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INTERVENTION OPPORTUNITY MODEL WITHIN TRANSPORT STUDIES

Vasile DRAGU[1], Stefan BURCIU[2], Eugen ROSCA[3], Florin RUSCĂ[4]

Transport studies play an important role in identifying the "ex-ante" and "ex-post" travel demand in concordance with the social-economic characteristics of the studied zones and also in the destination, modal and itineraries split, through the transport models. The result of applying these steps is being materialized in transport demand that by means specific to transport engineering transforms into traffic flow, necessary to travel on road infrastructure. This paper focuses on one of the destination split models - the intervention opportunity model. The case study within the paper presents the way that the origin - destination matrix is being realized through the intervention opportunity model. Also, specific conclusions to the model and also general conclusions regarding the models for destination split and their importance for the transport studies are being drawn.

Keywords: transport studies, destination split, intervention opportunity model.

1. Introduction

Quality of life in major cities is being determined by the congestion level, air quality, network vulnerability and traffic safety on the road transport infrastructures [2, 15]. The solutions regarding congestion decrease generally aim a strict transport planning with a specific focus on passengers' transportation through which an harmonious modes and transport itinerary traffic split would be achieved.

Identifying the "ex-ante" and "ex-post " transport demand is capable of leading to the formulation of empiric laws, useful in estimating the present and future needs for movements [6, 10, 12]. Mobility configures space; it might strike or ease a space from agglomeration, confusion, by imposing the attraction and compensation principle within the territory distribution of movements [18].

Mobility is the result of facility location policies and reflects the link between transports, social activities and transport behavior [13]. These actions are

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[1] Assoc.Prof., Dept.of Transport, traffic and logistics, University POLITEHNICA of Bucharest, Romania, e-mail: v_dragu@yahoo.com

[2] Lecturer, Dept.of Transport, traffic and logistics, University POLITEHNICA of Bucharest, Romania, e-mail: stefanburciu@yahoo.com

[3] Assoc.Prof., Dept.of Transport, traffic and logistics, University POLITEHNICA of Bucharest, Romania, e-mail: e-mail: eugen.rosca@gmail.com

[4] Lecturer, Dept.of Transport, traffic and logistics, University POLITEHNICA of Bucharest, Romania, e-mail: florin_rusca@yahoo.com

part of the so called area of transport planning realized by modeling demand and its interaction with supply [12]. Mobility is influenced by a multitude of factors through which service quality offered to passengers within the transport terminals [16], knowing the fact that the transport system users try to maximize utility by choosing travel solutions that need minimum resources consumption and a highly comfort and commodity degree.

2. Passenger transportation planning

Passenger transportation planning supposes knowing some elements, as [1, 4, 11, 14]:

a) data gathering (infrastructure state, transport means, management techniques and command and control equipment);
b) transport system exogenous data collecting, supplied by urbanists, demographers, economists, regarding population evolution and structure, life standards and urban sprawl (residential and social-economical repartition);
c) knowledge of the laws governing mobility behavior;
d) identifying the ”ex-ante” and ”ex-post” demand.

The above mentioned planning steps are forming the well-known model of four steps mobility analyze - generating, destination split (origin-destination matrix), modal split and route split. This paper will only focus on the second stage of this planning chain, the origin-destination matrix determination.

There are, mainly, two models for destination split,

1. growth factors models [7, 8, 17];
2. synthetic models that use different types of gravity models or opportunity models [17, 3, 9].

Destination split aims determining the number of trips exchanged between the analyzed urban zones in order to realize the transport system dimensioning.

Taking into account the trips realized by the other zones, the origin-destination matrix is formed for the analyzed city (table 1).

Table 1

Origin-destination matrix

Attraction **Generation**	1	2 . . .	j . . .	n	$\sum_j h_{ij}$
1	h_{11}	h_{12}	h_{1j}	h_{1n}	G_1
2…	h_{21}	h_{22}	h_{2j}	h_{2n}	G_2
i…	h_{i1}	h_{i2}	h_{ij}	h_{in}	G_i
n	h_{n1}	h_{n2}	h_{nj}	h_{nn}	G_n
$\sum_i h_{ij}$	A_1	A_2	A_j	A_n	$\sum_{ij} h_{ij} = N$

Notation are:

h_{ij} is the number of trips between zone i and j;
G_i – number of generated trips by zone i;
A_j – number of attracted trips by zone j;
n – number of zones that the city is divided into,

with the condition:

$$\sum_{i=1}^{n} G_i = \sum_{j=1}^{n} A_j \ , \tag{1}$$

that is likely known as the marginal closing condition. The intervention opportunity model formalizes rational users behavior that look to take the less and shorter possible trips to reach the proposed objectives. A constant probability p is supposed to exist so that a certain destination is to be selected and accepted as end of the trip. So, from the multitude of variants, one that makes the trip selects the variant that accomplish criteria on distance, travel time or cost imposed by him. The model assumes distance as choosing criterion. First, its being considered that the one making the trip makes a ranking of the distances from each zone to all the others, from the closest (named the first) to the most far away one (named last or origin trip). A trip to the first zone has a p probability, to the second p(p-1) and to the n^th^ $p(1-p)^{n-1}$, where n is the number of possible destinations. Considering m, a destination between the first and the nth, the probability for a trip with destination between zones m+1 and n can be expressed as:

$$(1\text{-}p)^m[1\text{-}(1\text{-}p)^n]. \tag{2}$$

As p is quite low, the relation becomes:

$$e^{-pm}(1\text{-}e^{-pn}). \tag{3}$$

In order to distribute g_i trips from zone i to zone j a ranking of the distances from zone i to zone j is necessary. So, for a given i, if the number of possible destinations is n and the number of destinations among i and j is m, the number of distributed trips will be:

$$h_{ij} = g_i e^{-pm}(1\text{-}e^{-p}), \text{ for } m \leq n\text{-}1 \ , \tag{4}$$

where: g_i is the number of trips generated by zone i;
e^{-pm} – refuse probability of any destination closer to home than zone j;
$e^{-p(m+1)}$ – refuse probability of any destination from zone j and from closer to home zones than zone j.

The relation shows that model does not take into account the values of the distances between the zones but the importance that they get in the increasing row of values. If the distances between the analyzed zones are little different there is great uncertainty in choosing one destination or another and p would have a reduced value, meaning that no matter the destination chosen, gains from making the trip do not differ sensitive from one destination to another; the trips distribution model will make a relative uniform and reduced distribution of the number of trips between the zones. The p probability of choosing zone j as destination is, like the β parameter from the gravity model, an essential element of the model that characterizes users' desire of not making long distance trips and is determined so that:

$$F = \sum_{i=1}^{n} \sum_{j=1}^{n} (h_{ij}^{*} - h_{ij})^2 \tag{5}$$

is minimum, where:

- h_{ij}^{*} is the value of number of trips between i and j obtained through surveys;
- h_{ij} – values of the number of trips approximated through calculation.

Just like other distribution models the obtained solutions do not comply with marginal closing conditions,

$$\sum_{j=1}^{n} h_{ij} = g_i \text{ and } \sum_{i=1}^{n} h_{ij} = a_j \ , \tag{6}$$

iterative corrections being needed to reach a certain imposed convergence. Iterative algorithms are defined by the relations:

$$h_{ij}^{(k)} = h_{ij}^{(k-1)} \frac{g_i}{\sum_{j=1}^{n} h_{ij}^{(k-1)}}, \qquad h_{ij}^{(k+1)} = h_{ij}^{(k)} \frac{a_j}{\sum_{i=1}^{n} h_{ik}^{(k)}} \ . \tag{7}$$

3. Case study

As a result of a transport study realized using the intervention opportunity model, the following elements were determined:

- a city divided into five zones, from which only three generate and attract trips, the others being only destinations;
- the number of generated and attracted trips is presented in table 2;

Table 2

Number of trips generated and attracted*

Zone / Trips	1	2	3	4	5
Generated (g_i)	2000	1000	1400	–	–
Attracted (a_j)	2000	800	1000	400	200

*the real numbers are multiplied with 10^2.

- the probability that a certain destination is selected as end of the generated trips in zone 1 is $p_1 = 0,8$, for zone 2, $p_2 = 0,9$ and $p_3 = 0,82$ for the 3rd zone.
- distances matrix between the city`s zones is presented in table 3.

Table 3

Distances matrix

d_{ij} (km)	1	2	3	4	5
1	1,5	2	6	5	3
2	9	1,5	4	7	6
3	4	3	2	8,5	5

Next, the study has to determine:

1. the matrix of distributed trips using the intervention opportunity model,
2. the correction of the distribution matrix using as a convergence criterion correction the indexes E_i and E_j, with: $1-0{,}05 \le E_i \le 1+0{,}05$ and $1-0{,}05 \le E_j \le 1+0{,}05$.

To solve the first point of the model the h_{ij} elements of the distribution matrix are being determined with the relation:

$$h_{ij} = g_i\, e^{-p_i m}\,(1-e^{-p_i}) \tag{8}$$

and used to form the increasing row of d_{ij} values for trips generated in the three zones: for zone 1: d_{11}, d_{12}, d_{15}, d_{14}, d_{13}; for zone 2: d_{22}, d_{23}, d_{25}, d_{24}, d_{21}; for zone 3: d_{33}, d_{32}, d_{31}, d_{35}, d_{34}.

By analysing the d_{ij} values, one can notice that the ratio between the maximum and the minimum element of the row is higher in case of trips with origin in zone 2, followed by the ones with origin in zone 3 and last, the ones from zone 1.

$$\frac{d_{1j}^{\max}}{d_{1j}^{\min}} = \frac{6}{1{,}5} = 4\,;\ \frac{d_{2j}^{\max}}{d_{2j}^{\min}} = \frac{9}{1{,}5} = 6\,;\ \frac{d_{3j}^{\max}}{d_{3j}^{\min}} = \frac{8{,}5}{2} = 4{,}25.$$

This fact is emphasized by the ordered row of values of probabilities that a certain destination is selected as end of routes $p_2 < p_3 < p_1$. Higher value of probability means that the ones travelling, with origin in that zone, are more interested in selecting a destination closer to that zone. The lower probability is, destination choosing is less important as distances that should be travelled are shorter and so, travel impedance is lower. Calculations with equation 8, number of trips, are shown in the primary distribution matrix from table 4.

Table 4

The primary distribution matrix

Destination **Origin**	**1**	**2**	**3**	**4**	**5**
1	1101	495	45	100	222
2	16	593	241	40	98
3	152	345	783	29	67

To establish if corrections are needed E_i and E_j indexes are determined:

$$E_i = \frac{g_i}{\sum_{j=1}^{5} n_{ij}} \quad \text{and} \quad E_j = \frac{a_j}{\sum_{i=1}^{3} h_{ij}} \ . \qquad (9)$$

Values for $E_i^{(1)}$ and $E_j^{(1)}$ are shown in tables 5 and 6.

Table 5

Values for $E_i^{(1)}$ indexes

Index / Zone	g_i	$\sum_j h_{ij}$	$E_i^{(1)}$
1	2000	1963	1,019
2	1000	988	1,012
3	1400	1376	1,017

Table 6

Values for $E_j^{(1)}$ indexes

Zone / Index	1	2	3	4	5
a_j	2000	800	1000	400	200
$\sum_i h_{ij}$	1269	1433	1069	169	387
$E_j^{(1)}$	1,57	0,56	0,93	2,36	0,52

By analysing the 8 values of $E_i^{(1)}$ and $E_j^{(1)}$ we can observe that 5 of them do not accomplish the convergence condition imposed (1,57; 0,56; 0,93; 2,36; 0,52). Under these circumstances, the matrix of distributed trips must be iteratively corrected. Only after the sixth iteration one can see that both $E_i^{(4)}$ and $E_j^{(5)}$ meet the convergence condition imposed $E_i \in [0{,}95; 1{,}05]$ and $E_j \in [0{,}95; 1{,}05]$ and so this is the solution to the problem.

Table 7

Distribution matrix - sixth iteration

Destination / Origin	1	2	3	4	5	g_i	$\sum_j h_{ij}^{(6)}$	$E_i^{(4)}$
1	1602	191	26	175	84	2000	2078	0,962
2	48	401	287	147	78	1000	961	1,041
3	347	206	687	78	39	1400	1357	1,03
a_j	2000	800	1000	400	200	–	–	–
$\sum_i h_{ij}^{(6)}$	1997	798	1000	400	201	–	–	–
$E_j^{(5)}$	1,001	1,002	1,00	1,00	0,99	–	–	–

Opposite to the primary distribution matrix where 1963 trips were distributed from zone 1, 988 trips from zone 2 and 1376 trips from zone 3, with a total of 4327 trips for all the zones; finally, the number of trips distributed was 4396. Starting from the primary matrix, given by the intervention opportunity model, the distribution was achieved proportional with the power of attraction of the 5 zones of the analysed city.

4. Conclusions

Models used in transport planning mainly focus on the transport demand – need for mobility or the transport offer and on the demand-offer feedback, its` equilibrium or resources allocation for an optimal satisfaction of the social needs for mobility and transportability.

Transport planning models speak about the need for movement and look after the responses of the natural-human environment to changes within transport systems and/or changes in the area of transportability induced by environmental changes. There are many ways individual can respond to the transport system changes, so using a certain model is mainly determined by the modeling objectives [10, 5]. Among the critics brought to the destination split model we can underline:

- the model does not take into account chain trips, when a destination becomes origin for a future trip. Nowadays, more people prefer such trips so they would not return home after every trip and waist time. Owning a car ease these chain trips that lead to reducing travel time in comparison to classic origin-destination trips.
- the model consider a closed city, meaning there are not any trips from zones outside the city with origin within the city or trips with origin in the city and destination in neighboring cities. Also, transit trips are neglected even though they might bring important traffic volumes, especially within cities economically developed that attract labor.

As noticed, there are many destination split models [6, 7, 8, 9, 10, 11, 17], determined by a sure need of modeling the human movement behavior. Differences appear in expression mode (utility, monetary or behavior).

The intervention opportunity model, just like the gravity model, may have variants regarding the level of adjustments or corrections. More accessibility zones can be distinguished as well as more categories of transport network users.

Comparing the three families of classic models for destination split one can notice:

- growth factors models are useful on short term forecasts, when population structure and also the network`s one does not suffer from major changes;
- the most used model is the gravity one, that needs corrections, sometimes difficult, being though practical enough to be used in cases where foreseen changes of the network are known and when the travel costs from i to j could be estimated;
- intervention opportunity model shows the best theoretical development.

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REFERENCES

[1] *E. Cascetta*, Metodi quantitativi per la planificatione dei sistemi di transporto, CEDAM Casa Editrice Dott. Antonio Milani, Padova, 1990.

[2] *Dorinela Costescu, Ş. Raicu*, On estimate of risk associated with urban road traffic, Proceedings ACMOS' 14, pp. 92- 97, Published by WSEAS Press.

[3] *A.J. Daly,* Applicability of disaggregate models of behaviour: a question of methodology, Transportation Research no.5,1982, pp. 45-58.

[4] *G. Dobias*, Les transports interregionaux de personnes, Presses de l' Ecolenationale des PontsetChaussees, Paris, 1989.

[5] *V. Dragu, Doina Olaru*, Accessibility measures in the public transport network. Case study: Suburban transport network in Bucharest metropolitan area, Buletinul Ştiințific al Universității Politehnica Bucureşti, no. 1,2000, pag.119-130.

[6] *V. Dragu*, Trafic urban şi suburban de călători – Îndrumar de laborator, Ed. BREN, Bucureşti, 2001.

[7] *T.J. Fratar*, Forecasting distribution of interzonal vehicular trips by successive approximation, Highway Research Board Proceedings, 1954, pp. 376-385.

[8] *K.P. Furness*, Time functions iteration, Traffic Engineering Control, 7, 1965, pp. 448-460.

[9] *F. Ghionea, M. Pirvan, Emma Popa*, The inconsistence of using the gravity model for determining the transport demand in a continous medium, Proceedings ACMOS'13, pp. 103-109, Published by WSEAS Press.

[10] *Doina Olaru*, Modele econometrice pentru estimarea cererii în transportul de călători urban şi regional, teză de doctorat, Universitatea Politehnică din Bucureşti, 2000.

[11] *A.N. Oppenheim*, Urban Travel Demand Modeling, John Wiley & Sons, New York, 1994.

[12] *J. Ortúzar*, Modelos de Demanda de Transporte, Ediciones Universidad Católica de Chile, Santiago, 1994.

[13] *Ş. Raicu*, Sisteme de transport, Editura AGIR, Bucureşti, 2007.

[14] *W. Recker*, The Household Activity Pattern Problem: General Formulation and Solution, Transportation Research B, 29 (1), 1995, pp. 61-67.

[15] *E. Roşca, et all.*, Evaluating vehicles emissions through traffic simulation, Proceedings ACMOS' 14, Braşov România, 2014, June 26-28, pp. 158- 163, Published by WSEAS Press.

[16] *F. Ruscă., et all.*, Queuing systems with non-uniform arrivals applied to estimate services quality in passenger transport terminals, Proceedings ACMOS'13, pp. 86- 91, WSEAS Press.

[17] *R. Salter*, Highway traffic analysis and design, Macmillan Education LTD, London, 1989.

[18] *A.M. Sandu*, Mişcare şi mobilitate urbană, Urbanismul, nr. 10, 2011, pp. 4-5.