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EVALUATION OF UMOT MODEL : CASE STUDY OF YAMAGATA AND MATSUE REGION

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The UMOT model presents a novel approach towards constructing simplified and quick response policy sensitive models. The simplistic nature (both in theory and application), low data requirements and the usage of transferable travel measures are the main attraction of this model. It utilizes the theory of utility maximization under the time and money constraints. This paper describes the UMOT model and its salient features, evaluates the model and discusses some of the major issues and the doubtful elements raised by some case studies. The case studies of two Japanese cities Yamagata and Matsue is also presented.

1. INTRODUCTION AND BRIEF HISTORY

The UMOT(Unified Mechanism Of Travel) model was proposed by Dr. Zahavi for World Bank and was further developed by U.S. Department of Transportation and Ministry of Transport, Federal Republic of Germany. It is claimed to be an important tool for policy analysis which is quick and sensitive to major policy variables. The simplistic nature (both in theory and application), low data requirements and the usage of transferable travel measures are the main attraction of this model. Being based on a very different approach than conventional models, it caught the fancy of the researchers. It was applied by different researchers in different cities e.g. Netherlands (Toon.V.D.Hoon et al,1986), Belgium and Osijek, Yugoslavia (Radovanac and Willumsen,1988), Reading,U.K.(Downes and Emmerson, TRRL,1985), Washington D.C, Munich and Nurenberg, Germany (Zahavi,1980), Nagpur, India (Ranganathan et al,1988). Based upon their case studies, some verified

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the applicability of this model while others raised serious doubts on certain elements of the model. The interest in UMOT gathered more as a concept than a model which led to the development of various variations of the original model like flexible budget model (Downes and Emmerson,TRRL,1985), and the Three-mode model. This paper describes and evaluates the UMOT model and discusses some of the major issues and the doubtful elements raised by some case studies. Its application to two Japanese cities Yamagata and Matsue is also presented.

2. UMOT model and its Salient features

This section describes the UMOT model and its salient features especially those which are strikingly different from the traditional approach.

2.1 UMOT

It is a macro model to estimate the area-wide travel measures like total travel distance, travel by each mode, car-ownership levels etc which may be used for evaluating the various policy options. UMOT represents a novel approach in exploiting the similarities in travel behavior as observed in different cities at different times. It uses certain in-built relationships (Eq 1 & 2) which are claimed to be transferable over cities and time thus eliminating the need for parameter calibration as required in conventional models.

The underlying theory of UMOT approach is utility maximization under constraints. Travel distance is used as a proxy for measuring the travel utility because maximizing the total travel distance means maximizing the available spatial and economic opportunities within the time and money constraints (also called travel budgets). These constraints of time and money budgets are not equal for all households but depends upon the average network speed in the area and the socio-economic characteristics of the group to which the household belongs. Thus UMOT presents a simple and quick approach for policy evaluation with little calibration efforts required whereas similar exercise with traditional approach would be time consuming and would require much data. But there are also some limitations in the application of the model. First, it can only produce aggregate results for an area. Thus the level of aggregation which is be useful or relevant for a particular case study should be decided first. Second, UMOT cannot produce all types of outputs as produced by conventional models like O-D matrix, link flows etc. The actual process including the inputs required, calculations and outputs are described in section 4.0 with the help of the case study.

2.2 Salient features

a) The various stages like generation, modal split, car ownership etc are all inter-linked through a feedback process which iterates till the convergence (equilibrium) is reached thus any change in the value of a variable at any stage affects all the outputs. This characteristic of the UMOT makes it a very effective tool for policy analysis whereas the traditional four stage approach works in a sequential manner with little feedback mechanism.

b) Travel distance is taken as the basic unit for measuring travel rather than trip rates which is used in the conventional models. The trip rate seems to be an abstract unit in the sense that it represents only the number of movements not the magnitude of these movements. It is the magnitude rather than their numbers which transport planners strive to decrease for accomplishing the desired activities.

c) In the traditional modeling, different sub- models are required for different stages like generation, modal split etc thus model/parameter estimation becomes necessary at each stage which requires additional data and esourses. In the UMOT model the parameter estimation stage is not required because of the assumption of transferable relationships of travel budgets.

d) Data requirements are minimum which makes it a preferred choice in the case of those areas where full and up-to-date data is not available.

e) Since conventional models utilize data regarding both, the input (independent variables) and outputs (dependent variables), only the models reproducebility can be checked with one set of data. So the models validity can only be best checked by using another set of data i.e. other that the data on which the model is calibrated. In UMOT, only input data (independent variables like income, household size, etc) is required. The outputs produced by the model are then compared with the observed data and the models validity can be checked, atleast partially. Thus model validation can be satisfactorily done with one set of data.

3. The Major Issues

This section describes some of the major issues of the UMOT model. First, regarding the stability of travel budgets and its interpretation and the second deals with its appropriateness for the intra-urban or inter-urban travel. The third deals with the method of calculating the average network speed.

3.1 Interpretation of the stability of travel time budget

This has been the most controversial issue and some times misinterpreted. Stability of travel time budget does not mean that every person or traveler or household will have an equal value of daily travel time which is stable over time and space. Surprisingly some studies have made a direct comparison of the daily travel time expenditures between such varied categories as a housewife with that of a salaried male to show the invalidity of the assumption. The assumption states that the relationships (Eq 1,2,3) for calculating the average daily travel time per household belonging to a particular socioeconomic category are transferable over time and space. First, it is the relationships not their calculated values which are stable. Second, it is the average value of daily travel time per traveler (not per person) and that to for a particular socioeconomic group. This daily travel time per traveler is a function of the average door-to-door network speed in the area. In Zahavi's own words (UMOT, pp 190,1979) "A TT budget does not mean that each and every traveler must travel a fixed time per day each and every day .....The question is that whether regularities that are transferable both in space and time exists at a useful level of disaggregation".

3.2 Intra-city travel vs Inter-city travel

In case of inter-city travel, the trade-offs for travel expenditures are made not only from total travel budgets but also from activities other than travel e.g. work or recreation. J.Supernak (1982) raised the question that if due to a pressing family matter one has to fly between Denver and Buffalo (cost $ 580), Would one consider walking three miles to work every day in order to lower the travel money budget for that month. It is a clear case of mixing inter-city travel with intra-city travel. Inter-city travel can be accounted only if the travel budgets are expressed (averaged) over a larger time period say, year. The original UMOT model is valid only for intra-city travel.

3.3 Calculation of average network speed

The calculation of network speed is one of the major problem. The UMOT model specifies a complex equation based on the daily travel time per car, household and network variables like the total length of the arterial road network and the so-called alpha-value, which was empirically developed by Zahavi (Zahavi, 1972). The validity or otherwise of this alpha-relationship has been a contentious issue and some studies on this relationship has produced dubious results (Ortuzar,1988). Moreover which roads should be treated as arterial roads is also not properly defined. It is also shown that this alpha-relationship is a special case of a general aggregate Q-V equation (Ohta and

Harata,1989). Unfortunately some case studies have used this relationship without discussing its appropriateness or doing any sensitivity analysis (Radovanc and Willumsen, 1988). This may well be the cause of rejection of the model in their case study.

4. UMOT process and its application to Yamagata and Matsue region

This section describes the step-wise application of the UMOT process along with the case studies of Yamagata and Matsue urban areas. The purpose of the case study was to show the application of the UMOT mechanism rather than calculate the estimates of travel measures for these regions. So some simplifying assumptions regarding data were made. Also only one component of UMOT (total distance traveled per household) is calculated. Others components like modal split and car ownership level were not calculated. Sensitivity tests were carried out to check the effects of data errors and small change in the value of policy variables on the output of the model.

4.1 Inputs

Mainly two types of data is required. Socioeconomic characteristics of the households (number, size and income distribution) and network characteristics like average network speed and unit cost of travel by mode. The calculation of the average network speed presents some difficulty. In the case of Yamagata and Matsue region the average network speed has been directly taken from other surveys. In fact the UMOT report does not stress the usage of the alpha relationship. It says "The network speeds are derived at this stage by alpha relationship ..... but any other speed/flow relationship can be used instead". The data regarding the cost per Km for both car and transit and the household travel money expenditure was not taken directly but was estimated from different sources because of data and practical limitations.

4.2 Data

Because of the repeating nature, data and calculations are shown only for Yamagata region but final results are presented for both Yamagata and Matsue region.

The data used is for the year 1985 (Showa 60)

P = Population = 365,351

HH = Households = 101,648

C = Total cars = 96,204

HS = Household size = P/HH =3.59

MOT= Cars/household = C/HH = 0.95

V_n = Average network speed (Peak Period) = 22.3 Kms/hr

C_c = Cost/Km of car travel = ¥ 25

C_t = Cost/Km for transit = ¥ 14

4.3 Calculations

Average door-to-door speed (V_{avg}) is assumed in the beginning to start the process. Based upon these assumed values, the

UMOT model produces its own value of average door-to-door speed. This calculated value should match the value assumed in the beginning. If not, the whole process is reiterated using the latest calculated value of the network speed. Three iterations has been shown in the case of Yamagata region.

TR/HH = 0.403 + 0.337(HS) + 0.490(MOT) Eq.1

TT/TR = 1.03 + 2.18/V_{avg} ..Eq.2

T = (TR/HH)(TT/TR) Eq.3

Where,

TR/HH = Travellers per household

TT/TR = Travel time per traveler

T = Daily travel time/household

The two regularities (Eq.1 and Eq.2 also consequently Eq.3 because it is a product of Eq.1 and Eq.2) are assumed to be stable or transferable over space and time not the absolute value calculated by them.

V_{avg} = 17 Kms/hr (Assumed)

TR/HH = 0.403 + 0.337(HS) + 0.490(MOT) = 2.10

TT/TR = 1.03 + 2.18/V_{avg}= 1.16 hr

T = 2.1 * 1.16 = 2.44 hrs.

M = Daily travel money/household = ¥ 750 (by expenditure survey)

The door-to-door speed is taken about 67% and 33% of the network speed for car and transit travel respectively.

V_c = Average d-to-d speed for car = 0.67*22.3 = 15km/hr

V_t = Average d-to-d speed(transit) = 0.33*22.3 = 7.5km/hr

t_c = Time required per km (car) = 60/V_c = 4 min

t_t = Time required/km for transit = 60/V_t = 8.15 min

D_c = Km/day by car

D_t = Km/day by transit

The utility theory behind the UMOT approach is that of maximizing the total travel distance without exceeding these travel budgets. Maximizing the travel distance is a proxy for maximizing the total spatial and economic opportunities. Fortunately in the case of two modes (because the number of modes is equal to the number of constraints), the model gets extremely simplified to the following two equations (Golob et al,1981).

$$D_c * C_c + D_t * C_t = M$$
$$D_c * t_c + D_t * t_t = T$$

<u>I st iteration</u> :

V_{avg} = 17 Km/hr (assumed)

T = 2.44 hr

Dt = 4.47 ; Dc = 27.5

V_{avg} = (D_t + D_c)/T = 13.10

<u>II iteration</u> : V_{avg} = 13.10

TT/TR = 1.2 ; T = 2.5

D_t = 5.17 ; D_c = 27.1

V_{avg} = 12.85

<u>III iteration</u> : V_{avg} = 12.85

TT/TR = 1.19 ; T = 2.52

D_t = 5.27 ; D_c = 27.0

Vavg = 12.8

4.4 OUTPUT

The various types of outputs which can be produced by UMOT are as follows :

a) Total distance traveled per household per day. b) Distance traveled by each mode (Modal split). c) Money spent on travel on each mode. d) Time spent on travel on each mode. e) Car ownership etc.

Only one of the output of the UMOT model (Daily distance per household) is calculated and it is found that it reasonably matches with the actual survey data as shown below (Table 1). The other outputs are not calculated because even if they were calculated they could not have been verified because the corresponding actual survey data was not available. Moreover the purpose was just to show the application of the model.

Table 1: Output of the model

City	Daily distance traveled per household (Km)	
	By UMOT	By survey
Yamagata	32.27	30.9
Matsue	33.42	32.9

Sensitivity tests shows (Table 2) that the output obtained from the UMOT model are not very sensitive to the input variables. Thus the minor errors (if ever present) in the input data can be reasonably overlooked.

5. Comments and Conclusion

The UMOT methodology has been well received especially more as a concept than the original model. It is a novel and simplified approach in using the regularities in travel behavior for building quick-response policy sensitive models. Some of its elements like arterial roads etc are not well defined which may be the reason for obtaining contradictory results in different case studies. The model can be useful where data availability is low and a quick method to estimate the area wide travel is required especially for the purpose of policy evaluation. In case of Yamagata and Matsue the results obtained from UMOT value reasonably matched with the actual survey figures.

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Table 2: SENSITIVITY TESTS

1) Sensitivity Test with respect to Money budget (M)

Money Budget(M) (Yen/day)	D = Distance traveled per HH(Km)	
	Yamagata Region	Matsue Region
600 (-20%)	28.11 (-12.9%)	29.22 (-12.6%)
675 (-10%)	30.22 (-6.4%)	31.32 (-6.28%)
750 (0%)	32.27 (0%)	33.42 (0%)
825 (+10%)	34.43 (+6.7%)	35.52 (+6.28%)
900 (+20%)	36.54 (+13.2%)	37.62 (+12.6%)

Note : Figures shown in the parenthesis indicate the percentage increase or decrease with respect to the standard calculated values (Bold Type).

2) Sensitivity Test with respect to average network speed (V_n)

MATSUE REGION

Average speed (V_n) Km/hr	Distance/HH (D) Km
23.12 (-20%)	30.95 (-7.4%)
26.01 (-10%)	32.19 (-3.7%)
28.90 (0%)	33.42 (0%)
31.79 (+10%)	34.66 (+3.7%)
34.68 (+20%)	35.65 (+6.7%)

YAMAGATA REGION

Average Speed (V_n)Km/hr	Distance/HH (D) Km
17.84 (-20%)	30.03 (-6.9%)
20.07 (-10%)	31.17 (-3.4%)
22.3 (0%)	32.27 (0%)
24.53 (+10%)	33.42 (+3.6%)
26.76 (+20%)	34.54 (+7.0%)

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