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# Research on the vehicle routing problem with interval demands

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ABSTRACT

In this paper, a vehicle routing problem with interval demands is investigated based on the motivation of dispatching vehicles to deliver perishable products in practice. A nonlinear interval-based programming method is used to build a model for the vehicle routing problem with interval demands, which assumes that demands of customers are uncertain but fall in given intervals and actual demand of a customer becomes known only when the vehicle visited the customer. A vehicle-coordinated strategy was designed to solve the service failure problem. A hybrid algorithm based on the artificial immune system is also proposed to solve the model for vehicle routing problem with interval demands. The validity of methods and sensitivity analysis are illustrated by conducting some numerical examples. We find that the tolerant possibility degree of interval number has significant impacts on the distances. The planned distance strictly increased, while the additional distance strictly decreased and the total distance after coordinated transport has a U-typed relationship with the tolerant possibility degree of interval number.



## 1. Introduction

With the development of the e-commerce platform and intelligent transportation systems, logistic activity has become an increasingly important part of our lives. Logistics has always been the third profit source, which drives fierce competition among companies. It is expected that more industries will become involved in e-commerce, which means that logistics will not involve only general transportation services. It is a synthetic system based on information technology and a management method. Thus, the study of logistics is becoming increasingly important. The vehicle routing problem (VRP) [1] is an important problem in modern logistics. The VRP is encountered in practice in many contexts, such as the home delivery of packages, morning newspapers and magazines [2]. In traditional VRP models, the variables, such as demand, service time and location, are always taken as fixed and unchangeable. In a number of situations, however, the variable cannot be considered fixed. For instance, when you ask your customer how much of a good he or she wants to order, the customer may give an imprecise answer with an interval that only includes lower and upper bounds, such as “3–6 pounds” [3].

The real problem that motivated this study is the distribution of perishable products in a city. A regional center delivers the supply to various locations in a particular geographic or administrative region in a distribution system for a perishable

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product [8]. Perishable products have some remarkable features such as a short sales cycle, low salvage and volatile market demand. From the point of view of demand, the demand of perishable goods have randomness and vagueness, lack of reliable historical data and only knowing the lower and upper bounds. For example, with the development of e-commerce, many fruit retail chain stores have appeared, such as JOYVIO, PAGODA, and HUASH. Each of these chains has a unified distribution center and many retail stores in a city. Each retail store needs to give a requirement number or weight to the distribution center, but sometimes, the total number or weight may be an interval number that is decided based on the daily experience. Thus, the distribution center will send vehicles to every retail store to meet its requirements. Similar logistics activities such as distributing crayfish, which is a popular food in most cities of China, can be viewed as VRPIDs.

It raises the following natural questions: how to deal with the imprecise demand with interval attributes and what is the optimal distribution strategy when the vehicle carrying capacity is constrained? It is well known that the VRP is an NP-hard problem. Since the interval variable is more complicated, the VRP with interval optimization is also an NP-hard problem. When faced with uncertainty, fuzzy and stochastic approaches are commonly used to describe imprecise characteristics. Cao and Lai [3] used a triangular fuzzy variable to represent the demand. In recent years, the vehicle routing problem with stochastic demands has been widely studied. In many research works [4–6], it is assumed that the demand follows a particular distribution. However, it is difficult to specify the membership function and probability distribution function in advance under the uncertain circumstances. Thus, it is necessary to study the VRP with the interval optimization method, which does not require knowledge of specific information about the demand. To the best of the author's knowledge, few works in the literature have used the vehicle-coordinated strategy to solve the VRP with uncertain demand. Liu et al. [7] used a coordinated strategy to solve the open vehicle routing problem while did not address the interval uncertain demand. The key contribution of this method is in solving the problem of service failure. However, this strategy did not make full use of the vehicle capacity.

In this paper, we consider a vehicle routing problem with interval demands (VRPID), and a coordinated strategy is designed to solve the problem of service failure and make full use of the vehicle capacity. We first use a nonlinear interval-based programming method to consider interval demand in order to decide whether to send a vehicle to the next customer. Then, we present a hybrid algorithm based on the artificial immune system to calculate the vehicle routing for the proposed problem, and the solution is improved by applying a vehicle-coordinated strategy. In addition, we can use the optimal decision-making risk preference values [3] that are produced by the coordinated strategy to help us solve the problem of service failure and make full use of the vehicle capacity in each route. Finally, the computational results show the effectiveness and performances of the solution approaches.

Our paper makes four contributions. The first is the methodology and model for adopting the interval optimization method to address VRPID. The interval optimization method is widely used in practical engineering problems [23–26,34–35]. However, no study has used the interval optimization method for the vehicle routing problem. The second contribution is showing that the interval optimization method does not require strict assumptions compared to traditional optimization methods. Compared to stochastic programming and fuzzy programming, interval optimization does not require a precise probability or fuzzy membership function. The third contribution is the provision of an artificial immune system to solve the VRPID model and a coordinated transport strategy, which we proved that it could reduce the actual distance of transportation. The last contribution is that we proved that when we need to decide whether we should serve the next customer, our risk preference value should be in the interval [0.6, 0.7].

This paper is organized as follows. In Section 2, we review the related literature. In Section 3, we introduce some basic concepts regarding uncertainty interval optimization theory and explain a mathematical transfer method used in our model in Section 4. In Section 4, we introduce the vehicle routing problem with uncertainty interval demands and create a mathematical model to formulate the possibility degree of interval number theory. In Section 5, we use the artificial immune system to solve the uncertainty programming problem in Section 4 to produce route plans, and then, we create a coordinated transport algorithm to adjust the route based on the actual demand, which is simulated by computer. In Section 6, we present the numerical results of our methods and discuss the change of parameters. Section 7 gives conclusions and recommendations for future work.

## 2. Literature review

The VRP, which focuses on the static situation and refers to a combination problem in operations research, was proposed by Dantzig and Ramser [1]. It is a problem of determining how to arrange the vehicle routing to minimize distance or cost under the constraint of capacity, knowing the demands and positions of customers. Clarke and Wright [9] designed a saving algorithm to improve the results of Rao and Zionts [10], who introduced a column generation method based on the shortest path algorithm to solve the VRP. Gillett and Miller [11] used a high-efficiency heuristic algorithm to solve the large-scale VRP. They used polar coordinates to find the path of the vehicle. This method can solve the dynamic VRP. Fisher and Jaikumar [12] designed a generalized heuristic algorithm to solve the VRP. Since the 1990s, many artificial intelligence algorithms have been applied, such as simulated annealing [13], the genetic algorithm [14], particle swarm optimization [15] and tabu search [16]. In recent years, researchers have tended to make the fixed variable value alterable. Duygu et al. [17] solved a vehicle routing problem with a flexible time window. Zhang et al. [18] solved a freight transport problem under a time uncertainty condition. Cao and Lai [3] solved the open vehicle routing problem with fuzzy demands. Their model is based on fuzzy measure theory. Lin et al. [19] designed a cooperative re-optimization strategy to solve the vehicle routing problem