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*Research Article*

# The Optimization Model of Earthquake Emergency Supplies Collecting with the Limited Period and Double-Level Multihub

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This paper constructed a multiobjective programming model and designed Particle Swarm Optimization (PSO) algorithm for earthquake emergency to solve the optimal decision-making question of Multihub emergency supplies collection network with constrained demand period and collection time as fuzzy interval numbers and capacity limit to hub nodes. As for algorithm design, a two-stage parallel solution mode was employed to achieve the global optimal solution in the solution space. At first, the paper is based on the constraint to the total time of emergency supplies collection system and the capacity limited to Multihub; this paper allocated the emergency supplies at each demand point to Multihub from which the emergency supply would be transferred. Secondly, this paper searched for the optimal plans from some feasible plans to determine the distribution directions and emergency supplies collection amount at emergency supplies provision points as well as the optimal collection cost that meet the constraint of demand time. Finally, the result of case verification showed that, compared with simulated annealing (SA) and sequential enumeration method (SEM), Multihub emergency supply collection model based on PSO parallel algorithm made a great improvement in the number of iterations and the optimal collection time, indicating that this model is feasible and effective and can be used in decision-making for earthquake emergency supply collection.

## 1. Introduction

In recent years, the frequent occurrence of earthquakes disaster poses a great threat to the safety of our people's property and lives, and earthquake emergency response has become a significant challenge that the communities and emergency response agencies of different levels have to face. Earthquake is inevitable; however, the potential loss and damage can be mitigated or avoided through active responses and scientific decisions. According to documentary records, in the losses caused from major natural disasters and man-made disasters, the loss caused from emergency supplies shortage or failure of timely emergency supplies provision in time contributes to 15–20% of total loss in disaster. Typically, this situation is much worse for earthquake, when the key reasons for failure of timely emergency supplies provision and low efficiency of collection works are the irrational structure of emergency supplies collection network and low level network optimization.

In order to improve the management level of emergency logistics, as well as to develop scientific planning for emergency supplies collection network, many researchers have conducted intense studies on construction and optimization of such network, and their achievements are mainly about the construction and optimization of a network with linear structure or hub-and-spoke structure. As a hot spot, there are many studies on the elements of emergency logistics network, including network flow, route selection, logistics location, and logistics distribution. For example, Lee and Whang [1] studied network flow with a great deal of algorithms; Tang [2] studied decision optimization of decentralization for the purpose of logistics facility location and logistics network structure designing; Bertsimas and Thiele [3] took into consideration many activities that influence the cost and operation of logistics network, such as product consumption, product manufacturing, and logistics transportation, and constructed a multiobjective programming model for logistics network optimization; Ju and Xu [4] studied the composition of logistics network system and suggested that logistics network is mainly composed of three subnetworks, namely, logistics information network, logistics infrastructure network, and logistics organization network; Kunyou et al. [5] constructed a hub-and-spoke logistics network for the central towns in riverside area in Anhui Province based on the shortest operation time of logistics network, the largest network coverage, and Multihub distribution of network structure. On the basis of these achievements above, some researchers took further steps to study the linkage pattern of emergency resource among regions and the cooperation of intercity Multihub emergency supplies logistics network. For example, Chunjing [6] studied the linkage of Multihub emergency supplies in hub-and-spoke network; Han and Ruizhu [7] employed system dynamics to study the cooperation of intercity Multihub emergency supplies logistics network. Lately, many scholars put forward many results of fuzzy optimization, including fuzzy multiobjects programming model, fuzzy integer programming model, fuzzy dynamic programming model, possibility linear programming model, fuzzy nonlinear programming model, sensitivity analysis, fuzzy sorting, and fuzzy sets operation (Kacprzyk J., 1987; Luhandjula., 1989; and Fedrizzi M., 1991).

In research methods, at present, the fuzzy optimal control problem of nonlinear discrete-time system has been researched by a large amount of scholars. The relation researches focused on the following three contents.

*(1) The Adaptive Fuzzy Control for a Class of Nonlinear Discrete-Time Systems*. Aimed at the problem of nonlinear system with unknown dynamics and matching conditions, Boulkroune et al. (2008) [8] and Li et al. (2011) [9] put forward the adaptive fuzzy control methods with the unknown dynamic; Zhang et al. (2013) [10] solved the approximate optimal control problem of a class of nonlinear discrete systems; Zhang et al. (2008) [11] adopted heuristic dynamic programming algorithm to solve the optimal neural network control problem of nonlinear discrete-time system.

*(2) The Adaptive Fuzzy Backstepping Control for an Unknown Nonlinear Discrete-Time System*. Chen et al. (2010) [12] used backstepping to construct stabilized adaptive fuzzy control methods; Boulkroune and M'Saad (2011) [13] put forward the adaptive fuzzy control method which is based on unknown nonlinear multiple-input-multiple-output with dead zone; Deolia et al. (2011) [14] designed the adaptive fuzzy neural network backstepping control to solve nonlinear discrete-time strict feedback system with dead zone; Zhang et al. (2009) [15] designed a controller of adaptive intensive leaning to settle a class of discrete nonlinear systems with asymmetric dead zone.

*(3) The Fuzzy Control for the Chaotic Discrete-Time System*. Lu et al. (2001) [16] put forward a solving method for nonlinear chaotic discrete-time system with known and unknown parameters to adapt backstepping adaptive control method; Yamamoto et al. (2001) [17] solved the delayed feedback control problem of nonlinear discrete-time system; Ying (2015) [18] adapted direct heuristic dynamic programming method to solve the optimal control problem of Henon mapping chaotic discrete-time system.

*Comparison with Results*. Results of the three aspects above have advantage and disadvantage. The literatures of [8–10] adapted neural network and adaptive control to solve the stability of nonlinear discrete system but neglect the optimal control of nonlinear optimization. The literature of [11] made up for the disadvantage of [8–10], but it only suited the problem of nonlinear discrete system with smooth input. So those methods cannot guarantee the stability or reality of the optimal control of system in (1). The results of (2) can solve the disadvantage of (1) because the backstepping control design can guarantee the stability of cover-cycle system and reduce the cost of controller. However, the control system was asked to meet the match conditions strictly in (2). The literatures of [16, 17] can solve the optimal control problem of chaotic discrete-time system, but it cannot obtain the strategies of the optimization control. The result of [18] showed that the method of Lyapunov can guarantee the stability of system and reduce the cost of controller. The paper will construct multiobject nonlinear programming model with unknown demand and adaptive fuzzy optimal control and design artificial intelligence to realize the optimal solution of discrete nonlinear programming.

According to the literatures above, it appears that the researchers paid more attention to the construction and optimization of hub-and-spoke emergency supplies collection network, which constitutes the basis for this paper to study the optimization of Multihub emergency supplies collection network. However, most of existing literatures focus on single-hub earthquake emergency supplies collection with identified demand and given collection time, so that there lays great limit to promotion of the outcomes. In fact, during earthquake emergency response, the complexity of disaster environment and its random evolution usually result in the uncertainty and vagueness of demand information, time for emergency supplies collection, and other factors. Therefore, it is required to consider the real situation of earthquake to construct a proper emergency supplies collection network and to make reasonable collection decisions. On the basis of existing studies, taking into consideration the time limit of emergency supplies demand, collection time as fuzzy interval number, and capacity limit of Multihub transfer center, this paper studies the optimal decision-making for double-layered hub-and-spoke emergency supplied collection network.

*The Main Contribution of This Paper.* This paper constructs a multiobjective programming model and designs PSO parallel optimization algorithm to optimize the decision-making problem of Multihub emergency supplies collection under fuzzy collection time, which will provide some methods and theoretic basis for emergency management department.

## 2. General Description and Hypotheses

Compared to commercial logistics, hub-and-spoke network has significant difference when being applied into emergency supplies collection system, which includes but is not limited to the following.

*2.1. The Emergency Supplies Flow Is Relatively in One-Way Direction.* In the practice of emergency rescue, in order to cut down the emergency supplies collection time in Multihub emergency supplies collection network, the emergency supplies flow usually starts from emergency supplies provision sites; then emergency supplies are gathered at emergency supplies distribution centers (mentioned as hub herein) in the region concerned, from which it will be transferred and distributed to demand points within such region. There is hardly the case of reverse emergency supplies flow or interflow between emergency supplies provision sites or emergency supplies distribution centers due to time limit and difficulties of collection activities, coordination problem between provision sites under different administrative divisions, and difficulty in resource allocation. Accordingly, the functions of emergency supplies provision sites are generally in two aspects:

(1) To realize the benefit of economy of scale by means of centralized transportation from emergency supplies distribution centers to emergency supplies demand points.

(2) To guarantee continuous emergency supplies provision for disaster areas, to reduce the difficulty of transportation in such areas, and to ensure orderly emergency supplies provision and fair distribution among disaster areas.

*2.2. Location of Emergency Supplies Distribution Center Mainly Depends on the Situation of Demand Points and Their Demands.* For commercial logistics, the hubs are often selected based on history data; then the network is optimized and quantified according to the intended targets in numerous spokes (namely, emergency supplies provision sites and demand points) to locate the hubs. On the contrast, the hubs in emergency supplies collection network are selected in a special way due to the contingency and uncertainty of disaster. Generally speaking, it is not possible to make decisions on hub location in a disaster area based on disaster data in history. Normally, it is more practical and effective to select a certain number of hubs with certain capacity in the vicinity of the disaster area concerned according to the number of emergency supplies demand points in such area, the condition of emergency facilities in the vicinity of the disaster area, level of disaster emergency supplies demand, and other factors, in order to centralize and transfer the supplies from so many emergency supplies provision sites.

Based on the analyses above, several inputs are given as follows: the set of emergency supplies provision sites $A = \{i \mid i = 1, 2, \ldots, n\}$; the set of emergency supplies distribution centers $H = \{p \mid p = 1, 2, \ldots, l\}$; the set of emergency supplies demand points $D = \{j \mid j = 1, 2, \ldots, m\}$; the set of emergency supplies categories $K = \{k \mid k = 1, 2, \ldots, g\}$; the emergency supplies demand at each demand point; the time limit of emergency supplies demand; the capacity limit of emergency supplies distribution centers; the fuzzy interval number of collection time from emergency supplies provision sites to emergency supplies distribution centers and its unit cost; the certain collection time from emergency supplies distribution centers to emergency supplies demand points and its unit cost; the unit cost of emergency supplies transfer; and the emergency supplies transfer time of each cycle. Now the following are required:

(1) To optimize multidistribution hub-and-spoke emergency supplies collection network with constraint on the time limit of emergency supplies demand in a collection time as fuzzy interval number in order to determine the distribution mode of emergency supplies provision sites and the classification method for emergency supplies demand points.

(2) To provide the candidate emergency supplies collection plans $Q = \{(A_1, x_1), (A_2, x_2), \ldots, (A_n, x_n)\}$. The optimal emergency supplies points are then selected to look as the response points from those candidate points while the amount of emergency supplies provision is determined with the minimum collection cost.

*Hypothesis 1.* There is no flow exchange between nodes $A_i$ at any collection cycle, and they are relatively independent; there is no flow exchange or direct connection path between $H_p$ and only emergency supplies are transported from emergency supplies distribution centers to emergency supplies demand points; no site is under the constraint on vehicle transportation capability, and no limit to the number of vehicles is taken into consideration; and the emergency supplies in each collection cycle are collected at only one time.

*Hypothesis 2.* There is a limit to the capacity of each emergency supplies distribution center $H_p$, and all of $k$ emergency supplies provided by emergency supplies provision sites $A_i$ must be transferred through emergency supplies distribution centers $H_p$ to emergency supplies demand points $D_j$.

*Hypothesis 3.* Emergency supplies provision sites $A_i$ feature mixed route distribution, so that they can carry out not only single distribution, but also multiple distributions.

*Hypothesis 4.* The collection time from emergency supplies demand points $D_j$ to emergency supplies distribution centers $H_p$ is a fuzzy interval number, and the fuzzy collection time in the same collection cycle $e$ remains the same.

## 3. Multihub Emergency Supply Collection Optimization Model under Fuzzy Collection Time

*3.1. Symbols.* The symbols of the model are defined as follows:

$CH = \{\mathrm{cap}h_1, \mathrm{cap}h_2, \ldots, \mathrm{cap}h_p\}$: the set of emergency supplies distribution center capacities,

$V = \{v_1, v_2, \ldots, v_n\}$: the set of emergency supplies provision sites, $B = \{h_1, h_2, \ldots, h_p\}$: the set of emergency supplies distribution centers, and

$U = \{u_1, u_2, \ldots, u_m\}$: the set of emergency supplies demand points,

$S = \{(v_1, h_1), (v_2, h_2), \ldots, (v_n, h_p)\}$: the set of routes from emergency supplies provision sites to emergency supplies distribution centers and $F = \{(h_1, u_1), (h_2, u_2), \ldots, (h_p, u_m)\}$: the set of routes from emergency supplies distribution centers to emergency supplies demand points,

$q_{eki}$: the amount of $k$ emergency supplies that emergency supplies provision site $A_i$ can supply at cycle $e$,

$q_{ekj}$: the demand for $k$ emergency supplies at emergency supplies demand point $D_j$ at cycle $e$,

$q_{ekih}$: the amount of $k$ emergency supplies supplied by emergency supplies provision site $A_i$ to emergency supplies distribution center $H_p$ at cycle $e$,

$q_{ekh}$: the amount of $k$ emergency supplies collected exogenously at emergency supplies collection centers at the start of cycle $e$,

$q_{ekhj}$: the amount of $k$ emergency supplies transferred from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$ at cycle $e$,

$\widetilde{T}_{eih} = [t^-_{eih}, t^+_{eih}]$: the time for emergency supplies provision site $A_i$ to collect all $k$ emergency supplies at one time and transport to emergency supplies distribution center $H_p$ at cycle $e$, where $\widetilde{T}_{eih}$ is a fuzzy interval number, $t^-_{eih}$ is its lower limit, and $t^+_{eih}$ is its upper limit,

$t_e$: the time limit for emergency supplies provision site $A_i$ to collect $k$ emergency supplies and transport to emergency supplies distribution center $H_p$ at cycle $e$,

$T^*$: the time limit to collect $k$ emergency supplies at cycle $e$,

$t_{eh}$: the detention time of all $k$ emergency supplies at emergency supplies distribution center $H_p$ at cycle $e$ (including loading/unloading time, sorting time, packaging time, and handling time),

$t_{ehj}$: the time to transfer all $k$ emergency supplies at one time from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$ at cycle $e$,

$c_{ekih}$: the collection cost in unit time for emergency supplies provision sites to collect each unit of $k$ emergency supplies and transport to emergency supplies distribution center $H_p$ at cycle $e$,

$c_{ekh}$: the unit cost of $k$ emergency supplies to be transferred when they are detained at emergency supplies distribution center $H_p$ at cycle $e$ (including loading/unloading cost, labor cost, depreciation cost of facilities, administrative cost, and handling cost),

$c_{ekhj}$: the unit time cost to transfer each unit of $k$ emergency supplies from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$ at cycle $e$,

$f_p$: the number of directions that emergency supplies provision site $A_i$ responding to collection allocates to emergency supplies distribution center $H_p$ at cycle $e$,

$n_j$: the number of directions from which emergency supplies distribution center $H_p$ transfers $k$ emergency supplies to emergency supplies demand point $D_j$ at cycle $e$,

$T, C$: the time to complete collection of $k$ emergency supplies and the total collection cost at cycle $e$. For an emergency supplies collection system, the shortest time $T$ will be the total collection time of the route from the start point $A_i$ that is the last one to complete collection through the transfer point $H_p$ to the end point $D_j$,

$U_{ei}$: 1 when emergency supplies provision site $A_i$ is selected to be the collection response site at collection cycle $e$ or 0 otherwise,

$Z_{eh}$: 1 when candidate emergency supplies distribution center $H_p$ is selected to be the response transfer site at collection cycle $e$ or 0 otherwise.

*3.2. Model Construction.* A multiobjective programming model for Multihub emergency supplies collection under the constraints of time limited and fuzzy collection time is as follows:

$$\min \quad T = \max\left(\widetilde{T}_{eih} \cdot U_{ei} + t_{eh} + t_{ehj}\right) \tag{1}$$

$$\begin{aligned} \min \quad C &= \sum_{k=1}^{g} \sum_{p=1}^{l} \sum_{i=1}^{n} q_{ekih} c_{ekih} \widetilde{T}_{eih} \cdot U_{ei} \cdot f_p \\ &\quad + \sum_{k=1}^{g} \sum_{p=1}^{l} c_{ekh} \left(q_{ekih} + q_{ekh}\right) \\ &\quad + \sum_{k=1}^{g} \sum_{p=1}^{l} \sum_{j=1}^{m} c_{ekhj} q_{ekhj} \cdot Z_{eh} \cdot n_j \end{aligned} \tag{2}$$

$$\text{s.t.} \quad \sum_{k=1}^{g} \sum_{i=1}^{n} q_{eki} \ge \sum_{k=1}^{g} \sum_{j=1}^{m} q_{eki}, \quad \forall k \in g,\ \forall i \in n,\ \forall j \in m \tag{3}$$

$$\sum_{k=1}^{g} \sum_{i=1}^{n} q_{ekih} \cdot U_{ei} \le \sum_{k=1}^{g} \sum_{j=1}^{m} q_{ekj}, \quad \forall k \in g,\ \forall i \in n,\ \forall j \in m \tag{4}$$

$$\sum_{p=1}^{l} \sum_{k=1}^{g} \mathrm{cap} h_p \ge \sum_{j=1}^{m} \sum_{k=1}^{g} q_{ekj}, \quad \forall k \in g,\ \forall i \in n,\ \forall j \in m \tag{5}$$

$$\sum_{i=1}^{n} q_{ekih} \le \sum_{i=1}^{n} q_{eki}, \quad \forall i \in n \tag{6}$$

$$\sum_{k=1}^{g}\sum_{i=1}^{n} q_{ekih}\cdot U+\sum_{k=1}^{g}\sum_{p=1}^{l} q_{khj}\cdot Z_{eh} = \sum_{k=1}^{g}\sum_{j=1}^{m} q_{ekj}, \quad \forall k\in g,\ \forall i\in n,\ \forall j\in m,\ \forall p\in l \tag{7}$$

$$\sum_{k=1}^{g}\sum_{p=1}^{l} q_{ekh}\cdot Z_{eh} < \sum_{k=1}^{g}\sum_{j=1}^{m} q_{ekj}, \quad \forall k\in g,\ \forall j\in m,\ \forall p\in l \tag{8}$$

$$\widetilde{T}_{eih} \le t_e \tag{9}$$

$$\widetilde{T}_{eih}\cdot U_{ei}+t_{eh}+t_{ehj}\le T^{*}, \quad \forall k\in g,\ \forall i\in n,\ \forall j\in m \tag{10}$$

$$U_{ei}\in\{0,1\},\quad Z_{eh}\in\{0,1\}, \quad \forall i\in n \tag{11}$$

$$1\le f_p\le p,\quad 1\le n_j\le m,\quad 2\le p\le l, \quad \forall p\in l,\ \forall j\in m \tag{12}$$

$$\widetilde{T}_{eih}=\begin{cases}\widetilde{T}_{eih} & \sum_{k=1}^{g} q_{ekih}>0\\ 0 & \sum_{k=1}^{l} q_{ekih}=0,\end{cases} \quad \forall i\in n,\ \forall k\in g \tag{13}$$

$$t_{ehj}=\begin{cases}t_{ehj} & \sum_{k=1}^{g} q_{ekhj}>0\\ 0 & \sum_{k=1}^{g} q_{ekhj}=0,\end{cases} \quad \forall i\in n,\ \forall j\in m,\ \forall k\in g \tag{14}$$

$$\widetilde{T}_{eih}+t_{eh}+t_{ehj}\le T^{*}. \tag{15}$$

In this model, the target function (1) is the target function of minimum collection time, which is composed of three parts: the first part is the collection time from emergency supplies provision site $A_i$ to emergency supplies distribution center $H_p$; the second part is the time to transfer $k$ emergency supplies at one time from emergency supplies distribution center $H_p$; and the third part is the time to transfer $k$ emergency supplies from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$. The target function (2) is the target function of collection cost, which is also composed of three parts: the first part is the total collection cost for the selected emergency supplies provision site $A_i$ to collect all $k$ emergency supplies and transport to emergency supplies distribution center $H_p$; the second part is the total detention cost of $k$ emergency supplies at emergency supplies distribution center $H_p$; and the third part is the total transfer cost of $k$ emergency supplies from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$.

The constraint function (3) represents that the amount of $k$ emergency supplies that emergency supplies provision site $A_i$ can provide is no less than the demand at emergency supplies demand point $D_j$ at cycle $e$; (4) represents that the emergency supplies amount that emergency supplies provision site $A_i$ provides to emergency supplies distribution center $H_p$ is no more than the emergency supplies demand at cycle $e$; (5) represents that the capacity of emergency supplies distribution center $H_p$ meets the emergency supplies demand at cycle $e$; (6) represents that the emergency supplies amount that emergency supplies provision site $A_i$ collects and transports to emergency supplies distribution center $H_p$ is no more than the amount that the emergency supplies provision sites can provide; (7) is the emergency supplies balance function, representing that the emergency supplies amount that emergency supplies provision site $A_i$ collects and transports to emergency supplies distribution center $H_p$, plus the amount of emergency supplies collected exogenously at the emergency supplies collection center, is equal to the demand at demand points at cycle $e$; (8) is to ensure that there is any emergency supplies provision site $A_i$ to collect emergency supplies and transport to emergency supplies distribution centers; (9) is the time constraint on transfer from an emergency supplies provision site to an emergency supplies distribution center; (10) is the constraint function of collection time to collect $k$ emergency supplies at cycle $e$; (11) is the decision variable (0 or 1); (12) is the constraint on the number of distribution directions; (13) and (14) are the actual time of transfer from an emergency supplies provision site to an emergency supplies distribution center and that from the emergency supplies distribution center to an emergency supplies demand point, respectively; and (15) is the time constraint of the emergency supplies collection network to collect $k$ emergency supplies at cycle $e$.

*3.3. Fuzzy Interval Processing.* The fuzzy set theory was founded by L. A. Zadeh who provides powerful mathematical tools for the study of the fuzzy uncertainty; a fuzzy concept can be described by the set. Fuzzy set theory does not do a simple affirmation and negation of things but uses membership grade to reflect the degree of one thing belonging to a certain category. Using this method to represent the fuzziness of objective existence, the fuzzy set theory can describe fuzziness well, but it uses a membership function of single value to represent a relationship of "belongs to a certain extent," so that it cannot represent neutral evidence. Therefore, fuzzy set has an obvious defect. In view of this, this paper selects the fuzzy interval which is suitable for the actual earthquake to describe the demand uncertainty and uses mature theories and methods of fuzzy mathematics to deal with the fuzzy interval.

In the model above, the target function (1) and the constraint functions (9), (10), and (13) to (15) are functions with a fuzzy constraint parameter $\widetilde{T}_{eih}$. $\widetilde{T}_{eih}$ is a fuzzy interval number and cannot be compared to real number. Therefore, it is necessary to perform obfuscation for $\widetilde{T}_{eih}$, so that it will be converted to a clear number that can be compared or described in order to solve the multiobjective programming model. This paper applies the definition of fuzzy interval number by Moore and Lodwick [19] and Sengupta and Pal [20] and uses the Certainty Factor (CF) of an event to describe the fuzzy constraint parameter $\widetilde{T}_{eih}$.

The CF of event $\{\widetilde{t}_i \le t\}$ is defined and denoted by $\mathrm{CF}(\widetilde{t}_i \le t)$, where $\widetilde{t}_i$ is the fuzzy interval parameter of time and $t$ the time constraint parameter. For the purpose of the discussion below, a definition is stated as follows.

*Definition 1* (see [19]). For fuzzy interval number $\widetilde{t}_i = [t_i^-, t_i^+]$, $t_i^- < t_i^+$, where $t_i^-$ is the lower limit of the interval number, $t_i^+$ is its upper limit, and $t$ is the time limit, the membership function of the fuzzy interval parameter $\widetilde{t}_i$ that satisfies the constraint time parameter $t$ is

$$\mathrm{CF}(\widetilde{t} \le t) = \begin{cases} 0, & t < t_i^- \\ \dfrac{t - t_i^-}{t_i^+ - t_i^-}, & t_i^- \le t \le t_i^+ \\ 1, & t > t_i^+, \end{cases} \tag{16}$$

where the interval number has a certain lower limit $t_i^-$ and a greater upper limit $t_i^+$ of the interval number results in greater $\mathrm{CF}(\widetilde{t} \le t)$. When $t_i^- = t_i^+$, the fuzzy interval number $\widetilde{t}_i$ is degraded to a real number, and the membership function (16) is degraded to

$$\mathrm{CF}(\widetilde{t}_i \le t) = \begin{cases} 0, & t < t_i^- = t_i^+ \\ 1, & t \ge t_i^- = t_i^+. \end{cases} \tag{17}$$

Then $S(\phi, t)$ is used to express the possibility for any plans $\phi$ to complete emergency supplies collection task within time constraint $t$, namely, the CF, where the transfer time from any emergency supplies provision site $A_i$ to the emergency supplies distribution center $H_p$ is no longer than $t$ in the program $\phi$; then

$$S(\phi, t) = \mathrm{CF}\left\{ \bigcap_{i=1,2,\ldots,n} \mathrm{CF}(\widetilde{t}_i \le t) \right\}. \tag{18}$$

Then, it can be gotten by using fuzzy inference technology that

$$\begin{aligned} S(\phi, t) &= \mathrm{CF}\left\{ \bigcap_{i=1,2,\ldots,n} \mathrm{CF}(\widetilde{t}_i \le t) \right\} \\ &= \min_{i=1,2,\ldots,n} \mathrm{CF}(\widetilde{t}_i \le t). \end{aligned} \tag{19}$$

When $\chi$ is used to represent the set of collection plans of emergency supplies provision site $A_i$ to collect all $k$ emergency supplies and transport to emergency supplies distribution center $H_p$ at cycle $e$, the target of optimization is to find an optimal plan which can realize the greatest CF such that the time to complete collection work according to this plans is no longer than $t_e$. Based on such optimal plans, the emergency supplies collection cost between nodes $(V, B)$ can be minimized.

### 3.4. Algorithm Design

*3.4.1. Algorithm Selection.* In the multiobjective programming model above, (1), the target function of minimum time has two different time parameters: the first one is the fuzzy interval number of collection time from emergency supplies provision site $A_i$ to emergency supplies distribution center $H_p$, which is corresponding to the second layer of emergency supplies collection network; and the second one is the exact number from emergency supplies distribution center $H_p$ to emergency supplies demand point $D_j$, which is corresponding to the first layer of emergency supplies collection network. This programming mode with mixed time parameters is much more suitable for the real situation of disaster relief. In the first layer of emergency supplies collection network, the emergency supplies distribution center $H_p$ mainly locates in the vicinity of the disaster area, resulting in a short distance from emergency supplies demand point $D_j$ (for which the shortest distance can be determined at the middle and late stages of disaster). Meanwhile, the emergency supplies demand at emergency supplies demand point $D_j$ is transferred from emergency supplies distribution center $H_p$, and once this transfer starts, the collection time for all road sections is decided. Therefore, the time is not fuzzy. In the second layer of emergency supplies collection network, each emergency supplies provision site $A_i$ usually can provide only a small emergency supplies amount, and it is necessary to gather emergency supplies from the third layer, namely, the emergency supplies gathering points, to guarantee the emergency supplies collection amount required at cycle $e$. Due to the complexity of earthquake emergency supplies to be collected, different emergency supplies collection channels are mixed for combined application. While the emergency supplies gathering points in the third layer and the emergency supplies provision sites in the second layer are generally subordinate to different administrative divisions and the nodes differ in the capability of emergency supplies collection, in addition to the limit to coordination capability, commanding capability, and transportation capability, and many other uncertain factors, so that the collection time from the emergency supplies gathering points in the third layer to the emergency supplies provision sites in the second layer is indistinct and uncertain, which is especially obvious at the early and middle stages of disaster, it is quite suitable to the actual situation of disaster to set fuzzy interval number at the second layer of emergency supplies collection network.

On the basis of the analysis above, the idea of algorithm design is changed for the convenience of solving multiobjective programming model and compiling computer program code. As the programming model mentioned above contains fuzzy interval number and many dynamic parameters, the solution space composed of target functions and constraints cannot satisfy the mathematical analysis condition that the functions will be differentiable, and the feasible domain will be continuous and a convex set. Therefore, it is necessary to solve the problem with highly adaptive intelligent optimization algorithm, for a greater rate of convergence of solving the problem and more reliable decision-making plans. For this purpose, this paper chooses Particle Swarm Optimization (PSO), which is easy to operate with high robustness and high rate of convergence, to solve the double-objective programming model of Multihub emergency supplies collection with constraint on time limit of demand in a collection time as fuzzy interval. This paper compares PSO algorithm to genetic algorithm, taboo search algorithm, and heuristic algorithm in respect to the degree of complexity. When there are a small number of nodes, heuristic algorithm is simpler and easier to understand, so that it takes the fewest time for the computer; when there are more nodes, the difficulty of operation raises exponentially, and the operation time of computer increases rapidly. This indicates that heuristic algorithm is only suitable for emergency supplies collection network with a small number of nodes and a small number of iterations. Comparatively, PSO algorithm, genetic algorithm, and taboo search algorithm are of the same degree of complexity. Under a certain population size, a certain number of iterations, and a certain number of nodes in emergency supplies collection network, the complexity of PSO algorithm is in direct proportion to the square of the number of nodes and in direct proportion to the population size and the number of iterations; when there are more nodes, the operation time of computer increases slowly. Therefore, it is feasible for this paper to employ PSO algorithm.

#### *3.4.2. Determination of Sites Participating in Collection Response*

*Definition 2* (Senguta A., 2003). If there is any sequence of emergency supplies provision sites $A_1^*, A_2^*, \ldots, A_n^*$ that lets $\sum_{i=1}^{\zeta-1} A_i^* < \sum_{i=1}^{n} q_{ekih} < \sum_{i=1}^{\zeta} A_i^*$ at $\zeta$ ($\zeta \le n$), then $\zeta$ is called the critical subscript of this sequence to $\sum_{i=1}^{n} q_{ekih}$.

*Step 1. Solving and Sorting* $\mathrm{CF}(\widetilde{T}_{eih} \le t_e)$. Get $\mathrm{CF}(\widetilde{T}_{eih}) \le t_e$ such that the collection time $\widetilde{T}_{eih}$ from each emergency supplies provision site $A_i$ to emergency supplies distribution center $H_p$ is less than the time limit of demand $t_e$ and sort the CFs $\mathrm{CF}(\widetilde{T}_{eih}) \le t_e$ of all emergency supplies provision sites in a descending order. A greater $\mathrm{CF}(\widetilde{T}_{eih}) \le t_e$ indicates a shorter collection time from corresponding convex set provision site $A_i$ to emergency supplies distribution center $H_p$ and a greater CF such that it satisfies the constraint time $t_e$.

*Step 2. Solving the Critical Subscript That Satisfies the Collection Amount.* Assuming that the sequence of emergency supplies provision sites in descending order of CF is $A_1^*, A_2^*, \ldots, A_n^*$, according to Definition 2, finding the first $i$ emergency supplies provision sites $A_i^*$ from the sorting sequence of $\mathrm{CF}(\widetilde{T}_{eih}) \le t_e$, and getting the critical subscript $\zeta$ that satisfies $\sum_{i=1}^{n} q_{ekih}$ by equation $\sum_{i=1}^{\xi-1} A_i^* < \sum_{i=1}^{n} q_{ekih} < \sum_{i=1}^{\xi} A_i^*$, then the emergency supplies provision sites that satisfy the critical subscript $\zeta$ compose the assembly of feasible plans that satisfy the collection amount at emergency supplies distribution center, which is denoted by $\phi(A_i, q_{ekih}, t_i)$.

When applying PSO to solve the programming model of Multihub emergency supplies collection network with constraint on the time limit in a collection time as fuzzy interval number, it is necessary to solve the problems in two stages: the first one is to distribute the $k$ emergency supplies at each emergency supplies demand point $D_j$ to the emergency supplies distribution centers required $H_p$ according to the constraint on total time $T^*$ of emergency supplies collection system and the capacity limit of emergency supplies distribution center $H_p$, so as to decide the distribution directions and collection amount of emergency supplies provision site $A_i$ participating in collection response; and the second one is to find the optimal solution among the feasible assembly $\phi(A_i, q_{ekih}, t_i)$, so as to decide the distribution directions and emergency supplies collection amount at emergency supplies provision site $A_i$, and the optimal collection cost that satisfies the constraint on demand time. Based on the targets of the two stages, this paper designs PSO to solve the problems in the two-stage parallel way to achieve the global optimal solution in the solution space.

*(1) Encoding Algorithm of PSO.* American electrical engineer Eberhart and psychologist Kennedy developed a new group of intelligent optimization technologies based on the foraging behavior of bird flock, which is called Particle Swarm Optimization (PSO). This technology employs velocity-displacement model and uses the special memory function of bird flock, which can track and search the path under the guidance of fitness function and adjust the searching strategy in a dynamic way, to complete the global search of the flock and to find the global optimal solution. Compared to genetic algorithm, PSO features simpler process and less adjustment to parameters. Each solution of this optimization model is a "particle" in the searching space of PSO, and, for the status of each particle, the fitness function is used to assess its current optimal position. PSO requires initializing the particle swarm at first and then performing continuous iteration until the optimal solution is found [21, 22]. For this purpose, this paper raises the assumptions as follows: (1) there are Q particles in an $n$-dimensional space, and the corresponding position vectors of these Q particles are $X_i = (X_{i1}, X_{i2}, \ldots, X_{in})$; (2) the fitness function of $X_{in}$ related to the target function to be optimized is $\mathrm{Fit}_i$; (3) the velocity vectors of these Q particles are $V_i = (V_{i1}, V_{i2}, \ldots, V_{in})$; and (4) the position interval of the particles is $[X_{\min}, X_{\max}]$ and the

velocity interval is $[V_{\min}, V_{\max}]$, so as to restrict any particle to escape from the searching space. Then, the optimal position vectors of any single particle and that in the flight history of particle swarm are denoted by $Y_i = [Y_{i1}, Y_{i2}, \ldots, Y_{in}]$ and $Y_k = [Y_{k1}, Y_{k2}, \ldots, Y_{kn}]$, respectively, and the position and velocity updating formulas of particle flight are as follows:

$$\begin{aligned} X_{id}(t+1) &= X_{id}(t) + V_{id}(t+1), \\ V_{id}(t+1) &= c_1 r_1 \left(Y_{id}(t) - X_{id}(t)\right) \\ &\quad + c_2 r_2 \left(Y_{kd}(t) - X_{id}(t)\right) + \omega V_{id}(t), \end{aligned} \tag{20}$$

where $c_1, c_2$ are acceleration constants and $c_1 > 0, c_2 > 0$; $r_1, r_2$ are random numbers uniformly distributed within $[0, 1]$; $\omega$ is the inertia weight factor; and $d$ is the dimension of the particle.

The key point of PSO design is finding the suitable description, so that the position of particle is corresponding to the solution to the two-stage problem of emergency supplies collection. Since emergency supplies provision site $A_i$, emergency supplies distribution center $H_p$, and emergency supplies demand point $D_j$ are discrete variables in this two-stage problem and the emergency supplies flows between nodes $(v_n, h_p)$ and nodes $(h_p, u_m)$ are continuous variable, position encoding for particle swarm calls for handling mixed encoding with both discrete variables and continuous variables. This paper adopts the encoding method to deal with the combined optimization with both discrete variables and continuous variables proposed by He and Wu [23], which divides the position vector $X_i = (X_{i1}, X_{i2}, \ldots, X_{in})$ of $Q$ particle into two parts: (1) the discrete variable part, corresponding to $p$ emergency supplies distribution centers, the collection time from $n$ emergency supplies provision sites to emergency supplies distribution centers, $m$ emergency supplies demand points, and the transfer time from $p$ emergency supplies distribution centers to emergency supplies demand points in the two-stage problem; meanwhile, the position codes of particle swarm are the first $p+n-1$ columns and the first $m+p-1$ columns of the matrix, respectively, and the sorting order is the sequence of distribution directions of each emergency supplies provision site participating in collection response and the sequence when emergency supplies demand points are allocated to emergency supplies distribution centers; (2) the continuous variable part, corresponding to the last $p$ columns and the last $m$ columns of the matrix, which represent the emergency supplies amount collected at $p$ emergency supplies distribution centers and the amount distributed to $m$ emergency supplies demand points, respectively.

*(2) Fitness Function of Two-Stage Parallel Algorithm.* The programming model in this paper is complicated, as the model of interest is double-objective nonlinear programming model, and the algorithm design has to be divided into two stages. Accordingly, it is necessary to find the suitable fitness for each stage in PSO design to update the state of each particle and to get its new position. At first, the problem of the first stage of programming model (i.e., the first layer of emergency supplies collection network) and the problem of the second stage of programming model (i.e., the second layer of emergency supplies collection model) are normalized by the equations below:

$$\begin{aligned} Z_1 &= \eta_1 \frac{T - T_{\min}}{T_{\max} - T_{\min}} + \eta_2 \left[1 - \frac{1}{m} \sum_{i=1}^{m} \mu_{\widetilde{\eta}_i}\left(q_{ekj}^{j}\right)\right], \\ Z_2 &= \eta_1 \frac{T - T_{\min}}{T_{\max} - T_{\min}} + \eta_2 \left[1 - \frac{1}{p} \sum_{i=1}^{p} \mu_{\widetilde{\eta}_i}\left(q_{ekih}^{p}\right)\right], \end{aligned} \tag{21}$$

where $q_{ekj}^{j}$ is the ES demand at each emergency supplies demand point, $q_{ekih}^{p}$ is the emergency supplies amount collected at each emergency supplies distribution center, $\eta_1, \eta_2$ are the weight of collection time and the weight of collection cost in the double-objective model, respectively, and $\eta_1, \eta_2 \in [0, 1], \eta_1 + \eta_2 = 1$, and $T, T_{\min}, T_{\max}$ are the emergency supplies collection at each stage, its minimum collection time, and its maximum collection time, respectively. Furthermore, when normalizing the two objectives of the programming model, in order to find the fitness function and simplify the problem, the optimal objective of the interesting model is taken into the consideration of PSO based on the weak economy feature of disaster. After several solution vectors of collection time have been obtained, several collection plans that satisfy the constraint on collection time are identified based on the time limit of collection, and from these plans, the one with lowest cost but satisfying the constraint on limit time is obtained, which is the optimal solution of the programming model.

The fitness function of the first stage is

$$\begin{aligned} \mathrm{Fit}_i^1 &= \min\left(\frac{1}{Z_1}\right) + R \\ &\quad * \left(\sum_{p=1}^{l} \max\left(\sum_{j=1}^{m} q_{ekj} - q_{ekhj}, 0\right)\right. \\ &\quad \left. + \sum_{p=1}^{l} \max\left(\max t_{ehj} - \min t_{ehj}, 0\right)\right). \end{aligned} \tag{22}$$

The fitness function of the second stage is

$$\begin{aligned} \mathrm{Fit}_i^2 &= \min\left(\frac{1}{Z_2}\right) + R * \left(\sum_{i=1}^{n} \max\left(\sum_{p=1}^{l} q_{ekh} - q_{ekih}, 0\right)\right. \\ &\quad \left. + \sum_{p=1}^{l} \max\left(\min \mathrm{CF}\left(\widetilde{T}_{eih} \le t_e\right) - \max \mathrm{CF}\left(\widetilde{T}_{eih} \le t_e\right), 0\right)\right). \end{aligned} \tag{23}$$

The first term of either (22) or (23) is the reciprocal of the combined target, which is used to outstand the difference on the coordinate axis by means of reciprocal; the last two terms are used to integrate the emergency supplies flow and collection time of the constraint into the fitness function; and $R$ is a greater positive number, which is used to intensify the influence level of this factor. For the solution of this algorithm, the basic method is to limit the encoding range and to judge whether the new position of the particle after updating meets the constraint, and then the current state of the particle is updated. If it does not meet the constraint, it is excluded to simplify solving the problem.

Table 1: Quantity of emergency supplies supply nodes.

| Points | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ |
|---|---|---|---|---|---|---|---|---|
| Water ($k_1$) | 500 | 550 | 610 | 580 | 700 | 620 | 710 | 530 |
| Food ($k_2$) | 280 | 260 | 320 | 280 | 360 | 300 | 270 | 330 |
| Disinfectant ($k_3$) | 420 | 390 | 290 | 410 | 400 | 480 | 370 | 340 |

Table 2: Average collecting time of emergency supplies under the hub network.

| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ |
|---|---|---|---|---|---|---|---|---|
| $H_1$ | 0.3 | 0.7 | 2.1 | 1.2 | 0.5 | 1.1 | 1.5 | 2 |
| $H_2$ | 0.5 | 0.4 | 0.8 | 0.6 | 1 | 0.9 | 1.3 | 1.4 |
| $H_3$ | 1 | 1.5 | 1.8 | 2.2 | 2 | 1.3 | 0.5 | 0.9 |
| | $D_1$ | $D_2$ | $D_3$ | $D_4$ | — | — | — | — |
| $H_1$ | 0.8 | 0.6 | 1.5 | 0.9 | — | — | — | — |
| $H_2$ | 1 | 0.7 | 2 | 1.3 | — | — | — | — |
| $H_3$ | 2 | 0.8 | 1.5 | 1.4 | — | — | — | — |

Note: set the average transit time as 1 for each emergency supplies distribution center during cycle $e$.

Table 3: Each unit collecting cost of each unit's emergency supplies under the hub network.

| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ |
|---|---|---|---|---|---|---|---|---|
| $H_1$ | 2 | 1 | 3 | 2 | 1.5 | 3 | 1 | 2 |
| $H_2$ | 3 | 2 | 4 | 1.5 | 1 | 2.1 | 2 | 1.4 |
| $H_3$ | 0.5 | 1 | 0.7 | 3.2 | 1.4 | 1.2 | 0.7 | 1.8 |
| | $D_1$ | $D_2$ | $D_3$ | $D_4$ | — | — | — | — |
| $H_1$ | 0.6 | 0.2 | 1 | 0.8 | — | — | — | — |
| $H_2$ | 1 | 0.7 | 0.9 | 1.7 | — | — | — | — |
| $H_3$ | 0.8 | 1.2 | 0.7 | 1 | — | — | — | — |

Note: the stranded costs are 0.1 for unit emergency supplies in the distribution center.

*(3) Updating the Position and Velocity of Particle*. Based on Tian et al.'s [24] special definition of the position and velocity of particle, "$\oplus$" is used to denote the addition of the positions of particles, and "$\odot$" is used to denote the subtraction between particles; then the PSO formulas of updating the position and velocity are

$$X_{id}(t+1) = X_{id}(t) \oplus V_{id}(t+1),$$
$$V_{id}(t+1) = \omega V_{id}(t) \oplus c_1 \cdot r_1 \cdot Y_{id}(t) \odot X_{id}(t) \oplus c_2 \cdot r_2 \cdot Y_{gd}(t) \odot X_{id}(t). \quad (24)$$

When applying these updating formulas, vector position and velocity updating are performed for each particle, in which (24) is used for the discrete part and (20) for the continuous part.

## 4. Case Verification

The data for verification is as shown in Tables 1–8. The constraint period of $A_i \rightarrow H_p$ collection time is 1.1, and the constraint period of collection time for $k$ emergency supplies at cycle $e$ is 5.5.

Table 4: Capacity and initial collecting quantity of each hub.

| | $H_1$ | $H_2$ | $H_3$ |
|---|---|---|---|
| $caph_p$ | 3100 | 2700 | 3400 |
| Water ($k_1$) | 40 | 0 | 50 |
| Food ($k_2$) | 0 | 30 | 8 |
| Disinfectant ($k_3$) | 60 | 0 | 0 |

For parameter setting of the optimal algorithm of PSO, see Table 8.

Based on the programming language used in algorithm design, this paper deals with the computer output to get the decision-making plan of Multihub emergency supplies collection network with constraint period and a collection as fuzzy interval number as shown in Tables 9 and 10.

The results of simulation show that, at collection cycle $e$, the shortest collection time to collection 3 emergency supplies is 4.6, with a collection cost of 19793.6.

In order to verify the validity of this algorithm, this paper employs SA intelligent optimization algorithm and sequential enumeration method (SEM) to solve the problem mentioned

Table 5: Demand quantity of emergency supplies.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $k_1$ | 1000 | 900 | 830 | 1000 |
| $k_2$ | 430 | 450 | 420 | 510 |
| $k_3$ | 600 | 580 | 550 | 690 |

Table 6: Fuzzy interval of the collecting time from $A_i \to H_p$.

| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ |
|---|---|---|---|---|---|---|---|---|
| $H_1$ | [0.2, 0.4] | [0.5, 0.7] | [1.8, 2.2] | [1.0, 1.25] | [0.4, 0.53] | [0.9, 1.15] | [1.3, 1.6] | [1.8, 2.2] |
| $H_2$ | [0.3, 0.6] | [0.3, 0.55] | [0.7, 0.9] | [0.5, 0.7] | [0.9, 1.1] | [0.8, 0.95] | [1.2, 1.4] | [1.3, 1.5] |
| $H_3$ | [0.85, 1.2] | [1.0, 1.2] | [1.7, 1.9] | [2.1, 2.3] | [1.0, 2.1] | [1.25, 1.4] | [0.4, 0.6] | [0.8, 1.0] |

Table 7: Collecting time from $H_p \to D_j$.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $H_1$ | 0.8 | 0.6 | 1.5 | 0.9 |
| $H_2$ | 1 | 0.7 | 2 | 1.3 |
| $H_3$ | 2 | 0.8 | 1.5 | 1.4 |

Note: set the average transit time as 1 for each emergency supplies distribution center during cycle $e$.

Table 8: Parameter setting of PSO.

| Particle size | Largest number of iterations ($T_{\max}$) | $c_1$ | $c_2$ | Initial inertiaweight ($\omega_{\text{ini}}$) | Inertia weight of the largest number of iterations ($\omega_{\text{end}}$) |
|---|---|---|---|---|---|
| 70 | 600 | 1.5 | 1.5 | 0.85 | 0.3 |

Note: the inertia weight factors according to the following formula: $\omega^t = (\omega_{\text{ini}} - \omega_{\text{end}})(T_{\max} - t)/T_{\max} + \omega_{\text{end}}$.

Table 9: Distribution and RANP scheme of emergency supplies demand nodes.

| Hub nodes | Distribution demand nodes | Transshipment quantity of $H_p \to D_j$ | | | Collecting time | Collecting costs |
|---|---|---|---|---|---|---|
| | | $k_1$ | $k_2$ | $k_3$ | | |
| $H_1$ | $D_1$ | 1000 | 170 | 0 | 0.8 | 655.2 |
| | $D_2$ | 900 | 450 | 580 | 0.6 | 347.4 |
| $H_2$ | $D_1$ | 0 | 260 | 600 | 1 | 946 |
| | $D_4$ | 1000 | 510 | 330 | 1.3 | 4305.6 |
| $H_3$ | $D_3$ | 830 | 420 | 550 | 1.5 | 2160 |
| | $D_4$ | 0 | 0 | 360 | 1.4 | 554.4 |

Table 10: Distribution and collecting schemes of emergency supplies supply nodes.

| Hub nodes | $A_i$ are assigned to $H_p$ | Collecting quantity of $A_i \to H_p$ | | | Collecting time | Collecting costs |
|---|---|---|---|---|---|---|
| | | $k_1$ | $k_2$ | $k_3$ | | |
| $H_1$ | $A_1, A_2, A_5, A_6$ | $(A_1, 500), (A_2, 550), (A_5, 700), (A_6, 110)$ | $(A_1, 280), (A_2, 260), (A_5, 80)$ | $(A_1, 420), (A_2, 100)$ | 1.15 | 2597 |
| $H_2$ | $A_3, A_4, A_5$ | $(A_3, 610), (A_4, 390)$ | $(A_3, 320), (A_4, 280), (A_5, 140)$ | $(A_3, 290), (A_4, 410), (A_5, 230)$ | 1.1 | 5933 |
| $H_3$ | $A_2, A_5, A_7, A_8$ | $(A_7, 710)$ | $(A_5, 140), (A_7, 270), (A_8, 2)$ | $(A_2, 30), (A_5, 170), (A_7, 370), (A_8, 340)$ | 2.1 | 2285 |

in this paper. The initial temperature of SA is 3000, and the decrease ratio is 0.95. When the temperature is below 15°, equal-step-length decreasing method is employed with a step length of 1. The number of iterations at a temperature is 30, and the algorithm is terminated when there is no change after 8 iterations. The result showed that when the number of iterations of PSO is $34 \times 10^2$, the optimal collection time is 4.6; when the number of iterations of SA is $37 \times 10^2$, the optimal collection time is 5.3; and when the number of iterations of SEM is $40 \times 10^2$, the optimal collection time is 6. This indicates that it is an effective way to use PSO to solve the interesting model in this paper, as it leads to the optimal result.

## 5. Conclusions

Earthquake emergency response features weak economy; however it is an important task in its management to achieve the shortest response time and the optimal cost under given time of emergency supplies demand and other constraints, such as uncertain time for emergency supplies collection and capacity limit of hubs, at different stages of earthquake, especially at the middle stage.

At first, this paper takes into consideration the parameter constraints including multiple emergency supplies, capacity limit of hubs, and collection time as fuzzy interval number and puts forward a multiobjective programming model of double-layer Multihub emergency supplies collection under the constraint of multiple parameters in a collection time as fuzzy interval number, based on the operation features of double-layer hub-and-spoke emergency supplies collection network. Meanwhile, based on the constraint on the total time of emergency supplies collection system and the capacity limit of Multihub, this paper designs PSO optimization algorithm to allocate the emergency supplies required at each emergency supplies demand point to Multihub from which the emergency supplies is to be transferred, which can determine the distribution directions and collection amount of emergency supplies provision sites participating in collection response. Secondly, this paper searches for the optimal plan among feasible plans to determine the distribution directions and emergency supplies collection amount at emergency supplies provision sites as well as the optimal collection cost that meet the constraint on demand time. The result of case verification shows that the model constructed in this paper features short iteration time, small number of iterations, and better decision-making outcome, so that it is possible to promote this model in emergence decision-making.

## Competing Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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