Multi-objective improved algorithm for flow allocations in hazardous chemicals logistics preference paths

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Abstract

The flow allocation of paths was a key stage of the transportation network's efficiency, particularly in the hazardous chemicals logistics network where many weights were stochastic. Over the years, a variety of methods (or heuristics) have been proposed to solve this complex optimization problem, with good results in some cases just with limitations in the special fields. In this work, we develop an algorithm for model multi-objective that combines ideas from stochastic weight. Our method performs well even when the order of magnitude and/or the range of the parameters were unknown. The method refines iteratively a sequence of parameter distributions through preference combined with partial exampling from a historical prior defined over the support of all previous iterations. We exemplify our method with multi-objective improved models using both simulated and real experimental data and estimate the weight efficiently even in the absence of a priori knowledge about the weight.

Keywords: Hazardous chemicals transportation, Flow allocation, Multi-objective optimization, Path preference, Control

1 Introduction

The efficiency and benefit of logistics network is determined directly by network topology and logistics nodes of the network and flow allocation of the transportation lines. But once the topology of logistics network is identified, it will not be changed in a fairly long period of time. However, the flow allocation in the logistics network will be influenced by many factors such as supply, demand and network capacity [1]. In the process of the flow allocation of logistics network, we often not only needs to consider cost of logistics, also the delivery time, the delivery distance, the reliability of the network and other factors, and also the preference of decision-makers (this issue is an important reason that causes the transportation problem as NP-hard problem [2, 3]). Therefore, how to realize the scientific and reasonable flow allocation in the hazardous chemicals logistics network of a fixed topology structure of is the overall optimal scheme of flow allocation of logistics network with the prerequisites of logistics demand such as goods transportation, storage and distribution from supply to demand of the goods. The goals of this problem are often coupled together, but also in competition with each other, contradictory, and each goal has its distinct significances and dimensions, and their competition complexity makes the optimization of the problem very difficult. Therefore, multi-objective optimization of logistics transportation is always a hotspot in the field of investigation [4, 5].

Considering the existing limitations of multi-objective algorithm in the flow allocation of logistics network, this study considers the preference of decision-makers and the comprehensive effect of the target value on the objective weight based on weighting method, and puts forwards the indefinite traffic assignment method. The flow assignment method of logistics network needs not to find all the optimal solution, but by adjusting preference coefficient, we can obtain the traffic assignment results in accordance with the actual needs of the flow allocation decision.

The flow allocation in logistics network is that the desired goods are distributed to the logistics nodes and the transportation lines of logistics network in order to achieve goods delivery from supply to demand. This study will take delivery task as a path connecting the supply and demand nodes of multi-strip, only need the allocation flow of each path to make the target value achieve the optimal, and guarantee the flow balance in all the transportation lines and the logistics nodes. The process is divided into three stages, i.e. the calculation of the path state value based on multiple optimization targets, the selection of optimal path and the flow allocation. The path is composed of a series of logistics nodes and transportation lines in order form. Path state value (weight) is determined by the logistics nodes and the state values of transportation line. According to the contingency theory, each logistics nodes and transportation lines of the path should not be absolute equality but fixed which are relative to the weight of the whole path. Therefore, the logistics nodes and the state value of transportation lines and weight becomes the critical for path selection; similarly, logistics nodes and the state value calculation of transportation lines should

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be based on the variable weight synthesis of multiple attribute of optimization objectives definition, not the constant weight sum method. According to this principle, we can avoid the NP-hard in the logistics activities to some extent.

2 Model and algorithm

Logistics nodes, transport routes and paths are collectively referred to as logistics network factors, in order to solve the problem easily; its expression form is [6]: $\Phi_i = \{u_\alpha, v_\alpha(\Phi_l), w_\alpha(\Phi_l)\}$, $\alpha, l \in N$.

Among them, Φ_i expresses No. l factor in the transportation network, u_α expresses No. property of Φ_i factor, $v_\alpha(\Phi_l)$ expresses No. α state of u_α property in Φ_i factor, $w_\alpha(\Phi_l)$ expresses No. α weight values (preference) of u_α property in Φ_i factor, and $\sum_\alpha w_\alpha(\Phi_l) = 1$.

The essence of flow allocation is to select the optimal path, i.e. optimal path of state value. A mathematical model:

$$\begin{array}{ll} Max & F(x) = (f_1, f_2, \cdots\cdots) \\ s.t. & G(x) \le 0 \end{array}. \quad (1)$$

Among them, $f_1, f_2, \cdots\cdots$ as optimization object, X as decision variables.

From the expression of path factor, we can select the path according to the state value and distribute the flow to the optimal path of state value. Calculation steps of state values for attributes:

Step 1: determine the path attribute and its initial weights;
Step 2: calculate the attribute state value and its preference of logistics nodes and the transportation lines;
Step 3: determine the state value of logistics nodes and the transportation lines taking optimization target as attributes;
Step 4: calculate the attribute state value of sub path and its preference;
Step 5: determine the state value of the sub path taking logistics nodes and the transportation line as attributes;
Step 6: calculate the path attribute values and its preference;
Step 7: determine the state values of the path taking sub path as attributes.

Because the attributes of all the logistics network factors are based on type (1) multi optimization objectives of problem, but the optimization target values have different dimensions. So, firstly, the optimization target values should be transformed into dimensionless quantity in the [1] interval and then conduct standardized processing. By using linear membership function, we can achieve the dimensionless transformation of optimal target values [7]. Membership function of optimization object represents the closeness between function of optimization target and the possible ideal values.

v^+ is defined as the upper bound of the state value, v^- as the lower bound of the state value, there is: $v_\alpha^+ = \max(v_\alpha(\Phi_l))$, $v_\alpha^- = \min(v_\alpha(\Phi_l))$, $\alpha, l \in N$.

According to the linear membership functions, the dimensionless and standardization process of the properties are [8-9]: $z_\alpha = \dfrac{v_\alpha(\Phi_l) - v_\alpha^-}{v_\alpha^+ - v_\alpha^-}$.

The factor attribute of the transportation network after normalization is:

$$v_\alpha(\Phi_l)' = \sum_\alpha (z_\alpha * w_\alpha(\Phi_l)). \quad (2)$$

By formulas (1) and (2), we can obtain the steps of freight traffic allocation algorithm of path preference.

Step 1: *initialization*. The initial volume of freight X_0 of the lines and nodes of logistics network is 0; the capacity is $Y_{\max}$.
Step 2: *path selection*. By formula (1) (2) we can calculate all the paths state value, and select the state optimal path $Q*$ (n as the network path number):

$$Q* = \max\left(v_{\alpha\beta}^1, v_{\alpha\beta}^2, ..., v_{\alpha\beta}^n\right). \quad (3)$$

Step 3: *the traffic volume allocation.* For $Q*$, distribute freight volume X^0, and $X^0 \le Y_{\max}$.
Step 4: update the path freight volume and capacity, there is:

$$X^1 = X_0 + X^0, Y^1 = Y_{\max} - X^0. \quad (4)$$

Step 5: judge whether the goods are distributed or not, if yes, then ending. Otherwise, change to ***Step 2***, until the freight task was all arranged.

3 Algorithm demonstration

As shown in Figure 1, the logistics transportation network is a simple logistics network which is composed of 2 supply nodes, 2 intermediate nodes, 3 demand nodes, and transportation lines among the logistics nodes [8] (each node and route preference coefficient is

$(\beta_1,\ \beta_2,\ \beta_3) = (-\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2})$, i.e. no difference in preference.)

As we know the capacity, the time, the cost attribute parameters of the network, the value after standardized processing is shown in Table 1. V is the rated capacity of unit carrier, C0 is the fixed cost, C1 is the variable cost.

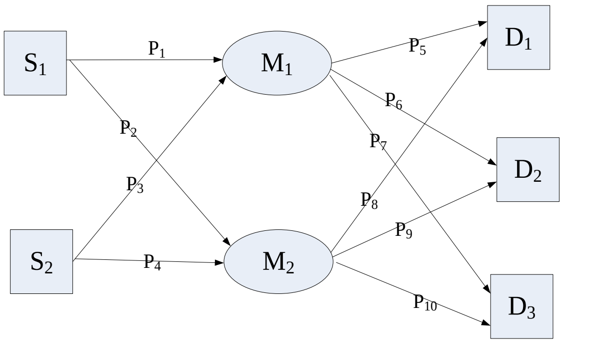

FIGURE 1 Transportation network

TABLE 1 The attribute parameters of transport network

Attribute	Nodes							Paths									
	S1	S2	M1	M2	D1	D2	D3	P1	P2	P3	P4	P5	P6	P7	P8	P9	**P10**
capacity (Y)	60	80	90	150	70	55	15	2	3	4	3	2	1	1	3	2	**1**
time (t)	-	-	0.5	0.4	-	-	-	89	62	94	77	10	7	14	18	11	**6**
cost (c)	-	-	**1.3**	**1.5**	-	-	-	**V=20, C0=1, C1=2**									

According to equation (1) and the corresponding algorithm, we can obtain:

$$V_s(y) = (v^{s_1}, v^{s_2});$$

$$V_d(y) = (v^{d_1}, v^{d_2}, v^{d_3});$$

$$V_m(y) = (v_y^{m_1}, v_y^{m_2}, v_y^{m_3});$$

$$V_m(t) = (v_t^{m_1}, v_t^{m_2}, v_t^{m_3});$$

$$V_m(c) = (v_c^{m_1}, v_c^{m_2}, v_c^{m_3}).$$

According to equation (2), we can carry out the dimensionless and standardization. The results are presented in Table 2.

Similarly, the attribute and weights of the network path factor can be obtained (see, Table 3).

By equations (3) and (4), we obtain

$$Q_1^* = (s_2, p_4, m_2, p_8, d_1),$$

$$x_1 = \min(y^{s_2}, y^{p_4}, y^{m_2}, y^{p_8}, y^{d_1}) = 60$$

TABLE 2 Attribute value and weight of network node factors

Path factor	y			t			c		
	v	z	w	v	z	w	v	z	w
s1	60	0.75	0.50	-	-	-	-	-	-
s2	80	1.00	0.50	-	-	-	-	-	-
m1	90	0.60	0.52	0.02	0.80	0.50	0.01	1	0.55
m2	150	1.00	0.48	0.03	1.00	0.50	0.01	0.87	0.45
d1	70	1.00	0.33	-	-	-	-	-	-
d2	55	0.79	0.34	-	-	-	-	-	-
d3	**15**	**0.21**	**0.33**	**-**	**-**	**-**	**-**	**-**	**-**

TABLE 3 The path attribute values and weight

Paths	y			t			c		
	v	z	w	v	z	w	v	z	w
p1	0.75	0.95	0.076	0.66	0.83	0.35	0.79	1.00	0.096
p2	0.75	0.79	0.081	0.91	0.95	0.33	0.95	1.00	0.096
p3	1.00	1.00	0.073	0.80	0.80	0.34	0.79	0.79	0.105
p4	1.00	1.00	0.074	0.81	0.81	0.35	0.95	0.95	0.099
p5	0.72	0.72	0.125	1.00	1.00	0.47	0.75	0.95	0.099
p6	0.68	0.87	0.118	0.79	1.00	0.49	0.75	0.79	0.105
p7	0.51	1.00	0.108	0.21	0.42	0.54	1.00	1.00	0.093
p8	0.67	0.67	0.125	1.00	1.00	0.46	0.66	0.83	0.105
p9	0.69	0.88	0.118	0.77	1.00	0.49	0.91	0.95	0.099
p10	**0.73**	**1.00**	**0.102**	**0.21**	**0.30**	**0.56**	**0.80**	**0.80**	**0.103**

Similarly we have:

$$Q_2^* = (s_1, p_2, m_2, p_9, d_2),\ x_2 = 40;$$

$$Q_3^* = (s_2, p_3, m_1, p_6, d_2),\ x_3 = 15;$$

$$Q_4^* = (s_1, p_2, m_2, p_{10}, d_3),\ x_4 = 15;$$

$$Q_5^* = (s_2, p_3, m_1, p_5, d_1),\ x_5 = 5;$$

$$Q_6^* = (s_1, p_1, m_1, p_5, d_1),\ x_6 = 5.$$

When the preference of the transportation network is identical, the final result of freight flow allocation is: $(Q_1^*, Q_2^*, Q_3^*, Q_4^*, Q_5^*, Q_6^*) = (60, 40, 15, 15, 5, 5)$.

4 Conclusions

Based on the method of the preference of decision-makers, this study integrates the objective evaluation values into state values of the hazardous chemicals logistics nodes and the transportation lines in stages, and puts forward the methods of goods flow allocation based on the path preference, which not only considers the influence of the optimization objectives on the decision results, but also the effect of each hazardous chemicals transportation network factor on the decision results, and synthesizes the preference of subjective decision-makers and influence of objective state value on decision-making, to make allocation of freight task more in line with the actual need to the decision. The method of flow allocation based on path preferences does not need to generate multiple optimal solutions, but through adjusting the preference we can obtain the optimal flow allocation scheme that conforms to decision-makers' expectation. The study can solve the NP problem of flow allocation in the hazardous chemicals logistics network.

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