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# STUDY ON THE MATHEMATICAL MODELLING OF THE URBAN TRAFFIC IMPACT FROM THE RESIDENTIAL DEVELOPMENTS

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**Abstract**: The mathematical model should be able to perform modal split and could be the classical 4-step transport model for a city: generation, distribution, modal split and assignment.

## 1. INTRODUCTION

In order to make forecasts on different time horizons regarding the evolution of road traffic in a specific area, it is important first to develop a transport model for the base year. The transport model makes the link between the socio-economic features and the transport demand and transport systems available

## 2. BASE YEAR TRANSPORT MODEL

The base year strategic transport model is essentially comprised of: transport networks, land use zoning system, transport demand, assignment and validation.
The base year modelling flow chart is presented overleaf.

<u>Transport Network</u>

The transport network is comprised of a road and a public transport network, where the public transport system in Bucharest is further comprised of: rail, metro, trolley-bus, bus, tram, maxi-taxi
A number of sources are available from which to construct the transport system in the model, namely: urban maps and images, CAD drawings, GIS networks and databases
A detailed road hierarchy of different road types has been developed. Specific speed flow relationships have been applied for each road type to make an allowance for congestion in the route choice. The model is strategic in nature and equivalent 24 hour speed flow curves have been applied in order to carry out an equilibrium capacity-constrained assignment.
Public transport routes, schedules, frequencies, dwell times, run times, interchanges, plus walk and wait times are all coded into the model.

<u>Land Use Zoning System</u>

Land uses are defined as zones in the transport modelling process. The zoning system for Bucharest follows the same zoning system developed in the JICA study. The zoning system will link to the administrative boundaries so that the planning data can be applied efficiently when forecasting the model demand.
A refined external zoning system is defined so that important daily inter-urban migration patterns can be captured and modelled accurately. This is particularly important as cities begin to sprawl and dormitory or satellite towns develop within the hinterland.

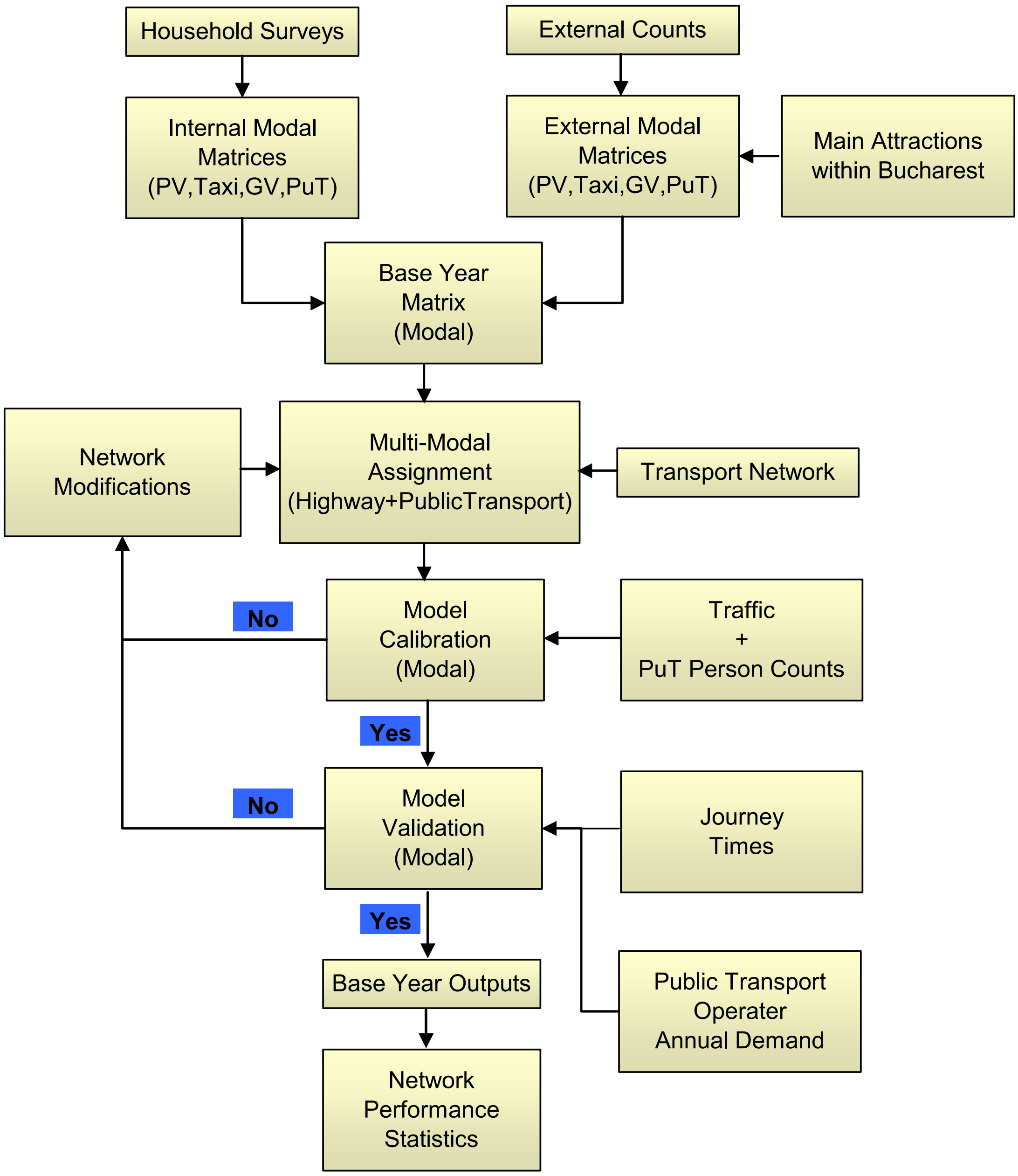


***Fig. 1 Base Year Modelling Flowchart***

Assignment and Validation

The base year transport model is the environment where the transport demand is assigned to transport supply, and then tested for validity.

In order to model mixed mode trips which are common in Romanian cities, public transport trips choose the public transport mode by assignment which incorporates a logit choice model. Significant scheduled public transport modes within Bucharest include metro, tram, bus, and trolley bus.

Highway vehicles are assigned according to Wardrop's equilibrium procedures where origin-destinations are assigned to user optimal routes and no alternative routes are faster. For public transport, where specific routes are defined, a timetable based approach is taken for assignment. This approach takes into account typical wait times, stop times and

transfer times when travelling by public transport. Appropriate wait/walk time co-efficient and interchange penalties are applied during calibration.
The base year model has been suitably calibrated by comparison of modeled and observed flows across screenlines, cordons, and at individual count locations. The observed counts are in terms of different vehicle types for the highway model and person counts for the public transport model. During the calibration process routing through the network is checked for realism. If the difference between modeled and observed flows is significant, then model calibration will be carried out to correct any coding issues. To improve the model fit, minimal matrix estimation has been carried out for private vehicles, taxi and goods vehicle trips only.
Model validation is ascertained by reference to: journey time surveys, public transport operator annual demand.
A series of peak hour journey times where carried out along major strategic routes throughout Bucharest. This provides a vital benchmark by which to check the validity of the model. The social economic benefits derived by the future year schemes are largely through time savings, hence, this is an important measure of the model suitability.
The model validity is further checked against public transport operator loading data, these are usually annual figures, but provide a good gauge with which to compare the model at the aggregate level.
Once the model validation is complete, the base year multi-model strategic model can be used for forecasting and scenario testing.

<u>Model Outputs</u>

The main model outputs are as followed: Modal Matrices and Desire Lines (Sectored), Link Modal Volumes, Network Performance Statistics
A trip generation and attraction model is calibrated by reference to the socio-economic planning data for each zone. The planning data at the household level was based on census 2002 data (where available). The same population data was used to expand the household surveys. During the household surveys information pertaining to where people went to school and work was collected. This provides valuable data from which to estimate attraction data, such as number of work place or school places by zone.
The following linear regression model was employed to estimate the trip generation and attractions. The model structure is assumed to remain the same in the future.

$$G_i = a_i + b_i.\ X_1 + c_i.\ X_2 + d_i.\ X_3 \quad (1)$$
$$A_j = a_j + b_j.\ X_1 + c_j.\ X_2 + d_j.\ X_3 \quad (2)$$

Where: $G_i$ = Trip generation in zone i
$A_j$ = Trip attraction in zone j
$X_1, X_2, X_3$ = Socio-economic indicators per zone
a, b, c = Parameters

The explanatory variables and estimated parameters are shown in the following Table.

***Table 1. Trip Generation and Attraction Model Parameters***

| Trip purpose | | Constant | Pop | Wht | Wh1 | Wh2 | Wh3 | Wwt | Ww1 | Ww2 | Ww3 | Sh | Ss | Correlation coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Car owner | | | | | | | | | | | | | | |
| To work | Gen | - | - | 0.23 | 0.11 | - | 0.60 | - | - | - | - | - | 0.01 | 0.98 |
| | Att | - | - | - | - | - | - | 0.59 | 0.03 | - | 0.07 | - | 0.00 | 0.98 |
| To study | Gen | - | - | - | - | 0.13 | 0.20 | - | - | - | - | 0.23 | - | 0.89 |
| | Att | 0.01 | - | - | - | - | 0.07 | - | - | - | 0.02 | - | 0.42 | 0.93 |
| To shop | Gen | - | 0.04 | - | - | - | 0.04 | 0.02 | - | 0.04 | - | - | 0.00 | 0.70 |
| | Att | 29.54 | - | - | - | 0.30 | - | - | - | 0.76 | 0.01 | 0.01 | - | 0.46 |
| For private | Gen | - | 0.05 | - | - | 0.04 | - | 0.04 | 1.44 | - | - | - | 0.03 | 0.73 |
| | Att | 0.00 | - | - | - | - | - | 0.11 | - | - | 0.07 | - | 0.03 | 0.70 |
| For business | Gen | - | 0.00 | - | 0.26 | 0.03 | - | 0.01 | - | - | - | 0.01 | - | 0.33 |
| | Att | - | - | - | - | - | - | 0.01 | - | - | 0.03 | - | - | 0.43 |
| Other | Gen | - | 0.03 | - | - | - | - | 0.04 | 0.09 | - | - | - | - | 0.58 |
| | Att | - | 0.01 | - | 0.08 | - | - | 0.00 | 0.43 | - | 0.11 | - | 0.00 | 0.36 |
| To home | Gen | - | 0.05 | - | - | - | - | 0.61 | - | 0.36 | 0.48 | - | 0.37 | 0.86 |
| | Att | 0.01 | 0.19 | 0.20 | - | - | 0.82 | 0.00 | - | - | 0.05 | 0.06 | 0.03 | 0.98 |
| Non car owner | | | | | | | | | | | | | | |
| To work | Gen | - | 0.02 | 0.16 | - | 0.70 | - | - | - | - | - | 0.02 | 0.01 | 0.88 |
| | Att | 36.49 | - | - | - | - | - | 0.25 | - | 0.10 | 0.08 | 0.02 | - | 0.92 |
| To study | Gen | - | - | - | - | - | - | - | - | - | - | 0.37 | - | 0.75 |
| | Att | - | - | - | 1.06 | 0.00 | - | - | - | - | - | - | 0.38 | 0.92 |
| To shop | Gen | - | 0.07 | - | - | - | - | 0.01 | 0.00 | 0.00 | - | - | 0.04 | 0.74 |
| | Att | - | - | - | - | 0.47 | - | - | - | 0.52 | - | 0.05 | - | 0.42 |
| For private | Gen | - | 0.05 | - | 0.84 | 0.09 | - | 0.00 | 0.54 | - | 0.02 | - | 0.03 | 0.62 |
| | Att | - | 0.00 | - | - | - | - | 0.00 | - | - | 0.23 | - | 0.01 | 0.61 |
| For business | Gen | - | - | - | 0.00 | - | - | 0.01 | - | - | - | 0.01 | - | 0.43 |
| | Att | - | - | - | - | - | - | 0.01 | - | - | - | - | - | 0.42 |
| Other | Gen | - | 0.03 | - | - | - | - | - | 0.00 | 0.07 | 0.03 | 0.03 | - | 0.62 |
| | Att | 13.75 | 0.01 | - | 1.23 | - | - | - | 1.29 | - | 0.09 | - | - | 0.39 |
| To home | Gen | 0.03 | 0.04 | - | 0.16 | 0.21 | - | 0.00 | - | 0.91 | 0.80 | - | 0.31 | 0.61 |
| | Att | - | 0.25 | - | - | 0.69 | - | - | - | - | - | 0.41 | 0.05 | 0.89 |

Where:

Pop = population
Wht = Number of workers in residence place
Wh1 = Number of workers in primary industry in residence place
Wh2 = Number of workers in secondary industry in residence place
Wh3 = Number of workers in tertiary industry in residence place
Wwt = Number of workers in residence place
Ww1 = Number of workers in primary industry in residence place
Ww2 = Number of workers in secondary industry in residence place
Ww3 = Number of workers in tertiary industry in residence place
Sh = Number of students and pupils in residence place
Ss = Number of students and pupils in school place

## 3. FORECASTING AND ASSIGNMENT

Essentially, base year synthetic modal matrices are developed, as described earlier, as part of a 4 stage demand modelling process, where trips generated by mode are based upon economic data for each zone. For forecast years, the planning and network data is then updated. The synthetic model is then re-run to produce future year modal matrices for different scenarios.

A pivoting process is then carried out whereby the synthetic changes in modal trips by origin-destinations are then applied to the base year modal matrices.

The forecast year synthetic model is derived by adjusting the planning data and transport infrastructure projects in the base year to that of future years. The synthetic forecasts provide scale factors between base and future years for each origin-destination movement. These factors are then applied to the base year observed modal matrices in a process called pivoting, as shown to follow.

$$F_{ijm} = O_{ijm} * S_{ijmf} / S_{ijmb} \quad (3)$$

Where: $F_{ijm}$ - predicted trips from i to j by mode m after pivoting
$O_{ijm}$ - observed trips from i to j by mode m in the base year
$S_{ijmf}$ - synthetic trips from i to j by mode m in the forecast year
$S_{ijmb}$ - synthetic trips from i to j by mode m in the base year

Special consideration and care is taken when, for example, scale factors are applied to zeros in the base year, new major settlements are added and excessive scaling factors are derived

## 4. CONCLUZII

The transport model makes possible estimating the impact of futuire developments on the traffic flows, and also the evaluation of the effects of implementing various transport projects and related transport policies.

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