Data Mining of Geographical Accessibility for Traffic and Transportation Planning

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Abstract

Geographical advantage is important index when we select location. Before setting up house, determining meeting place and opening business shop, it is natural that we consider the geographical advantage depending on the purpose. In this paper we propose extended spatial interaction model permitting consideration of several path selection for each origin-destination pair. The spatial interaction model is known as a general model because it has been developed by entropy maximization principle. From observed data about traffic flow, our model can estimate traffic volume from origin to destination. It can be regarded as a merged concept between the geographical advantage and accessibility of the spatial interaction model in unified way. The parameter estimation procedure for the proposed model is developed. The availability of our model which can consider not only a network structure but also a traffic flow is shown in a numerical experimentation.

Key words: Geographical advantage; Accessibility; Spatial interaction model; Entropy maximization principle; Eigen vector; Traffic volume

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1 Introduction

Geographical advantage is one of theoretical value for the advantage of position. It was proposed to evaluate the street network from view of quantitative analysis. The geographical significance is assumed to satisfy the following recursive structure; the activity value at any point is calculated by considering the effects from other points of traffic network, any point also affects other points through traffic network according to its activity value. Such recursive structure of activity can be calculated as the eigen vector corresponding to the maximum eigenvalue of the adjacent matrix representing the structure of graph (1). Furthermore, based on maximizing interaction between any two points of traffic network a logical basis to quantitative index of geographical significance by formulating activity distribution has been proposed (2).

In conventional research of an urban planning, a retail trade area model (3) where an effect to certain point from certain city is assumed to be proportional to city population size and be inversely proportional to a distance from point to city, which is based on a concept that spatial distance affects to human behavior like a friction phenomenon. It is known as a gravity low of retail trade because a mechanism is similar to gravity low of Newton. The retail trade area model has been extended to represent interactions among plural points (4), (5), and they are called a spatial interaction model. As an attenuation function with respect to distance, a negative polynomial function, a negative exponent function and a normal density function and so on can be considered, especially a case using a negative exponent function is called a gravity model. Based on an entropy maximization principle, maximum entropy model whose attenuation function is given by a negative exponent function has been proposed (6). For the basic spatial interaction model without considering path selection, we have formulated traffic assignment for urban planning (7).

In this paper we first explain the concept of geographical advantage and describe the conditions that such index should satisfy. It is understood that the eigen value and eigen vector play important role in derivation of geographical advantage. Next we develop a spatial interaction model which permits consideration of several path selection for each origin-destination (OD) pair. Based on the entropy maximization principle, we derive theorem about relationship between the geographical advantage and accessibility in spatial interaction model. Furthermore in order to obtain the traffic volume from origin to destination depending on observed data about traffic flow, algorithm to estimate model parameters must be derived. For the purpose we give useful theorem about derivation of model parameters. The relationship between the geographical advantage and accessibility of the spatial interaction model is revealed based on entropy maximization principle.

This paper is organized as follows. The next section devotes to introduce the explanation of concept of geographical advantage from adjacency matrix representing network structure. In section 3, we formulate extended spatial interaction model in which path selection can be considered from origin to destination and propose accessibility based on an entropy maximization principle. In section 4, a relation among a geographical advantage and accessibility is shown, and an estimation algorithm to derive traffic volume from observed data will be derived. In numerical examination the availability of application of properties to data mining of geographical accessibility is also shown in section4.

2 Geographical Advantage Based on Congestion Degree

We consider the path selection in the spatial interaction model based on travel time ratio assignment from decision maker side. Travel time is important factor to select route from o_i to d_j, thus the travel time function is assumed to be

$$t_l(f_l) = t_l(0)\left\{1 + \eta\left(\frac{f_l}{c_l}\right)^{\theta}\right\} \tag{1}$$

where f_l is traffic flow in link l, c_l is flow capasity of link l and η, θ are coefficient.

The traffic flow f_l at link l can be estimated by

$$f_l = \sum_{i=1}^{n}\sum_{j=1}^{m} p(l|ij) r_{o_i d_j} \tag{2}$$

where $p(l|ij)$ is the probability that link l is used in OD pair from o_i to d_j. It is natural that several pathes are exist for each OD pair, thus we can define $p(l|ijk)$ which is the probability that link l is used in a kth path of OD pair from o_i to d_j. This probability can be found from network structure as

$$p(l|ijk) = \begin{cases} 1 & \text{if the } k\text{th path of OD pair } (o_i, d_j) \\ & \qquad \text{involves link } l \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

The probability $p(l|ij)$ can be derived by using a path selection probability $p(k|ij)$ as follows;

$$p(l|ij) = \sum_{k=1}^{K_{ij}} p(l|ijk)p(k|ij) \tag{4}$$

The path selection probability $p(k|ij)$ can be considered based on concept of efficient path [**] for the OD pair (o_i, d_j), efficient path does not involve possibility of back track, therefore link l in efficient path satisfies the following conditions;

$$s_t(o_i, l_s) < s_t(o_i, l_e) \text{ and } s_t(l_e, d_j) < s_t(l_s, d_j) \tag{5}$$

where $l_s,\ l_e$ represent the edge nodes of link l if it connects from l_s to l_e, respectively. The function of $s_t(x, y)$ describes the psychological shortest time from x to y.

It is natural that the value of $r_{o_i d_j}$ should take 0 if the condition $i = j$ is satisfied. In usual spatial interaction model, however, can not realize such design vanishing exixtence of probability for self loop. Furthermore the definition of $c_{o_i d_j}$ is difficult and unclear. We try to develop an extended model to solve such problems by applying the following theorem.

[**Theorem 3**]

The total cost condition of Eq. (17) can be regarded as the congestion degree which is given by expectation of transit time for the OD pair (o_i, d_j)

[**Proof**]

We assume that the likelihood of link by

$$L_l = \begin{cases} \exp\left[\gamma\left\{s_t(o_i, l_e) - s_t(o_i, l_s) - t_l\right\}\right] \\ \quad \text{if the link } l \text{ is efficient path} \\ 0 \quad \text{otherwise} \end{cases} \tag{6}$$

where t_l is travel time of link l. The kth path for OD pair (o_i, d_j) can be represented by the product of each likelihood of link L_l involved in the OD pair as follows;

$$p(k|ij) = \kappa \prod_l (L_l)^{p(l|ijk)}$$

$$= \kappa \exp\left[\gamma\left\{\min_k(t_k^{(i,j)}) - t_k^{(i,j)}\right\}\right] \tag{7}$$

where

$$t_k^{(i,j)} = \sum_l p(l|ijk)t_l \tag{8}$$

The coefficient κ can be determined from the normalization condition of probability $p(k|ij)$, thus

$$p(k|ij) = \frac{\exp(-\gamma t_k^{(i,j)})}{\sum_{k'=1}^{K_{ij}} \exp(-\gamma t_{k'}^{(i,j)})} \tag{9}$$

If we consider that the cost of kth path of OD pair (o_i, d_j) can be obtained by

$$c_{o_i d_j}^k = -t_k^{(i,j)} \log \delta^{(i,j)} \tag{10}$$

where $\delta^{(i,j)}$ takes 1 if the possibility of path from o_i to d_j exists ($k \geq 1$), otherwise ∞. The proportion of selecting kth path is

$$\frac{r_{o_i d_j}^k}{\sum_{k'=1}^{K_{ij}} r_{o_i d_j}^{k'}} = p(k|ij) \tag{11}$$

Thus the total cost condition of Eq. (17) can be rewritten as

$$C = \sum_{i=1}^{n}\sum_{j=1}^{m} \mathrm{E}[t^{(i,j)}] \tag{12}$$

where the expectation of travel time for the OD pair (o_i, d_j) is

$$\mathrm{E}[t^{(i,j)}] = \sum_{k=1}^{K_{ij}} p(k|ij) t_k^{(i,j)} \log \delta^{(i,j)} \tag{13}$$

Maybe decision maker receives such information from feeling when he/she drives a road. □

From above discussion, we can find the following properties;

(1) The cost of transition $c_{o_i d_j}^k$ at kth path from o_i to d_j can be given by travel time $t_k^{(i,j)}$ if the possibility of path from o_i to d_j exists.

(2) By considering $\delta^{(i,j)}$, it can remove the probability of the assignment case that there is no possibility obviously.

(3) The total cost C can be regarded as the degree of network congestion over the network, which is represented by expectation of travel time $\mathrm{E}[t^{(i,j)}]$.

Based on new concept, again we apply the algorithm to estimate the elements of OD matrix for the same condition. The network structure is given by Figure 1, the vectors $\mathbf{V}_o$ and $\mathbf{U}_d$ are assumed like Eqs. (39) and (40). It is assumed to be the inverse of $\delta^{(i,j)}$ takes 0 if $i = j$ is satisfied otherwise 1.

$\delta^{(i,i)}$ which is the possibility of path from o_i to d_i exists is assumed to be ∞ $(\forall i)$. The cost of transition $c^k_{o_i d_j}$ at kth path from o_i to d_j is assumed to be given by the expected transit time which is estimated by decision maker.

2.1 Accessibility in Spatial Interaction Model

An OD matrix usually represents the transportation on a network. If the origins are listed as the rows and the destinations as the columns a from/to or $r_{o_i d_i}$ matrix is produced like Table 1. The row sums, V_i, will be the total origin traffic, the column sums, U_j, the total destination traffic and T denotes total traffic counts. Especially traffic counts at the OD pair is a required input to estimate the elements of future OD matrix, estimation of zone traffic volume from base OD matrix is a fundamental problem for the planning and evaluation of transportation systems. The OD matrix information is important for not only traffic volume analysis but also information network model, if we regard the interaction $r_{o_i d_i}$ reflects data packet (8).

Table 1 Information of OD matrix.

origin	destination node					
node	d_1	d_2	d_3	$\cdots$	d_m	
o_1	$r_{o_1 d_1}$	$r_{o_1 d_2}$	$r_{o_1 d_3}$	$\cdots$	$r_{o_1 d_m}$	V_{o_1}
o_2	$r_{o_2 d_1}$	$r_{o_2 d_2}$	$r_{o_2 d_3}$	$\cdots$	$r_{o_2 d_m}$	V_{o_2}
o_3	$r_{o_3 d_1}$	$r_{o_3 d_2}$	$r_{o_3 d_3}$	$\cdots$	$r_{o_3 d_m}$	V_{o_3}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
o_n	$r_{o_n d_1}$	$r_{o_n d_2}$	$r_{o_n d_3}$	$\cdots$	$r_{o_n d_m}$	V_{o_n}
	U_{d_1}	U_{d_2}	U_{d_3}	$\cdots$	U_{d_m}	T

A spatial interaction model which permits several paths for each OD pair can be derived from an entropy maximization principle as follows:

$$\text{Maximize} \quad \frac{T!}{\prod_{i=1}^{n} \prod_{j=1}^{m} \prod_{k=1}^{K_{ij}} r^k_{o_i d_j}!} \tag{14}$$

$$\text{Subject to} \quad E_{V_i} = V_{o_i} - \sum_{j=1}^{m} \sum_{k=1}^{K_{ij}} r_{o_i d_j}^k = 0 \quad (\forall i) \tag{15}$$

$$E_{U_j} = U_{d_j} - \sum_{i=1}^{n} \sum_{k=1}^{K_{ij}} r_{o_i d_j}^k = 0 \quad (\forall j) \tag{16}$$

$$E_C = TC - \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{K_{ij}} c_{o_i d_j}^k r_{o_i d_j}^k = 0 \tag{17}$$

where $c_{o_i d_j}$ denotes measure reflecting distance concept from an origin node o_i to a destination node d_j and C is constant.

Consider an application of Stirling's approximation, $\ln T! \approx T \ln T - T$, Lagrange undetermined multipliers γ_i, μ_j, ρ for each constraint and the condition of total sum of $r_{o_i d_j}^k$ must be equivalent to T, the interaction can be derived as

$$r_{o_i d_j}^k = \varphi \exp(-\gamma_i - \mu_j - \rho c_{o_i d_j}^k) \tag{18}$$

where coefficient φ is defined by

$$\varphi = \frac{T}{\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{K_{ij}} \exp(-\gamma_i - \mu_j - \rho c_{o_i d_j}^k)} \tag{19}$$

Now introduce the following variables:

$$\alpha_{o_i} = \frac{\exp(-\gamma_i)\sqrt{\varphi}}{V_{o_i}} \tag{20}$$

$$\beta_{d_j} = \frac{\exp(-\mu_j)\sqrt{\varphi}}{U_{d_j}} \tag{21}$$

so that

$$r_{o_i d_j}^k = \alpha_{o_i} V_{o_i} \beta_{d_j} U_{d_j} \exp(-\rho c_{o_i d_j}^k) \tag{22}$$

In a maximum entropy model with a negative exponential distribution as an attenuation function, consider the following translation:

$$c_{o_i d_j}^k = \log \phi_{o_i d_j}^k \tag{23}$$

therefore we obtain

$$r_{o_i d_j} = \sum_{k=1}^{K_{ij}} \alpha_{o_i} V_{o_i} \beta_{d_j} U_{d_j} \left(\phi^k_{o_i d_j}\right)^{-\rho} \tag{24}$$

This means a gravity model with negative polynomial function as an attenuation function can be regarded as one kind of the maximum entropy model.

From constraints about sums of row and column in OD matrix, we can define

$$\alpha^{-1}_{o_i d_j} = \sum_{k=1}^{K_{ij}} \beta_{d_j} U_{d_j} \exp(-\rho c^k_{o_i d_j}) \tag{25}$$

$$\beta^{-1}_{o_i d_j} = \sum_{k=1}^{K_{ij}} \alpha_{o_i} V_{o_i} \exp(-\rho c^k_{o_i d_j}) \tag{26}$$

In order to understand what accessibility means, suppose that there is two side like decision maker side and facility side. An inverse value of $\beta_{o_i d_j}$ represents sum of accessibilities for all decision makers, each decision maker's accessibility is calculated by damping with respect to distance concept of decision maker at zone o_i to facility at zone d_j. That is, it means the accessibility (or attraction and so on) of each facility from decision maker's viewpoint. Similarly, an inverse value of $\alpha_{o_i d_j}$ represents an accessibility of each decision maker from facility's viewpoint. Note that absolute of it value has no meaning, it is only possible to compare relatively.

3 Derivation of Geographical Advantage from Accessibility

Here we will show the relationship between the geographical advantage and the accessibility in spatial interaction model. The geographical advantage has been given for each node, thus we derive the same one about the accessibility as follows;

$$\alpha^{-1}_{o_i} = \sum_{j=1}^{m} \alpha^{-1}_{o_i d_j} \tag{27}$$

$$\beta^{-1}_{d_j} = \sum_{i=1}^{n} \beta^{-1}_{o_i d_j} \tag{28}$$

$\alpha^{-1}_{o_i}$ is total accessibility of decision maker in zone o_i from all facilitys' viewpoint, also $\beta^{-1}_{d_j}$ is total accessibility of facility in zone d_j from all decision makers' viewpoint. We can show the following theorem to recognize the relationship between the geographical advantage and the accessibility.

[**Theorem 1**]

The geographical advantage $\mathbf{g}_s \in \Re^n \times \Re^1$ is derived as the eigen vector for the matrix $\mathbf{M} \in \Re^n \times \Re^n$ whose element consists of the accessibility $\alpha^{-1}_{o_i d_j}$ of each decision maker from facility located in zone $d_j$and the total accessibility π_{o_i} in zone o_i from all facilitys' viewpoint.

[**Proof**]

We can obtain the transition probability from o_i to d_j as follows;

$$\begin{aligned} m_{ji} &= \frac{r_{o_i d_j}}{V_{o_i}} \\ &= \alpha_{o_i} \sum_{k=1}^{K_{ij}} \beta_{d_j} U_{d_j} \exp(-\rho c^k_{o_i d_j}) \end{aligned} \tag{29}$$

This relationship implies that the modified matrix $\mathbf{M}$ can be reconstructed by using accessibility as follows;

$$m_{ij} = \frac{\alpha^{-1}_{o_j d_i}}{\alpha^{-1}_{o_i}} \tag{30}$$

From these results, the geographical advantage can be regarded as the eigen vector for the matrix whose element consists of the total accessibility from all facilitys' viewpoint and the accessibility of each decision maker from facility located. □

Therefore derivation of geographical advantage from observed data based on the input-output flow at node is extension model for usual one. In order to derive the index of geographical advantage the parameters must be estimated, for the purpose we can apply the nonparametric approach like a mixture of expert model (9). However a prospective convergence time of parameter estimation may be long, thus we derive the following useful theorem and an estimation algorithm based on the theorem is developed.

[**Theorem 2**]

Assuming $\gamma_i = -\log g^{(\gamma)}_i$, then the derivation of geographical advantage $\mathbf{g}^{(\gamma)} = [g^{(\gamma)}_1, g^{(\gamma)}_2,\ g^{(\gamma)}_3, \cdots, g^{(\gamma)}_n]^{\mathrm{T}} \in \Re^n \times \Re^1$ is the same of finding eigen vector for matrix $\mathbf{M}^{(\gamma)} \in \Re^n \times \Re^n$.

[**Proof**]

From Eqs. (15) and (18) we can find

$$g_i^{(\gamma)} = \frac{V_{o_i}}{T} \sum_{j=1}^{n} \frac{\sum_{s=1}^{m} \sum_{k=1}^{K_{js}} \exp(-\mu_s - \rho c_{o_j d_s}^k)}{\sum_{s'=1}^{m} \sum_{k'=1}^{K_{is'}} \exp(-\mu_{s'} - \rho c_{o_i d_{s'}}^{k'})} g_j^{(\gamma)} \tag{31}$$

Also we consider

$$a_{ij}^{(\gamma)} = V_{o_i} \sum_{s=1}^{m} \sum_{k=1}^{K_{js}} \exp(-\mu_s - \rho c_{o_j d_s}^k) \tag{32}$$

then we can obtain

$$g_i^{(\gamma)} = \sum_{j=1}^{n} \frac{a_{ij}^{(\gamma)}}{\sum_{t'=1}^{n} a_{t'i}^{(\gamma)}} g_j^{(\gamma)} \tag{33}$$

Let define an element of matrix $\mathbf{M}^{(\gamma)}$ by

$$m_{ij}^{(\gamma)} = \frac{a_{ij}^{(\gamma)}}{\sum_{t'=1}^{n} a_{t'i}^{(\gamma)}} \tag{34}$$

then the following formulation can be considered

$$\mathbf{M}\mathbf{g} = \lambda \mathbf{g} \tag{35}$$

We can find that the sum of row in matrix $\mathbf{M}^{(\gamma)}$ becomes as follows;

$$\sum_{i=1}^{n} m_{ij}^{(\gamma)} = 1 \tag{36}$$

This means that the maximum eigen value is $\lambda_{max} = 1$ and the vector $\mathbf{g}^{(\gamma)}$ is an eigen vector for the maximium eigen value of matrix $\mathbf{M}^{(\gamma)}$. □

Similarly for the parameter μ_j we have

$$a_{ij}^{(\mu)} = U_{d_i} \sum_{s=1}^{n} \sum_{k=1}^{K_{sj}} \exp(-\gamma_s - \rho c_{o_s d_j}^k) \tag{37}$$

and

$$m_{ij}^{(\mu)} = \frac{a_{ij}^{(\mu)}}{\sum_{t'=1}^{n} a_{t'i}^{(\mu)}} \tag{38}$$

The eigen vector for the maximum eigen value of matrices $\mathbf{M}^{(\gamma)}$ and $\mathbf{M}^{(\mu)}$ can be obtained by using power method.

[**Algorithm of Parameter Estimation**]

Step 1 Give the initial values of $\rho^{(0)}$ and $\mu_i^{(0)}$.

Step 2 Calculate $\gamma_i^{(t+1)}$ as an elememt of eigen vector for maximim eigen value based on Eqs. (35) and (34) by using parameters $\rho^{(t)}$ and $\mu_i^{(t)}$. t denotes iteration number.

Step 3 Calculate $\mu_i^{(t+1)}$ as an elememt of eigen vector for maximim eigen value based on Eqs. (35) and (38) by using parameters $\rho^{(t)}$ and $\gamma_i^{(t+1)}$.

Step 4 If $|\mu_i^{(t+1)} - \mu_i^{(t)}| < \epsilon$ and $|\gamma_i^{(t+1)} - \gamma_i^{(t)}| < \epsilon$ are satisfied then go to next, otherwise return to **Step 2**. ϵ is small value given to judge convergence for $t > 0$.

Step 5 Check the condition of Eq. (17) if the condition is satisfied then stop procedure, otherwise calculate $\rho^{(t+1)} = \rho^{(t)} + \delta(E_C)$ where $\delta(E_C)$ takes a positive small value ϵ^+ if E_C is negative otherwise a negative small value ϵ^- if E_C is positive, then return to **Step 2**.

4 Illustrative example

We regard the network structure of Figure 1 as the 7 interchanges of express highway. One way traffic is included in the network. The number of car which enters from each interchange is assumed to be observed like

$$\mathbf{V}_o = [195, 230, 160, 100, 160, 180, 215] \tag{39}$$

where the vector $\mathbf{V}_o$ denotes $[V_{o_1}, V_{o_2}, V_{o_3}, \cdots, V_{o_n}]$. Also the number of car which exit from each interchange is as follows;

$$\mathbf{U}_d = [260, 130, 300, 150, 200, 90, 110] \tag{40}$$

where $\mathbf{U}_d$ denotes $[U_{d_1}, U_{d_2}, U_{d_3}, \cdots, U_{d_m}]$.

The cost of transition $c_{o_i d_j}^k$ at kth path from o_i to d_j is assumed to be given by the hop number in Fugure 1, that is $c_{o_i d_i}^1 = 0$ $(\forall i)$, $c_{o_1 d_2}^1 = 1$ $(1 \rightarrow 2)$,

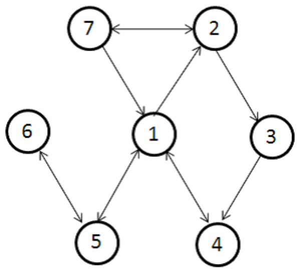

Fig. 1. Sample of network structure

$c^1_{o_1d_3} = 2$ $(1 \to 2 \to 3)$, $c^1_{o_1d_4} = 1$ $(1 \to 4)$, $c^2_{o_1d_4} = 3$ $(1 \to 2 \to 3 \to 4)$ and so on. The total cost is assumed to be 1000. We apply the algorithm to estimate the elements of OD matrix. The result is shown in Table 2.

In Fugure 5, that is $c^1_{o_1d_2} = 2.0$ $(1 \to 2)$, $c^1_{o_1d_3} = 3.8$ $(1 \to 2 \to 3)$, $c^1_{o_1d_4} = 3.0$ $(1 \to 4)$, $c^2_{o_1d_4} = 6.3$ $(1 \to 2 \to 3 \to 4)$ and so on. The total cost is assumed to be 3.0. We apply the algorithm to estimate the elements of OD matrix. The result is shown in Table 3.

In this case the absolute errors are $|E_V| = 0.16$, $|E_U| = 0.03$ and $|E_C| = 1.40$. The small value is $\epsilon = 0.001$. The obtained parameter is $\rho = 0.86$. γ_i and μ_j are as follows;

$$\gamma = [2.32, 2.88, 0.16, 1.23, 2.38, 1.10, 1.44] \tag{41}$$

$$\mu = [2.13, 2.20, 0.52, 2.82, 2.42, 1.78, 0.27] \tag{42}$$

The matrix $\mathbf{M}$ can be constructed by Eq. (30), thus the geographical advantage for the obtained OD matrix can be derived as

$$\mathbf{g}_a = [0.23, 0.10, 0.19, 0.17, 0.15, 0.09, 0.08]^{\mathrm{T}} \tag{43}$$

We can understand our model can reflect information of traffic flow from the

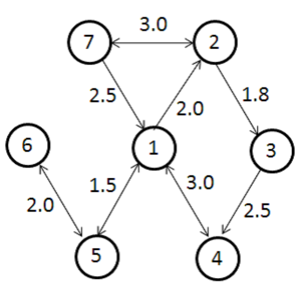

Fig. 2. Expected transit time estimated by decision maker

Table 3 Estimated OD matrix.

origin	destination node							
node	d_1	d_2	d_3	d_4	d_5	d_6	d_7	
o_1	0.00	42.72	48.94	10.35	52.55	17.98	22.44	194.98
o_2	1.58	0.00	154.92	1.88	0.33	0.11	71.05	229.87
o_3	19.73	3.33	0.00	129.78	4.09	1.40	1.75	160.08
o_4	57.87	9.76	11.17	0.00	12.00	4.10	5.12	100.02
o_5	66.18	11.12	12.78	2.70	0.00	61.31	5.86	159.99
o_6	42.87	7.23	8.28	1.75	116.11	0.00	3.80	180.03
o_7	71.76	55.818	63.93	3.52	14.90	5.10	0.00	215.02
	159.99	130.00	300.01	149.99	199.98	90.00	110.02	1240

results, because the nodes 1 and 3 have a large amount of input-output traffic flow thus they have large values about geographic advantage and node 4 which receives input arrows from them also becomes large value.

5 Conclusion

In this paper, we explained the concept of geographical advantage and proposed an extended spatial interaction model permitting consideration of several path selection for each origin-destination pair. Based on the entropy maximization principle, we derived theorem about relationship between the geographical advantage and accessibility in spatial interaction model. From observed data about traffic flow to obtain the traffic volume from origin to destination, algorithm to estimate model parameters has been derived by using eigenvalue problem. It can be regarded as a merged procedure between the geographical advantage and accessibility of the spatial interaction model in unified way. In numerical experiment, the availability of our model which can consider not only a network structure but also a traffic flow has been shown. As the furtherwork, project management have a number of common points with traffic assignment (10), thus we think that such research area is one of applicable scope.

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