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STUDY ON THE MATHEMATICAL MODELLING OF THE CAR OWNERSHIP IN ROMANIAN CITIES

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Abstract: Car ownership growth has been significant in recent years in Romania, and with the recent accession to the EU, is predicted to continue. Therefore, a major consideration of this study is to accurately predict car ownership, so that sufficient measures can be put in place to mitigate the adverse impacts on society.

1. INTRODUCTION

A key factor driving the generation of trips and indeed, the efficient use of the transport network, is the prevalent growth in car ownership. As the number of licensed cars increases with affluence, the mode share inevitably moves towards private vehicle usage. There is also a tendency for the real cost of motoring to decrease, as public transport becomes more expensive, which reinforces this shift towards car dependency - unless travel demand management measures are introduced. Car ownership growth has been significant in recent years in Romania, and with the recent accession to the EU, is predicted to continue. Therefore, a major consideration of this study is to accurately predict car ownership, so that sufficient measures can be put in place to mitigate the adverse impacts on society.

2. MODELUL DE PROGNOZA A EVOLUTIEI GRADULUI DE MOTORIZARE

A car ownership model was developed based on the household surveys. A relationship has been developed based on car owning households and income levels. Income growth will then be proxied to GDP growth. This will predict the number of households with 0, 1, 2 or 3+ cars.

The following model was adopted to project the relationship between future car ownership rate and average income level, for car ownership levels 0, 2 and 3+

$$P(N)_i = (1 + (a_i \cdot I_i)^b)^{-1} \qquad (1)$$

Where: $P(N)_i$ = Probability of N number of cars per household in zone i
I = average income per household in zone i
a,b = calibration co-efficients

For car ownership of 1:

$$P(1)_i = 1 - P(0)_i - P(2)_i - P(3+)_i \qquad (2)$$

The Table below presents the model co-efficients at the different levels of car ownership.

Table 1 Car Ownership Model Co-efficients

Car Owning Rate		Co-efficient a	Co-efficient b	Correlation Co-efficient
Non Car Owning	NCO	0.000042	1.645	0.99
One Car Owning	CO1	-	-	0.94
Two Car Owning	CO2	84,487	-1.339	0.96
Three Plus Car Owning	CO3	8,093,820	`-1.770	1.00

The graph shows the predicted relationship between household car ownership and average income, with increasing income.

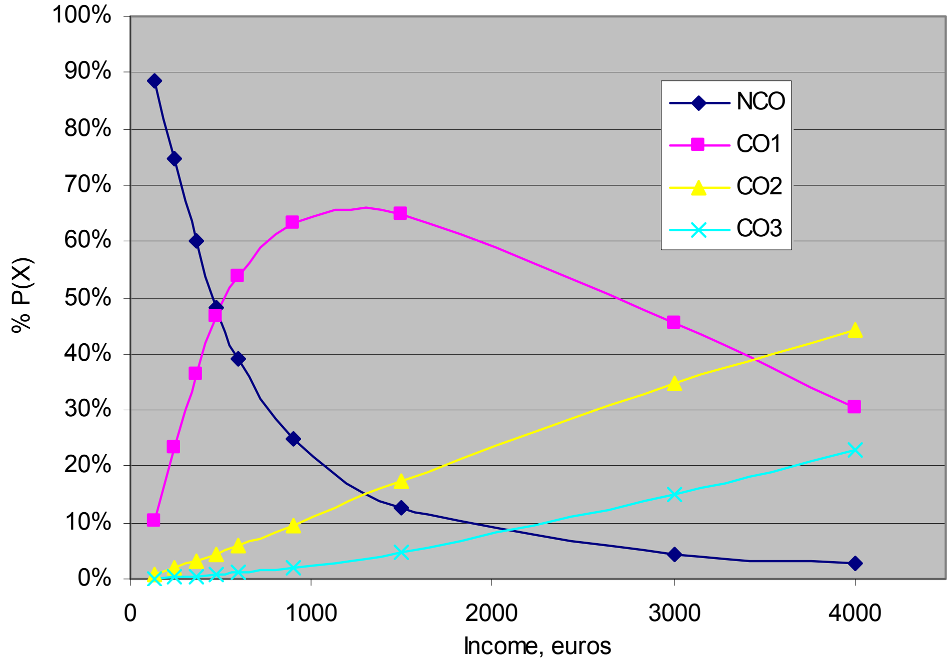

Fig. 1 Model Relationship between Average Household Income and Car Ownership

To carry out the forecasts, real income growth is proxied by real GDP growth per capita which is currently forecast to grow at 6.3% pa in the short term and 4.8% pa beyond this The car ownership model produces a synthetic estimation of the base year car ownership levels, as well as, forecast years. Growth in car ownership is measured by applying the synthetic growth factors, to the base year observed car ownership in a process called pivoting

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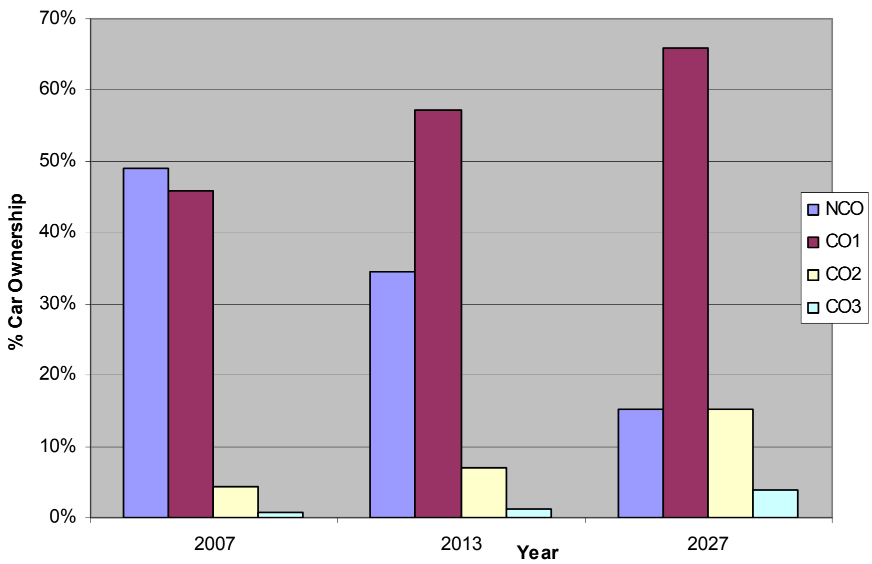

Fig. 2 Prevederea creşterii gradului de motorizare pentru anii viitori

The car ownership model predicts 32% growth in car owning per head by 2013, and 93% by 2027. In 2013, 34% of the households will not have direct access a car, whereas in 2027, this figure is set to reduce to 16%.
The car ownership model assumes that the cost of motoring will growth in line with inflation, and hence, will not change in real terms. If fiscal policies are implemented to increase the cost of motoring (fuel tax, import tax, other duties), then this will dampen the expected car ownership growth and forecast traffic growth
The household surveys provide the mode split at different levels of household car ownership. As income and car ownership grow, the use of cars become more accessible to household members, leading to more trips made by car. Where, there is one car in a household, it is likely that the head of the household will have the primary use, with other members of the household using alternative forms of transport.
It is expected that once the car ownership is growing the total number of car trips will increase, as well as the average number of daily car trips for various purposes. In the table hereunde is shown that for non-car users the average number of trips per day is 1.90, while for housholds with 2, 3 or more cars the average number of trips per day is 1.98 and 1.98 by person.

Table 2

	Nivel posesie maşini				
	NCO	**CO1**	**CO2**	**CO3**	**All**
Deplasări	1,477,760	1,653,394	368,384	73,568	3,573,106
Populaţie (recensământul 2002)	779,450	852,662	186,220	37,420	1,855,752
Rata producerii călătoriilor	1.90	1.94	1.98	1.97	1.93

The table hereunder shows a detailed analysis of the trips rates by trip purpose and category of population (car owners and non-car owners) for the base year 2007, and the forecasted total number of trips for years 2013 and 2027.

Table 3 ***Trip rate by trip purpose and type of car ownership***

Journey Purpose	Car ownership 2007		Non car ownership 2007		Trips production in 2013			Trips production in 2027		
	Trips	Rate of production	Trips	Rate of production	Car ownership	Non car ownership	Total	Car ownership	Non car ownership	Total
to work	447183	0.46	313364	0.33	587792	226225	814017	843980	102798	946779
To study	186302	0.19	172620	0.18	244881	124619	369500	328171	56628	384798
To shop	97257	0.10	164959	0.17	127838	119088	246927	171319	54115	225433
For private	114696	0.12	146807	0.15	150760	105984	256743	202036	48160	250196
For business	17255	0.02	7723	0.01	22681	5576	28257	30396	2534	32929
Other	67352	0.07	92794	0.10	88530	66991	155520	118641	30441	149081
To home	838405	0.86	822849	0.86	1102027	594035	1696062	1476850	269934	1746783
Total Trips	1768451	1.82	1721118	1.80	2324509	1242517	3567027	3171392	564608	3736000
Total Population	970685		956630		1275900	690,614		1709860	313820	

The Figure below presents the mode split in Bucharest for different levels of car ownership. The graph shows the significant growth in private vehicle trips with car ownership, and the decrease in public transport usage

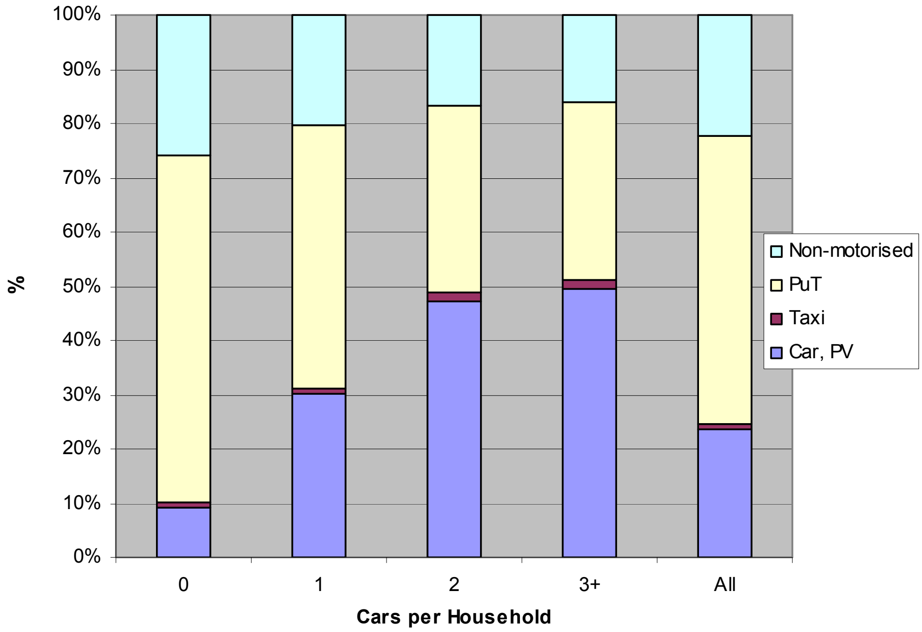

Fig. 3 Mode Split by Car Ownership, Household Surveys

MODE SPLIT FORECASTING MODEL

The total person trips from the trip distribution stage are then assigned to different modes according to the mode choice model. The mode choices are comprised of three different categories: slow modes, non car owning motorised mode choice, car owning motorised mode choice.

Slow modes include walking and cycling, and in some cities this is a very important mode especially for short distance and intra-zonal trips. Therefore, the first step is to separate slow mode trips from motorised trips. Slow modes where extracted from all trips according to a distance decay curve i.e. with increased distance, people are less likely to walk (or cycle).

The following slow mode model was adopted:

$$Pw_{ij} = 1 / (1 + e^{(a + b\,Dij)}) \tag{3}$$

Where: Pw_{ij} = mode split of slow modes over motorised modes
D_{ij} = distance between zones i and j
a, b = parameters

The model was calibrated by reference to household surveys. Initially, the slow mode model was calibrated for all journey purposes and car ownership levels. After inspection of relationships for each car owning levels, journey purposes were aggregated where similar relationships were observed.

The following Table presents the slow mode model parameters and the aggregation.

Table 4. Mode Split Parameters for Slow Mode Model

Journey Purpose	a	b	Correlation coefficient
Car owner			
business	1.84	0.35	0.60
Work/private	-0.77	1.08	0.99
Shop/study/home/other	-1.83	1.06	0.98
Non car owner			
Business	-1.81	1.80	0.95
Work	-0.94	1.00	0.98
Private	-1.16	1.31	0.96
Shop/study/home/other	-1.77	0.90	0.98

Of the remaining person trips, some of the trips are from a non-car owning and car owning households. Naturally, you may expect that non car owning households to travel by public transport. However, the household surveys showed that a significant proportion still travelled by car, which is likely to be a lift given by a friend or colleague. In order to represent this phenomena in the mode choice, a fixed mode split was applied to these trips

The remaining trips are from car owning (or access) households, where residents will have a direct choice between public transport and private car. The mode split between private car and public transport is predicted based the calibration of a mode split logit model for car available households

$$T_{ij}m = T_{ij^*}\, e^{-\lambda(U_{ij}m)} \,/\, \Sigma\, e^{-\lambda(U_{ij}m)} \qquad (4)$$

$$C_{ij} = (1/-\lambda)\ \ln\,(\Sigma\, e^{-\lambda(U_{ij}m)}) \qquad (5)$$

$$U_{ij}m = \alpha_1(m) + \alpha_{2^*}cost(m) + \alpha_{3^*}in\text{-}vehicle\ time(m) + \alpha_{4^*}wait\ time(m) + \alpha_5 \qquad (6)$$

Where: T_{ij} = trips between zone i and zone j by mode m
C_{ij} = composite generalised time between zone i and zone j for all modes
$U_{ij}m$ = the disutility of using mode m for travel between zone i and zone j
m = mode of transport
α, β, γ (n), λ, μ = calibration constants
α_1,α_2,α_3,α_4 = coefficients of the disutility function for mode m
α_1 = modal constant
α_2 = value of time
α_3 = in vehicle time co-efficient (usually 1)
α_4 = wait time co-efficient
α_5 = interchange penalty

The scaling parameters and mode constants are calibrated based on the trip making behaviour observed in the household surveys

The Table to follow shows the mode choice parameters used to calibrate the mode choice model .

Table 4. Mode Choice Parameters

Co-efficient	Parameter	
VOT (euros/ora), α_2	for mode split	2.00
	for PuT only assignment	1.14
Scaling co-efficient	λ	0.02
Mode Constant for PuT	α_1	8 mins
In vehicle time	α_3	1.00
PuT transfer waiting and walking time	α_4	1.60
PuT number of transfer	α_5	5 mins
Captured Public Transport		24%

3. CONCLUSION

The strategies and policies for the up-grading and extension of the street networks in urban areas needs to offer optimum solutions in a changing environment, in such a way to ensure the minimisation of the traffic congestions supporting also the economic developments.

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