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TRANSPORTATION PLANNING MODEL

The traffic congestion represents a very important problem of the cities at present. The results are a frustration of motorists; longer travel times; an increase of accidents and fuel consumption and negative effect to the environment. The transport relations modeling by exact analysis of the real traffic state is a complex solution. This solution enables a determination of the future demands depending on traffic forecast. The article presents the main process of transport modeling based on four-step solution. This process is completed by its practical using in the town of Žilina. The transport relation analyses, the modal split and traffic distribution are described. The focus of the article is approaching the transport-modeling dilemma.

1. Introduction

The traffic requirements are increasingly more extensive and demands for the road network expand. The exact traffic forecast is one of basic assumptions of sustainable transport. It allows to determinate the future transportation relations and a network loading. The requirements to the new infrastructure elements would be defined.

The transportation model became one of the basic tools of transportation engineers. The model is wide-spectrum and it would be oriented to the wide area but also to the individual intersection. However, the real state of traffic is an imperative assumption of the model. So the quality of the model is directly depending on input parameters.

The phase in a four steps model became the wide-spread. The process of determination of the future traffic demands includes, first, a trip generation, second, a trip distribution, third, a modal split and fourth, a traffic assignment. The result of the four step analysis is forecast of the infrastructure and intersections loading and specification of the demands for future network developing.

Two types of models are generally used. The disaggregate model is used above all at present. Contrary to the aggregate model, the disaggregate model evaluates the habitants from the point of view of effect to the transport behaviour in dependence on a trip purpose.

The North Region of Slovakia and Žilina especially is a rapidly developing area. The new investments launched, above all, the development of car industry. The industry expansion brought new problems in infrastructure loading, especially in the road infrastructure. Creation of an exact transport model has a markedly accruing account. The Department of Highway Engineering of Civil Engineering Faculty collects the essential data for the model creation in frame of its research activities. The PTV VISION software is used as a modelling tool.

2. Trip generation

Trip generation deals with productions and attractions of the parts of the region. The solved region is divided to zones depending on selected parameters which are defined by a detailed analysis of urban, transport, economic, and sociological conditions. The basic parameter needed for traffic forecast is the generation of the trips by origin zones. Žilina was divided into 36 zones to analyse the internal transport; and new six fictive zones were created to define the origin, destination and transit transport. The fictive zones are located on the town periphery.

The number of trips depends on a zone character, above all. The greatest source of the trips is a living zone. The majority of the trips are connected with a household. The home based trips mean that one end of the trip is at home (home – work, sport – home, etc). On the other hand the industry zones are the most attractive for trips inducing by destination zone.

The most important parameters of the trip generation are regional economics, regional demographics, and population of the zone and distribution of the subzonal traffic relation. The described parameters markedly affect the car ownership. Philosophy of the zone creation is a very important factor.

2.1 The zone creation

The exact definition of the zone functionality is inevitable. The function determines the type of transport, the trip's purpose and attractiveness. The zone functionality represents the land uses of the area, the population, employment, retail space etc.

The models included a big territory define from 5 to 8 types of the zone. The minimal 4 types of zone are necessary for forecast of the traffic demands:
- habitable,
- industry,

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- service,
- recreation.

Each zone is characterized by a number of inhabitants, employment offer, school capacity, commercial service and recreation abilities. The division of Žilina to the zones is shown in Fig. 1. The 7 external zones for transit transport were created besides 42 internal zones.

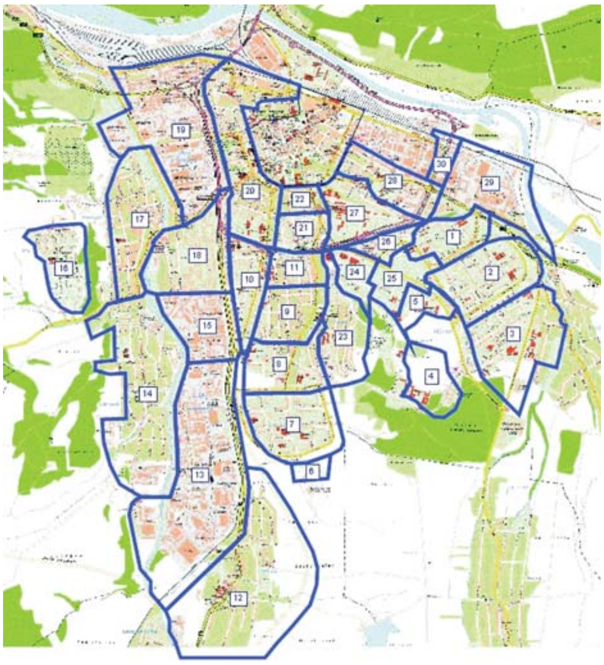

Fig. 1 Zones in Žilina

2.2 Transport potential

The transport potential of the zone is the transport production depending on possibility of a trip generation. The potential depends on more factors; the car ownership is very important. The average number of vehicles per household is used for calculation the most frequently. The car ownership defines the basic group for calculation of traffic generation by individual car transport. The economically active people without car are the basic group for generation of the traffic by public transport. These two groups of habitants are the source of essential traffic. The generated traffic potential of the zone D_i involves also next groups of habitants – students, unemployed, children etc.

The employment offer and service providing are a secondary source of the potential and they are used as a source of attractiveness above all.

The solution of Zilina region issues from transport-sociological analysis. The present specimen is more than 3000 inhabitants, which is about 4%. The process of data collection continues. The specimen 6% of inhabitants is an aim of research team. The homogenous groups characterised by uniform transport behaviour were crested by division of the inhabitants to the specific groups.

The next groups were created:
- *E+c* Employed persons. car available
- *E−c* Employed. no car available
- *NE+c* Not Employed persons. car available
- *NE−c* Not Employed. no car available
- Child Children
- Stud Students
- Pens Pensioners

The division of inhabitants to the groups is shown in Fig. 2.

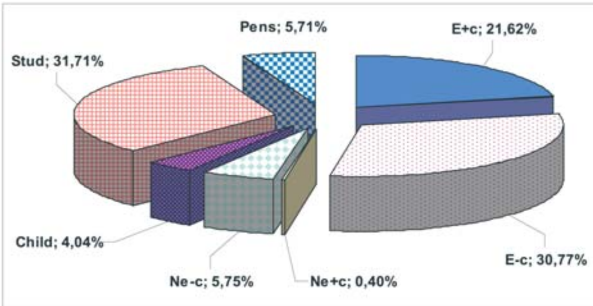

Fig. 2 Inhabitants' groups

The mobility of the groups of inhabitants was the source of a trip number generation for each zone. The average mobility in Žilina is 2.26 trips per day. The mobility is shown in Fig. 3.

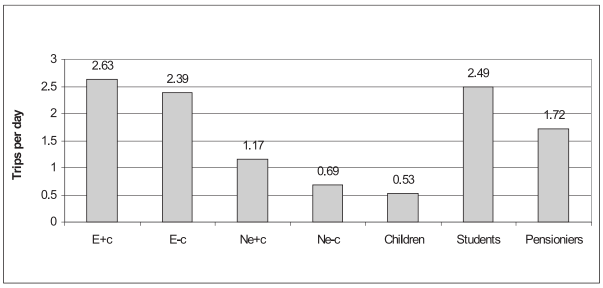

Fig. 3 Mobility of groups

3. Trip distribution

When speaking of a trip generation, a 'trip' is defined as travel between two places of activity. The analysis deals separately with *trip productions*, which are trips generated by residential zones to serve a need, and *trip attractions*, which are trips generated by activities such as employment, retail services etc. and are related to satisfaction of a need. The traffic volumes induced by potential of the zone must be predicted to the interzonal travel volumes $D_{i,j}$ as a function of the attractiveness of the destination zone and expe-

dience of the offers of next zones. The traffic volumes are defined by the following parameters:
- transported subject D
- origin of transport (zone i)
- destination of transport (zone j)
- travel time t
- transport mode m
- transport purpose p
- transport route r.

The chains of activities of inhabitants were created by results of the analysis. The chain represented a structure of movements during day and forms a traffic relation between zones. So, the volume of origin transport is described by formula (1)

$$Do_{ip} = a_{ip} \times t_p \times X_{ip} \,. \tag{1}$$

Volume of destination transport is described by formula (2)

$$Dd_{jp} = a_{jp} \times t_p \times X_{jp} \tag{2}$$

Where Do_{ip} (Dd_{jp}) is the volume of origin (destination) transport of zone i (j) by purpose p, a_{ip} (a_{jp}) is specific moving of an structural element X_{ip} (X_{jp}); X_{ip} (X_{jp}) is a structural element of beginning or ending activity; t_p is proportion of the trips during observed period for purpose p.

The volume of transport is divided between the solved zones in the next step and *O-D* Matrix is created by a trip distribution.

3.1 Methodology of the trip distribution

The simpliest method for calculation of the trip distribution is a method of growth factor. The predicted trips are depended on observed trips at present and some growth factor, outgoing from the zone development forecast. The more effective and the most common method is the gravity model derived from Newton's Gravitation Law. The basic structure of the model is as follows:

$$D_{i,j} = \frac{D_i \times D_j \times k_i \times k_j}{w_{ij}} \,. \tag{3}$$

Where $D_{i,j}$ is the number of trips between zone i and j, D_i is the total trips produced in zone i, D_j is the total trips attracted to zone j, k_j, k_j are constants derived so the model could satisfy the production and attraction constraints, w_{ij} is a deterrence function that describes a disutility of travel.

A very simple gravity model substitutes the total trip produced in zone i and attracted to zone j by number of inhabitants and deterrence function that is described only by a distance between the zones (4).

$$D_{ij} = \frac{\alpha \times O_i \times O_j}{d_{ij}^2} \tag{4}$$

Where α is factor of region, O number of inhabitants, d distance between zones i-j.

The gravity model arises on the dependence of direction of transport flows by determination of the probability P_w of the transport relation between zones i-j. The function is named deterrence function $F(w_{ij})$. The classical deterrence function has the shape:

$$F(W_{ij}) = \frac{1}{f(W_{ij})} = \frac{1}{W_{ij}^{\alpha}} \,. \tag{5}$$

This type of deterrence function suits the overvaluation of traffic flows in specific conditions. The different shapes of the function are presented in Fig. 4 [2].

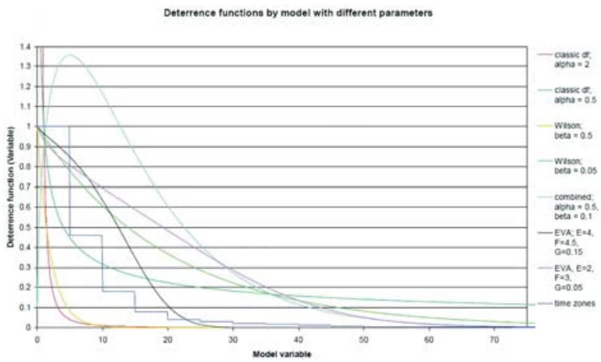

Fig. 4 Deterrence functions

The most frequently used formulae for the function description are:

- Wilson model:

$$f_{ij} = W_{ij}^{-\alpha} \exp(-\beta W_{ij}) \tag{6}$$

- EVA formula (Bayesian formula by Lohse and Lätzsch 1997):

$$f_{ij} = \frac{1}{(1 + W_{ij})^{\varphi(W_{ij})}}; \;\; \varphi(W_{ij}) = \frac{E}{1 + \exp(F - G \times W_{ij})} \tag{7}$$

Where E, F, G are parameters of travel mode, W_{ij} is resistance of the route, $\varphi(W_{ij})$ is deterrence function.

- Another author's models.

The next methods used for the trip distribution are Fratar's method, Detroid's method, method of entropy. Fratar's and Detroid's method established the local growth factor for definition of the region development. The entropy method is defined as a rate of uncertainty in a process of trip direction distribution

3.2 O-D Matrix

The result of the trip distribution is *O-D* Matrix (origin - destination). The origin (rows of matrix) represents the zone responsible for producing a trip; destination (columns of matrix) represents the zone responsible for attracting the trip. So in the same cell appear both the home to work and work to home trips; the sum of row values represents origin trips from the zone and the sum of column represents destination trips to the zone.

It is very important than the trip generation describes origin traffic volumes and the trip distribution describes interzonal relation. *O–D* matrix includes all the trips between the zones independent on type and transport mode. The *O–D* matrix can be seen in Fig. 5.

from i/$_{to\ j}$	1 … j … n	Σ	
1	D_{11}	O_1	
.	.	.	
i	D_{ij}	O_i	$(=\sum_j D_{ij})$
.	.	.	
m	D_{mn}	O_m	
Σ	D_1 … $D_j(=\sum_i D_{ij})$ … D_n	D	$(=\sum_i O_i = \sum_j D_j)$

Fig. 5 O-D matrix

4. Modal split

The third step of the transportation modelling is modal split among the available modes of travel. The travel mode must be allotted to each trip. The travel modes are defined like a one-person mode (cycle, car driver) and group's mode (walk, public transport, car passenger). PTV software uses a multimodal model with 5 modes. These models consider the time, costs and other characteristics of each mode. The characteristics determine a proportion of travellers which will choose each mode.

In the process of modal split the probability of particular mode choice is found. The logit model is the most frequently used for this activity. The logit model predicts the probability that an individual will choose a particular alternative (mode m) as follows:

$$P_{gij}(m) = \frac{e^{U_{gij}(m)}}{\sum_{k=1}^{M} e^{U_{gij}(k)}} \quad (8)$$

Where i, j are indices of the zones, g is the group of inhabitants, m is index of travel mode, $U_{gij}(m)$ is a group-specific utility if transport mode m is chosen to get from i to j. The quality of model is dependent above all on utility that accents a resistance of the travel mode to the route. PTV Vision defines this function by formula

$$U_{gij}(m) = -p_{1gm} * T_{ij}(m) - p_{2gm} * Z_{ij}(m) +$$

$$+ p_{3gm} * \log(D_{ij}/p_{4gm}) - p_{5gm} \times C_{ij}(m) + p_{6gm} \quad (9)$$

Where $T_{ij}(m)$ is travel time from i to j by transport mode m, $Z_{ij}(m)$ is a sum of access time i and egress time j for transport mode m, $C_{ij}(m)$ is a travel cost from i to j by transport mode m, $D_{ij}(m)$ is a distance from i to j, $A_{ij}(m)$ is an additional supply attribute, p_{igm} is parameter of utility.

The described coefficients are determined for each travel mode separately. The KONTIV 89 coefficients (PTV VISION) are nonfactual for Slovak conditions, so new ones are solved at present. Besides the logit model the *binary model* is used for two modes. The more complicated models are used in case of more travel modes (by example *NESTED model*).

The solved modal split in Žilina is presented in Fig. 6 for all the observed groups.

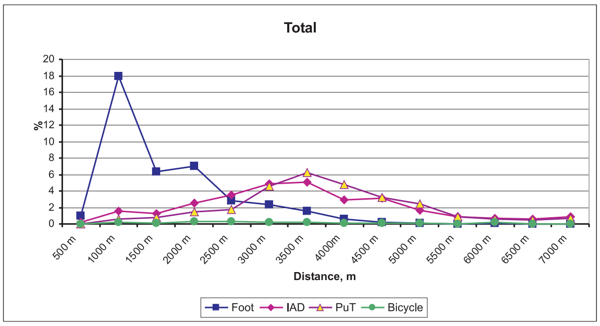

Fig. 6 Modal split according to distance

5. Traffic assignment

The final step of modelling is traffic assigning to the transport network using traffic assignment models. These essentially represent travellers' route choice decisions and would indicate the number of elements travelling between zones *i* and *j*.

The traffic assignment process requires traffic volumes between zones described by vehicle flows depending on car and public transport occupancy, and parameters of network, the capacity determination, of course. The parameters of network parts determine the travel time of the link. The more different methods are used for traffic assignment – equilibrium, self-teaching. The method of limited capacity is mostly used. First, the shortest path (in terms of travel time) between each origin and each destination is found. The assignment is realised by calculation of the capacity sufficiency and next routes are found in the next steps.

5.1. The model calibration

The model would be the working tool only in case of its comparability with the real conditions. O-D Matrix created from the realised analyses defines real matrix of interzonal transport relations. In addition the traffic censuses were realised within the of Žilina to compare real and calculated traffic loading of the road network. The complement of the model by further sociological and transport censuses will be the source of its next precision. The first results from the traffic analyses of Žilina can be seen in Fig. 6.

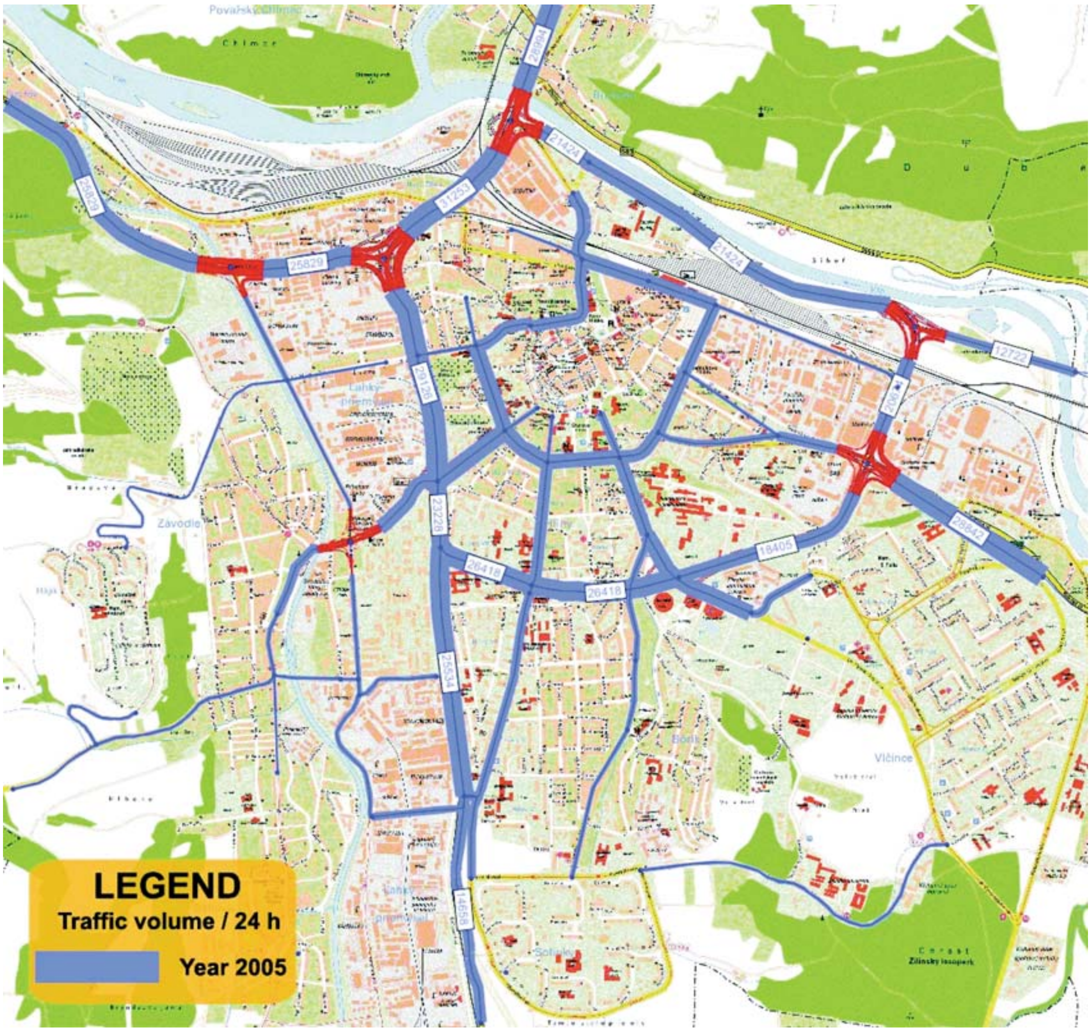

Fig. 7 Traffic loading of Žilina road network

6. Conclusions

Transport development is a very important part of the town's policy. Sustainable development of the regions needs the necessary increase of public transport depending on increasing demands of individual transport including traffic loading, parking problems etc. The complex traffic model is one of the best ways of exact and immediate solution of current problems.

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