. **5**, 2454–2462 (2005)

67. Simchi-Levi, D., Chen, X., Bramel, J.: The logic of logistics. Algorithms, and Applications for Logistics and Supply Chain Management, Theory (2005)
68. Sörensen, K.: Metaheuristics-the metaphor exposed. Int. Trans. Oper. Res. **22**(1), 3–18 (2015)
69. Sulieman, D., Jourdan, L., Talbi, E.-G.: Using multiobjective metaheuristics to solve vrp with uncertain demands. In: 2010 IEEE Congress on Evolutionary Computation (CEC), pp. 1–8. IEEE (2010)
70. Suzuki, Y.: A new truck-routing approach for reducing fuel consumption and pollutants emission. Transp. Res. Part D: Transp. Environ. **16**(1), 73–77 (2011)
71. Tang, L., Wang, X.: Iterated local search algorithm based on very large-scale neighborhood for prize-collecting vehicle routing problem. Int. J. Adv. Manuf. Technol. **29**(11), 1246–1258 (2006)
72. Taniguchi, E., Kakimoto, Y.: Modelling effects of e-commerce on urban freight transport, chapter Chapter 10, pp. 135–146. emeraldinsight (2004)
73. Taniguchi, E., Thompson, R., Yamada, T., Duin, R.V.: City Logistics: Network Modelling and Intelligent Transport Systems. Pergamon (2001)
74. Torres, I., Cruz, C., Verdegay, J.L.: Solving the truck and trailer routing problem with fuzzy constraints. Int. J. Comput. Intell. Syst. **8**(4), 713–724 (2015)
75. Toth, P., Vigo, D.: Vehicle Routing. Society for Industrial and Applied Mathematics. Philadelphia, PA (2014)
76. Tricoire, F., Romauch, M., Doerner, K.F., Hartl, R.F.: Heuristics for the multi-period orienteering problem with multiple time windows. Comput. Oper. Res. **37**(2), 351–367 (2010)
77. Tsiligirides, T.: Heuristic methods applied to orienteering. J. Oper. Res. Soc. 797–809 (1984)
78. Vansteenwegen, P., Oudheusden, D.V.: The mobile tourist guide: an or opportunity. OR Insight **20**(3), 21–27 (2007)
79. Verdegay, J.: Fuzzy Information and Decision Processes, chapter Fuzzy mathematical programming. North-Holland (1982)
80. Verdegay, J.L.: Fuzzy optimization: models, methods and perspectives. In: In proceeding 6th IFSA-95 World Congress, pp. 39–71 (1995)
81. Verdegay, J.L., Yager, R.R., Bonissone, P.P.: On heuristics as a fundamental constituent of soft computing. Fuzzy Sets Syst. **159**, 846–855 (2008)
82. Verma, M., Shukla, K.K.: Application of fuzzy optimization to the orienteering problem. Adv. Fuzzy Syst. **2015**, 8 (2015)
83. Visser, J., Nemoto, T., Browne, M.: Home delivery and the impacts on urban freight transport: a review. Procedia—Soc. Behav. Sci. **125**, 15–27 (2014)
84. Wang, S., Ma, Z., Zhuang, B.: Fuzzy location-routing problem for emergency logistics systems. Comput. Modell. New Technol. **18**(2), 265–273 (2014)
85. Wang, Y., Ma, X., Xu, M., Wang, Y., Liu, Y.: Vehicle routing problem based on a fuzzy customer clustering approach for logistics network optimization. J. Intell. Fuzzy Syst. **29**, 1427–1442 (2015)
86. Wang, Y., Ma, X.L., Wang, Y.H., Mao, H.J., Zhang, Y.: Location optimization of multiple distribution centers under fuzzy environment. J. Zhejiang Univ. Sci. A **13**(10), 782–798 (2012)
87. Wassenhove, L.N.V.: Humanitarian aid logistics: supply chain management in high gear. J. Oper. Res. Soc. (2006)
88. Wong, B.K., Lai, V.S.: A survey of the application of fuzzy set theory in production and operations management: 1998–2009. Int. J. Prod. Econ. **129**(1), 157–168 (2011)
89. Xiao, S.C., Wu, J.F., He, H., Yang, Z.D., Shen, X.: An emergency logistics transportation path optimization model by using trapezoidal fuzzy. In: 2014 11th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), pp. 199–203 (2014)
90. Xiong, N., Molina, D., Ortiz, M.L., Herrera, F.: A walk into metaheuristics for engineering optimization: principles, methods and recent trends. Int. J. Comput. Intell. Syst. **8**(4), 606–636 (2015)
91. Xu, J., Goncalves, G., Hsu, T.: Genetic algorithm for the vehicle routing problem with time windows and fuzzy demand. In: Evolutionary Computation, 2008, pp. 4125–4129. IEEE (2008)

92. Zhang, M.-X., Zhang, B., Zheng, Y.-J.: Bio-inspired meta-heuristics for emergency transportation problems. Algorithms **7**(1), 15–31 (2014)
93. Zhang, S., Lee, C., Chan, H., Choy, K., Wu, Z.: Swarm intelligence applied in green logistics: a literature review. Eng. Appl. Artif. Intell. **37**, 154–169 (2015)
94. Zulvia, F.E., Kuo, R., Hu, T.-L.: Solving cvrp with time window, fuzzy travel time and demand via a hybrid ant colony optimization and genetic algortihm. In: 2012 IEEE Congress on Evolutionary Computation (CEC), pp. 1–8. IEEE (2012)