Application Study of All-or-Nothing Assignment Method for Determination of Logistic Transport Route in Urban Planning

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Abstract

With the increasing need for urban logistic transportation, the establishment of a reasonable urban logistic transport route with high efficiency has become a critical element in alleviating urban traffic jam, meeting urban logistics and infrastructure construction, and improving the efficiency of urban logistics. The determination of a logistic transport route based on the all-or-nothing optimization algorithm in an urban system is investigated in this study. A logistic assignment model is established, and logistic transportation examples are combined. The optimized method retains the characteristic of simple calculation through the all-or-nothing algorithm. Owing to the consideration of road network conditions in the assignment process, the assignment results are more practical and can adapt to the characteristics of urban systems, such as complicated road networks and heavy traffic volume. Therefore, the logistic transport route in urban planning can be planned and designed with the optimized all-or-nothing algorithm.

Keywords: All-or-nothing algorithm, Logistic transportation, Urban system

1 Introduction

The all-or-nothing assignment method involves the concept of traffic distribution, planning, and management [1]. Traffic assignment refers to the process in which existing origin–destination (OD) trips are assigned to various paths of the network according to a specific assignment algorithm to obtain the assignment flow of each OD at each road segment and the total flow of each road segment [2]. Supposing that the impedance of a road segment is a constant (the traveling time is not influenced by the traffic flow of this road segment), all trips of a producing point are assigned; an attracting point is likewise assigned to the shortest path between such points at one time, and no point is assigned to other road segments. Such assignment method is called the all-or-nothing assignment method, shortest path assignment method, or 0-1 assignment method [3]. This method is the simplest among assignment methods and serves as the basis of other assignment methods.

A city is an inevitable product of the development of economic activities. Its emergence and development should meet the needs of commodity exchange, and it is closely correlated with the deepening of commodity circulation and logistics development [4]. A city functions as the center of production. The mass labor force for industrial production and the large-tonnage products produced inevitably represent great demands for logistics and result in a remarkable increase in urban freight volume [5]. Continuous development is viewed as a requirement for the optimization of the economic structure and scope of logistic activities [6]. Personalized consumer demands generate increasing requirements for logistics service quality [7]. The urban logistic channel system (ULCS) is a highly integrated system that is connected with main urban logistic nodes through urban logistic channels of different functions and conveys one-way or two-way logistics at a certain scale through relevant transportation organizations [8]. ULCS includes all physical fundamental service facilities that satisfy the circulation of urban goods. With the continuous development of modern logistics, urban logistic transport demands have continued to increase and have thus led to a significant increase in the number of freight vehicles on urban roads and the aggravation of urban traffic congestion and environmental pollution [9]. The establishment of a high-efficiency urban logistic transport route is a critical element for alleviating urban traffic jam, meeting urban logistics and infrastructure construction, and improving the efficiency of urban logistics.

Urban logistics is closely integrated with traffic transportation. Urban transportation is the main carrier of urban logistics and involves a highly comprehensive integration with high complexity [10]. Unobstructed urban traffic is an important standard and influencing factor of rational urban logistics. A city is a node of the entire logistics network in a country and the busiest place with the highest probability to be jammed. Railways, highways, aviation, navigation, water channels, and pipelines are connecting lines in the logistic network [11]. Logistic obstruction at the node will cause regional logistic obstruction and even affect the logistic efficiency of the entire country. In this study, some achievements are attained in the functional analysis and system configuration of the transmission channel, spatial layout form and spatial logistic capability, optimization of the 0-1 method, software modelling, empirical analysis, adaptability evaluation, and other aspects. Such achievements are of certain guiding significance for the determination of a logistic transport route in urban planning.

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2 Basic theories

2.1 ULCS

The producing and attracting points of logistics and the logistic channels that connect such points are the main elements of ULCS.

The producing and attracting points of logistics refer to nodal points that produce freight circulation and mainly include integrated transportation station hubs, logistic nodes, and commerce circulation markets and enterprises. The specific definition and classification of these points are shown in Table 1.

TABLE 1 Main classification of logistic producing and attracting points

Producing and Attracting Points of Logistics	Definition	Classification
Integrated transportation station hub	Trans-shipment nodes formed by the intersection of at least two transportation routes and modes	Transfer station, freight station or container junction center, entrance and exit of the main channel, airport and port
Logistic node	Integrated nodes used for the realization of freight packaging, loading and unloading, handling, circulation, and information processing	Logistic park, logistic center, and logistic station
Commerce circulation market	Collection and distribution regions for urban production and exchange of consumption goods	Hardware, machine, and electricity market, steel market, paper product market, auto and motorcycle parts market, small commodity market, and medical market
Enterprise	Modern enterprise with high logistic service demands	Equipment manufacturing industry, enterprise manufacturing industry, mining enterprise, and coal processing enterprise

The transportation route of an urban logistic channel refers to the logistic channel that connects the producing and attracting points of logistics. It is composed of highways and urban roads. Transportation route is a path system that combines expressways, urban express roads, traffic trunk roads, trunk roads, and other roads with different functions. Roads of different types have different characteristics.

With the freight function of the channel path as the standard of classification, the functional types of ULCS are described as follows.

1. Express freight transport road (EFTR) that connects an integrated transportation station hub and a logistic node or logistic parks in different places;
2. Express distribution road (EDR) that connects logistic nodes at different levels or logistic nodes and main logistic nodal points downtown;
3. Main distribution road (MDR) that connects EDR and the main logistic nodal points or users (plants, markets, and consumers) downtown;
4. Ordinary distribution road that connects the main

logistic nodal points and users or users and users.

2.2 FUNDAMENTAL ALL-OR-NOTHING ASSIGNMENT METHOD

All-or-nothing assignment is one of the assignment methods in the non-balance assignment model. All-or-nothing assignment is also referred to as the 0-1 assignment method. It has the following characteristics.

1. The influence of congestion on traveling time is not considered; that is, the traveling time of all paths is a constant that does not change with the size of traffic flow on roads.
2. All drivers in the same OD pair select the same route. Therefore, the main calculation step of this method is to use various algorithms to determine the shortest path and then assign all traffic flows of all OD pairs to the shortest path accordingly.

The frequently used algorithms in the all-or-nothing assignment method mainly include Dijkstra, Ford, and Moore algorithms.

2.3 OPTIMIZED ALL-OR-NOTHING ASSIGNMENT METHOD

The most significant advantage of the all-or-nothing assignment method is its simple calculations. The method can be accomplished by assignment for only one time; it involves an approximate algorithm. However, this method fails to completely conform to practice. It can be applied to remote regions with relatively few roads but is not recommended for use in urban networks. In this study, the 0-1 assignment method is improved and its inapplicability to complex urban traffic networks is resolved by combining the 0-1 and multi-path assignment methods. Thus, unification of the two methods is realized.

Supposing that n routes exist from A to B, namely, $a_1, a_2..., a_n$, then $a_1, a_2..., a_n$ constitute the route assembly of logistic transportation from A to B. Supposing that logistic transportation only occurs at route a_i and the corresponding network condition is b_i, then the assembly of the road network is $\{ b_1, b_2..., b_n \}$ and the loss matrix consisting of logistic transportation is

$$
\begin{array}{c}
\begin{array}{cccc} a_1 & a_2 & a_3 & a_4 \end{array} \\
\begin{array}{c} b_1 \\ b_2 \\ ... \\ b_n \end{array}
\left[\begin{array}{ccccc}
a_{11} & a_{12} & ... & a_{1n} \\
a_{21} & a_{22} & ... & a_{2n} \\
... & ... & ... & ... \\
a_{n1} & a_{n2} & ... & a_{nn}
\end{array} \right]
\end{array} \quad (1)
$$

a_{ij} denotes the traveling time of route j when all traffic trips are assigned to route i.
If the formula

$$
\max_i \min_j a_{ij} = \min_i \max_j a_{ij} = a_{kl} \quad (2)
$$

exists in the matrix in Equation (1), then all OD trips at this time are assigned to route k, consistent with the shortest path

assignment model. The corresponding situation is that the traveling time of route k is still the shortest among all travelling routes after all OD trips are assigned to route k. This is the typical 0-1 assignment method.

However, Equation (2) is generally applicable to the case with light traffic volume and relatively simple route. It is inapplicable to ULCS with heavy traffic volume and complex road traffic. Therefore, we improved the 0-1 algorithm.

When Equation (2) is inapplicable, a mixed solution exists inevitably. The mixed solution indicates different selection strategies of each route or different selection proportions of each route in several transportations. Decision making based on this mixed solution can obtain the minimum loss matrix [Equation (1)]. At this point, logistic transportation route assignment can be translated into a linear planning issue, as shown in Equation (3).

$$\max z = \sum_i x_i{}'$$
$$\begin{cases} \sum_i a_{ij} x_i{}' \le 1, j = 1, 2..., n \\ x_i{}' \ge 0, i = 1, 2..., n \end{cases} \quad (3)$$

$$\max w = \sum_i y_i{}'$$
$$\begin{cases} \sum_i a_{ij} y_i{}' \le 1, j = 1, 2..., n \\ y_i{}' \ge 0, i = 1, 2..., n \end{cases} \quad (4)$$

where z and w are the values of the objective function, $z = w = 1/v$; v is the value of this issue that represents the average loss value in logistic transportation; a_{ij} is the loss matrix element of this issue; $x_i{}' = x_i / v$, x_i is the probability of route a_i during transportation; and $y_i{}' = y_i / v$, y_i is the probability of b_i during transportation. The mixed solution can be obtained by calculating Equations (3) and (4).

To simplify the issue, the following method can be adopted.

When elements corresponding to a_k and a_l in the loss matrix meet $a_{il} \le a_{ik}$, line a_l is superior to line a_k. In other words, line a_k can be disregarded. The corresponding situation is that the traveling time of this route at this time is shorter than the traveling time of a_k without trip distribution when all trips are distributed to a_l. Therefore, no traveller will select route a_k. Similarly, when elements corresponding to b_m and b_n meet $a_{mj} \le a_{nj}$, line b_n is superior to line b_m. In other words, line b_m can be disregarded in the analysis.

3 Logistic Transportation Route in an Urban System

Questionnaires were designed according to the research objectives to evaluate the adaptability of logistic transportation routes. The adaptability evaluation indexes and weights of the logistic transportation route are shown in Table 2.

TABLE 2. Adaptability evaluation indexes and relevant weight distribution

Category	Evaluation Index	Weight
Adaptability Evaluation	Connectivity of the route	0.146
	Accessibility of the node	0.325
	Efficiency of the route	0.098
	Transport network coverage	0.081
	Route accommodation coefficient	0.144
	Invalid degree	0.112
	Load uniformity	0.095

Each item in the questionnaire survey includes scores of 1 to 10. In the survey on the connectivity of the route, a score of 0 indicates a relatively weak connectivity, and a score of 1 indicates a relatively strong connectivity. High scores represent good connectivity and vice versa.

Four large-scale logistics companies (XXX1, XXX2, XXX3, and XXX4) were selected as the research objects. Twenty logistic transportation staff and management personnel were randomly selected from each logistics company for the questionnaire survey. For the survey to become realistic and effective, an individual with no logistic experience and less than two working years was excluded from the survey.

Among the 100 questionnaires distributed, 88 were recovered, among which 86 were deemed valid. The questionnaire recovery rate is 88%, and the effective rate is 86%. The questionnaire distribution and recovery results are shown in Figure 1.
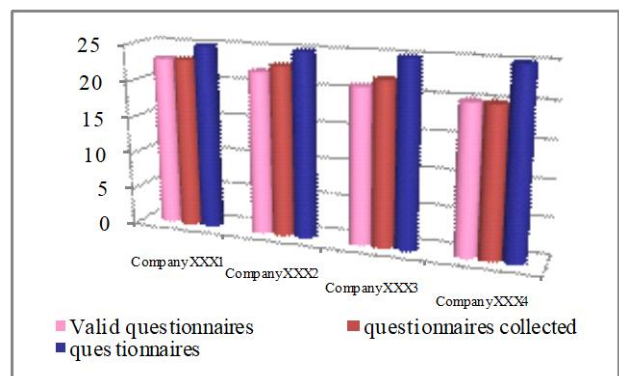

FIGURE 1. Distribution and recovery of the questionnaires.

4 Case Study

4.1 LOGISTIC TRANSPORTATION MODELING

We utilize City A's logistic traffic as an example to establish logistic transportation routes between Optics Valley Square and Jiedaokou. The established road traffic network is shown in Fig. 2. Four routes exist from Optics Valley Square to Jiedaokou. In the first route, Nuoyu Road (L1) is passed to arrive at Guangbutun, and Nuoyu Road (L2) is passed to arrive at Jiedaokou. In the second route, Huquan Road (L3) is passed to arrive at Guangbutun, and Nuoyu Road (L2) is passed to arrive at Jiedaokou. In the third route, Chuxiong

Avenue (L4) is passed to arrive at Jiedaokou. In the last route, Bayi Road (L5) is passed to arrive at Jiedaokou.
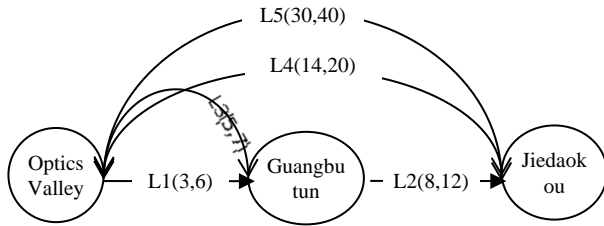

FIGURE 2. Traffic network.

We suppose that the value of OD is 2000 pcu/d. The available transport strategy assembly is { $a_1(L1, L2), a_2(L3, L2), a_3(L4), a_4(L5)$ } to realize logistic transportation from Optics Valley to Jiedaokou. The meanings of figures in Li (tqi, thi) marked beside each road segment in Fig. 7 are as follows: tqi stands for the traveling time of road segment *i* before logistic transportation at this road segment, and thi means the traveling time of this road segment when all logistics are transported from this road segment.

To calculate using the improved 0-1 assignment method, the loss matrix of logistic transportation is shown as follows:

$$\begin{bmatrix} 18 & 17 & 14 & 30 \\ 15 & 19 & 14 & 30 \\ 11 & 13 & 20 & 30 \\ 11 & 13 & 14 & 40 \end{bmatrix}. \tag{6}$$

The above matrix can be translated into a linear planning issue for the solution according to Equations (3) and (4). We adopted the simplified method for the calculation.

$$\begin{bmatrix} 18 & 17 & 14 & 30 \\ 15 & 19 & 14 & 30 \\ 11 & 13 & 20 & 30 \\ 11 & 13 & 14 & 40 \end{bmatrix} \xrightarrow{a_1 \text{ better than } a_4} \begin{bmatrix} 18 & 17 & 14 \\ 15 & 19 & 14 \\ 11 & 13 & 20 \\ 11 & 13 & 14 \end{bmatrix} \tag{7}$$

$$\xrightarrow{b_3 \text{ better than } b_4} \begin{bmatrix} 18 & 17 & 14 \\ 15 & 19 & 14 \\ 11 & 13 & 20 \end{bmatrix}$$

This process (i.e., simplification in linear algebra) has consistent principles for easy comprehension. After simplification in two steps, the matrix cannot be continuously simplified. At this point, the linear planning equation set represented by the new matrix is as follows:

$$\max z = x_1' + x_2' + x_3'$$

$$\begin{cases} 18x_1' + 15x_2' + 11x_3' \leq 1 \\ 17x_1' + 19x_2' + 13x_3' \leq 1 \\ 14x_1' + 14x_2' + 20x_3' \leq 1 \\ x_1' \geq 0, x_2' \geq 0, x_3' \geq 0 \end{cases}. \tag{8}$$

The solution of Equation (7) is

$x_1' = 0.0429, x_2' = 0.0011, x_3' = 0.0192$

The fourth route is optimized. Therefore, $x_4' = 0$. The four items are unified. The distribution rates of various routes are:

$x_1 = 67.88\%, x_2 = 1.74\%, x_3 = 30.37\%, x_4 = 0\%$.

## 4.2 COMPARISON OF LOGISTIC ROUTES

Many algorithms can be utilized to determine logistic transportation routes. In this study, the inapplicability of the all-or-nothing algorithm to complex urban traffic networks was resolved via optimization. The algorithm's advantage of simple calculations was retained. The results were made to more conform to the distribution of logistic transportation in the urban system. A comparison of the results obtained through different logistic distribution methods is presented in Table 3.

TABLE 3 Comparison of different logistic distribution methods

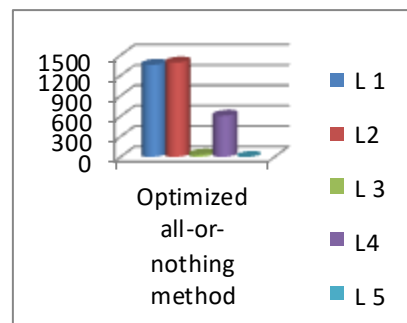| Distribution Method	Route				
	L1	L2	L3	L4	L5
All-or-nothing method	2000	2000	0	0	0
Multi-path method	834	1518	684	462	20
Optimized all-or-nothing method	1358	1392	34	608	0
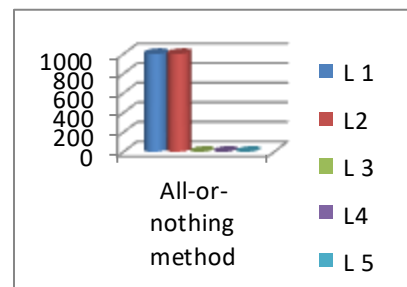
(a)
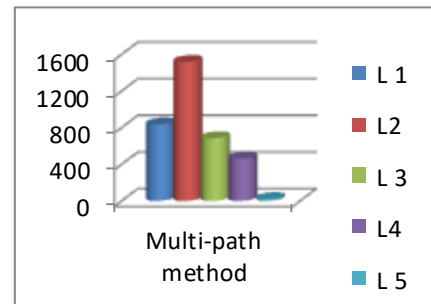
(b)

(c)

FIGURE 3. Results of (a) all-or-nothing method,
(b) multi-path method, and
(c) optimized all-or-nothing method.

Even when all trips are distributed to routes L1 to L4, the traveling time of these routes remains shorter than that of route L5. Therefore, OD volume should not be distributed to route L5. An explanation for this decision is that when no logistic transport exists, the traveling time of route L5 is 30 min, which is longer than the time when all logistics are transported on other routes. Therefore, logistics should not be transported on this route. However, freight volume is distributed to L5 in the multi-path method, which is unreasonable.

Two competitive routes (a_1 and a_2) exist for the road network system in Fig. 1. Route a_1 shares a relatively long route (L2) with a_2, but the traveling time of a_1 is less than that of a_2. a_2 is given up while a_1 is given up in the transportation process. Therefore, a_2 cannot be considered an independent route. The volume of traffic distributed to a_2 should be very small. However, a relatively large volume is distributed to a_2 in the multi-path method. This condition may lead to congestion because of the excessively heavy traffic load at L2, which is unreasonable. The optimized 0-1 method can avoid the occurrence of this circumstance.

The optimized method was then improved based on the 0-1 algorithm. The result of the optimized method is consistent with the result of the all-or-nothing method when the volume of road traffic is very small and the road network is relatively simple. When the traffic flow is heavy, the traveling distribution rate (mixed solution) of each line can be obtained; hence, unification of the two methods is realized.

4.3 ADAPTABILITY OF THE LOGISTIC TRANSPORTATION ROUTE

After line planning with the optimized 0-1 algorithm, the aforementioned logistic transportation route adaptability evaluation indexes were utilized for evaluation. Four large-scale logistics companies (XXX1, XXX2, XXX3, and XXX4) were selected as research objects. Twenty logistic transportation staff and management personnel were randomly selected from each logistics company for the questionnaire survey. The selected personnel were asked to evaluate the logistic transportation plan determined by the optimized algorithm.

The practical attribute value of each evaluation index was determined according to the layout of the logistic channel system from Optics Valley to Jiedaokou in City A. Based on non-dimensionalization of the adaptability evaluation index, the layout adaptability evaluation indexes and relevant attribute and evaluation values of Chengdu City's logistic channel system were obtained through arrangement, as shown in Table 4.

TABLE 4　Non-dimensionalization results of adaptability evaluation indexes

Evaluation Index	Weight	Attribute Value	Standard Value	Evaluated Value
Connectivity of the route	0.146	3.28	3.22	1
Accessibility of the node	0.325	21.5	22	0.93
Efficiency of the route	0.098	1	1	1
Transport network coverage	0.081	0.93	1	0.95
Route accommodation coefficient	0.144	0.915	1	0.915
Invalid degree	0.112	1.20	1.32	0.872
Load uniformity	0.095	0.82	1	0.880

The optimized layout plan of Chengdu City's logistic channel system was subjected to adaptability evaluation through improved grey correlation analysis comprehensive evaluation. The relevant results are shown in Table 5.

TABLE 5. Comparative sequence correlation

Evaluation Index	Weight	x_0	x_1	$\xi_{01}(k)$	$\bar{r}_{01}$	$\varepsilon_{01}(k)$	r_{01}
Connectivity of the route	0.146	1	1	1.000		0.090	
Accessibility of the node	0.325	1	0.93	0.878		−0.032	
Efficiency of the route	0.098	1	1	1.000		0.090	
Transport network coverage	0.081	1	0.95	0.909	0.910	−0.001	0.887
Route accommodation coefficient	0.144	1	0.915	0.855		−0.055	
Invalid degree	0.112	1	0.872	0.828		−0.082	
Load uniformity	0.095	1	0.880	0.806		−0.103	

The logistic channel system determined with the optimized algorithm is evaluated as adaptive by combining evaluation standards for the layout adaptability of an urban logistic channel system. The logistic channel after layout planning combines all key logistic nodes along the route from Optics Valley to Jiedaokou. The channel planning level is relatively high and can promote urban logistic transportation and distribution.

5 Conclusions

Complicated road environments, dense highway traffic networks, and random congestion in urban systems aggravate the difficulties of logistic transportation. Traffic jams result in decreased speed of freight vehicles, increase in urban logistic transportation costs, and decrease in the customer service level. Hence, establishing rational urban logistic transportation routes with high efficiency, improving the timeliness of the logistic system, and reducing generalized logistic costs are urgently required.

The optimized method retains the characteristic of simple calculation in the all-or-nothing algorithm. Owing to the consideration of road network conditions in the assignment process, the assignment results are more practical and can adapt to the characteristics of the urban system, such as complicated road network and heavy traffic volume. The optimized method reflects the unification of all-or-nothing and multi-path assignment.

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