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Road and Rail Infrastructure IV

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THE NATIONAL TRANSPORT MODEL
FOR THE REPUBLIC OF CROATIA – DEVELOPMENT
OF THE PASSENGER DEMAND MODEL

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Abstract

The Croatian Ministry of Maritime Affairs, Transport and Infrastructure commissioned the development of the National Transport Model to a Consortium combining local national knowledge with international expertise. The scope of the project is to develop the National Transport Model, collect all available data, carry out necessary surveys, develop networks models and demand models for freight and passenger demand for the base year, calibrate and validate the models, and develop forecast models for the time horizons of 2020, 2030 and 2040. This paper describes development of passenger demand model, including methodology, data collection and validation. Passenger demand model is an integral part of National Transport model that consists of common network with common zoning, passenger and freight demand models and assignment.

Keywords: Transport Model, Household survey, Origin-Destination Groups, Synthetic model

1 About the project

The National traffic model for the Republic of Croatia is co-financed by the EU from the European Regional Development Fund under Transport Operational Programme 2007–2013 within the project "Support for the preparation of the Republic of Croatia´s Transport Development Strategy and designing of the national Traffic Model for the Republic of Croatia – National Traffic Model for the Republic of Croatia".

2 Introduction – role of passenger demand model within a national transport model

There are several types and levels of transport models. Strategic are wider and more global, particularly suitable for strategic studies. They include in particular a direct correlation between urbanistic, socioeconomic and traffic conditions, and also between the elements of the transport system itself. This applies to so-called synthetic transport models. They cover very large, usually at least partially simplified, networks. National transport model for Republic of Croatia consists of passenger and freight models and is of strategic nature. While the network and zoning is equal, methodology differs between passenger and freight model. Basic model-based units are trip purposes for the passenger transport and types of vehicles as well as types of cargo for the freight (commodities). The results are presented in the "average workday traffic" unit in season and offseason, from which also the peak hour is developed.

Details of applications of national transport model and freight demand model are described in the other two papers of this conference, namely
• The National Transport Model for the Republic of Croatia – Application and Use [1]
• The National Transport Model for the Republic of Croatia – Development of the Freight Demand Model [2]

3 Model development

Passenger demand model consist of first three steps in traditional four-step model (Figure 1):
• generation (production and attraction),
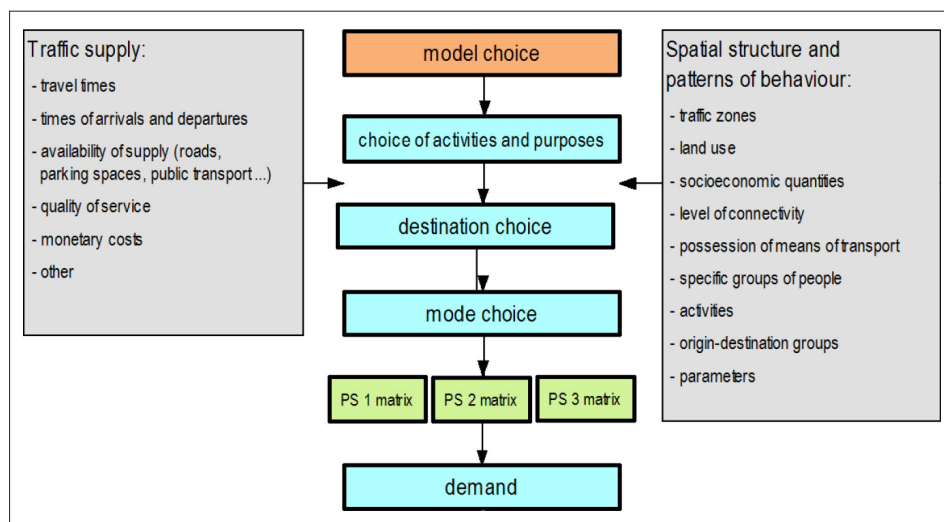• distribution and
• modal split.

Figure 1   Structure of passenger demand model

Production and attraction primarily depend on the gross domestic product, motorization rate and spatial socioeconomic structure as well as of behaviour patterns, whilst attraction also partly of the traffic supply. Distribution approximately equally depends on the spatial socioeconomic structure and behaviour patterns on one hand and on the traffic supply on the other. Modal split particularly depends on the traffic supply and to a considerable extent also on the spatial structure. Last step is assignment of demand on the multimodal network. Static stochastic learning procedure (Lohse) is used. Public transport is assigned by the intermodal method based on timetables. Both, internal and external transport, are assigned simultaneously.

3.1 Methodology

This approach enables that the forecast calculation considers changes in spatial structure, gross domestic product, motorization rate, residents, jobs, etc., as well as transport supply while calibrated parameters of the model remain unchanged.
Production and attraction were calculated by the method of origin-destination groups (13 origin-destination groups were considered for passenger transport). These 13 origin-destination groups actually represent 5 trip purposes (work, school, shopping, leisure and vacation, other) in conjunction with the location of residence and combinations between them. The trip purpose of business was specifically modelled.

From the household survey (performed within the project itself and described in 3.3) it was found that different parts of Croatia have different travel behaviour patterns. Therefore, the model of passenger transport production and attraction on the average workday was specially developed for Continental and Adriatic regions of the country. For each of the thirteen origin-destination groups a mobility rate (number of trips per day per person concerned) was determined. In most of these groups, the person concerned is a resident. However, in groups home-work, work-home, work-other and other-work, the concerned person is an employee, or in school trips, the person concerned is a pupil, secondary school or university student. Based on surveys across households in Republic of Croatia certain mobility rates were determined for all origin-destination groups. Development of the seasonal traffic was based on the same basis as the average workday model.

Thirteen origin-destination groups were taken into account to calculate the generation of passenger traffic, but the destination groups home-school and school-home were replaced by the destination groups home-vacation and vacation-home. Modified destination groups include trips from home to holiday and private facilities intended for vacation use (home-vacation) and trips in the opposite direction (vacation-home); there are no school trips during the holidays. Therefore, the purpose of (daily) leisure was extended for a special holiday subcategory of leisure (vacation). Distribution and modal split were calculated simultaneously. That is to say, at the same time the destination and the transport mode by which the trip is done were chosen. The calculation was carried out on the basis of the EVA probability function, for the average workday traffic and for the traffic during the tourist season. Input data for the distribution and modal split sub-model were:
• productions and attractions,
• generalized prices or generalized times for the road motorized and public transport,
• EVA model parameters.

Basic parameters of the model were set based on the stated researches, recommendations of the software manufacturer and previous experiences in modelling of the national and regional models. Based on these data and the EVA functions, within the multiple iterations, the trip matrices for passenger car transport, public transport, cycling and walking were calculated. Road assignment was carried out in several iterations. Based on the information obtained in the previous iteration, users find a new optimal route in the next iteration. Therefore, in the iterative process search for optimal route runs until the network equilibrium and the appropriate impedance matrix convergence were reached. Network assignment was based on the function of generalized price or generalized time. In seeking the optimal routes, also the effects of traffic congestions and jams were taken into account, i.e., the effects of driving speed reductions. BPR function was used for this, the most common volume-delay function, which reflects the travel time, depending on the volume and road capacity. It was useful both for modelling of non-urban and urban roads. Toll was incorporated through the function of generalized time, where the monetary values were converted into the equivalent of time.

Different free flow speeds were considered for freight transport than for personal transport, because also in free traffic flow the freight vehicles must not drive faster than allowed. Intermodal method for public transport assignment allowed the entire public transport network to operate as an unified system that includes rail, bus and maritime lines of various levels. The method, based on timetables, requires precise arrival and departure times of vehicles or trains at stations and stops to be set for all public transport lines. The network was therefore modelled in that way. For each origin-destination pair of zones a favourable connection was found or calculated. It was assumed that passengers are aware of the timetable, and will take the first available line of public transport offering a favourable route. Among various combinations of routes, more favourable routes were chosen. The most favourable routes were determined on the basis of the whole chain of route segments, including ticket price, which was included in the function of generalized time.

3.2 Network and zoning

The network system was composed of road and rail systems, airports, maritime and inland ports. The national and international connections were mainly established by primary road network (motorways, trunk roads and state roads), railway network and ports, Figure 2. In addition, roads in major urban areas have relevant functions for the national network and a significant impact on connectivity and accessibility. These network elements also serve as public transport routes and as alternative routes. Therefore, urban main roads were also included in road network. As result the following network elements were included in the model:
- Road network with all relevant levels (motorways; state, county, local and urban roads) with design standard and condition characteristics;
- Railway lines of importance to international, regional and local transport with design standard, traction, gauge, interoperability, conditions – restrictions and reliability characteristics, strategic national and international connections, capacity utilization, rolling stock, operators and safety;
- Public transport routes for rail, boat (ferry), tram, city and intercity bus lines with itineraries and rolling stock;
- Seaports (Rijeka, Zadar, Šibenik, Split, Ploče and Dubrovnik) with their characteristics, purpose and capacities;
- Inland ports (Sisak, Slavonski Brod, Osijek and Vukovar) with their characteristics
- Airports (Zagreb, Split, Zadar, Dubrovnik, Pula, Rijeka and Osijek), for which the land-side traffic will be modelled (by car, public transport and freight traffic);
- Intermodal facilities for passenger and freight transport.

Republic Croatia was divided into 985 traffic zones. Basic level for zoning were cities and municipalities. Traffic zones with population greater than 8.000 persons were brake down to lower level of territorial unit, i.e. city and municipality to settlement, settlement to statistical circle.
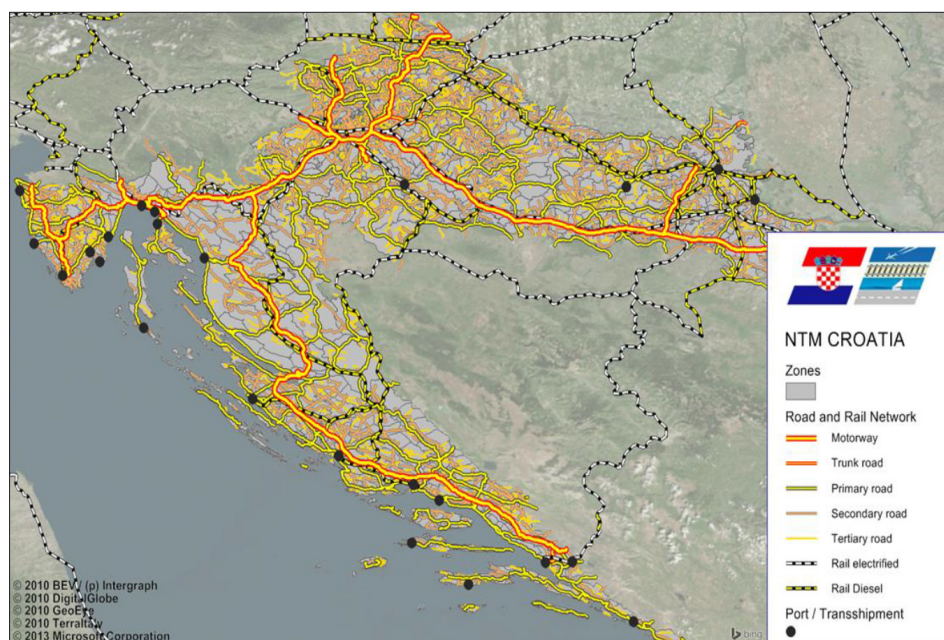

Figure 2   Road and rail network

3.3 Input data

The main input data of the passenger model is listed below:
• Transport network data for all modes (road, public transport),
• Socio-economic data, i.e. population and employment data, disaggregated to traffic zone level,
• Behavioural data from household survey (n=3.000),
• Transport cost parameters (distance related, time related, toll costs) per transport mode.

4 Model validation

In modern society the transport model represents one of the key bases for decision-making on transport and spatial policy, on the investments in the infrastructure demanding time and funds, on the form and dimensions of roads and railways, their impacts, etc. It is therefore important that the model results are reliable.

Reliability and credibility are the key characteristics of good and useful transport models. The necessary precision of the model is achieved by the calibration, whilst the reliability and credibility required are proved by the validation.

The growing role of the transport policy has initiated that transport models are becoming increasingly complex. Validation became an obligatory part of a model and the only way to justify its quality. Increasing complexity of models also led to greater complexity of the validation procedures. Validation procedure for the verification of the adequacy of the National traffic model for the Republic of Croatia (NTMC) was based on following documents:
• JASPERS Appraisal Guidance (Transport) The Use of Transport Models in Transport Planning and Project Appraisal, August 2014
• Design Manual for Roads and Bridges, Volume 12, 1997.
• Variable Demand Modelling – Convergence Realism and Sensitivity, TAG Unit 3.10.4, 2010.

Critical opinions on these documents and examples of good practice have also been taken into account.

4.1 Demand validation

Validation criteria for demand is less standardized than for validation of the assignment. Mostly due to lack of independent statistical data (as it is case with traffic counts and assignment). Nevertheless few quantitative and qualitative tests were done to prove the model. First step was checking the input data for demand that are socioeconomic and behavioural data. Socioeconomic data (number of population, workplaces, school places…) were taken from the official databases where they have already been submitted to various checks and should be reliable. There were some issues that required additional analyses (e.g. number of workplaces assigned to company's seat, no data available on shopping areas…).

Results of household survey were compared with existing data from previous studies and practice. It was established that most important indicators lie within expected benchmark values (e.g. between 2.5-3 daily trips per person, cca. 40% of work and school trips, characteristic morning and afternoon peak hours, average trip length and duration…).

First actual calculation for validation was done for trip duration distribution. Although such distribution is also input data, it serves also for checking results of the model. Modelled distribution is not only direct result from the survey, but also considers impedance (travel time, length…) between all pairs of zones, Figure 3.
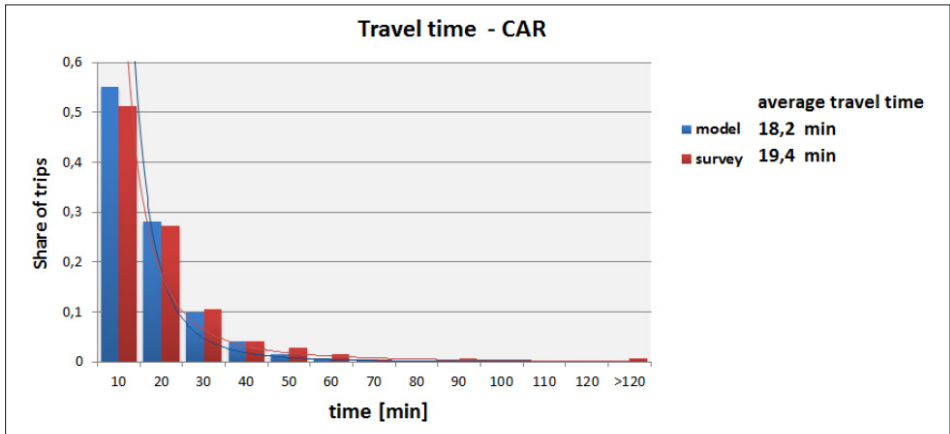
Figure 3   Validation of travel times distributions

4.2 Transport flow validation

Most traditional type of validation is validation of transport flows, Figure 4. Considering mentioned guidelines and recommendations we suggested following criteria to be accepted by the client for NTMC:
• R2 › 0,9
• 65% of GEH ‹ 5
• 85% of GEH ‹ 10
• difference in transport work ‹ 3%

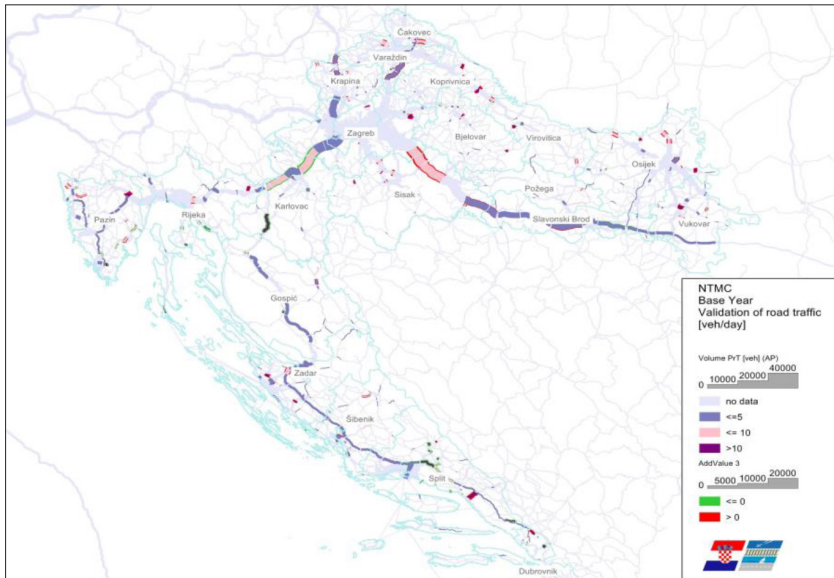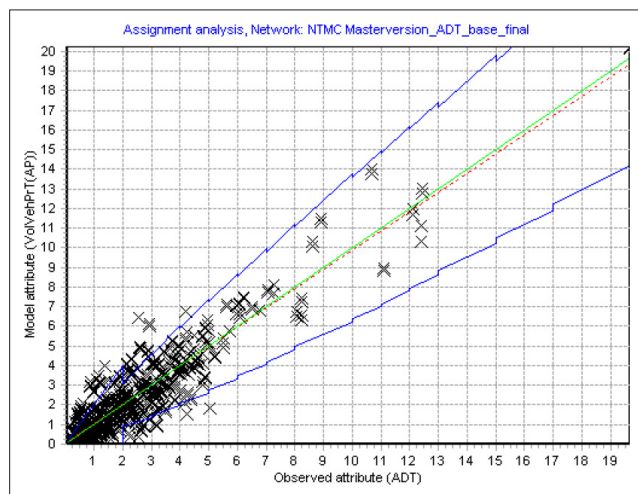In the table 1 and figure 5 goodness of fit is presented.

Figure 4   Validation of link volumes

Table 1 Goodness of fit

	correlation	GEH ‹ 5	GEH ‹ 10	difference [veh*km]
offseason weekday	0,94	67%	88%	‹ 1%
offseason peak hour	0,91	65%	91%	‹ 1%
season weekend	0,96	70%	82%	‹ 3%
season peak hour	0,92	61%	84%	‹ 1%

Figure 5   Correlation between observed and modelled car flows (weekday in offseason)

Only two indicators do not match expected criteria, but this is for season traffic, where input data were less reliable (no household survey, data about overnight stays, count data).
With the use of matrix estimation for internal (Croatian) traffic numerical results would be much better and would fit all criteria. We do not encourage it, as this would decrease quality of forecasting models.

4.3 Realism test

If a model adequately reproduces the existing situation, it does not yet mean that it is appropriate for traffic forecasts. The demand model should also behave realistically. A change in the traffic supply should lead to a realistic change in the demand. A change in the demand should be consistent with general experiences. A change in travel time or trip price (cost in one word) particularly affects the mode choice and trip distribution. This impact must be in realistic limits. Acceptability of the model response is determined by the elasticity of demand. The equation of arc elasticity is as follows:

$$e = (\log (T1) - \log (To)) / (\log(C1) - \log (Co)) \tag{1}$$

where:
e   – elasticity;
T1   – demand after change;
To   – demand before change;
C1   – changed travel cost;
Co   – original travel cost.

Recommended elasticities for 20% changes in costs are presented in Table 2. According to the WebTAG recommendations, the elasticity on travel time must be significantly greater than on monetary costs, but not greater than -2.0. This means that a change in travel time has a significantly greater impact on the demand than a change in monetary cost. However, also the latter influences to some extent. But with the increasing value of time, travel time gains importance, whilst the impact of direct monetary costs decreases.

Table 2   Recommended elasticities of demand to a change in supply

mode	travel time change	recommended elasticity	result [change in car]	result [change in public transport]
car	± 20%	$\langle -2,0^{[4]}$	-0,29 to -0,38	0,58-0,66
public transport	± 20%		0,28-0,35	-1,42 to -1,66

Sensitivity of the model must be within the recommended limits. For passenger cars the sensitivity is tested to a 20-percent change in travel time. Sensitivity for cars is between 0,29 and 0,38. This is consistent with the WebTAG recommendations. For public transport the sensitivity is also tested to a change in travel time. Sensitivity to the change in travel time is greater than for passenger cars and is 1,42 to 1,66, but still well within benchmark. Elasticity is negative in all cases. It means that the reduction of travel time results in more trips, whilst the extension of travel time causes fewer trips. Based on the sensitivity analysis we concluded that the model responds realistically on systemic and developmental changes and is therefore suitable to offer realistic traffic predictions. This test demonstrates an ability for a real change in modal split.

5   Limitations, applications and further use

Advantages of having validated complex national transport model are explained in the paper "The National Transport Model for the Republic of Croatia – Application and Use" [1] of this Conference. It is only fair that the developers of such powerful tool point out also its limitations. As it was mentioned in the second chapter, National traffic model for the Republic of Croatia is strategic model and as such particularly suitable for strategic studies. This also means that it is not automatically suitable for all kind of transport studies. Although there are 985 traffic zones in Croatia, such strategic zoning cannot provide accurate and reliable results for e.g. municipal bypasses, local public transport, tertiary roads, specific junctions... Second aspect of national model is that behavioural data observed with household survey are reliable on the distinction between Continental and Adriatic Croatia (e.g. specific differences between Istria and Dalmatia or between Karlovac and Osijek are not represented in the survey results). Another consequence of probabilistic methods used in national transport model is that trips with very low probability (established in surveys) are sometimes calculated as zero values. This of course affect only specific (less frequented) sections and does not influence model results on strategic level. All mentioned shortcomings can be vastly improved by further development of the model where we would suggest:
• development of regional models where national model serves as methodological foundations and basis of interregional/international flows
• additional household surveys on level of regions, municipalities using same/similar methodology (this would enable further refinement of next versions of national transport model as well)
• specific modal survey especially on public transport in order to gain better insight in its specifics.

Part of the project is also development of maintenance process which should serve as starting point for further activities wit national transport model.

6 Conclusion

Passenger demand model is an integral part of the National traffic model for the Republic of Croatia, commissioned by The Ministry of Maritime Affairs, Transport and Infrastructure. During project duration socioeconomic data were collected and analysed, household survey executed, model developed and in final step validated. The result is a powerful tool that needs to be used according to professional rules.

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