PROC. OF JSCE,
No. 209, JAN. 1973

A MODEL OF TRAVEL ROUTE CHOICE FOR COMMUTERS

By Shogo KAWAKAMI*

ABSTRACT

The factors affecting the route choice of commuters who utilize the public transportation facilities are found out by a survey.

The conditions that the route choice model should satisfy are discussed, and the model that satisfies these conditions is developed. And the model is tested by using the data in Nagoya City for 1969. It provides a fair overall fit and yields plausible regression coefficients.

1. INTRODUCTION

This paper develops and tests a model of route choice for commuters. The model that has been developed reproduces the existing conditions to a fairly high accuracy in the limited tests to which it has been subjected.

In the past, the following models have been developed for predicting the route choice[1]:

1) $P_1=a(x_2-x_1)+b(y_2-y_1)+c(z_2-z_1)+d$ (for 2 routes) ……(1)

2) $P_l=a'(\bar{x}-x_l)+b'(\bar{y}-y_l)+c'(\bar{z}-z_l)+\frac{1}{g}$ ……(2)

3) $P_1=\left[1+\exp\left\{-\frac{x_2-x_1}{R}\right\}\right]^{-1}$ (for 2 routes) ……(3)

where a, b, c, d, a', b', c' and R are empirical constants.

P_l=probability that a commuter chooses route l.

x_l=commuting time required for route l (in minutes).

y_l=commuting cost for route l (in yen per month).

z_l =number of changes of route l (in times). The change means changing trains or buses, changing from a bus to a train or changing from a car to a train or a bus.

g =total number of routes considered.

$$\bar{x}=\sum_{l=1}^{g} x_l/g\,,\quad \bar{y}=\sum_{l=1}^{g} y_l/g\,,\quad \bar{z}=\sum_{l=1}^{g} z_l/g$$

In some models of type 1), x_2/x_1, y_2/y_1 and z_2/z_1 are used instead of (x_2-x_1), (y_2-y_1) and (z_2-z_1).

In addition to these, a method using the linear discriminant function that contains commuting time, cost and number of changes as factors, a method using the diversion curve that is given by the function of commuting time ratio or commuting cost ratio, a probabilistic method assuming the distribution of appraised values of routes and a method using the information theory have been developed[2),3),4)]. These methods have merits and demerits.

Some problems involved in these models are as follows:

(1) The number of factors considered in the hitherto used methods is small, though many factors affect the commuter's choice of route.

(2) In some models, the value of P_l varies with calculation processes. That is, some models do not satisfy the following equation, assuming that the general form of the model is expressed by equation $P_l/P_m=f(x_l, x_m)$:

$$\frac{P_m}{P_l}=\frac{1}{f(x_l, x_m)}=f(x_m, x_l)$$

(3) Some models do not satisfy the following conditions:

$$0\leqq P_l\leqq 1\,,\quad \sum_{l=1}^{g} P_l=1$$

(4) Some models assign to a route the number of passengers that exceeds the transport capacity of the route.

In this paper, we determine first of all for what reasons people consciously are used to decide the route between two places. Then a model

* Dr. Eng., Assistant Professor, Department of Civil Engineering, Nagoya University.

of route choice which has not problems mentioned above is developed.

The model is tested on the 1969 Nagoya data. It provides a fair overall fit and yields plausible regression coefficients.

2. FACTORS AFFECTING THE ROUTE CHOICE[5)]

In order to clarify the reasons why the commuters have chosen the route, a questionaire survey was carried out for the commuters in Nagoya City in 1967. The survey was designed to collect details of the usual habits of commuters, including their commuting time, cost and number of changes, and a question was added to know the reasons that influence their choice of route for attending office or work. The question was as follows:

Why do you attend office or work through this route? (Please give your reasons as fully as possible.)

The questionaire was despatched to 20,000 persons and 908 forms were returned. Six hundred and eighty-four of these replies were effective, which were analyzed and grouped by transportation facilities, and the percentages of persons who gave the particular reason were tabulated. These are shown in Table 1. The public transportation users are 647 persons, car users are 30 persons and bicycle users are 7 persons.

Table 1 Reasons of choice of route in the Nagoya City survey (The sum of percentages are more than 100 per cent since most people gave two or more answers)

Public transportation users		Car users	
Fastest	41%	Fastest	100%
Smallest number of changes	38		
Least waiting time	31		
Cheapest	31		
Shortest distance for walk	26		
Least crowded	24		
Shortest distance from the alighting station to the destination	18		

From an examination of all the reasons given and the numbers of people giving respective reasons, it becomes clear that the most important factors for public transport users are commuting time, cost, number of changes, comfort and convenience. The effect of these reasons on the route choice appears to change according to the income and age of the users. And all car users attach importance to the reason "Fastest".

3. DESIGN OF THE MODEL

Since there has been a difficulty in quantitatively expressing about the comfort and convenience, it was decided to attempt to design the models in terms of money cost, time and number of changes only. The following arguments are made at first for obtaining a suitable model.

The model for predicting the distribution of commuters among competitive public transportation routes must satisfy the following five conditions:

1) The choice probabilities calculated by the model agree with the actual values.
2) The value of probability is between 0 and 1 and the sum of probabilities is equal to 1.
3) The probability calculated by the model remains constant regardless of the calculation process.
4) Independently of the number of routes and the number of factors which influence the commuters' choice of route, the model can be applied.
5) The number of passengers that is assigned to each route by the model does not exceed the transportation capacity of the route.

In this paper we try to develop the model which satisfies these conditions 1)～5).

It is supposed that there are three competitive routes, i, j and k, for an individual who goes from zone A to B. Let t_l be the number of passengers on the route l and C_l be the transportation capacity of the route l. Generally it is enough to treat the case that the t_l and C_l satisfy the following equation:

$$\sum_l t_l \leqq \sum_l C_l \quad \cdots\cdots(4)$$

Denote the probability that an individual chooses the route l ($l=i, j, k$) for his commutation by P_l and assume that his choice depends on commuting time, cost and number of changes only. Then the value of t_l increases as the total number of passengers T between zones A and B increases, where $T=t_i+t_j+t_k$. But the value of t_l cannot exceed the value of C_l.

On the basis of the considerations stated above, the t_i may be expressed by the following equation:

$$t_i=C_i \exp\left[-\left(\frac{\sum C_l-T}{\sum C_l}\right)^h\right.$$

$$\times f_0(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k)\Big] \quad \cdots\cdots(5)$$

where $\sum C_l = C_i + C_j + C_k$ and h is an empirical constant.

Here, the function f_0 must satisfy the following equation:

$$0 \leqq \exp\left[-\left(\frac{\sum C_l - T}{\sum C_l}\right)^h \times f_0(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k)\right] \leqq 1 \quad \cdots\cdots(6)$$

Then the probabilities of using the three routes, P_i, P_j and P_k, are given by

$$P_i = \frac{t_i}{T}, \quad P_j = \frac{t_j}{T}, \quad P_k = \frac{t_k}{T} \quad \cdots\cdots(7)$$

respectively.

From Eqs. (5) and (7), we obtain

$$\frac{P_j}{P_i} = \frac{t_j}{t_i} = \frac{C_j}{C_i} \exp\left[-\left(\frac{\sum C_l - T}{\sum C_l}\right)^h \times \{f_0(x_j, x_k, x_i, y_j, y_k, y_i, z_j, z_k, z_i) - f_0(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k)\}\right] \quad \cdots\cdots(8)$$

We introduce a new function f defined by the following equation:

$$f(x_j, x_i, x_k, y_j, y_i, y_k, z_j, z_i, z_k) = \left(\frac{\sum C_l - T}{\sum C_l}\right)^h \times \{f_0(x_j, x_k, x_i, y_j, y_k, y_i, z_j, z_k, z_i) - f_0(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k)\} \quad \cdots\cdots(9)$$

Then, Eq. (8) is rewritten as follows:

$$\frac{P_j}{P_i} = \frac{C_j}{C_i} \times \exp[-f(x_j, x_i, x_k, y_j, y_i, y_k, z_j, z_i, z_k)] \quad \cdots\cdots(10)$$

Also, Eqs. (11), (12) and (13) are obtained from Eqs. (5), (7) and (9):

$$\frac{P_i}{P_j} = \frac{C_i}{C_j} \times \exp[-f(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k)] \quad \cdots\cdots(11)$$

$$\frac{P_k}{P_j} = \frac{C_k}{C_j} \times \exp[-f(x_k, x_j, x_i, y_k, y_j, y_i, z_k, z_j, z_i)] \quad \cdots\cdots(12)$$

$$\frac{P_i}{P_k} = \frac{C_i}{C_k} \times \exp[-f(x_i, x_k, x_j, y_i, y_k, y_j, z_i, z_k, z_j)] \quad \cdots\cdots(13)$$

Multiplying both sides of Eq. (10) and Eq. (11) respectively and rearranging, we have

$$f(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k) + f(x_j, x_i, x_k, y_j, y_i, y_k, z_j, z_i, z_k) = 0 \quad \cdots\cdots(14)$$

The function f must satisfy Eq. (14).

If we express the function f by a polynomial expression of x_l's, y_l's and z_l's,

$$f(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k) = \left(\frac{\sum C_l - T}{\sum C_l}\right)^h \left\{\sum_{n=1}^{\infty} (a_{1n}x_i^n + a_{2n}x_j^n + a_{3n}x_k^n + b_{1n}y_i^n + b_{2n}y_j^n + b_{3n}y_k^n + d_{1n}z_i^n + d_{2n}z_j^n + d_{3n}z_k^n) + e\right\} \quad \cdots\cdots(15)$$

and substitute Eq. (15) into Eq. (14), we obtain

$$\sum_n \{(a_{1n} + a_{2n})(x_i^n + x_j^n) + 2a_{3n}x_k^n + (b_{1n} + b_{2n})(y_i^n + y_j^n) + 2b_{3n}y_k^n + (d_{1n} + d_{2n})(z_i^n + z_j^n) + 2d_{3n}z_k^n\} + 2e = 0 \quad \cdots\cdots(16)$$

where a_{mn}, b_{mn}, d_{mn} and e, $(m = 1, 2, 3)$, are constants. The condition that Eq. (16) always holds is given by

$$a_{1n} + a_{2n} = 0, \quad b_{1n} + b_{2n} = 0, \quad d_{1n} + d_{2n} = 0,$$
$$a_{3n} = b_{3n} = d_{3n} = 0, \quad e = 0$$

Hence, the following polynominal Eq. (17) expresses all possible solutions of this type for Eq. (14):

$$f(x_i, x_j, x_k, y_i, y_j, y_k, z_i, z_j, z_k) = \left(\frac{\sum C_l - T}{\sum C_l}\right)^h \sum_n \{a_n(x_j^n - x_i^n) + b_n(y_j^n - y_i^n) + d_n(z_j^n - z_i^n)\} \quad \cdots\cdots(17)$$

where a_n, b_n and d_n are constants.

Though various functions can be considered as the solutions for Eq. (14), a simple function should be used in such a problem of commuting route choice. Moreover, since the trigonometrical and exponential functions can be expanded in a series of x, y and z, so that we may consider that Eq. (17) is a general solution of Eq. (14).

We introduce here a notation "$F(i, j)$" defined by

$$F(i, j) = \left(\frac{\sum C_l - T}{\sum C_l}\right)^h \sum_n \{a_n(x_i^n - x_j^n) + b_n(y_i^n - y_j^n) + d_n(z_i^n - z_j^n)\} \quad \cdots\cdots(18)$$

After all, Eqs. (10), (11), (12) and (13) are re-written as follows:

$$\frac{P_j}{P_i}=\frac{C_j}{C_i}\exp[-F(j,i)] \quad\cdots\cdots(19)$$

$$\frac{P_i}{P_j}=\frac{C_i}{C_j}\exp[-F(i,j)] \quad\cdots\cdots(20)$$

$$\frac{P_k}{P_j}=\frac{C_k}{C_j}\exp[-F(k,j)] \quad\cdots\cdots(21)$$

$$\frac{P_i}{P_k}=\frac{C_i}{C_k}\exp[-F(i,k)] \quad\cdots\cdots(22)$$

And we obtain

$$\frac{P_k}{P_i}=\frac{C_k}{C_i}\exp[-F(k,i)] \quad\cdots\cdots(23)$$

Now, P_i, P_j and P_k must satisfy the following condition:

$$P_i+P_j+P_k=1 \quad\cdots\cdots(24)$$

By solving the three equations (19), (23) and (24) as simultaneous equations of three unknown variables, we obtain

$$\left.\begin{aligned} P_i&=\frac{1}{1+\frac{C_j}{C_i}\exp[-F(j,i)]+\frac{C_k}{C_i}\exp[-F(k,i)]}\\ P_j&=\frac{\frac{C_j}{C_i}\exp[-F(j,i)]}{1+\frac{C_j}{C_i}\exp[-F(j,i)]+\frac{C_k}{C_i}\exp[-F(k,i)]}\\ P_k&=\frac{\frac{C_k}{C_i}\exp[-F(k,i)]}{1+\frac{C_j}{C_i}\exp[-F(j,i)]+\frac{C_k}{C_i}\exp[-F(k,i)]}\end{aligned}\right\} \quad\cdots\cdots(25)$$

It is obvious that P_l's given by Eq. (25) satisfy the condition 2) mentioned in the section 2 in this paper.

Now, the P_l's must be given by definite values regardless of the calculation process. We will discuss this point in the following. By solving the three equations (20), (21) and (24), we obtain

$$\left.\begin{aligned} P_i&=\frac{1}{1+\frac{C_j}{C_i}\exp[F(i,j)]+\frac{C_k}{C_i}\exp[-\{F(k,j)-F(i,j)\}]}\\ P_j&=\frac{\frac{C_j}{C_i}\exp[F(i,j)]}{1+\frac{C_j}{C_i}\exp[F(i,j)]+\frac{C_k}{C_i}\exp[-\{F(k,j)-F(i,j)\}]}\\ P_k&=\frac{\frac{C_k}{C_i}\exp[-\{F(k,j)-F(i,j)\}]}{1+\frac{C_j}{C_i}\exp[F(i,j)]+\frac{C_k}{C_i}\exp[-\{F(k,j)-F(i,j)\}]}\end{aligned}\right\} \quad\cdots\cdots(26)$$

The P_i, P_j and P_k given by Eq. (25) must be equal to those given by Eq. (26) respectively. This condition is satisfied, if the following Eqs. (27) and (28) hold:

$$F(i,j)=-F(j,i) \quad\cdots\cdots(27)$$

$$F(k,j)-F(i,j)=F(k,i) \quad\cdots\cdots(28)$$

$F(i,j)$ defined by Eq. (18) satisfies Eqs. (27) and (28). Therefore, it is obvious that Eqs. (25) and (26) give the same P_l's.

Since the value of P_j/P_i in Eq. (19) generally increases as $(x_j^n-x_i^n)$, $(y_j^n-y_i^n)$ and $(z_j^n-z_i^n)$ decrease, a_n, b_n and d_n should satisfy the following inequalities in principle:

$$a_n\geqq 0,\quad b_n\geqq 0,\quad d_n\geqq 0 \quad\cdots\cdots(29)$$

We can also assume that the function f is given by a function of the ratios of factors, x_i/x_j, x_j/x_k, etc. But this assumption is not suitable, because the function f does not satisfy Eq. (14).

Though the values of n in Eq. (17) can be taken as $1, 2, \cdots, \infty$, suitable values should be selected within the scope of $n=1, 2$ and 3 from the viewpoint of practicability and agreement with the existing values. To obtain the simplest, non-trivial solution we may terminate the summations at $n=1$. Then

$$F(i,j)=\left(\frac{\sum C_l-T}{\sum C_l}\right)^h\{a_1(x_i-x_j)+b_1(y_i-y_j)+d_1(z_i-z_j)\} \quad\cdots\cdots(30)$$

On the other hand, the following polynomial (31) may also be considered as a possible solution of Eq. (14)[6].

$$\begin{aligned} F(j,i)&\equiv f(x_i,x_j,x_k,y_i,y_j,y_k,z_i,z_j,z_k)\\ &=\left(\frac{\sum C_l-T}{\sum C_l}\right)^h\\ &\quad\times\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\{a_{mn}(x_j^m x_i^n-x_i^m x_j^n)\\ &\quad+b_{mn}(y_j^m y_i^n-y_i^m y_j^n)\\ &\quad+d_{mn}(z_j^m z_i^n-z_i^m z_j^n)\} \quad\cdots\cdots(31)\end{aligned}$$

where a_{mn}, b_{mn} and d_{mn} are constants. However, since this polynomial expression does not satisfy Eq. (28), it is not desirable to assign this expression to the model in question.

As it is obvious that the model developed in the above satisfies the above-mentioned condition 4), we will investigate whether the model satisfies the condition 5) or not in the following.

Let us consider route i as an example. The difference between the number of passengers assigned to route i and the transport capacity of the route, ΔT is given by the following equation.

$$\Delta T = C_i - P_i\alpha(C_i + C_j + C_k)$$
$$= \frac{(1-\alpha)C_i + \{\exp[-F(j,i)] - \alpha\} C_j}{1 + \frac{C_j}{C_i}\exp[-F(j,i)]} \frac{+\{\exp[-F(k,i)] - \alpha\} C_k}{+\frac{C_k}{C_i}\exp[-F(k,i)]}$$

where α is constant and $0 \leq \alpha \leq 1$.

$$\alpha(C_i + C_j + C_k) = T$$

If ΔT is always zero or positive, the model satisfies the condition 5). But ΔT is not always zero or positive. The conditions that ΔT is zero or positive are as follows:

1) $\exp[-F(j,i)] \geq 1$ and $\exp[-F(k,i)] \geq 1$
2) $\exp[-F(j,i)]$
$$\geq \frac{C_i}{C_k}(\alpha - 1) + \frac{C_j}{C_k}(\alpha - \exp[-F(j,i)]) + \alpha$$
if $\exp[-F(j,i)] < 1$ and $\exp[-F(k,i)] \geq 1$.
3) $\exp[-F(j,i)] \geq -\frac{(1-\alpha)(C_i + C_j)}{C_k} + \alpha$
if $\exp[-F(j,i)] \geq 1$ and $\exp[-F(k,i)] < 1$.
4) $\exp[-F(k,i)]$
$$\geq \frac{C_i}{C_k}(\alpha - 1) + \frac{C_j}{C_k}(\alpha - \exp[-F(j,i)]) + \alpha$$
if $\exp[-F(j,i)] < 1$ and $\exp[-F(k,i)] < 1$.

In general, the number of passengers which is assigned to the route i grows greater, as the number of passengers between zones A and B grow greater. Therefore, this model may assign the number of passengers which exceeds the transport capacity of the route to the route i, when $\sum t_l$ is close to $\sum C_l$. However, in this model, we can determine the value h so that $\exp[-F(j,i)]$ and $\exp[-F(k,i)]$ are close to 1 when $\sum t_l$ is close to $\sum C_l$.

The number of passengers which is assigned to a route by the model scarcely exceeds the transportation capacity of the route, since the terms $\exp[-F(j,i)]$ and $\exp[-F(k,i)]$ in Eq. (25) tend to 1 as the number of passengers between zones A and B gets near to the sum of the capacities of the routes considered. Therefore, it can be said that this model satisfies the condition 5).

4. FITTING THE MODEL TO DATA

In order to check whether the probabilities given by the model agree with the actual values, the constants in the model were evaluated by using the data of commuters in Nagoya City in 1969[7]. The transportation status of 13,369 persons who were commuting to the CBD was surveyed. The data were collected on the cost, time and number of changes in their present routes. Twelve percent of all the persons who gave the answers was car users, and the rest were public transportation users. In this paper we deal with the route choice of the public transportation users. The public transportation includes bus, street-car and rapid transit.

They were divided into groups according to pairs of starting place and destination. Then, the number of available routes between the two zones was obtained from the survey. We also obtained the cost, number of changes and mean time for each route. The value of P_l fo reach route was evaluated by the proportion of the traffic volume relating to the route l in the group. Transportation capacity C_l is the number of passengers which transportation facilities can carry during a given time period (a day or an hour).

The number of passengers on the most routes during a day were relatively small compared to the route capacities, excepting a few routes.

Regression analyses were carried out between the value of P_l and the individual value of x_l, y_l and z_l, using the following equation (32) derived from Eqs. (19) and (30):

$$\log\left(\frac{P_j}{P_i}\right) = \log\frac{C_j}{C_i} - \frac{\sum C_l - T}{\sum C_l}\{a_1(x_j - x_i) + b_1(y_j - y_i) + d_1(z_j - z_i)\} \quad \cdots\cdots(32)$$

Here, since we could not obtain data on transportation capacity of the route, it was assumed that $C_j/C_i = 1$ and $(\sum C_l - T)/\sum C_l$=constant. This assumption implies that the capacity of each route is the same and the total number of passengers is relatively small compared to the route capacities. (Since it is not necessary to consider the route capacity seriously in the case that the number of passengers is relatively small compared to the route capacity, this assumption may be permissible.)

From this regression analysis the model was found to be:

$$\log\left(\frac{P_j}{P_i}\right)=-\{0.03482(x_j-x_i)-0.000441(y_j-y_i)+1.0699(z_j-z_i)\} \quad \cdots\cdots(33)$$

$r=0.503$

$$F(i,j)=0.03482(x_i-x_j)-0.000441(y_i-y_j)+1.0699(z_i-z_j) \quad \cdots\cdots(34)$$

$$\left.\begin{aligned} P_i&=\frac{1}{1+\exp[-F(j,i)]+\exp[-F(k,i)]}\\ P_j&=\frac{\exp[-F(j,i)]}{1+\exp[-F(j,i)]+\exp[-F(k,i)]}\\ P_k&=\frac{\exp[-F(k,i)]}{1+\exp[-F(j,i)]+\exp[-F(k,i)]}\end{aligned}\right\} \quad \cdots\cdots(35)$$

where i, j, k = individual routes between two zones. The multiple correlation coefficient for Eq. (33), $r=0.503$, shows that the choice probabilities given by the model agree with the observed ones to some extent.

The constants in the model vary with the passenger's route choice behaviour which seems to change with his income and age. Therefore, if the constants are determined for only the groups that have the same tendency of route choice, the fit of the model will result in better.

For the purpose of comparison, a linear equation was fitted to the above data. A least-squares regression fit was made for an equation with the general form such as given in Eq. (2). The results of this are shown below:

$$P_l=0.00442(\bar{x}-x_l)-0.0000215(\bar{y}-y_l)+0.0617(\bar{z}-z_l)+\frac{1}{3} \quad \cdots\cdots(36)$$

$r=0.406$

Comparing the r value in Eq. (33) with that in Eq. (36), we find that the linear regression fit of Eq. (33) is as suitable as Eq. (36). However, since P_l given by Eq. (36) does not always satisfy the condition 2) and the capacity constraint, or the condition 5), that the number of passengers assigned to each route by the model cannot exceed its capacity, it may be considered that the model developed in this paper is superior to the model of Eq. (2).

As a result of investigation stated above, it may be considered that the model developed here satisfies the five conditions that the route choice model should satisfy.

Though all regression coefficients in Eqs. (33) and (36) should be positive or zero judging from the tendency of passenger's route selection behaviour, the coefficients for (y_j-y_i) in Eq. (33) and $(\bar{y}-y_l)$ in Eq. (36) became negative. This can be considered to be caused by the correlation between independent variables, or multicollinearity.

However, since these values b_1 and b' are close to zero, we can consider that these values are equal to zero and the effects of terms (y_j-y_i) and $(\bar{y}-y_l)$ on P_l's are hardly significant. Hence, what Eqs. (33) and (36) imply can be considered to be consistent with the tendency of passenger's route selection behaviour.

5. CONCLUSION

The factors affecting the commuters' route choice on the public transportation facilities were found out by the survey in Nagoya City to be commuting time, cost, number of changes, comfort and convenience.

The conditions that the route choice model should satisfy were discussed, and the model that satisfies these conditions was developed. And the model was tested by use of the data in Nagoya for 1969. It provided a fair overall fit and yielded plausible regression coefficients.

The model will provide a closer fit than the model mentioned above, if the regression coefficients are estimated for each income group and for the group that has similar trip length.

In this paper, we could not discuss the problem positively taking consideration of the capacities of routes characterized by the model owing to lack of data. It is necessary to investigate this point in more detail on the basis of many observational materials.

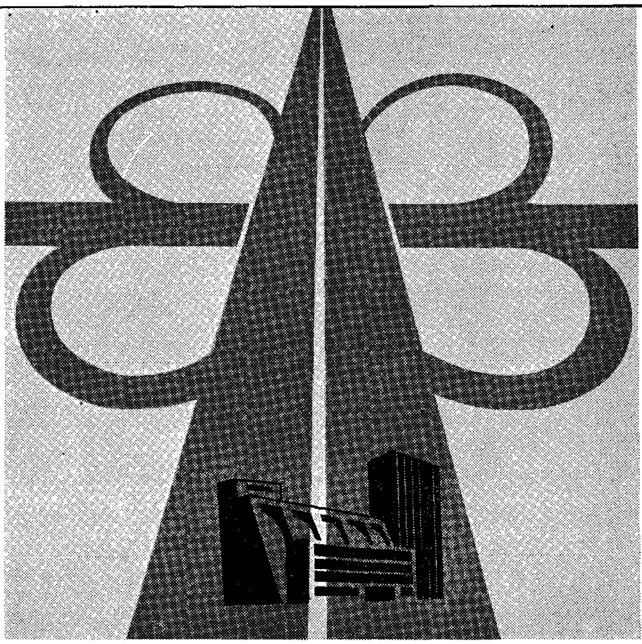
The model presented herein may also be applicable to the prediction of travel mode choice.

REFERENCES

1) Stopher, P. R.: Predicting Travel Mode Choice for the Work Journey, Traffic Engineering & Control, 436-439, 1968.
2) Lave, C. A.: Behavioral Approach to Modal Split Forecasting. Transpn Res. 3, 463-480, 1969.
3) Martin, B. V., Memmott, F. W., III and Bone, A. J.: Principles and Techniques of Predicting Future Demand for Urban Area Transportation. The M.I.T. Press, Cambridge, 1961.
4) Warner, S. L.: Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice.

Northwestern University Press, Evanston, 1962.
5) Kawakami, S.: Predicting the Distribution of Commuters among Competitive Routes. Trans. Japan Soc. Civil Engrs., No. 179, 61-68, 1970.
6) See Stopher 1).
7) Commuter Transportation Study in CBD of Nagoya City, Nagoya City Government, 1970.

(*Received Dec. 20, 1971*)



NISSO MASTER BUILDERS

最良の製品を以て奉仕する

"The Performance Admixture"

性能の混和剤…それはポゾリスの代名詞です

設計者、施工業者、品質に忠実な生コンメーカに、ポゾリスは圧倒的な信頼をいただき今日も、明日もポゾリスが指定されております。——何故でしょうか。

それはポゾリスが性能を重視するからです。　即ち工場で、現場で、完成したコンクリート構造物に種々の利益をもたらすからです。

研究所で、一定の環境の下に行われるテストでは、良い性能を出す混和剤は他にもあります。然し現場で研究所に於て予知した通りの立派な性能を（地域、材料、コンクリートの性質の条件がいかなるものであっても）つくりだすことをポゾリスは実証しております。

これらが、ポゾリスをして〝**性能の混和剤**〟の名をほしいままにしている理由であります。

セメント分散剤

ポゾリス

コンクリート減水剤

標準型／遅延型／早強型

大阪市東区北浜３～７(広銀ビル)　☎ 202—3294
仙台市一番丁３－１－１(富士ビル)　☎ 24—1631
名古屋市中区栄４－１－７(朝日生命館)　☎ 262—3661
広島市八丁堀１２－２２(築地ビル)　☎ 21—5571

ポゾリス物産株式会社
日曹マスタービルダーズ株式会社
東京都港区六本木３－１６－２６　☎ 582—8811

福岡市中央区天神1-10-17(西日本ビル)　☎ 75—7471
札幌市北三条西3の1の44(札幌富士ビル)　☎ 251—2691
新潟県中頸城郡中郷村(日曹二本木工場)　☎ 中郷 51
高岡・千葉・高松

昭和三十七年五月二十八日第三種郵便物認可
昭和四十八年一月十五日印刷（毎月一回二十日発行）
昭和四十八年一月二十日発行

定価四五〇円