About the Destination Split within Transport Planning Models

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Abstract: The quality of life within major cities is also determined by the level of congestion on the transport networks. Solutions meant to reduce congestion aim a strict planning of transports in general but of the passengers transport mainly, supposed to realise a harmonious traffic split on modes and transport routes. This paper presents the main stages in passengers transport planning and focuses on one of the ways to distribute trips on destinations - intervention opportunity model. The model for determining the origin-destination matrix is also presented through the intervention opportunity model and conclusions regarding the model and the destination split model are drawn. The advantages, disadvantages and limits of utilisation are also presented.

Key words: transport planning, destination split, intervention opportunity model.

1 Introduction

Knowing the transport demand, characterized by mobility, is capable of leading to the formulation of empiric laws, useful in estimating the present and future needs for movements [5, 8, 10]. 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 [14].

Mobility is the result of facility location policies and reflects the link between transports, social activities and transport behaviour [11]. These actions are part of the so called area of transport planning realised by modelling demand and its interaction with supply [10].

2 Passenger transportation planning

Passenger transportation planning means [1, 3, 9, 12]:

a) data gathering (infrastructure state, transport means, management techniques and command and control equipments);
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 behaviour;
d) identifying the”ex-ante” and ”ex-post” demand.

The above mentioned planning steps are forming the well-known model of four steps mobility analyse - 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 [6, 7, 13];
2. synthetic models that use different types of gravity models or opportunity models [13, 2].

Destination split aims determining the number of trips exchanged between the analysed urban zones in order to realise the transport system dimensioning. Figure 1 exemplifies the way of achieving trips between zone 1 and the other city zones, in a city divided in six homogenous zone regarding the activities within.

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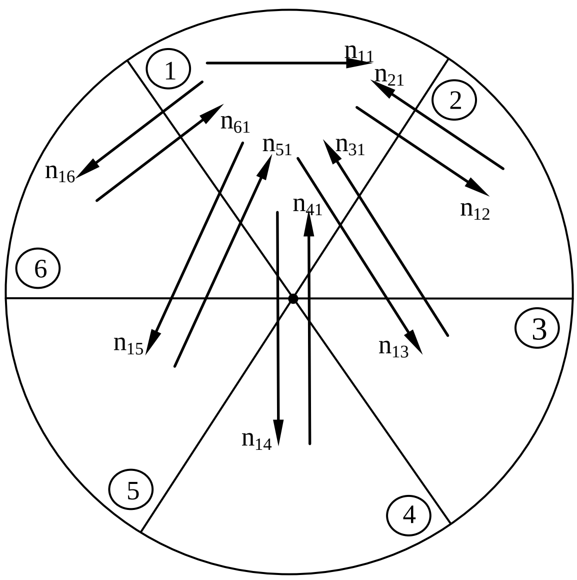

Fig. 1.Passenger exchange between zone 1 and the other 5 zone of the city

Similarly, taking into account the trips realised by the other zones, the origin-destination matrix is formed for the analysed city (table 1).

Table 1.Origin-destination matrix

Attraction / Generation	1	2 . . .	j . . .	z	$\sum_j n_{ij}$
1	n_{11}	n_{12}	n_{1j}	n_{1z}	G_1
2 ⋮	n_{21}	n_{22}	n_{2j}	n_{2z}	G_2
i ⋮	n_{i1}	n_{i2}	n_{ij}	n_{iz}	G_i
z	n_{z1}	n_{z2}	n_{zj}	n_{zz}	G_z
$\sum_i n_{ij}$	A_1	A_2	A_j	A_n	$\sum_{ij} n_{ij} = N$

Notation are:

$n_{ij}$is thenumber 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;

z – number of zones that the city is divided into,

with the condition:
$$\sum_{i=1}^{z} G_i = \sum_{j=1}^{z} A_j \,, \qquad (1)$$
that is likely known as the *marginal closing condition*.

The intervention opportunity model formalises rational users behaviour 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 selectedand accepted as end of the trip. So, from the multitude of variants, the one that makes the trip selects the one that accomplish criteria on distance, travel time or cost imposed by himself. The proposed 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 $z^{th}p(1-p)^{z-1}$, where z is the number of possible destinations. Considering m, a destination between the first and the z^{th}, the probability for a trip with destination between zones m+1 and z can be expressed as:
$$(1-p)^m[1-(1-p)^z] \qquad (2)$$
As p is quite low, the relation becomes:
$$e^{-pm}(1-e^{-pz}). \qquad (3)$$

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 z and the number of destinations among i and j is m, the number of distributed trips will be:
$$n_{ij}= g_i e^{-pm}(1-e^{-p}), \text{ for } m \le z-1 \quad (4)$$
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 the intervention opportunity model does not take into account the value of the distances between zones but the importance that they get in the increasing row of values. If the distances between the analysed zones are little different there is great uncertainty in choosing one destination or another and p would have a reduced

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value, meaning that no matter the destination chosen, gains from making the trip do not differ sensitive from one destination to another. In this case, the trips distribution model will make a relative uniform and reduced distribution of the number of trips between the zones.

On the other way, we have the situation when a distance to a certain zone becomes dominant (is much shorter in relation with all the others) and then the majority of the trips will aim that zone, corresponding to a normal behaviour of users trying by any means to maximize utility.

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 distances trips.Maximum caution is needed in its determination.

The p parameter is determined so that the following function:

$$F = \sum_{i=1}^{z} \sum_{j=1}^{z} (n_{ij}^{*} - n_{ij})^2 \qquad (5)$$

is minimum, where:

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

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

$$\sum_{j=1}^{z} n_{ij} = g_i \text{ and } \sum_{i=1}^{z} n_{ij} = a_j, \qquad (6)$$

iterative corrections being needed to reach a certain imposed convergence.

Iterative algorithms are defined by the relation:

$$n_{ij}^{(k)} = n_{ij}^{(k-1)} \frac{g_i}{\sum_{j=1}^{z} n_{ij}^{(k-1)}}, \qquad (7)$$

followed at the next step by:

$$n_{ij}^{(k+1)} = n_{ij}^{(k)} \frac{a_j}{\sum_{i=1}^{z} n_{ik}^{(k)}} \qquad (8)$$

3 Case study

As a result of a transport study, the following elements were determined:

- a city divided into 5 zones, from which only the first two 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)	1000	2000	-	-	-
Attracted (a_j)	1000	1400	200	300	100

- the probability that a certain destination is selected as end of the generated trips in zone 1 is p_1 = 0,85, and for the generated trips in 2, p_2 = 0,9;
- 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	2,5	6	8	10	12,5
2	6	3	15	12	18

For the analysed city we have determined:

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

1. The determination of the n_{ij}elements of the distributionmatrix is realised with the relation:

$$n_{ij} = g_i\, e^{-p_i m} (1 - e^{-p_i}) \qquad (9)$$

by forming the increasing row of d_{ij} values for trips generated in zone 1: d_{11}, $d_{12,}$ d_{13}, d_{14}, d_{15} and for those generated in zone 2: d_{22}, $d_{21,}$ d_{24}, d_{23}, d_{25}.

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.

$$\frac{d_{1j}^{max}}{d_{1j}^{min}} = \frac{12{,}5}{2{,}5} = 5; \qquad \frac{d_{2j}^{max}}{d_{2j}^{min}} = \frac{18}{3} = 6 \qquad (10)$$

This fact is emphasized by p_2 value which is higher than p_1, meaning that the ones traveling are more interested in selecting a destination closer to zone 2, opposite to trips generated in zone 1, with shorter distances making destination choosing less important. Speaking about number of trips, the

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values were approximated to integer numbers. The primary distributionmatrix is presented in table 4.

Table 4. The primary distributionmatrix

Destination / Origin	1	2	3	4	5
1	573	245	105	45	19
2	483	1187	80	196	32

2. To establish whether corrections are needed E_i and E_j indexes are being determined:

$$E_i = \frac{g_i}{\sum_{j=1}^{5} n_{ij}} \quad \text{and} \quad E_j = \frac{a_j}{\sum_{i=1}^{2} n_{ij}} \qquad (11)$$

Values for $E_i^{(1)}$ are shown in table 5.

Table 5. Values for $E_i^{(1)}$ indexes

Index / Zone	g_i	$\sum_j n_{ij}$	$E_i^{(1)}$
1	1000	987	1,013
2	2000	1978	1,011

Values for $E_j^{(1)}$ are shown in table 6.

Table 6. Values for $E_j^{(1)}$ indexes

Zone / Index	1	2	3	4	5
a_j	1000	1400	200	300	100
$\sum_i n_{ij}$	1056	1432	185	241	51
$E_j^{(1)}$	0,947	0,978	1,081	1,244	1,961

By analysing the 7 values of $E_i^{(1)}$ and $E_J^{(1)}$ we can observe that 4 of them do not accomplish the convergence condition imposed (0,947; 1,081; 1, 244 and 1,961). Under these circumstances, the matrix of distributed trips must be iteratively corrected. Determining $n_{ij}^{(1)}$ with the relation:

$$n_{ij}^{(1)} = n_{ij} \cdot E_i^{(1)}, \ (12)$$

the new values for $E_j^{(2)}$ determined as previously are presented in table 7.

Table 7.Distributionmatrix after the first iteration

Destination / Origin	1	2	3	4	5
1	580	248	106	46	19
2	488	1200	81	198	32
a_j	1000	1400	200	300	100
$\sum_i n_{ij}$	1068	1448	187	244	51
$E_j^{(2)}$	0,936	0,967	1,07	1,23	1,961

As noticed from table 7, 4 out of 5 values of $E_j^{(2)}$ correction indexes do not respect the convergence condition (0,936; 1,07; 1,23 and 1,961). So, iterations continue with the calculation of $n_{ij}^{(2)} = n_{ij}^{(1)} \cdot E_j^{(2)}$. Results, also for $E_i^{(2)}$, are shown in table 8.

Table 8.Distributionmatrix after the second iteration

Destination / Origin	1	2	3	4	5	g_i	$\sum_j n_{ij}^{(2)}$	$E_i^{(2)}$
1	543	240	113	57	37	1000	990	1,01
2	457	1160	87	243	63	2000	2010	0,995

The values of $E_i^{(2)}$ accomplish the imposed convergence condition and so this is the solution to the problem. Opposite to the primary distributionmatrix where 987 trips were distributed from zone 1 and 1978 trips from zone 2, finally, the number of trips distributed was 990 and, respectively, 2010. 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

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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 modelling objectives[8, 4].

As noticed, there are many destination split models, determined by a sure need of modelling the human movement behaviour. Differences appear in expression mode (utility, monetary or behaviour).

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 jcould be estimated;
- intervention opportunity model shows the best theoretical development. Through its limitations we can specify:
    - p values vary in relation with the trip length and though trips are to be ranked by cost or travel time;
    - if in the future, the number of possible destinations increases, the number of short distance trips also has the tendency of increasing. To annihilate this tendency in the future situations the same proportion of short trips in relation with the other trips should be maintained;
    - from the theoretical point of view, to distribute all the generated trips an infinite number of destinations is necessary as,

$$p + p(1-p) + \cdots + p(1-p)^{z-1} \neq 1 .(13)$$

The little p is, the number of destinations needed to distribute trips is greater.

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