Acta Technica 62 (2017), No. 7A, 625–650

Fuzzy multi objective location routing problem model and solution algorithm for distribution network of electricity supplier

Hong Li[1], Sujian Li[1], Xiang Li[1]

Abstract. Problems in logistic distribution system such as high logistic cost, bad service level, etc have been unusually prominent with fast development of e-commerce. The multi objective problem of integrated two-level location –routing of mix fuzzy time windows was proposed in this thesis and facility node location and distribution routing planning in multi-level distribution network were comprehensively considered to guarantee increasing satisfaction degree of customers in premise of certain cost in combination with forward and reverse logistics to optimize logistics distribution network of e-commerce. Simulated annealing algorithm of multi objectives of filing insertion taboo research was designed to solve them and simulated annealed algorithm framework was adopted to comprehensively solve the problem of two-level location-routing pertinent to problem complexity; facility node location change and route change of distribution vehicles were considered at the same time in the aspect of constructing neighborhood and Pareto solution form was solution result. Finally validity verification was respectively conducted on algorithm and model design experiment.

Key words. Multi location-routing problem, Mix fuzzy time window, Integration of distribution and assembling, Multi objectives of filing, Simulated annealed algorithm

.

1. Introduction

Prominent problems in logistic distribution system of e-commerce distribution such as high logistic cost, bad service level, etc attract attention of many research scholars. On one hand, facility location and route optimization in distribution network need to be comprehensively considered to reduce distribution cost and total

[1]School of Mechanical Engineering, University of Science and Technology Beijing, Beijing 100083, China

cost of distribution network can be reduced through reasonable location of distribution service points, arranging distribution capacity and planning distribution route. E-commerce enterprises need to complete distribution service within the scope of time window proposed by the client to increase satisfaction degree of the client and delivery earlier or later than the scope of time window will both cause reduction of satisfaction degree of the client.

Currently most researches are focused on one-level location-route problem and research on two-level location-route problem is not rich enough. Two-level location-route problem was proposed by Jacobsen and Madsen[1] at the earliest and this problem is to solve three NP-hard[2] sub-problems: determine number and location of facility points in logistic network, determine distribution route of one-level vehicles and determine distribution route of two-level vehicles. Nguyen, etc[2] proposed a kind of local search algorithm of multi-origin iteration and further optimized solution scheme with taboo search algorithm frame through route reconnection. Chen Jiumei, etc [3] proposed a kind of artificial bee colony algorithm of variable neighborhood to solve 2E-LRP. Deng Xueping, etc[4] established 2E-LRP model in the environment of B2C e-commerce and proposed a kind of modified genetic algorithm to solve the problems. Zhao Xiaonan, etc considered fuzzy needs of the client based on simultaneous logistic mode of distribution-alteration in B2C distribution network, established fuzzy location model of double objectives and proposed genetic algorithm of embedded random algorithm and taboo search algorithm to solve the problems in pertinence to fuzziness and static nature and location-distribution and certainty and dynamism of distribution.

Literature research indicates that there are not many researches on multi location route problem of e-commerce logistics distribution field currently and multi objectives are not considered or multi objectives are switched into a single objective according to certain weight in most literatures. Integration of distribution and assembling and multi location route problem are comprehensively considered in this thesis and the conception of mix fuzzy time window is proposed; multi location route problem of integration of distribution and assembling of multi objectives for mix fuzzy time window is considered on the basis and mathematical optimization model is established. Simulated annealing algorithm of multi objectives of filing insertion taboo research was designed to solve them pertinent to problem complexity and Pareto solution form is solution result, finally validity verification is respectively conducted on algorithm and model design experiment.

2. Mix fuzzy time window

The clients can be divided into two types according to mix fuzzy time window of clients and the first type is clientN_C' with requirement of fuzzy time window; user satisfaction degree is the highest if distribution or return service is completed within required time window by such clients and user satisfaction degree reduces if the task is completed beyond specified time window and user satisfaction degree reduces to zero if it is beyond limit of the lowest time window which can be tolerated by clients. The second type is clientN_C'' without requirement of time window and distribution or return service needs to be completed as soon as possible for such clients; satisfaction degree of the client is higher if the time needed from placing an order to completion of distribution is shorter.

In reality, limit of time window for the client with requirement of fuzzy time window is not totally rigid. If starting service time of this client is just within the required scope of time window, then user satisfaction degree is the highest; but if it is beyond the requirement of this time window, it does not indicate that this service is totally not acceptable. So it is assumed that the client has satisfaction time window $[E_{DT_i}, L_{DT_i}]$ and maximum time window $[E_{T_i}, L_{T_i}]$ the client can tolerate. Satisfaction degree of clients with requirement of fuzzy time window will reduce if starting service time is early or late, so fuzzy degree of membership function is adopted in this thesis to describe client satisfaction degree with requirement of fuzzy time window. Calculation equation of user satisfaction degree $S(T_i)$ of client $i\,(i \in N'_C)$ is as follows:

$$S(T_i) = \begin{cases} \left(\dfrac{T_i - E_{T_i}}{E_{DT_i} - E_{T_i}}\right)^{\beta_1} & T_i \in [E_{T_i}, E_{DT_i}] \\ 100\% & T_i \in [E_{DT_i}, L_{DT_i}] \\ \left(\dfrac{L_{T_i} - T_i}{L_{T_i} - L_{DT_i}}\right)^{\beta_1} & T_i \in [L_{DT_i}, L_{T_i}] \\ 0 & T_i \notin [E_{T_i}, L_{T_i}] \end{cases} \tag{1}$$

When starting service time of client i is within the expected service time window, the user satisfaction degree is the highest as 1, or user satisfaction degree will reduce with difference increase between service start time and expected service time until start service time of client i exceeds maximum time window $[E_{T_i}, L_{T_i}]$ the client can tolerate; user satisfaction degree of client i reduces to zero at this moment. In the equation, $\beta_i\,(\beta_i > 0)$ is sensitivity coefficient of client i on service time and the bigger β_i indicates that client i is more sensitive to service time.

The client without requirement of time window does not designate time scope of expected service and the client wished to obtain needed service as soon as possible. So, it is assumed that the latest start service time the client can tolerate is L_{T_i} in this thesis for the client without requirement of time window and user satisfaction degree of such clients will reduce with increase of waiting time before order time E_{T_i} to service completion timeT_i. Calculation equation of user satisfaction $U(T_i)$ for client $i\,(i \in N''_C)$ is as follows:

$$U(T_i) = \begin{cases} 100\% & T_i \leq E_{T_i} \\ \left(\dfrac{L_{T_i} - T_i}{L_{T_i} - E_{T_i}}\right)^{\beta_i} & T_i \in [E_{T_i}, L_{T_i}] \\ 0 & T_i \geq L_{T_i} \end{cases} \tag{2}$$

When start service time T_i of client i is earlier than the earliest service time E_{T_i} which can be achieved, then user satisfaction degree of the client at this moment is one, or user satisfaction degree will reduce with increase of time difference between service start time and ordering time until start service time of client i exceeds the latest start service time L_{T_i} the client can tolerate; user satisfaction degree of client i reduces to zero at this moment. In the equation, $\beta_i\,(\beta_i > 0)$ is sensitivity coefficient of client i on service time and the bigger β_i indicates that client i is more sensitive to service time.

Competition in e-commerce field is increasingly fierce, so enterprises tend to specify minimum user satisfaction degree λ_i of each client i. Besides, it needs to limit start service time of each client , namely handle fuzzy time window of the client because each client has minimum user satisfaction degree requirement.

For the client $i\,(i \in N_C')$ with requirement of fuzzy time window, it can be set that

$$S\left(T_i\right) = \begin{cases} f\left(T_i\right) = \left(\dfrac{T_i - E_{T_i}}{E_{DT_i} - E_{T_i}}\right)^{\beta_i} & T_i \in [E_{T_i}, E_{DT_i}] \\ 100\% & T_i \in [E_{DT_i}, L_{DT_i}] \\ g\left(T_i\right) = \left(\dfrac{L_{T_i} - T_i}{L_{T_i} - L_{DT_i}}\right)^{\beta_i} & T_i \in [L_{DT_i}, L_{T_i}] \\ 0 & T_i \notin [E_{T_i}, L_{T_i}] \end{cases} \tag{3}$$

It can be considered that scope of start service time of the client is $[I'_{nf}(\lambda_i), S'_{up}(\lambda_i)]$ on constraint condition of minimum user satisfaction degree λ_i of the client i; in the equation:

$$I'_{nf}\left(\lambda_i\right) = f^{-1}\left(\lambda_i\right) = \sqrt[\beta_i]{\lambda_i} \times E_{DT_i} - \left(\sqrt[\beta_i]{\lambda_i} - 1\right) \times E_{T_i}\,. \tag{4}$$

$$S'_{up}\left(\lambda_i\right) = g^{-1}\left(\lambda_i\right) = \sqrt[\beta_i]{\lambda_i} \times L_{DT_i} - \left(\sqrt[\beta_i]{\lambda_i} - 1\right) \times L_{T_i}\,. \tag{5}$$

For the client $i\,(i \in N_C'')$ without requirement of time window, it can be set that

$$U\left(T_i\right) = \begin{cases} 100\% & T_i = E_{T_i} \\ h\left(T_i\right) = \left(\dfrac{L_{T_i} - T_i}{L_{T_i} - E_{T_i}}\right)^{\beta_i} & T_i \in [E_{T_i}, L_{T_i}] \\ 0 & T_i \geq L_{T_i} \end{cases} \tag{6}$$

It can be considered that scope of start service time of the client is $\left[E_{T_i}, S''_{up}\left(\lambda_i\right)\right]$ on constraint condition of minimum user satisfaction degreeλ_i of the client i; in the equation:

$$S''_{up}\left(\lambda_i\right) = h^{-1}\left(\lambda_i\right) = \left(1 - \sqrt[\beta_i]{\lambda_i}\right) \times L_{T_i} - \sqrt[\beta_i]{\lambda_i} \times E_{T_i}\,. \tag{7}$$

It can be known according to cut set definition of λ_i level of fuzzy set A that start service time window $\left[I'_{nf}\left(\lambda_i\right), S'_{up}\left(\lambda_i\right)\right]$ satisfying minimum user satisfaction degree is a cut set of original fuzzy time window specified by the client for client $i\,(i \in N_C')$

with requirement of fuzzy time window; $I'_{nf}(\lambda_i)$ is the earliest start service time and $S'_{up}(\lambda_i)$ is the latest start service time. Start service time window satisfying minimum user satisfaction degree is $\left[E_{T_i}, S''_{up}(\lambda_i)\right]$ for client $i\,(i \in N''_C)$ without requirement of fuzzy time window; E_{T_i} is ordering time of client i and $S''_{up}(\lambda_i)$ is the latest start service time of the client. Fig. 1 is sketch map of fuzzy time window.

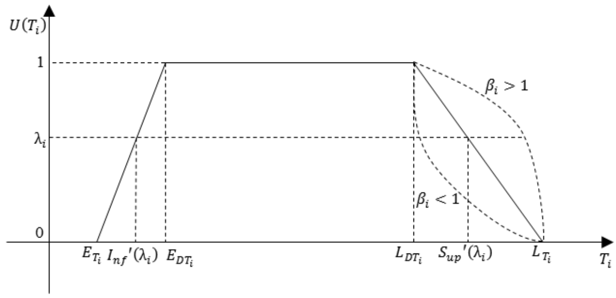

Fig. 1. Sketch map of fuzzy time window

3. Problem description and mathematic model

3.1. Problem description

Definition of multi location-route problem of integrated assembly and distribution of multi objectives of mix fuzzy time window is as follows: it is assumed that a logistic enterprise needs to establish multi-level logistic distribution center in an area to provide distribution and return service for all clients in the area; the clients are divided into two types and one type of the clients has requirement of time window and require that time window is fuzzy time window; the other type of clients have no requirement of time window. Logistic distribution network includes: the first-level distribution network composed of distribution center, transfer station and corresponding distribution route and the second-level distribution network composed of transfer station, demand point and corresponding distribution route. Proper distribution station can be determined in alternative places and distribution vehicles and distribution route can be arranged reasonably. Multi objects refer to reducing total logistic cost in premise of guaranteeing user satisfaction degree. Fig. 2 is sketch map of two-level location-route problem.

3.2. Mathematical model

Actual load of vehicles in the model of this thesis presents trend of dynamic fluctuation in distribution process, namely that it needs to be guaranteed that total goods quantity is not over load limitation of the vehicle itself in the whole distribution process in premise of considering load limitation of vehicles. Besides load limitation of vehicles, capacity limitation of transfer station is also considered in the model in this thesis and it shall be guaranteed that the transfer station has inventory capacity

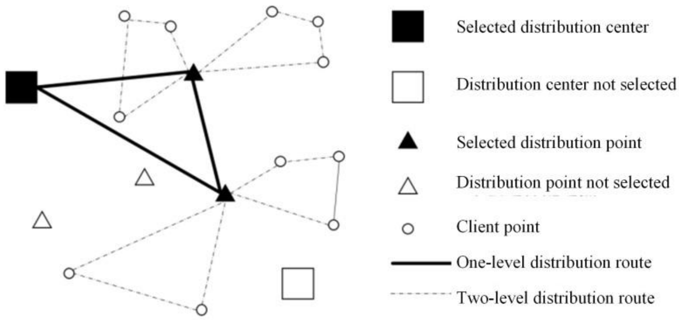

Fig. 2. Sketch map of two-level location-route

to handle this partial return need after return service.

The following hypothesis is conducted on multi location-route problem model of integrated assembly and distribution of multi objectives of mix fuzzy time window in this thesis:

(1) Candidate distribution center, transfer station and number, geographical position and fixed cost of client point are known; fixed cost of multi-level distribution vehicles is known; demand quantity and return quantity of distribution in client point are known.

(2) Capacity of multi-level logistic facility is known and total demand quantity distributed to multi-level logistic facility cannot be over capacity limitation of facility.

(3) Capacity of multi-level distribution vehicles is known and vehicle load in all distribution routes cannot be over capacity limitation.

(4) Distance among all nodes should be calculated according to Euclidean distance and distribution cost of unit distance of multi-level distribution vehicles is known.

(5) Each client point can only be served once by a vehicle and multi-level distribution vehicles depart from logistic facility node and return to the same logistic facility node. Multi location-route problem model of integrated assembly and distribution of multi objectives of mix fuzzy time window is proposed according to hypothesis and symbol description of above problems.

$$\begin{aligned}\mathrm{Min}Z_1 = &\sum_{d\in N_{\mathrm{D}}} C_{\mathrm{D}d}w_d + \sum_{s\in N_{\mathrm{S}}} C_{\mathrm{S}s}z_s + \sum_{i\in N_{\mathrm{D}}}\sum_{j\in N_{\mathrm{S}}}\sum_{v\in V} C_{\mathrm{V}v}x_{ijv} \\ &+ \sum_{i\in N_{\mathrm{S}}}\sum_{j\in N_{\mathrm{C}}}\sum_{k\in K} C_{\mathrm{K}k}y_{ijk} + \sum_{i\in N_{\mathrm{D}}}\sum_{j\in N_{\mathrm{S}}}\sum_{v\in V} c_v x_{ijv} c_{\mathrm{f}ij} \\ &+ \sum_{i\in N_{\mathrm{S}}}\sum_{j\in N_{\mathrm{C}}}\sum_{k\in K} c_k y_{ijk} c_{\mathrm{s}ij}\,. \end{aligned} \tag{8}$$

$$\mathrm{Min} Z_2 = \left[\sum_{i \in N_C'} S(T_i)(p_i + d_i) - \sum_{i \in N_C''} U(T_i)(p_i + d_i) \right] \Big/ \sum_{i \in N_C} (p_i + d_i) . \tag{9}$$

S.t.

$$\sum_{i \in N_1} \sum_{v \in V} x_{ijv} = z_j, \forall j \in N_S . \tag{10}$$

$$\sum_{i \in N_2} \sum_{k \in K} y_{ijk} = 1, \forall j \in N_C . \tag{11}$$

$$\sum_{i \in N_1} x_{ijv} - \sum_{i \in N_1} x_{jiv} = 0, \forall j \in N_1, \forall v \in V . \tag{12}$$

$$\sum_{i \in N_2} y_{ijk} - \sum_{i \in N_2} y_{jik} = 0, \forall j \in N_2, \forall k \in K . \tag{13}$$

$$x_{iiv} = 0, \forall i \in N_1, \forall v \in V . \tag{14}$$

$$y_{iik} = 0, \forall i \in N_2, \forall k \in K . \tag{15}$$

$$\sum_{i \in N_D} \sum_{j \in N_D} x_{ijv} = 0, \forall v \in V . \tag{16}$$

$$\sum_{i \in N_S} \sum_{j \in N_S} y_{ijk} = 0, \forall k \in K . \tag{17}$$

$$\sum_{d \in N_D} m_{sd} = 1, \forall s \in N_S . \tag{18}$$

$$\sum_{s \in N_S} n_{cs} = 1, \forall c \in N_C . \tag{19}$$

$$\sum_{i \in N_D} \sum_{j \in N_S} x_{ijv} \leq 1, \forall v \in V . \tag{20}$$

$$\sum_{i \in N_S} \sum_{j \in N_C} y_{ijk} \leq 1, \forall k \in K . \tag{21}$$

$$\sum_{g \in N_1} x_{sgv} + \sum_{h \in N_1} x_{dhv} \leq 1 + m_{sd}, \forall s \in N_S, \forall d \in N_D, \forall v \in V . \tag{22}$$

$$\sum_{g \in N_2} y_{cgk} + \sum_{h \in N_2} y_{shk} \leq 1 + n_{cs}, \forall c \in N_C, \forall s \in N_S, \forall k \in K . \tag{23}$$

$$\sum_{j \in N_2} D_{jik} - \sum_{j \in N_2} D_{ijk} = d_i, \forall i \in N_C\,. \tag{24}$$

$$\sum_{j \in N_2} P_{jik} - \sum_{j \in N_2} P_{ijk} = p_i, \forall i \in N_C\,. \tag{25}$$

$$D_{jik} + P_{ijk} \le Q_K y_{ijk}, \forall k \in K\,. \tag{26}$$

$$\sum_{i \in N_D} \sum_{j \in N_1} \sum_{c \in N_C} x_{ijv} n_{cj} d_c \le Q_V, \forall v \in V\,. \tag{27}$$

$$\sum_{i \in N_D} \sum_{j \in N_1} \sum_{c \in N_C} x_{ijv} n_{cj} p_c \le Q_V, \forall v \in V\,. \tag{28}$$

$$\sum_{c \in N_C} d_c n_{cs} \le Q_S, \forall s \in N_S\,. \tag{29}$$

$$\sum_{c \in N_C} p_c n_{cs} \le Q_S, \forall s \in N_S\,. \tag{30}$$

$$\sum_{s \in N_S} \sum_{c \in N_C} d_c n_{cs} m_{sd} \le Q_D, \forall d \in N_D\,. \tag{31}$$

$$\sum_{s \in N_S} \sum_{c \in N_C} p_c n_{cs} m_{sd} \le Q_D, \forall d \in N_D\,. \tag{32}$$

$$S\left(T_i\right) \ge \lambda_i, \forall i \in N_C'\,. \tag{33}$$

$$U\left(T_i\right) \ge \lambda_i, \forall i \in N_C''\,. \tag{34}$$

$$I_{nf}'\left(\lambda_i\right) \le T_i \le S_{up}'\left(\lambda_i\right), \forall i \in N_C'\,. \tag{35}$$

$$T_i \le S_{up}''\left(\lambda_i\right), \forall i \in N_C''\,. \tag{36}$$

$$T_j = \sum_{i \in N_C} x_{ijk}\left(T_i + t_{ij} + t_d d_i + t_p p_i\right), j \in N_C, k \in K\,. \tag{37}$$

$$\sum_{d \in N_D} m_{sd} \ge w_d, \forall s \in N_S\,. \tag{38}$$

$$m_{sd} \le w_d, \forall s \in N_S, d \in N_D\,. \tag{39}$$

$$\sum_{s \in N_S} n_{cs} \ge z_s, \forall c \in N_C\,. \tag{40}$$

$$n_{cs} \leq z_s, \forall c \in N_C, s \in N_S \tag{41}$$

Equations (8) and (9) are objective function. Equation (8) is total logistic cost, including: fixed cost of selected distribution center, fixed cost of selected transfer station, fixed cost of one-level distribution vehicles, fixed cost of two-level distribution vehicles, transportation cost of one-level distribution route and transportation cost of two-level distribution route. Equation (9) is the highest overall weighted user satisfaction degree, namely that influence of clients with great demand quantity of purchasing or return on overall user satisfaction degree is great and influence of clients with little demand quantity of purchasing or return on overall user satisfaction degree is less.

Equations from (10) to (41) are binding conditions. Equation (10) guarantees that each selected transfer station can only be served once by a one-level distribution vehicle and transfer station not selected cannot be served; Equation (11) guarantees that each client point can only be served by a two-level distribution vehicle; Equation (12) guarantees that in-and-out vehicles of each node in one-level distribution network is the same; Equation (13) guarantees that in-and-out vehicles of each node in two-level distribution network is the same; Equation (14) guarantees that there is no loop among all nodes in one-level distribution network; Equation (15) guarantees that there is no loop among all nodes in two-level distribution network; Equation (16) restricts that there shall be no route among all distribution centers in one-level distribution network; Equation (17) restricts that there shall be no route among all distribution centers in two-level distribution network; Equation (18) indicates that task of each transfer station can only be completed by a single distribution center; Equation (19) guarantees that task of each client point can only be completed by a single transfer station; Equation (20) guarantees that any one-level distribution vehicle can only complete a single service route and the start point shall be distribution center; Equation (21) guarantees that any two-level distribution vehicle can only complete a single service route and the start point shall be transfer station; Equation (22) guarantees that all transfer stations on each one-level distribution route are served by the distribution center on this route; Equation (23) guarantees that all client points on each two-level distribution route are served by the transfer station on the route; Equations (24)-(25) guarantee delivery and collection quantity of each client point in two-level distribution network satisfies need of each client point and sub-loop is removed; Equation (26) guarantees dynamic load capacity constraint of distribution vehicles in two-level distribution network; Equations (27)-(28) guarantee that delivery and collection quantity of one-level distribution vehicles is not over vehicle load capacity constraint; Equations (29)-(30) guarantee that total quantity of delivery and return of client points served by transfer stations will not exceed capacity limitation of transfer station; Equations (31)-(32) guarantee that total quantity of delivery and return of transfer stations served by distribution centers will not exceed capacity limitation of transfer stations; Equations (33)-(34) guarantee that specified minimum user satisfaction degree of the client is satisfied; Equations (35)-(36) guarantee that start service time of the client satisfies fuzzy time window constraint of the client; Equation (37) indicates time calculation expression for vehicles to reach client points; Equations (38)-(39) guarantee service can only be completed through selected distribution center for transfer station; Equations (40)-(41) guarantee that service can only be completed through selected transfer station for client point.

Insertion of multi-objective simulated annealed algorithm of taboo search

Multi-objective simulated annealed algorithm of archiving of inserted taboo search is proposed in this thesis to solve multi location-route problem of integrated assembly and distribution of multi objectives of mix fuzzy time window. Bottom-to-up solving process is adopted for the algorithm and neighborhood solution of two-level distribution network is firstly constructed in iteration process for the algorithm; then one-level distribution network solution is achieved with taboo search according to neighborhood solution of two-level distribution network. Archiving acceptance criteria is adopted for acceptance criteria of simulated annealed algorithm, namely calculate multi objective value of current solution, neighborhood solution and archiving concentrating solution; acceptance probability is calculated and neighborhood solution is accepted according to different dominance relation and taboo search is adopted to achieve optimized solution of one-level distribution network; taboo search algorithm can get optimal solution or satisfactory solution of one-level distributive network rapidly and effectively because scale of one-level distribution network is relatively small.

3.3. Algorithm step

Simulated annealed algorithm frame is adopted for the algorithm to solve LRP2E-SPDFTW. Initialization parameter and initial solution are firstly generated and then recorded in archive for concentration for the algorithm. In iteration process, neighborhood solution of two-level distribution network is generated according to neighborhood construction method and then one-level distribution network solution is achieved with taboo search algorithm according to neighborhood solution; objective function values of overall neighborhood solution including total logistic cost and user satisfaction degree are also calculated. An acceptance criteria of neighborhood solution is calculated and Pareto set is updated according to multi objective function values and dominance relation of current solution, neighborhood solution and Pareto set. Finally temperature is updated until termination condition of algorithm is satisfied to return to Pareto set.

Specific steps of the algorithm are as follows and algorithm flow chart is shown in Fig. 3.

Step 1: initial temperature is $T = T_0$ for initialized algorithm and final temperature of the algorithm is T_{f}; coefficient of temperature drop is α and inner loop time is M_{it}; generation number is $F = 0$ without update and current generation number is $I = 0$; maximum generation number without update is N_{notimp} and initial solution is randomly generated.

Step 2: achieve optimal solution of one-level distribution network of initial solution with taboo search algorithm; calculate total cost X_{Cost} and user satisfaction degree X_{US} of current initial solution X. Initial solution X is added to P set.

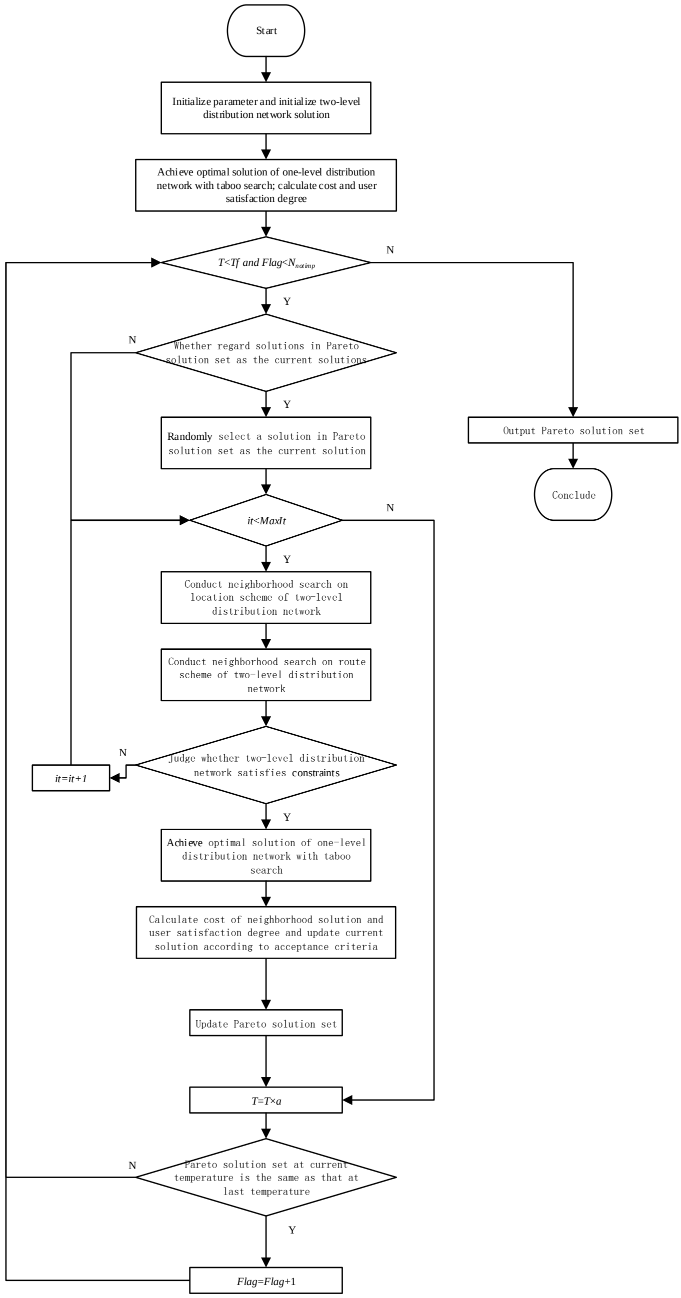

Fig. 3. Sketch map of multi-objective simulated annealed algorithm of inserted taboo search

Step 3: if $I < M_{\mathrm{it}}$, execute step 4, or set $I = 0$ and execute step 9.

Step 4: randomly select a solution in P set as current solution every other certain generation number.

Step 5: construct neighborhood solution of two-level distribution network. Respectively conduct neighborhood search on location and route of two-level distribution network of current solution in succession to generate two-level distribution network solution of neighborhood solution X' and judge whether X' satisfies constraint; calculate one-level distribution network solution for total quantity of distribution and return of client points served by each transfer station as quantity of distribution and return for the transfer station to randomly generate X' according to selected transfer station of X' two-level distribution network solution if it satisfies the constraint, or $I = I + 1$ and return to step 3.

Step 6: optimize one-level distribution network solution with taboo search. Conduct taboo search on initial solution of one-level distribution network of X' to generate optimal solution of one-level distribution network of neighborhood solution X'; calculate total logistic cost X'_{Cost} and user satisfaction degree X'_{US} of neighborhood solution X'.

Step 7: calculate acceptance probability of X' according to current solution X, neighborhood solution X' and dominance relation of solutions in P set and then update X according to the probability.

Step 8: update Pset. Judge whether X' enters into P set according to dominance relation between solutions in P set and neighborhood solution X'. If it enters, then order $F = 0$, or $F = F + 1$. $I = I + 1$ and return to step 3.

Step 9: $T = \alpha T$. If optimal solution value of current temperature is the same as that at last temperature, then $F = F + 1$.

Step 10: if $T < T_{\mathrm{f}}$ or $F = N_{\mathrm{notimp}}$, terminate the algorithm and output P set, or return to step 3.

3.4. Coding

LRP2ESPDFTW includes two-level distribution network and the same coding way in this thesis is adopted to achieve solution[10] because two-level distribution network solutions are similar.

Real coding way is adopted in this thesis with two-level distribution network as the example. Solution coding of two-level logistic distribution network includes c demand points with serial number as $\{1, 2, \cdots, c\}$, s alternative transfer stations with serial number as $\{c+1, c+2, \cdots, c+s\}$ and some zero to indicate route segmentation. Fig. 4 is coding sketch map of two-level distribution network of ten demand points and five alternative transfer stations and 11, 12 indicate that transfer stations 1 and 2 are selected for use and 13, 14, 15 not appearing indicate that transfer stations 3, 4, 5 are not selected for use; zero indicates route segmentation symbol and node before zero is conclusion demand point of last route and the node after zero is start demand point of the next route. Coding of two-level distribution network shown in Fig. 4 can be converted to three routes:

11→ 1 →2 →3 →11

Route 1: 11$\to$ 1 $\to$2 $\to$3 $\to$11
11 $\to$ 4 $\to$ 5 $\to$ 6 $\to$ 11
Route 2: 11 $\to$ 4 $\to$ 5 $\to$ 6 $\to$ 11
12 $\to$ 7 $\to$ 8 $\to$ 9 $\to$ 10 $\to$ 12
Route 3: 12 $\to$ 7 $\to$ 8 $\to$ 9 $\to$ 10 $\to$ 12

11	1	2	3	0	4	5	6	12	7	8	9	10

Fig. 4. Coding sketch map of ten demand points and five alternative transfer stations

3.5. Initialization

Bottom-to-up solving progress is adopted for the algorithm and two-level and one-level distribution networks need to be initialized respectively. The same greedy random initialization method is adopted in this thesis to generate initial solution. Specific steps of greedy random initialization are as follows with two-level distribution network as the example.

Step 1: allocate client points to any transfer station not used according to random order until total quantity of demand or return of allocated client point exceeds capacity limitation of the transfer station; judge whether there is client not allocated, if so, execute step 2, or execute step 3.

Step 2: randomly open transfer stations not selected and return to step 1.

Step 3: optimize greedy route of each transfer station. Calculate the distance between previous node and client point as the next node closest to it until all clients allocated to this transfer station are all reordered with transfer station as the initial node.

Step 4: create a route for route of lower part of start service time exceeding dynamic load capacity constraint of vehicles and minimum user satisfaction degree limitation according to above routes and vehicle capacity limitation of two-level distribution network; start and end points are both nodes of current transfer station.

3.6. Neighborhood construction

The same neighborhood construction method is adopted in solving process because LRP2ESPDFTW includes two-level distribution network and two-level distribution networks are similar and the second-level distribution network is the example as follows. Neighborhood construction process of two-level distribution network includes two parts: state update and route update of transfer station.

(1) State update of transfer station

State update of transfer station includes three ways: close transfer station, open transfer station and exchange state of transfer station.

Close transfer station: if transfer station number opened of current solution is over one, a randomly selected transfer station can be closed and the route it includes can be allocated to previous transfer station of solution coding. If the closed transfer station is the first transfer station of solution coding, then the route can be allocated to the next transfer station of solution coding.

Open transfer station: if there are transfer stations not opened, then a randomly selected transfer station in transfer stations not opened can be set open and inserted into solution coding. Route upon inserting position for transfer stations newly opened automatically belongs to this newly opened transfer station.

Exchange state of transfer station: if there is a transfer station not opened, then randomly select an opened transfer station and a transfer station not opened and exchange the state of the two transfer stations. The route originally belonging to closed transfer station automatically belongs to the newly opened transfer station.

It is not allowed to execute state update of transfer stations again and it is only allowed to execute route update so as to find better route scheme in current open state of transfer stations for sure within certain period after executing any state update way of transfer stations because state update of transfer stations can greatly change solutions. Specific steps of state update of transfer stations are as follows:

Step 1: set state change parameter of transfer station when algorithm is initialized: generation number g of algorithm iteration after open or close operation of transfer stations, state generation number $g_{\max}$ of transfer stations forbidden to be changed, probability P_S of changing state of transfer stations, set $g = 0$.

Step 2: if $g > g_{\max}$ and random number $r < P_S$, then execute step 3, or $g = g+1$, conclude.

Step 3: Randomly select one from three state update ways of transfer station and execute it, set $g = 0$.

(2) Route update

Route update includes three ways[11][12]: 2-opt*, exchange, insertion, randomly select and execute a route update way at the time of constructing two-level distribution network neighborhood each time.

2-opt*: in solution coding of two-level distribution network, the first node of coding is excluded and randomly select two nodes among the rest nodes as start and end nodes of 2-opt*; order of all nodes in start and end nodes can be inverted.

Exchange: the first node of coding is excluded and randomly selects two nodes among the rest nodes as exchange nodes; then exchange position of the two nodes.

Insertion: the first node of coding is excluded and randomly selects two nodes among the rest nodes as insertion nodes; then insert the first selected insertion node after the second selected insertion node.

3.7. Taboo search algorithm

Taboo search is adopted for the algorithm to solve one-level distribution network. Firstly calculate demand quantity of distribution and return of all clients served by each transfer station as distribution and return quantity of the transfer station according to two-level distribution network solution. Then conduct search to generate candidate solution set according to above methods of initialization and neighborhood construction and update current solution and optimal solution according to taboo rule and despising rule; finally when termination rule of taboo algorithm is satisfied, conclude the algorithm and return to current optimal solution.

Flow chart and specific algorithm step of taboo search algorithm are shown in Fig. 5.

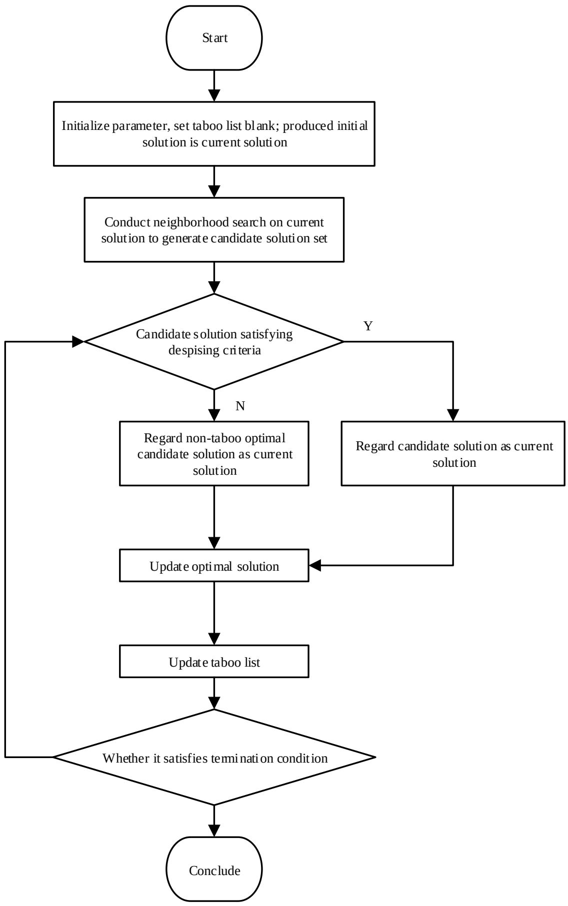

Fig. 5. Flow chart of taboo search algorithm

Step 1: initialize algorithm parameter of taboo search and maximum generation number of algorithm is M_{it}; length of candidate solution set is C_L and length of taboo list is L; maximum generation number without update is N_{notimp} and generation number of optimal solution without update is $F = 0$; current generation number is $I = 0$ and initial solution is generated.

Step 2: conduct neighborhood search to generate candidate solution set.

Step 3: update current solutions according to despising criteria and taboo criteria.

Step 4: update optimal solution and set $F = 0$ if optimal solution changes, or $F = F + 1$. Update taboo list, set $I = I + 1$.

Step 5: if $I = M_{\mathrm{it}}$ or $F = N_{\mathrm{notimp}}$, terminate algorithm and return to current optimal solution, or return to step 2.

3.8. Acceptance criteria of archiving

Traditional simulated annealed algorithm can only optimize problems of a single objective and acceptance strategy of neighborhood solution is single, thus it is applicable to multi objective problems. Acceptance strategy of multi objective neighborhood solution in AMOSA[13] is adopted in this thesis in solving process because LRP2ESPDFTW has two objective functions and direct superiority-inferiority comparison and further acceptance of neighborhood solution cannot be conducted like problems of a single objective.

(1) Number of Pareto solution set

On one hand, number of Pareto solution needed by decision maker is limited and too many Pareto solutions cannot help decision maker a lot; on the other hand, too many Pareto solutions will reduce solving efficiency of algorithm. Grid method is adopted in this algorithm to delete redundant Pareto solutions and firstly judge solution number in Pareto solution set at the time of updating Pareto solution set; if it exceeds maximum allowable Pareto solution number, then divide many grids according to distribution of objective function value in Pareto solution set other than corner solutions and calculate Pareto solution number contained in the grids; the way of roulette is adopted to select grids according to solution number in grids and the grid is more likely to be selected with more number of Pareto solutions. Randomly select a Pareto solution an delete it in selected grids and repeat above steps until solution number in Pareto solution set satisfies maximum number limit of Pareto solution set.

(2) Energy difference between two solutions

Energy difference is used to calculate acceptance probability of neighborhood solution; it is assumed that there are two solutions a, b and Pareto solution set is P, then its energy difference $\Delta D_{a,b}$ is:

$$\Delta D_{a,b} = \prod_{i \in P, f_i(a) \neq f_i(b)} \left(\frac{|f_i\,(a) - f_i\,(b)|}{R_i} \right). \tag{42}$$

$f_i\,(x)$ Is the ith objective function value of solution x and R_i is value range of the ith function value. Maximum and minimum of objective value of solution in current solution, neighborhood solution and Pareto solution set are adopted in the algorithm to calculate objective value range because there are two objective values in LRP2ESPDFTW and there is no determined value range of objective value for total cost and user satisfaction degree.

(3) Acceptance strategy of three dominance situations

Suppose current solution is X and neighborhood solution is X' and Pareto solution set is P. It can be divided into three types according to dominance relation between current solution and neighborhood solution: current solution predominate neighborhood solution and neighborhood solution predominates current solution; there is no dominance relation between current solution and neighborhood solution.

Situation 1: current solution predominate neighborhood solution and $k\,(k \geq 0)$ Pareto solutions predominate neighborhood solution. Acceptance probability p_1 of neighborhood solution is:

$$p_1 = \frac{1}{1 + \exp\left(\Delta D_{avg} T\right)}. \tag{43}$$

T is current temperature of the algorithm and ΔD_{avg} is average energy difference; the calculation method is as follows:

$$\Delta D_{avg} = \frac{\sum_{i=1}^{k} \Delta D_{i,X'} + \Delta D_{X,X'}}{k+1}. \tag{44}$$

Situation 2: neighborhood solution predominate current solution.

It can be divided into three situations according to dominance relation between neighborhood solution and solutions in Pareto solution set on condition that neighborhood solution predominate current solution.

Neighborhood solution predominate current solution, but $k\,(k \geq 1)$ Pareto solutions predominate neighborhood solution and current solution at this moment is not Pareto. Calculate Pareto solution with minimum energy difference $\Delta D_{\min}$ between k Pareto solutions predominating neighborhood solution and neighborhood solution and the probability of it as current solution is p_2; probability of neighborhood solution as current solution is $1 - p_2$ and calculation equation of p_2 is as follows:

$$p_2 = \frac{1}{1 + \exp\left(-\Delta D_{\min}\right)}. \tag{45}$$

There is no dominance relation between neighborhood solution and solutions (exclude current solution if it belongs to Pareto solution set) in Pareto solution set and then neighborhood solution can be accepted as current solution.

Neighborhood solution predominate $k\,(k \geq 1)$ Pareto solutions (exclude current solution if it belongs to Pareto solution set) and then neighborhood solution can be accepted as current solution.

Situation 3: there is no dominance relation between current solution and neighborhood solution.

It can be divided into three situations according to dominance relation between neighborhood solution and solutions in Pareto solution set on condition that there is no dominance relation between current solution and neighborhood solution.

$k\,(k \geq 1)$ Pareto solution predominate neighborhood solution and then acceptance probability p_3 of neighborhood solution is:

$$p_3 = \frac{1}{1 + \exp\left(\Delta D_{avg} T\right)}. \tag{46}$$

ΔD_{avg} is average energy difference between neighborhood solution and $k\,(k \geq 1)$ Pareto solutions it predominates and calculation equation of ΔD_{avg} is:

$$\Delta D_{avg} = \frac{\sum_{i=1}^{k} \Delta D_{i,X'}}{k}. \tag{47}$$

Neighborhood solution predominate k ($k \geq 1$) Pareto solutions and neighborhood solution at this moment is accepted as current solution.

There is no dominance relation between neighborhood solution and solutions in Pareto solution set and neighborhood solution at this moment is accepted as current solution.

4. Experimental result and analysis

4.1. Validity check of algorithm

(1) Experimental example

2E-LRP standard example is adopted in this thesis to solve and verify AMOSA algorithm because there is no standard example of LRP2ESPDFTW currently. It can be found that LRP-2E is a special situation of LRP2ESPDFTW through analysis, namely user satisfaction degree is the same and return quantity of all clients is zero. Algorithm logic is similar to frame and algorithm performance will not change in solving process of these two problems for AMOSA-TS algorithm. MATLAB is used to compile the algorithm in operation system environment of Intel(R) Core(TM) i5-4200H CPU, 8GB RAM, Windows10 so as to solve Nguyen standard example set and compare it with current known international optimal solution and algorithms of GRASP[14] and MS-ILS[15]

Example name of Nguyen example set can be indicated as: $n - m$–N(MN)[b]; n indicates number of demand points and m indicates number of transfer stations; N indicates that position of demand point is univariate normal distribution and MN indicates that position of demand point is multivariate normal distribution; demand quantity of demand point is normal distribution with mean value $\mu = 15$ and variance $\delta^2 = 25$; capacity constraint of one-level distribution vehicle is {750, 850} and MNb and Nb in the name indicate that capacity constraint is 850 and capacity constraint of two-level distribution vehicles is {100, 150}.

(2) Algorithm parameter

Parameters in part of simulated annealed frame include: initial temperature: T_0, termination temperature: T_{f}, coefficient of temperature drop: α, inner cycle number: M_{it}, maximum generation number without update: N_{notimp}, maximum number M_P of Pareto solution. Parameters of taboo search part include: maximum iteration generation number: T_{Mit}, maximum generation number without update: T_{notimp}, number of maximum candidate solution set: M_{CL}, taboo list length: L. Specific parameter setting is shown in Table 1 and Table 2.

Table 1. Parameter setting of simulated annealed algorithm

Algorithm	T_0	T_{f}	α	M_{it}	N_{notimp}	M_P
SA	10000	0.1	0.96	500	50	20

Table 2. Parameter setting of taboo search algorithm

Algorithm	T_{Mit}	T_{notimp}	M_{CL}	L
TS	5	3	10	2

(3) Contrastive analysis of experimental result

Nguyen example set is adopted in this thesis to verify validity of AMOSA-TS algorithm and the algorithm is compared with GRASP algorithm and MS-ILS algorithm; specific result is shown in Table 3. Only solving result map and convergence graph of objective function value of example 50-5-MN is provided in this thesis, as shown in Fig. 6 and Fig. 7.

Table 3. Solving result of Nguyen example set

Calculating example	BKS*	GRASP	CPU	Gap	MS-ILS	CPU	Gap	AMOSA-TS	CPU	Gap
25-5N	80, 370	81, 152	0.9	0.97%	80, 370	1.6	0.00%	80, 370	5.1	0.00%
25-5Nb	64, 562	64, 572	0.8	0.02%	64, 562	1.1	0.00%	64, 562	5.3	0.00%
25-5MN	78, 947	80, 412	0.9	1.86%	79593	1.6	0.82%	78, 947	5.8	0.00%
25-5MNb	64, 438	64, 438	0.8	0.00%	64, 438	1.5	0.00%	64, 438	8.2	0.00%
50-5N	137, 815	145, 942	2.4	5.90%	138, 126	10.4	0.23%	137, 815	58.6	0.00%
50-5Nb	110, 094	113, 234	2.3	2.85%	111, 290	6.3	1.09%	110, 094	86.5	0.00%
50-5MN	123, 484	126, 313	2.2	2.29%	123, 484	5.2	0.00%	123, 484	65.3	0.00%
50-5MNb	105, 401	106, 033	2.3	0.60%	105, 401	7.7	0.00%	105, 401	74.4	0.00%
50-10N	115, 725	116, 709	4.5	0.85%	116, 132	36.8	0.35%	115, 725	100.7	0.00%
50-10Nb	87, 315	90, 559	6.4	3.72%	87, 315	15.9	0.00%	87, 315	96.9	0.00%
50-10MN	135, 519	137, 321	5.4	1.33%	136, 123	21.9	0.45%	135, 519	84.4	0.00%
50-10MNb	110, 613	110, 703	6.7	0.08%	110, 613	19.4	0.00%	110, 613	82.9	0.00%

Note: * indicates international known optimal solution currently. CPU indicates calculating time of the algorithm, unit: second; CPU calculating time of algorithms GRASP and MS-ILS is completed on equipment with configuration of 3.4GHz Pentium 4 PC with 1GB of RAM.

In the aspect of solving effect, experimental result indicates that solving effect of AMOSA-TS is excellent and optimal solutions can all be found at the time of solving the problems in scale of 25 and 50 client points. Solving effect of AMOSA-TS is better than that of GRASP algorithm and better results are obtained in all test examples; its error with optimal solution is less. Compared with MS-ILS algorithm, it obtains better result in scale problem of 25 client points; solving effect is similar at the time of solving scale problem of 50 client points, thus they are comparable; but optimal solution is not found in partial examples for MS-ILS algorithm.

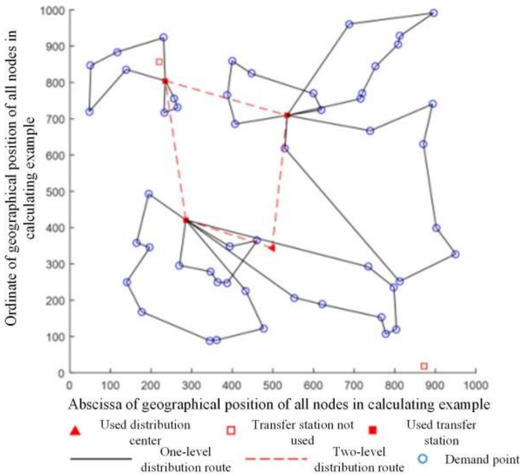

Fig. 6. Solving result route of example 50-5-MN

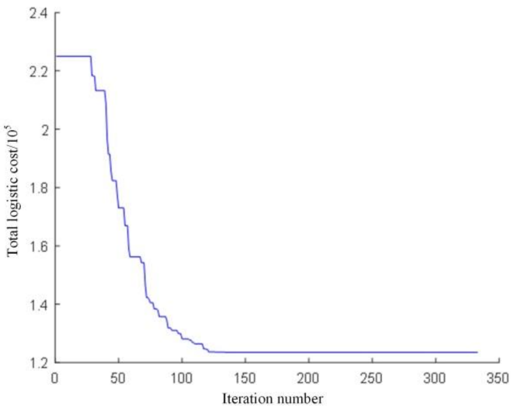

Fig. 7. Convergence graph of example 50-5-MN

4.2. Validity check of model

Related data is added to 25-5N example of concentrated examples in example Nguyen in this thesis as experimental example data to verify validity of LRP2ESPDFTW model and it is solved through AMOSA-TS algorithm.

Return quantity: generation method of return quantity proposed in literature[16] by Angelelli and Mansini is adopted in this thesis. Return quantity is generated one by one according to serial number of clients and return quantity p_i of client i is:

$$p_i = \begin{cases} (1+\alpha)\, d_i, i \text{is odd number} \\ (1-\alpha)\, d_i, i \text{is even number} \end{cases} \tag{48}$$

d_i is delivery quantity of client i and α is random number between $[0.2, 0.8]$.

Mix fuzzy time window: 25 clients in the example of this thesis are divided into two types evenly; there are 13 clients with requirement of fuzzy time window and 12 clients without requirement of fuzzy time window. For clients with requirement of fuzzy time window, their fuzzy time window is trapezoidal fuzzy number $[ET_i, EDT_i, LDT_i, LT_i]$. Upper and lower limit of expected service time window EDT_i and LDT_i are respectively generated according to uniform distributions $Unif\,[0, 50]$ and $Unif\,[EDT_i + 50, EDT_i + 100]$; tolerated maximum time window ET_i and LT are respectively generated by expanding 50 to both ends, namely $ET_i = \max\{EDT_i - 50, 0\}$ and $LT = LDT_i + 50$.

Sensitivity coefficient of time: sensitivity coefficient β_i of time of client β_i is a random number between $[0.2, 0.8]$.

Minimum service level of client: minimum service level λ_i of client i is a random number between$[0, 1)$.

Other parameters: vehicle speed: 10; service time of unit delivery quantity: 1; service time of unit return quantity: 1;

(1) Number of optimal Pareto solutions

A certain number of solving schemes need to be provided at the time of solving the problem pertinent to development directions of different emphasis so as to satisfy enterprise needs in different development phases because e-commerce enterprises need to formulate corresponding development strategy according to current development phase of the enterprise in reality.

Four types of different maximum number respectively as: 5, 10, 20 and 30 of Pareto solutions are designed in the experiment of this chapter to solve the problem. Each number of maximum Pareto solutions respectively solves above example for ten times and Table 4 is average solving time; Fig. 8 and Fig. 9 are comparison diagrams of solving result.

Table 4. Average value of solving time for number of different maximum Pareto solutions

Number of Pareto solutions	5	10	20	30
Solving time (s)	626.34	849.58	1159.24	2037.40

When number of maximum Pareto solutions is five, solving speed is high, but solving result does not reach optimal boundary and coverage scope is small. Because number of maximum Pareto solutions is small, thus search space of the algorithm is small and solving can easily get into local optimum.

When number of maximum Pareto solutions is ten, solving speed is high and solving result is good, but coverage scope is still small. Solving result of algorithm at this moment can be close to optimal boundary and solving speed is higher than that when there is more number of Pareto solutions, but there is still the problem that coverage scope is small for the ten solving schemes and it may result in failure of decision making support.

When number of maximum Pareto solutions is 20, solving speed is low and solving result is good; coverage scope is big. Solving result of the algorithm at this moment can be close to optimal boundary and solving speed is within acceptable scope. Meanwhile, 20 solving schemes can effectively cover development demands

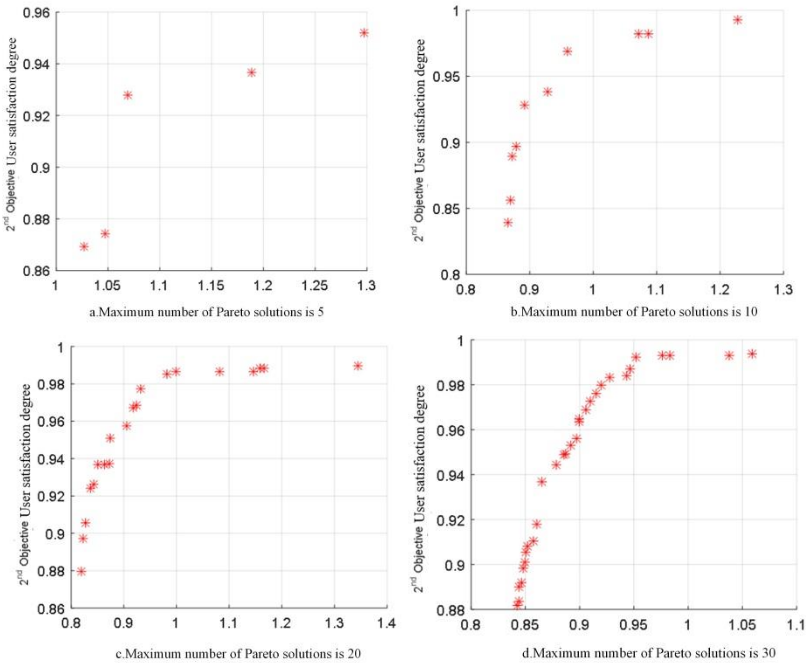

Fig. 8. Solving result of maximum number of different Pareto solutions

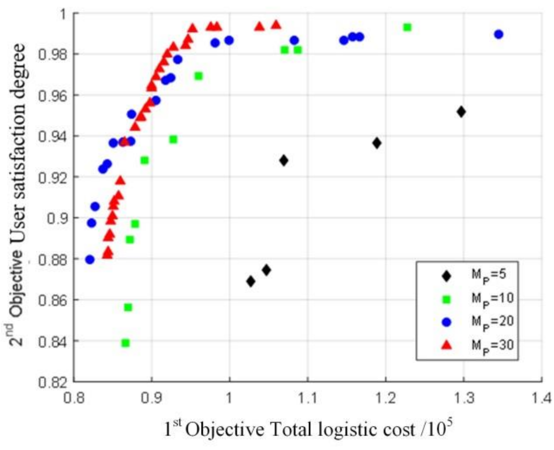

Fig. 9. Contrastive sketch map of solving result of maximum number of different Pareto solutions

in different phases and propose reasonable suggestions and support for formulating development strategies.

When number of maximum Pareto solutions is 30, solving speed is low and solving result is good; coverage scope is big. Solving result of the algorithm at this moment can be close to optimal boundary and coverage scope of result is wide, thus it can effectively provide support for decision makers; but compared with 20 kinds of solving schemes, there is no more support help and improvement of solving effect. Besides, solving efficiency of algorithm reduces and solving speed is low.

So, number of 20 maximum Pareto solutions is adopted in this chapter to solve the model.

(1) Example solution

Parameter setting of AMOSA-TS algorithm is the same as above solving of LRP-2E problem. Because experimental result data is too much, only a sketch map of an experimental result is provided in this thesis. Table 5 and Fig. 10 are solving result of example 25-5N upon expansion. Fig. 11 and Fig. 12 are respectively convergence graphs of two objective values.

Table 5. Solving result of example 25-5N set upon expansion

No.	Objective function value		No.	Objective function value	
	Total logistic cost	User satisfaction degree		Total logistic cost	User satisfaction degree
1	82017	87.95%	11	91735	96.71%
2	82284	89.74%	12	92388	96.83%
3	82759	90.56%	13	93280	97.74%
4	83714	92.39%	14	98170	98.52%
5	84325	92.62%	15	99924	98.66%
6	85053	93.67%	16	108264	98.66%
7	86279	93.69%	17	114634	98.67%
8	87263	93.74%	18	115788	98.83%
9	87468	95.08%	19	116607	98.83%
10	90591	95.74%	20	134466	98.96%

It can be found through analysis of experimental result that total logistic cost continues to increase with increase of user satisfaction degree of clients, which conforms to trade off principle between service level and logistic cost. On coverage scope, experimental result indicates that total logistic cost is concentrated between 82017∼134466 and client satisfaction degree is concentrated between 87.95%∼98.96% among offered solving schemes of the algorithm. When client satisfaction degree is in range of 87%∼95%, amount 90.6 of total logistic cost needs to be increased to increase user satisfaction degree by 0.1% on average; when client satisfaction degree is in range of 95%∼98%, amount 218.5 of total logistic cost needs to be increased to increase user satisfaction degree by 0.1% on average; when client satisfaction degree is in range of 98%∼99%, amount 8249.1 of total logistic cost needs to be increased to increase user satisfaction degree by 0.1% on average;

Experimental result totally offers 20 Pareto solutions for leaders of e-commerce enterprises to make decisions and different solving schemes can be adopted according to different operation strategy and operation target of enterprises. Too many Pareto solutions do not help decision makers of B2C enterprises much, but they can greatly reduce algorithm efficiency; too less Pareto solutions will cause early convergence and early-maturing of solving process of the algorithm and optimal solution or satisfactory solution also cannot be provided thus.

Fig. 10 and Fig. 11 respectively offer convergence graph of objective value of total logistic cost and user satisfaction degree; the result indicates that the algorithm can consider optimization of two objective values well so as to guarantee overall solving effect of the algorithm when the algorithm is used to solve multi objective problems.

The experiment indicates that LRP2ESPDFTW problem model is correct and AMOSA-TS algorithm proposed in this thesis is reasonable and effective to solve LRP2ESPDFTW problem, thus it is a good method to solve such complex problems.

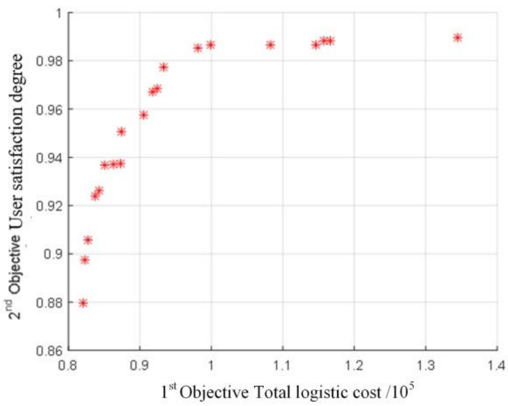

Fig. 10. Solving result of example 25-5N set upon expansion

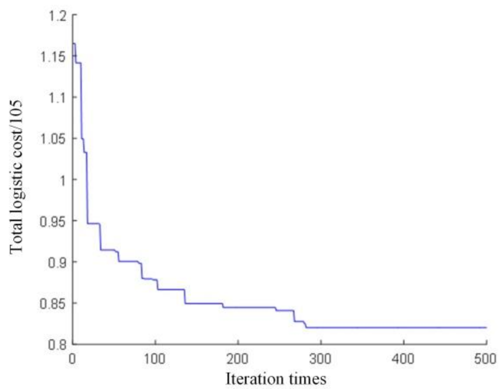

Fig. 11. Convergence graph of total logistic cost

5. Conclusions

(1) Problem model of multi location-route of integrated assembly and distribution of multi objectives for mix fuzzy time window is established and optimized in

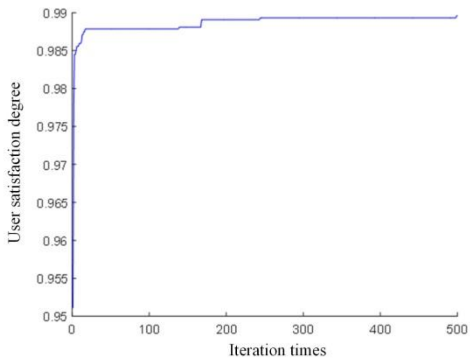

Fig. 12. Convergence graph of user satisfaction degree

this thesis on the basis of features of B2C distribution network. The model integrates node location of two-level logistic distribution network and route planning of distribution vehicles and it reduces total cost of logistic operation overally with double objectives of model solving of total cost of logistic distribution and user satisfaction degree. Feature of visiting tour of distribution vehicles, forward and reverse logistics and mix fuzzy time window of clients are comprehensively considered in the model. Overall client demand with and without time window requirement is calculated so as to guarantee the highest overall client satisfaction degree for mix fuzzy time window. Dynamic load constraint of vehicles is introduced into the model to guarantee effectiveness of forward and reverse logistic operation in combination with goods returning issue of B2C e-commerce business.

(2) Simulated annealed algorithm of multi objective of archiving for embedded taboo search proposed in this thesis is reasonable and effective. Currently known international optimal solution can be found for the standard example when the algorithm is used to solve problem of two-level location-route, thus it proves effectiveness and universality of the algorithm. Archiving acceptance criteria of the algorithm can guarantee solving effect of the algorithm and form of Pareto solution as solving result at the time of solving problem of multi objectives.

Acknowledgement

National Natural Science Foundation of China(71102118).

References

[1] Z. Lv, A. Halawani, S. Feng, H. Li, & S. U. Réhman: *Multimodal hand and foot gesture interaction for handheld devices. ACM Transactions on Multimedia Computing*, Communications, and Applications (TOMM), *11* (2014), No. 1s, 10.

[2] Y. Z. Chen, F. J. Tang, Y. Bao, Y. Tang, G. D. Chen: *A Fe-C coated long period fiber grating sensor for corrosion induced mass loss measurement.* Optics letters, *41*

(2016), 2306–2309.

[3] Y. Du, Y. Z. Chen, Y. Y. Zhuang, C. Zhu, F. J. Tang, J. Huang: *Probing Nanostrain via a Mechanically Designed Optical Fiber Interferometer.* IEEE Photonics Technology Letters, *29* (2017), 1348–1351.

[4] W. S. Pan, S. Z. Chen, Z. Y. Feng: *Automatic Clustering of Social Tag using Community Detection.* Applied Mathematics & Information Sciences, *7* (2013), No. 2, 675–681.

[5] Y. Y. Zhang, Q. Li, W. J. Welsh, P. V. Moghe, and K. E. Uhrich: *Micellar and Structural Stability of Nanoscale Amphiphilic Polymers: Implications for Anti-atherosclerotic Bioactivity*, Biomaterials, *84* (2016 , 230–240.

[6] J. W. Chan, Y. Y. Zhang, and K. E. Uhrich: *Amphiphilic Macromolecule Self-Assembled Monolayers Suppress Smooth Muscle Cell Proliferation*, Bioconjugate Chemistry, *26* (2015), No. 7, 1359–1369.

[7] M. Gitizadeh, M. Kalantar M.: *Genetic Algorithm Based Fuzzy Multi-Objective Approach to FACTS Devices Allocation in FARS Regional Electric Network*[J]. Scientia Iranica, *15* (2008), No. 6, 534–546.

[8] F. Niakan, M. Rahimi: *A multi-objective healthcare inventory routing problem; a fuzzy possibilistic approach*[J]. Transportation Research Part E Logistics & Transportation Review, *80* (2015), 74–94.

[9] A. Mirakhorli: *Fuzzy multi-objective optimization for closed loop logistics network design in bread-producing industries*[J]. International Journal of Advanced Manufacturing Technology, *70* (2014), No. 1-4, 349–362.

[10] D. Kannan, R. Khodaverdi, L. Olfat, et al.: *Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain*[J]. Journal of Cleaner Production, *47* (2013), No. 9, 355–367.

[11] I. Bernetti, S. Sacchelli, V. A. Sottini, et al.: *Optimisation of the regional energy supply network: a multi-objective analysis in the province of Florence (Italy).*[J]. International Journal of Sustainable Energy, *33* (2014), No. 6, 1076-1089.

[12] X. Li, S. X. Yang, C. F. Huang: *Evaluation of electricity customers credit based on fuzzy multi-attribute decision making method*[J]. Power System Technology, *28* (2004), No. 21, 55–59.

[13] B. Du, S. Guo, X. Huang, et al.: *A Pareto supplier selection algorithm for minimum the life cycle cost of complex product system*[J]. Expert Systems with Applications, *42* (2015), No. 9, 4253–4264.

[14] O. Boutkhoum, M. Hanine, H. Boukhriss, et al.: *Multi-criteria decision support framework for sustainable implementation of effective green supply chain management practices*[J]. Springerplus, *5* (2016), No. 1, 664.

Received May 7, 2017