DRIVER'S ROUTE CHOICE MODEL: An Assessment of Residential Traffic Management

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1. INTRODUCTION

Despite the fact that residential areas in large cities have faced serious conflicts among residents, drivers, and pedestrians due to the increase of through traffic and of car ownership, little attention has been paid to driver's behavioral modeling for route choice and residential area transportation planning methodology. Especially previous researches which emphasize minimum time-distance criterion for driver's choice fail to discuss route choice set and to model microscopic driver's route choice behavior, that is essential to assess residential traffic management schemes. [See Ratcliff (1972), Ueberschaer (1971), Kido (1977), Ikenoue (1976).]

The purpose of this paper is, thus, twofold: 1) to analyze a route choice behavior to develop a route choice model, and 2) to present a quantitative method to assess residential traffic management schemes.

This study defines a unit zone as a basic area which is surrounded by trunk roads and sub-trunk roads and whose latus is 0.5 to 1.5 km, and a residential district as a set of unit zones surrounded by trunk roads with latus of 2 to 5 km. The scope of this study is limited in the route choice within a residential district or an area which covers from origin to a point where drivers exit or enter trunk roads. Interim destination is also defined as four vertexes of a residential district or an exit point (see Fig. 1).

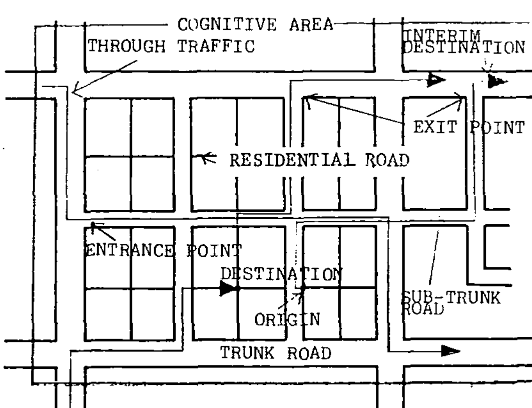


Fig 1. Types of Roads and Traffic

The remainder of the paper is organized as follows. First in section 2, the study develops conceptual framework of driver's route choice decision process. In section 3, the study empirically analyzes the driver's route choice behavior in residential areas in order to examine the framework. In section

4, two stages model to predict driver's route choice is developed. First, the study formulates choice set model to select possible routes and exit/entrance points where individual driver goes out/into residential zones. And then the study estimates exit/entrance choice model to identify actual route from origin to the interim destination among various alternative routes. Based upon above findings, in section 5, the paper proposes a quantitative method to assess impacts of residential traffic schemes on various agents at any point of road network.

2. DRIVER'S ROUTE CHOICE DECISION PROCESS

Large number of transportation studies have been made in the development of behavioral demand modeling in modal split. Those models handle quite limited number of alternatives; therefore, it is difficult to apply them to route choice modeling. Route choice in residential areas has salient characteristics, i.e., 1) large number of alternatives, 2) uneven level of information concerning alternatives; especially networks closed to origins and destination are well recognized, 3) and individual choice decision structure which may vary sensitively due to traffic condition (time of day, level of congestion, etc.). Recently destination choice mechanism whose characters are similar to route choices, especially non-work trips, is analyzed and several models are developed. In those modeling, focuses are given to choice set formation and non-compensatory decision process [see Landan (1982), Ansah (1977), and Foerster (1979)]. This study, then, attempts to identify the route choice process structure from the viewpoints of choice set formation.

Fig. 2 shows the basic concept of traffic information (i.e. network structure, level of congestion, etc.) possessed by a driver from origin to destination. Route choice behavior can be formulated as follows: in stage 1, to find choice set, e.g. exit and entrance point choice set within the cognitive area and route choice set, e.g. possible routes from origin to exit point. And in stage 2, to decide exit points from residential zone to trunk road (see Fig. 3).

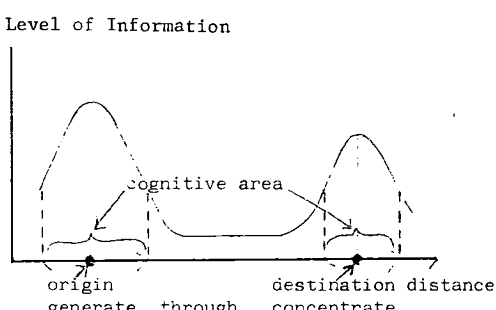


Fig 2. Level of Information & Traffic Type

3. ROUTE CHOICE BEHAVIOR

Following the hypothetical framework in section 2, questionnaire survey and gas station interview survey were conducted to find driver's route choice characteristic in three residential areas in Tokyo. The study first examines the driver's cognitive area, which defines the spatial limits of choice set. It is found that in all types of traffic and traffic conditions, spatial coverage of actual exit/entrance points are limited in 3 km from the origins. As to through traffic, it is also found that drivers take only sub--trunk roads network and never enter in residential level. Thus their cognitive roads are limited in trunk and sub-trunk roads networks.

This study, then, adopts three criteria to find route choice set. In addition to conventional criteria, a) distance and b) number of turns, c) driver's willingness to choose higher rank of roads in road hierarchy is introduced. c) explains the drivers attitude for higher rank roads, e.g. residential roads to sub-trunk roads and trunk roads.

Table 1 depicts deviation of route choice from minimum distance and number of turns. Actual route choices are done within two turns larger than minimum number of turns and 20-40 % longer distance from the minimum routes from origin to interim destination. In the case of through traffic, the results are shown in Table 2 and Fig. 4. Minimum distance routes in trunk roads are clearly taken by drivers. But even if the sub-trunk route is shorter than the trunk roads route, the latter is selected 41 %. And 97 % of through traffic choose less turned route whose number of turns are less than three (see Fig. 4). It is shown that through traffic seeks for very simple route as well as minimum distance routes.

In respect to c) criterion, Table 3 shows the tendency of the drivers to take higher rank roads. In particular, the attitude is highly reinforced in off peak hours. Note that drivers who commute from outside of the area follow this rule, since they have less information about the network than residents (see Table 4). From this empirical analysis, the driver's route choice set characteristics can be identified.

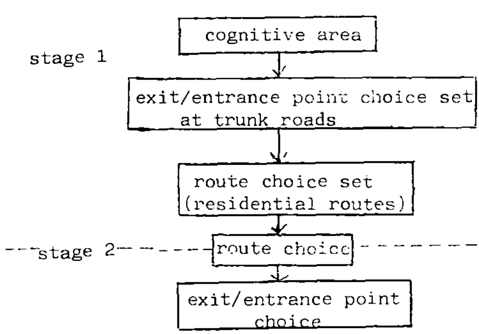


Fig 3 .Driver's Decision Process of Route Choice

Table 1 Deviation of Route Choice from Minimum Distance and Number of Turns (Residence)

type of traffic	generate						concentrate					
distance \ turns	+0	+1	+2	+3	+4∿	cumulative %	+0	+1	+2	+3	+4∿	cumulative %
minimum distance	14	1	3	0	0	32.1	11	3	0	1	3	35.3
∿+10	14	0	0	0	0	57.1	12	1	2	0	1	66.7
∿+20	9	0	1	0	0	76.8	0	1	1	0	1	72.5
∿+30	1	0	0	0	0	78.6	0	3	1	0	0	80.4
∿+40	1	0	0	0	0	80.4	2	0	3	0	0	92.2
+41∿	2	2	2	2	2	100	2	0	1	0	1	100
cumulative %	73.2	78.6	91.1	94.6	100		52.9	68.6	84.3	86.3	100	

Table 2 Higher Rank Road Attitude (Through)

	trunk only	through	total
trunk min.	146	4	150
sub-trunk min.	76	108	184

Table 3. Ranking up Behavior of Driver's Route Choice by Time of Day

Residential Area (resident)

time of day	Ranking up	Non-Ranking up	Total
peak	21 (62 %)	13 (30 %)	34 (100 %)
off-peak	48 (86 %)	8 (14 %)	56 (100 %)
total	69 (76 %)	21 (24 %)	90 (100 %)

Table 4 Ranking up Behavior of Driver's Route Choice (Non-Residence)

peak hours

Residential Area (commuter)

type of traffic	Ranking up	Non-Ranking up	Total
generate	139 (95 %)	8 (5 %)	147 (100 %)
concentrate	132 (94 %)	9 (6 %)	141 (100 %)
total	271 (94 %)	17 (6 %)	288 (100 %)

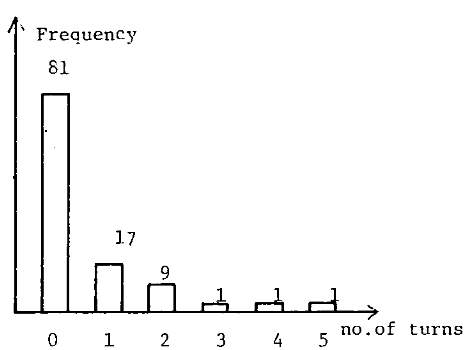


Fig 4.No.of Turns of Through Traffic in Residential District

4. ROUTE CHOICE MODEL

Based upon the findings in section 3, predictive models are developed in this section.

Choice Set Model

Although possible routes can be obtained by a), b), c) criteria in residential districts, there still remain many number of alternative routes in the choice set some of whose characteristics are quite similar. Thus to avoide unbalanced parameter estimation as well as simple alternative generation, it is necessary to identify the most typical but distinct types of routes in the choice set. Minimum distance route to interim destination, that to trunk roads, and minimum number of turns route are chosen after comparing several types of alternatives formation criteria. They are found to cover 80% of actual routes. In order to find important variables for route choice, disaggregate logit type models are estimated with these alternatives. It is found that numbers of turns, distance and the minimum width of roads are major factors for route choice mechanism (see Table 5).

As to through traffic, with the similar specification of the choice set model, choices among trunk road, minimum distance route with sub-trunk roads and second minimum route are examined. It is also found that 90 % of actual through traffic are included in this choice set. The study shows that drivers are willing to take shorter, less turned and trunk roads (Table 5).

Table 5 . Route Choice Model (Disaggregate Logit Type) (t statistics)

Type of Traffic	Total dist.	Distance in resid.	Turns	Min. width	Turns in resid.d	Trunk Rd	Goodness-of-fit percentage of correct route
residential*	$-1.7*10^{-3}$ (-2.3)	$2.8*10^{-3}$ (2.2)	-4.2 (-12.2)	3.5 (10.0)			78
through**	$-1.7*10^{-3}$	-1.3			$-9.2*10^{-1}$	$2.9*10^{-1}$	72

* three choices and 94 observations

** three choices and 334 observations, t-statistics are not given

Table 6 Time Prediction for EXIT/ENTRANCE Point Model

	Estimated Formula
Trunk Road*	$t_t = 0.0015L + 0.146S + 0.143N$
Sub-Trunk Road	$t_S = 0.002L + 0.14SI + 2N/M + 0.29C + 0.62SIT$
Residential Road	$t_R = 0.003L + 0.14SI + 2N/M + 0.29C + 0.62SIT + 0.15T$

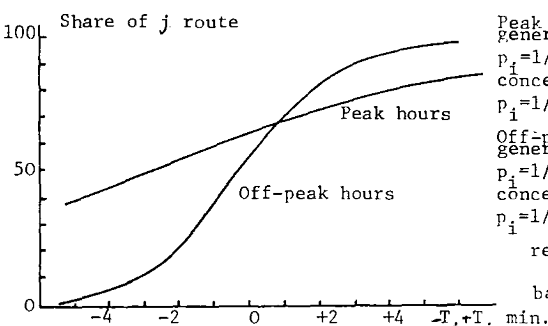
L=total length, S=number of signals, N=number of queueing cars at trunk road crossing, M=number of cars per one blue time, SI=number of signals in residential district, SIT=number of signals at trunk road crossing, T=number of turns, C=number of transit crossing

*This is Mohori's formula (see Mohori).

Exit/Entrance Model

It is important to find exit/entrance points from/in trunk roads in order to identify the route. The study develops an exit point choice model which determines the ratio of alternative points within a cognitive area of stage 2. Based upon the choice set model, time factor is adopted as the variable and is estimated by route length, congested route length, speed of cars (depend on width of roads) and number of turns. The generalized travel time estimation formula are examined by experimental driving in one of study areas (see Table 6), For estimating exit point model, the shortest generalized time route from choice set is taken as a representative route for each exit point.

The results in Fig 5 show that both generate and concentrate traffic have the quite similar time sensitibity parameter. Note that time sensitibity during peak hours is less than that during off-peak hours. It indicates that during peak hours because of heavily congested traffic conditions, travel times at each alternative route do not differ much and drivers are willing to choose a route in which they can drive smoothly but sometimes take longer times without involved in traffic jams (see Fig. 5). Note that during off--peak hours most of exit/entrance points are located on the four latus of residential districts.



Peak hours

generate

$p_i=1/(1+\exp(0.201(T_i-T_j)+0.633))$ R=0.77

(6.0) (4.0)

concentrate

$p_i=1/(1+\exp(0.214(T_i-T_j)+0.743))$ R=0.76

(6.4) (7.3)

Off-peak hours

generate

$p_i=1/(1+\exp(0.725(T_i-T_j)+0.247))$ R=0.83

(7.0) (1.6)

concentrate

$p_i=1/(1+\exp(0.568(T_i-T_j)+0.650))$ R=0.74

(5.9) (3.3)

resluts are obtained by binary choices

base route=min.time route i

( ); t-statistics

Fig 5. Share of Route j as a Function of Travel Time Difference T_i and T_j

5. AN ASSESSMENT METHOD AND ITS APPLICATIONS

The study proposes an assessment method to predict the impacts of schemes based upon driver's choice models. Concept of the method is to assign traffic volume to each links using the exit/entrance model as shown in Fig. 6. It is hierarchical forecasting method to predict traffic volume at each level of road networks. The most salient characteristics of the method is that it can assess both residential and trunk road traffic control schemes at the same time through exit/entrance point model using its travel time variable. The models developed in this study are applied in residential and sub-trunk road networks. The criteria for traffic management schemes are, in this study, accessibility, pedestrian safety, noise and air pollution, etc. which are mainly dependent on traffic volume. The method enables planners to examine the impacts of schemes not only on various conflicting agents in any place of roads but also on the traffic of higher rank roads. Assessment procedures are as follows, viz.,

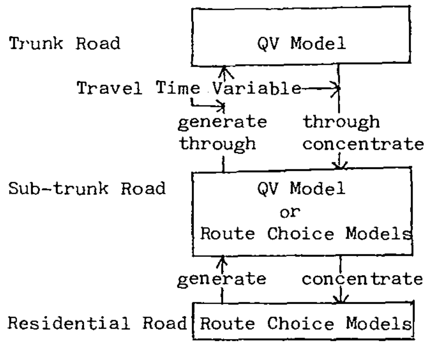


Fig 6.Hierarchical Prediction Method for Residential Traffic

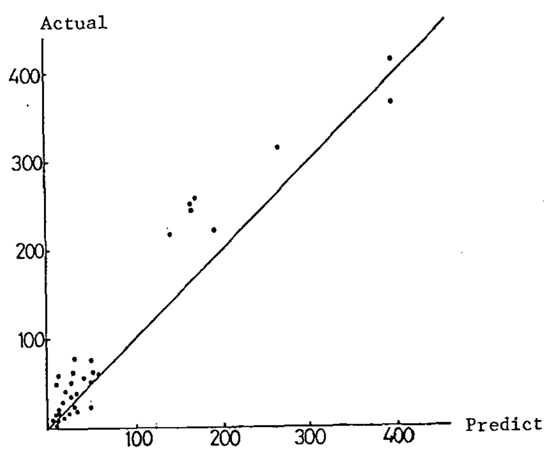


Fig. 7. Comparison of Actual and Predict Traffic Volume (Morning)

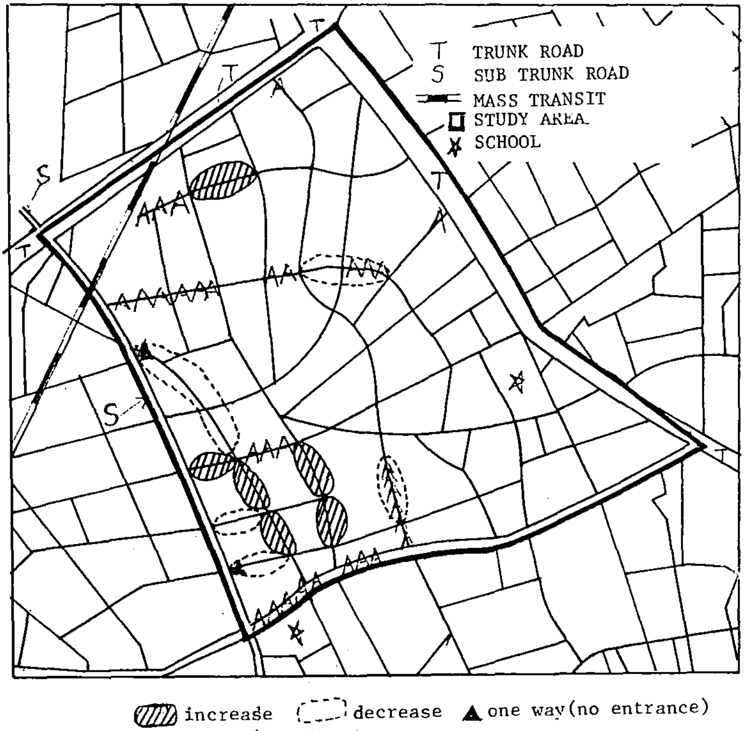


Fig. 8. Residential Traffic Management Scheme A and its Impacts on Air Pollution Distribution

Step 1. identify cognitive area
2. identify exit and entrance points for each agent
3. with the choice set formation procedure, possible routes are identified for through, go-out, come-in traffic.
4. determine the shortest time route among choice set for each exit point from origins.
5. determine the ratio to choose each alternative route with exit/entrance and through traffic model.
6. assign the traffic volume to each link of roads.
7. predict the impacts of schemes.

This traffic assignment method is examined by using number plate survey. It shows good fittness between predictive and actual link traffic volume. (see Fig. 7)

Some residential traffic control schemes (1) one way control (2) narrowing streets in Fig. 8 are examined by this method. The results are shown in Fig. 9 obtained by the method. This scheme may reduce the through traffic during morning peak hours. And changes of level of air pollution are calculated spatially as shown in Fig. 8.

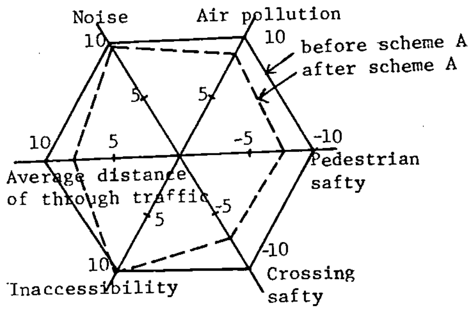


Fig 9. Evaluation of Traffic Management Scheme A

6. CONCLUDING REMARKS

This study attempts to identify drivers route choice behavior and to develop models to predict an impacts of residential traffic schemes. The paper preliminarily focuses on the choice set (for route choice) definition by empirical data and several logit models are developed. Because of limited number of data and study areas, the results may not be applicable to other types of road networks areas. The study demonstrates the method to reduce tremendously the number of alternative routes in residential area and it enables the study to develop behavioral choice models to assess residential traffic scheme impact. The findings are, viz.,

1) route choice process can be explained by two stage decisions, i.e. choice set and entrance/exit point choice.
2) in exit/entrance point choices, time sensitivity of route choice is highly dependent on traffic condition, i.e. it unexpectedly decreases under congested traffic conditions.
3) choice set for route choice can be defined by numbers of turns, distance, and especially willingness to take higher rank roads attitude.

Finally, several policy implications are, viz.,

1) to increase the number of turns in sub-trunk roads networks systems is recommendable to avoid through traffic.
2) to reduce the width of roads for reducing speed of cars is very effective, but the numbers of cars in residential roads may not be reduced in peak hours because of heavy traffic in trunk roads.
3) to clarify the rank of roads in road networks, i.e. to improve sub-trunk roads in a residential districts is quite effective to reduce the number of cars at residential road, i.e. to lessen environmental problem.

ACKNOWLEGEMENT

The author is deeply indebted to Prof. Tadayoshi Suzuki (former professor of Tokyo Institute of Technology) and Prof. Hideo Nakamura (University of Tokyo) for their continuous encouragement during this study, and greately acknowleges Prof. Moshe Ben-Akiva (Massachusetts Institute of Technology) for his constructive comments.

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