AN APPLICATION METHOD OF SYNTHETIC MODEL TO A LARGE-SCALE ROAD NETWORK

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1. INTRODUCTION

A number of techniques for estimating an OD matrix from observed link flows in a network, which are generally called as synthetic models, have been developed and improved rapidly for these fifteen years. The features of the synthetic model are that this model can drastically save labor and computation works in the estimation process, compared with the conventional sequential step method, and that it could yield highly accurate estimates of OD matrix and of link flows by each of the OD pairs in a form of matching with a real world road network in consideration. It should be noted here, however, that a set of the route choice probabilities by each of the OD pairs is in general treated as the exogenous variables in this type of model. In this case a huge amount of computer memory will be required for a large-scale road network, because the number of the elements is given by the product of the number of the links and that of the OD pairs.

Traffic assignment techniques for a large-scale road network developed so far could be classified into the following four types of method, which have close relation to the synthetic model because the route choice probabilities by each OD pair should be given or estimated in it. The first is a method by simple division of the study road network(Hu, T. C., 1968, Hayashi, Y. et al., 1982). The aim of this model is to reduce the shortest route search work. The second method is one that networks are represented differently according to the road level, for example interregional and regional roads. Daganzo C.F.(1980) suggested a useful representation scheme that it is possible to streamline LeBlanc's adaptation of the Frank-Wolfe algorithm in order to deal with large numbers of centroids. The method improves the calculation efficiency of the shortest path search between each of OD pairs by treating separately the trunk roads and non-trunk roads. Uchiyama H. et al.(1982) proposed a traffic assignment algorithm in which OD pairs are classified into two groups, or long distance trips and short distance trips, corresponding to the two levels of road network representation, or interregional and regional road network. The third is a simplification method of network representation by extraction of the minor links from the original road network. But the problem remains in the adequacy of the traffic assignment to the simplified road network (Edamura E.et al.,1981). The fourth is a continuous approach that a highly dense network is approximated as a continuum. Newell(1979) has suggested the use of a continuum approximation for road network. Daganzo C.F.(1977) showed the algorithm to a continuous network with link capacities.

A number of synthetic models have been developed recently. Most of these models have been constructed as optimization problem by incorporating a convex objective function subject to link flow constraints. The objective function have been formulated from various consideration, such as information minimization (Van Zuylen,H.,1978), entropy maximization (Inoue H.,1977 ,Van Zuylen,H. and Willumsen, L.G.,1980), likelihood maximization (Holm,J.,et al.,1976, Inoue,H.,1979, Takayama,J. and Iida,Y.,1984, Iida,Y. and Takayama,J.1987), and least squares (Robillard,P.,1975, Iida,Y. and Takayama,J.,1983,1986). Each one of these objective functions has the form of a closeness measure between the estimated and the past (or the outdated) OD matrix.

In most of these models with a few exceptions, a set of route choice probabilities by each of the OD pairs is treated as exogenous variables. Therefore, a huge amount of computer memory is required for a large-scale real road network.

In order to reduce the amount of computation work and time in an application of the synthetic model to a large-scale road network, we thus propose a square mesh model and investigate the properties for the prediction errors in the mesh model.

2. SIMPLIFIED REPRESENTATION AND DIVISION OF ROAD NETWORK

We describe here the algorithms of the simplified representation and the division method of road network. In general, there are two kinds of the aggregation processes, viz., zone aggregation and link aggregation (Chan Y.,1976). Zone aggregation refers to the procedure of collapsing a few adjacent detailed (or original) zones to an aggregated (or simplified) zone. This means a number of contiguous zone centroids and nodes are grouped together. Link aggregation, on the other hand, refers to the procedure of collapsing a set of detailed links into an aggregated link. It means detailed links " in series " and/or " in parallel " are joined together.

In our present research, we adequately divide the study road network into several mesh subareas as shown in Fig.1. Moreover, each of the mesh subareas is represented as simplified network with a single centroid and a set of access and passing-through links. Accordingly, the entire simplified road network consists of a set of the simplified mesh subareas ,which are connected by dummy links as shown in Fig.2 .

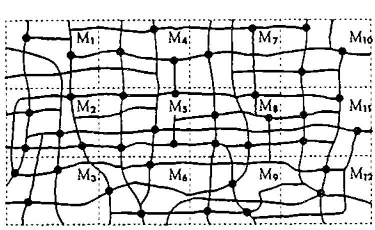

Fig. 1 Detailed representation of road network divided by mesh subareas

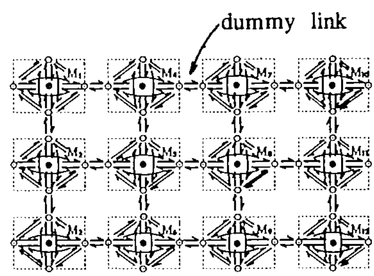

Fig. 2 A simplified road network representation by mesh model

2.1 Node aggregation in a mesh subarea

There is a set of detailed (or original) zone centroids, nodes, and links in one mesh subarea. Suppose we aggregate a set of original zone centroids and nodes into a simplified zone centroid,

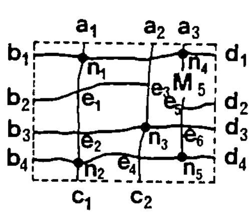

Fig. 3 Detailed representation of road in a mesh subarea network

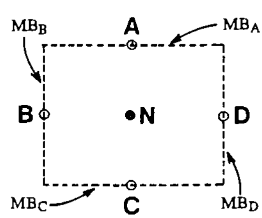

Fig. 4 Aggregated (or simplified) zone centroid and passing-through nodes in a mesh subarea

and a set of original passing-through nodes on the individual mesh boundaries into four simplified passing-through nodes, which are taken as temporary nodes. Thus, the set of original centroids $\{n_i\}$ and nodes $\{e_i\}$ are aggregated into the single simplified mesh centroid N for generation/attraction trips of the subarea; and the original passing-through nodes, $\{a_k\}$, $\{b_k\}$, $\{c_k\}$, $\{d_k\}$, on the mesh boundaries , MB_A, MB_B, MB_C, MB_D, as shown in Fig.3, are respectively aggregated into the simplified passing-through nodes, A, B, C, D, as shown in Fig.4.

In general, the computation time of the shortest route search in the entire simplified network becomes efficiently short, in the case of the large mesh size and the small number of the meshes. In this case, the efficiency of the calculation to the original network in one mesh subarea dose not improve, because of the large number of original zone centroids and nodes in the mesh subarea. On the contrary, when the number of the meshes are increased, the efficiency of the calculation in the entire simplified network decreases due to the increase in the number of simplified passing-through nodes in the entire simplified network.

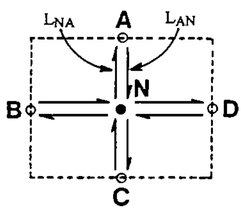

Fig. 5 Aggregated (or simplified) access links in a mesh subarea

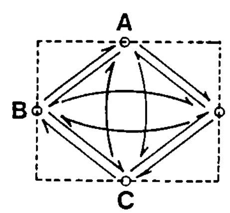

Fig.6 Aggregated (or simplified) passing-through links in a mesh subarea

2.2 Link aggregation in a mesh subarea

Various kinds of link aggregation approaches have been considered. These approaches can be classified into two categories : (1) link extraction, and (2) link abstraction. Link extraction refers to removing from the network "minor" links, such as access or collector roads. Link abstraction refers to incorporating the properties of a set of detailed (or original) links into an aggregated (or simplified) link (Chan Y.,1976).

In our present research, link abstraction is applied to link aggregation approach in each of mesh subareas. Link abstraction is the task of constructing a simplified link between two nodes on the network served by a set of original links, where the simplified link has the same level of service (e.g. travel time) as the original links. We assume that the simplified road networks in each of mesh subarea are represented by two kinds of aggregated links : (1) simplified access links, and (2) simplified passing-through links.

The simplified access links serve as arcs for the trip originating in or terminating to a mesh subarea. The separate sets of original links between the original centroids $\{n_i\}$ or nodes $\{e_i\}$ and the original passing-through nodes $\{a_k\}$ on the mesh boundary MB_A are collapsed together to form the simplified access links L_{NA}, L_{AN} that connect between the aggregated mesh centroid N and the aggregated passing-through node A as shown in Fig.5. The other simplified access links are served in much the same way as access links L_{NA} and L_{AN}. The simplified passing-through links, on the other hand, are provided to serve as links for the trip transfer getting through the mesh subarea. The separate sets of original links between all pairs of original passing-through nodes on the several mesh boundaries are collapsed together to form the simplified passing-through links that connect all pairs of aggregated passing-through nodes as indicated in Fig.6.

The problem of network aggregation becomes one of finding an abstract representation of level-of-service functions between an aggregated (or simplified) zone centroid and the several aggregated (or simplified) passing-through node, and of level-of-service functions between each of aggregated (or simplified) passing-through nodes.

2.3 Level-of-service function for simplified access and passing-through links

Consider the detailed (or original) network in a mesh subarea. Here, let us define

$S(n_i,a_k)$ = travel time of the shortest route from original zone centroid n_i to original passing-through node a_k,

$P(n_i,a_k)$ = proportion of trips from n_i to a_k using its shortest route,

where $\sum_k P(n_i, a_k) = 1.0$,

$S(N,A)$ = travel time on aggregated link from aggregated mesh centroid N to aggregated passing-through node A,

$S(n_i,A)$ = average value of travel time from the original zone centroid n_i to the aggregated passing-through node A,

$to(n_i)$ = generation trips from the original zone centroid n_i,

$P(to_i)$ = proportion of generation trips from the original zone centroid n_i,

where $P(to_i) = to(n_i) / \sum_j to(n_j)$,

$\sum_i P(to_i) = 1.0$,

$td(n_i)$ = attraction trips to the original zone centroid n_i,

$P(td_i)$ = proportion of attraction trips from the original zone centroid n_i,

where $P(td_i) = td(n_i) / \sum_j td(n_j)$,

$\sum_i P(td_i) = 1.0$,

$v(a_k, c_{k'})$ = traffic flows passing through the mesh subarea from the original passing-through node a_k to $c_{k'}$,

$V(A,C)$ = total traffic flows passing through the mesh subarea from mesh boundary MB_A to MB_C ,

where $V(A,C) = \sum_k \sum_{k'} v(a_k, c_{k'})$.

Then we can represent the travel time on the simplified link from the aggregated mesh centroid N to the aggregated passing-through node A as the average value of travel time from the original zone centroid n_i to the original passing-through node a_k , as

$$S(N,A) = \sum_i S(n_i ,A) * P(to_i) \quad \text{-------------------------------------} \quad (1),$$

where $S(n_i,A) = \sum_k S(n_i,a_k) * P(n_i,a_k)$ ------------------------------------ (2) .

Similarly, travel time on the simplified link from A to N as the average value from a_k to n_i, is shown as

$$S(A,N) = \sum_i S(A,n_i) * P(td_i) \quad \text{------------------------------------ (3),}$$

where $S(A,n_i) = \sum_k S(a_k,n_i) * P(a_k,n_i)$ ------------------------------------ (4) .

We can also represent the travel time on the simplified link passing through the mesh subarea from mesh boundary MB_A to MB_C as the average value from a_k to $c_{k'}$, is shown as

$$S(A,C) = \sum_k \sum_{k'} S(a_k,c_{k'}) * P(a_k,c_{k'}) \quad \text{------------------------------ (5),}$$

where $P(a_k,c_{k'}) = v(a_k,c_{k'}) / V(A,C)$ ------------------------------------ (6) .

The other travel times on the simplified network can be represented in the same way as the average values of travel times, or S(N,A), S(A,N) and S(A,C).

In general, however, the proportion of traffic flows between pairs of detailed (or original) centroids and passing-through nodes, or pairs of original passing-through nodes in a mesh subarea is unknown. If a set of the proportion is appropriately estimated by using a suitable assignment technique, such as all-or-nothing method or stochastic assignment model, levels of service (travel time) in the simplified vs. detailed (or original) networks become the same.

Various kinds of estimation methods for the proportion can be considered. For example, a set of traffic flows can be obtained by assigning the past trips among every detailed OD pair to the entire original network. However, it is impossible to apply the existing assignment methods to a large-scale road network, because a great amount of both computer memory and computation time will be required. In our present research, we estimate the proportion of traffic flows according to the following approach.

With respect to the simplified access link, take notice of a certain mesh subarea and pick out both its subarea and adjacent one to before , behind , right or left itself. A set of traffic flows and travel times in each of the corresponding minimum path can be estimated by assigning the past trips between every detailed OD pair to the original network in those subareas as shown in Fig.7. Therefore, the travel time in the simplified access link is calculated by eqs. (1) and (2) or eqs. (3) and (4). Here we make use of the incremental assignment method with capacity restrant for the original network.

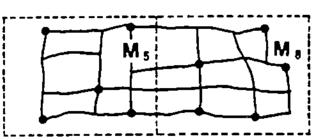

Fig. 7 Detailed representation of road network for traffic assignment (simplified access link)

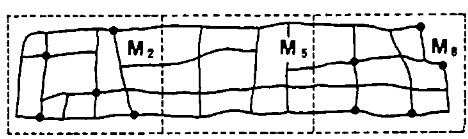

Fig. 8 Detailed representation of road network for traffic assignment (simplified passing-through link)

With respect to the simplified passing-through link, on the other hand, pick out both the noted subarea and adjacent ones to before and behind or right and left themselves as shown in Fig.8. Sets of traffic flows and travel times in the original network in the subareas picked out can be estimated by assigning the past trips between every detailed OD pair in two subareas excepting the noted one to the original network in those three subareas. Therefore, the travel time in the simplified passing-through link is similarly calculated by eqs. (5) and (6). Here also the incremental assignment method with capacity restrant is used for the original network. Hence it follows that the effective capacities of simplified networks are indirectly defined by using its assignment method.

The characteristic of this approach is that the route choice properties on the detailed-whole network can be approximated by ones on the part network which consists of the original links in a few mesh subareas. Therefore, the minimum routes between every detailed OD pair are searched with both the simplified entire network in the study area and the detailed part network in a few mesh subareas.

The traffic assignment method used in this mesh model, which is simplified by means of the simplified representation and the division of road network, is called as the traffic assignment method divided by mesh subareas.

3. MODEL FORMULATION FOR SIMPLIFIED NETWORK

In order to reduce the computer memory in an application of the synthetic model to a large-scale road network, we incorporate an efficient traffic assignment technique which can treat the set of route choice probabilities as endogenous variables into the estimation process. Then, we make use of Dial's probabilistic traffic assignment method for the entire aggregated (or simplified) road network and employ the incremental assignment method for the detailed (or original) mesh subarea. In our present research, therefore, the aggregated OD matrix between mesh subareas can be estimated by combining the above assignment method with the synthetic model based on the observed flows on the simplified links.

Consider an original road network which is divided into N mesh subareas with the corresponding observed link flows on the mesh boundaries. Let us define

T(I,J) = the number of trips between origin mesh I and destination mesh J, where I consists of original zone centroid (n_i) and J, (n_j),

TO(I) = the total number of trips originating from mesh I,

$$\text{where} \quad TO(I) = \sum_{J} T(I,J) \quad \text{------} \quad (7) ,$$

TD(J) = the total number of trips terminating to mesh J,

$$\text{where} \quad TD(J) = \sum_{I} T(I,J) \quad \text{------} \quad (8) ,$$

P(I,J,M) = proportion of using the simplified link M on the mesh boundary, by trips from mesh I to mesh J,

$$\text{where} \quad 0.0 \leq P(I,J,M) \leq 1.0 \ .$$

Suppose that OD trips T(I,J) is in terms of a gravity model as below.

$$T(I,J) = BFO(I)*TO(I)*BFD(J)*TD(J)*R(I,J) \quad \text{------} \quad (9) ,$$

where R(I,J) is a trip interchange factor (or a trip impedance factor), and BFO(I) and BFD(J) are balancing factors satisfying trip end constraints written by eqs. (7) and (8). In this model, the trip interchange factor is given by eq. (10) ,

$$R(I,J) = AF(I,J)*Fun(S(I,J)) \quad \text{------} \quad (10) ,$$

where AF(I,J) is an adjusting factor peculiar to OD pair I J to agree with an existing or an earlier OD pattern, Fun (S(I,J)) is a deterrence function between mesh I and mesh J, and S(I,J) is the average travel time or cost between I and J. This trip interchange factor could be provided by eq.(11).

$$R(I,J) = T''(I,J) \;/\; \{TO''(I)*TD''(J)\} \quad \text{------------------------------} \; (11) \;,$$

where
- T"(I,J) = the number of trips from mesh I to mesh J, in the past (or the sampled) OD table,
- TO"(I) = the total number of generation trips from mesh I, in the past (or the sampled) OD table,
- TD"(J) = the total number of attraction trips to mesh J, in the past (or the sampled) OD table.

The difference between generation and attraction trips at a mesh subarea is equal to the difference between the totals of outward and inward link flows observed at the mesh boundaries. That is,

$$TO(I) - TD(I) = \sum_{K} \{ RV(I,K) - RV(K,I) \} \quad \text{--------------------------------} \; (12) \;,$$

$$\sum_{K} \{ RV(I,K) - RV(K,I) \} = Delta(I) \quad \text{--------------------------------} \; (13) \;.$$

Where RV(I,K) is the total number of traffic flows from mesh I to mesh K, observed on the mesh boundaries between mesh I and mesh K. Since the model is based on the assumption that traffic volumes are observed on every link over the mesh boundaries in the network, the value of the right-hand side of eq.(12) is definite, which is shown by Delta(I). It follows, therefore, that the aggregated attraction trips TD(I) are determined from the aggregated generation trips TO(I).

$$TD(I) = TO(I) - Delta(I) \quad \text{--} \; (14) \;.$$

Thus substituting eqs.(11) and (14) into eq.(9) leads to eq.(15).

$$T(I,J) = BFO(I)*TO(I)*BFD(J)*\{TO(J)-Delta(J)\} *[T''(I,J) / \{ TO''(I)*TD''(J) \}] \text{---} \; (15)$$

From this, we can derive a calculated or an estimated flow on the mesh boundary M, or EV(M) as shown in eq.(16).

$$EV(M) = \sum_{I} \sum_{J} \; BFO(I)*TO(I)*BFD(J)*\{TO(J)-Delta(J)\} *[T''(I,J)/\{TO''(I)*TD''(J)\}]*P(I,J,M) \text{---------------------} \; (16)$$

Also, it is possible to estimate a set of the route choice probabilities P(I,J,M) by making use of Dial's probabilistic traffic assignment method for the entire simplified road network. Then the estimates of the elements of the aggregated OD matrix can be obtained by determining the Dial's parameter and the generation trips at each mesh subarea minimizing the sum of square errors between the estimated and the observed traffic flows on the mesh boundary. That is,

$$Z = \sum_{M} \{EV(M) - RV(M)\}^2 \quad \text{--} \; (17)$$

$$= \sum_{M} \Big[\sum_{I} \sum_{J} \Big\{ BFO(I)*TO(I)*BFD(J)*(TO(J)-Delta(J)) * \frac{T''(I,J)}{TO''(I)*TD''(J)} \Big\}*P(I,J,M) - RV(M) \Big]^2 \longrightarrow \text{Min.}$$

$$\text{----------------------------------} \; (18) \;,$$

where

EV(M) = the estimated flow aggregated on the mesh boundary M,
RV(M) = the observed flow aggregated on the mesh boundary M.

Traffic flows on the simplified links can be estimated by assigning the estimates of the aggregated OD matrix to the entire simplified road network using Dial's probabilistic traffic assignment method. The aggregated traffic flow passing through the mesh boundary can be given by the estimated flows on the dummy links.

The optimum Dial's parameter may be determined by the direct search method, while the solution of generation trips can be obtained by the iterative procedure as follows, where, $<q>$ is the number of iteration.

Step 1 --- give a set of interchange factor (or impedance factor) R(I,J) by using eq.(11).
Step 2 --- aggregate the observed traffic flows on the original links for the mesh boundary M, RV(I,K).
Step 3 --- calculate Delta(I) by using eq.(13).
Step 4 --- calculate average travel time S(I,K) by using the traffic assignment method divided by mesh subareas as described in chapter 2.
Step 5 --- assume generation trips $TO(I)^{<q=0>}$ and the Dial's parameter $Theta^{<q>}$ as the initial value.
Step 6 --- calculate $T(I,J)^{<q>}$ by using eq.(15).
Step 7 --- estimate $EV(I,K)^{<q>}$ by assigning $T(I,J)^{<q>}$ to the entire simplified network using Dial's probabilistic traffic assignment.
Step 8 --- update a set of $TO(I)^{<q>}$ by using eqs.(19) and (20),

$$TO(I)^{<q+1>} = \frac{TO(I)^{<q>}}{\sum_K RV(I,K)} * \{ \sum_K RV(I,K) - \sum_K EV(I,K)^{<q>} \} + TO(I)^{<q>} \quad \text{--- (19)},$$

$$TO(I)^{<q+1>} = \frac{TO''(I)}{\sum_J TO''(J)} * \sum_I TO(I)^{<q+1>} \quad \text{--- (20)}.$$

Step 9 --- determine the optimum parameter $Theta^{<q>}$ by the direct search method.
Step 10 -- continue the calculation of TO(I) and Theta from Step 6 to Step 9 until a closeness measure shown by eq.(21) is satisfied,

$$\max_{I,K} \left[\left| \{ RV(I,K) - EV(I,K)^{<q>} \} / RV(I,K) \right| \right] < e \quad \text{--- (21)}.$$

4. CASE STUDY TO KANAZAWA URBAN AREA

4.1 Network division and data base

In this paper, the above square mesh model is applied to Kanazawa urban area as a case study in order to know the properties of the mesh model for practical use. Fig.9 is the original road network in Kanazawa urban area with 75 zone centroids, 89 nodes and 534 directed links..In this study, three kinds of mesh sizes, namely, 2.5km square mesh, 5.0km square mesh and 2.5km * 5.0km rectangular mesh, are considered to see how the mesh size will affect the prediction error, the necessary computer memory and computation time. Table 1 shows the comparison of the number of elements of the simplified road network, or zone centroids, nodes and links with that of the original road network.

OD matrices to be estimated by the synthetic model are artificially produced through simulations reflecting growth trend in traffic demand with year and temporal fluctuation in OD pattern based on the OD survey data in Kanazawa urban area in 1974 as shown eq.(23) and eq.(24). Let us here denote the past OD flow between i and j as t"(i,j) and write the true OD flow to be estimated at present as Rt(i,j).

$$Rto(i) = KAP * to''(i) * \{ 1.0 - SIGO * Z(i) \} \quad \text{------------ (23)}$$

$$Rtd(j) = KAP * td''(j) * \{ 1.0 - SIGD * Z(j) \} \quad \text{------------ (24)}$$

where
Rto(i) = the true number of generation trips from i at estimation time,
to"(i) = the number of generation trips from i in the past survey,
Rtd(j) = the true number of attraction trips to j at estimation time,
td"(j) = the number of attraction trips to j in the past survey,
SIGO = the relative deviation of fluctuation in the node generation trips (%),
SIGD = the relative deviation of fluctuation in the node attraction trips (%),
KAP = the growth trend coefficient of traffic demand,
Z(i) = the standard random normal deviates for node i.

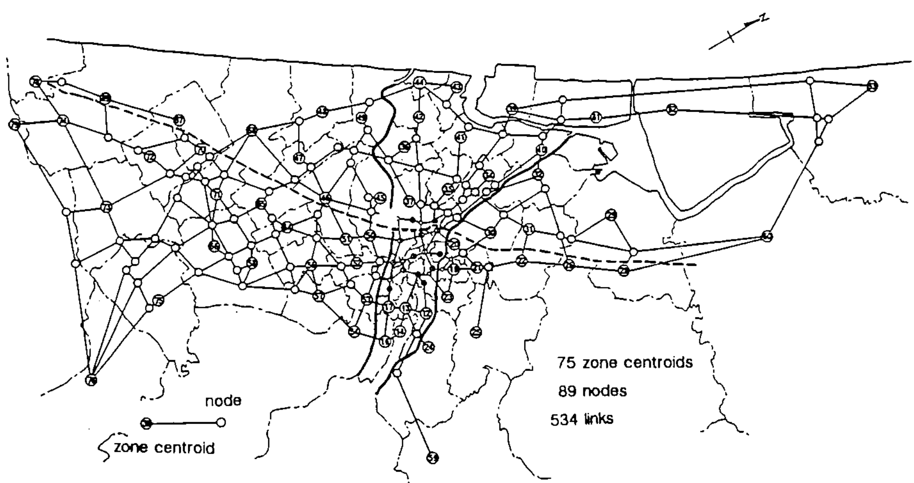

Fig. 9 The detailed (or original) road network in Kanazawa urban area

In this case, five kinds of OD matrix as the true OD flows to be estimated are produced by changing the value of KAP from 1.0 to 2.0 by 0.25 interval, assuming that SIGO=SIGD=0.15. Suppose that the observed link flows could be given by traffic assignment of the OD matrix, produced through simulation, to the original road network in consideration. In this numerical analysis, Dial's probabilistic traffic assignment technique is employed. The flow observed on the link m, or Rv(m), however, will be different from the flow given by the assignment, or Rv'(m), because of the existence of various kinds of errors such as observation error and network representation error. Accordingly, the observed link flow as an actual value is given by

$$Rv(m) = Rv'(m) * \{ 1.0 - SIGV * Z(m) \} \quad \text{------------} \quad (25),$$

where SIGV = the relative error in observed link flows (%),
Z(m) = the standard random normal deviate.

Table 1 The number of elements of the original and the simplified road networks

elements	centroids	nodes	links
original road network	75	89	536
simplified road network			
2.5km square mesh	28	82	422
5.0km square mesh	14	38	186
rectangular mesh	16	46	232

The aggregation of observed link flows on the mesh boundary M, or RV(M), is done by the summation of the observed link flows in the detailed (or original) network, or Rv(m), as below.

$$RV(M) = \sum_{m} Rv(m) \quad \text{------------} \quad (26)$$

Besides, the estimated traffic flows on the detailed (or original) link m, or Ev(m), are obtained by assigning ET(i,j) to the original road network using the traffic assignment method proposed in this paper (as shown in chapter 2).

Next, let us look at the properties of the mesh model in relation to the prediction errors by changing SIGV, KAP and mesh sizes. In this research, the measure of the prediction error DELTA(T) is given by

$$DELTA(T) = \sqrt{\frac{1}{\sum_{I}\sum_{J} RT(I,J)} \sum_{I}\sum_{J} RT(I,J)*\left\{\frac{ET(I,J) - RT(I,J)}{RT(I,J)}\right\}^2} \quad \text{------} \quad (27)$$

which represents the degree of relative error between RT(I,J) and ET(I,J).

Table 2 Relative error between the original OD matrix and the individual OD matrix at estimation time.

	growth trend coefficient KAP				
	1.00	1.25	1.50	1.75	2.00
DELTA1(t)	0.00 %	32.0 %	63.6 %	99.8 %	140.7 %
DELTA2(t)	0.00 %	14.9 %	24.5 %	35.2 %	46.5 %

Similarly, the measures of relative errors between t"(i,j) and Rt(i,j), and between KAP*t"(i,j) and Rt(i,j),that is, DELTA1(t) and DELTA2(t), are obtained by substituting the corresponding values of t"(i,j) and Rt(i,j),and KAP*t"(i,j) and Rt(i,j) into eq. (27). The reason of using this representation comes from the idea that, from a viewpoint of traffic engineering, the accuracy for the heavy traffic volume is more important than that for the light traffic volume.

The degree of relative variation between the original OD matrix as the basic data and the fluctuated OD matrix produced by the simulations at estimation time are shown in Table 2. The degree of relative variation for the OD pattern naturally increases with the growth of traffic demand.

4.2 Necessary computer memories and computation times

When a set of route choice probabilities by each of the OD pairs is treated as exogenous variables, the approximate computer memory required for the original and simplified road networks are shown in Table 3.

Table 3 Approximate computer memories of route choice probabilities as exogenous variables for the original and simplified road networks

	computer memories
original road network	12,060 KB
simplified road network	
2.5km square mesh	1,324 KB
5.0km square mesh	146 KB
rectangular mesh	238 KB

A huge amount of computer memory is required for the original road network, because the number of the elements is given by the product of the number of the links and that of the OD pairs. It will be difficult,therefore, to apply the synthetic model to the original road network when the route choice probabilities are treated as exogenous variables.

Table 4 Approximate computer memories required for the shortest route search on the original and simplified road networks

	computer memories
original road network	314 KB
simplified road network	
2.5km square mesh	120 KB
5.0km square mesh	28 KB
rectangular mesh	40 KB

If the route choice probabilities are treated as endogenous variables and the original road network is represented as a simplified one, however, we can drastically reduce the necessary memory for the computation works. This is because the necessary computer memory is mainly determined by the shortest route search work. Table 4 shows the approximate necessary computer memories required for the shortest route search work.

Besides, Table 5 shows the computation times required to estimate the simplified OD matrix by means of the mesh model. It is shown that the computation time decreases with the mesh size, resulting in that the difference of that between 2.5km square mesh and 5.0km square mesh (or rectangular mesh) is outstandingly large.

Table 5 Necessary computation times by mesh size

	computation times
simplified road network	
2.5km square mesh	6 min. 15 sec.
5.0km square mesh	1 min. 3 sec.
rectangular mesh	2 min. 52 sec.

4.3 Prediction errors by mesh size

The prediction errors in the estimates for the simplified OD matrix by the mesh model are shown in Fig.10, in which the growth trend coefficient KAP is changed but the observation error in the link flows is assumed to be zero, say SIGV=0. The figures on the curve show the number of iterative calculation.

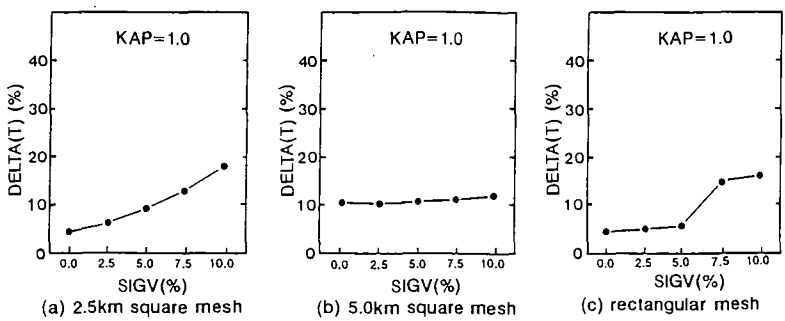

Fig 10 Prediction errors in OD matrix by mesh model with respect to growth coefficient

Generally, the mesh model seems to indicate that the degree of the prediction error in the estimates of simplified OD trips, or DELTA(T), increases with the growth in the value of KAP. However, the degree of prediction error for each of the mesh sizes is smaller than that of relative variation between the existing OD matrix and the individual OD matrix at estimation time produced by means of this simulation as shown in Table 2. Moreover, comparing with the degree of relative variation without consideration of the growth coefficient, or DELTA1(t), its tendency is still more remarkable.

As for the number of iterations in the mesh model, it is seen that the number of iteration for 5.0km square mesh size is larger than that for 2.5km square mesh size. We can consider that the number of original links and the total number of observed link flows on the mesh boundary in a mesh subarea increases with the expansion of mesh size. Therefore, it can be inferred that since an increase in the number of the denominator in eq.(19) relatively decrease the degree of one modification by means of eq.(19), the number of iteration for the large mesh size becomes large.

Besides, it can be said that the degree of prediction error for 2.5km square mesh size is smaller than that for 5.0km square mesh size. However, the computation time for 2.5km square mesh size is larger than that for 5.0km square mesh size as shown in Table 5.

4.4 Prediction errors by the degree of errors in observed link flows

The prediction errors for each of the mesh sizes are shown in Fig.11, in which the degree of errors in the observed link flows, or SIGV, is changed without fluctuation in the OD pattern and the growth in the OD traffic demand, say SIGO= SIGD=0 and KAP=1.0 .

It seems that the sensitivity of SIGV to the prediction error is trivial for 5.0km square mesh size, but appreciably high for 2.5km square mesh size or rectangular mesh size as shown in Fig.11. The reason is that the errors in the observed link flows might cancel each other in the aggregation process.

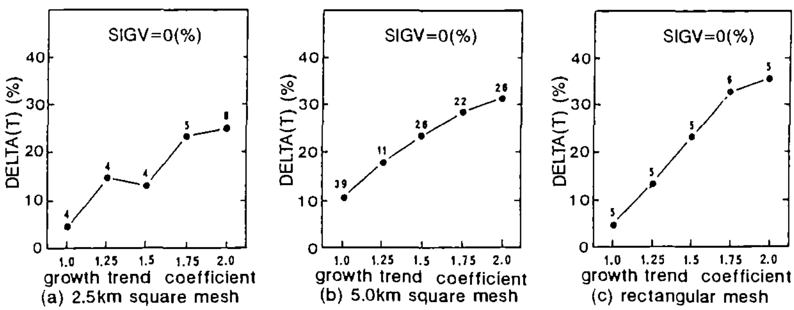

Fig. 11 Influence of observation errors in link flows to prediction errors in OD matrix by mesh model

5. CONCLUSION

In this paper, we proposed a synthetic model in which the traffic assignment method is incorporated into the estimation process by simplifying the network representation, and applied to Kanazawa urban area in order to know the properties of the mesh model for practical use. In this study, three kinds of mesh sizes were considered to see how the mesh size will affect the prediction error, the necessary computer memory and computation time.

The results are summarized as follows.

1) The simplified representation of road network and the incorporation of Dial's probabilistic traffic assignment method into the estimation process can drastically save necessary computer memories and computation times.

2) The mesh model seems to indicate that the degree of the prediction error in the estimates of simplified OD matrix increases with the growth in the trend coefficient of traffic demand, but are smaller than that of relative variation by means of those simulations.

3) It appears that the sensitivity of the relative error in observed link flows to the prediction error in the estimates of simplified OD matrix is appreciably high for small mesh size, but the observation error in link flows does not give significant influence on the prediction error.

The proposed mesh model has been shown to be very useful for the application to a large-scale road network. Moreover, the special feature of this mesh model is that we can estimate easily an OD matrix through an iterative calculation of generation trips from simplified zone centroids as unknown variables. Since the number of unknowns is only that of the simplified zone centroids, we can achieve an enormous saving of necessary computer memories.

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