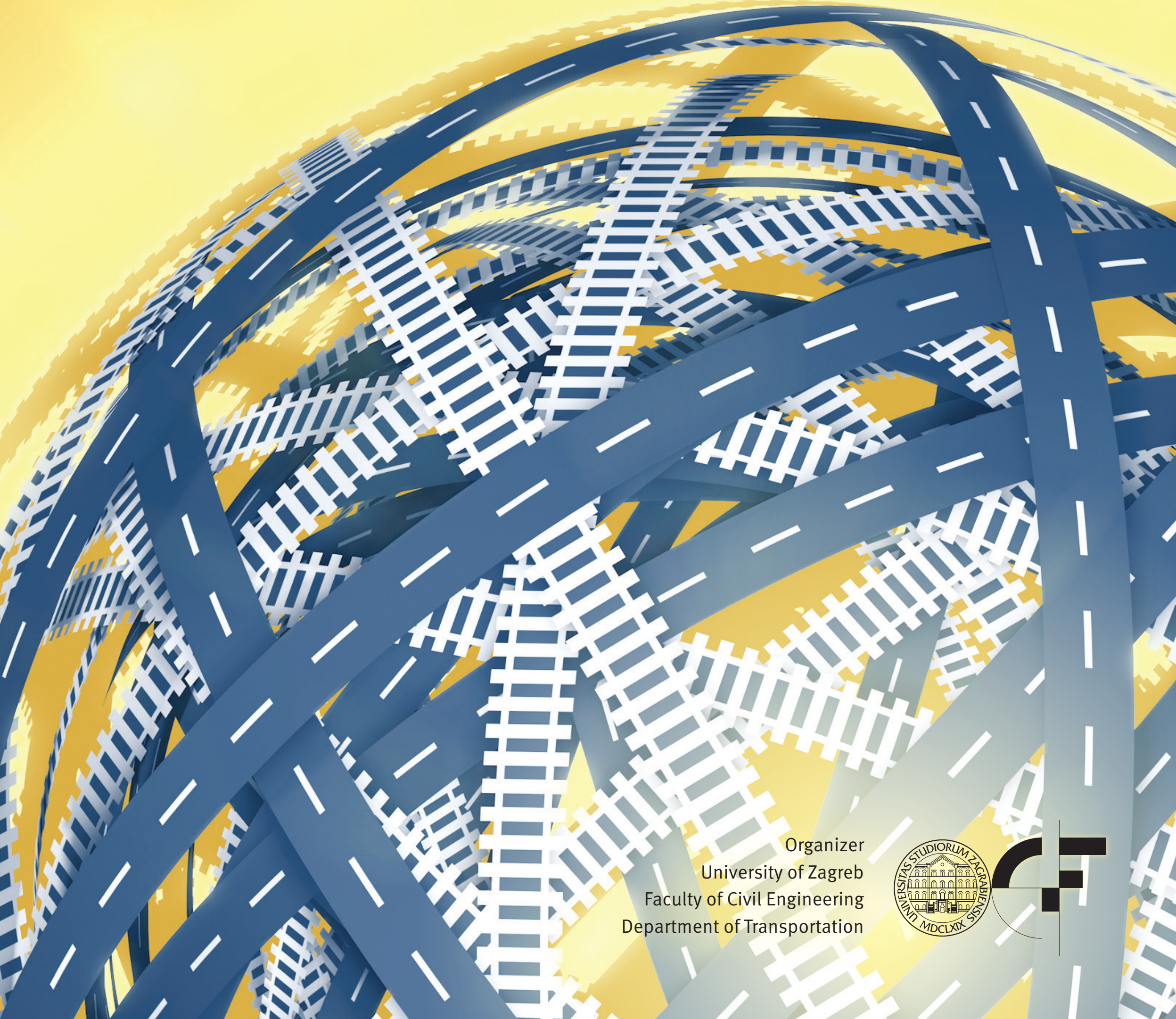
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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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 FREIGHT DEMAND MODEL

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Abstract

National transport model of Croatia (NTMC) consists of network, demand and assignment submodels. Whilst network model (nodes, links, zones) is common, approaches for demand and assignment differ between passenger and freight transport. Each type of transport requires specific methods. This paper describes development of the freight demand model, namely its input data, modelling methods, calibration and validation.
The main inputs for modelling of freight transport are socioeconomic data and national statistics on production and trade flows (import / export). Socioeconomic data was collected on the zoning level. For production and import / export, the statistical data was available at national level and was broken down to zoning level according to the socioeconomic data of each zone. Main source for socioeconomic data (population, employment, working places by economic sector) were national statistics (Croatian Bureau of Statistics). Sources for production data depend of the type of commodity, while import / export data was derived from the national trade statistics. The freight demand model considers all transport modes relevant from a national perspective, i.e. road (HGV and LGV), rail and vessel. The modal freight trip matrices are calculated with a commodity based multi-modal model using an enhanced 4-step approach. For the adequate consideration of commodity-specific affinities, the freight traffic is segmented into 50 different commodities; each of them having specific generation and attraction rates as well as specific modal transport cost rates. The calculation steps of the enhanced 4-step approach are conducted separately for each commodity. The multi-modal freight model, which mainly generates the long-distance trips, is supplemented by a sub-model for generating the freight trips from / to the airports and by a sub-model for the local (short-distance) distribution trips by HGV and LGV.

Keywords: transport model, freight demand model, calibration, validation

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

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 National Transport Model comprises both, a transport demand model for the passenger traffic and a transport demand model for the freight traffic. National transport model of Croatia (NTMC) has been developed for the base year first. After calibration and validation of the base year, forecast models for the time horizons of 2020, 2030 and 2040 have been developed. NTMC consists of network, demand and assignment submodels. Whilst network model (nodes, links, zones) is common, approaches for demand and assignment differ between passenger and freight transport. Each type of transport requires specific methods. This paper describes the development of the freight demand model, namely its input data, modelling methods, calibration and validation and model results.

3 Freight demand model

Freight transport as a whole is a very complex and heterogeneous process. The multi-modal freight model follows a highly disaggregated approach to calculate the freight volumes based on origins and destinations of homogenous commodity types. This includes both, domestic freight flows and external freight flows (import/ export/ transit). The freight model considers all transport modes relevant from a national perspective, i.e. road (HGV and LGV), rail and vessel. The same network as for the passenger model is used, enhanced with additional mode-specific freight parameters and transhipment infrastructure for intermodal handling of goods.

3.1 Approach

The modal freight trip matrices are calculated with a commodity based multi-modal model using an enhanced 4-step approach. As a big advantage of this synthetic multi-modal approach, the proposed methodology guarantees:

- the adequate consideration of commodity-specific affinities regarding different transport modes,
- the ability to reflect multi-modal transport and inter-modal transport chains,
- a realistic calculation of future freight demand based on socio-economic changes and/ or network modifications (e.g. new links or transhipment hubs),
- the consideration of all possible transportation modes for route choice.

Figure 1 shows the calculation steps, which are applied for the multi-modal freight model calculations. These steps are calculated separately for each commodity to consider their specific characteristics regarding freight generation, distribution, mode choice and assignment. The different commodity types, which are considered, range from agricultural goods (e.g. cereals, fruits, vegetables), raw materials (e.g. coal, raw wood, ores), oil products, industrial products (e.g. steel and metal products, chemical products) to construction materials and consumer goods.

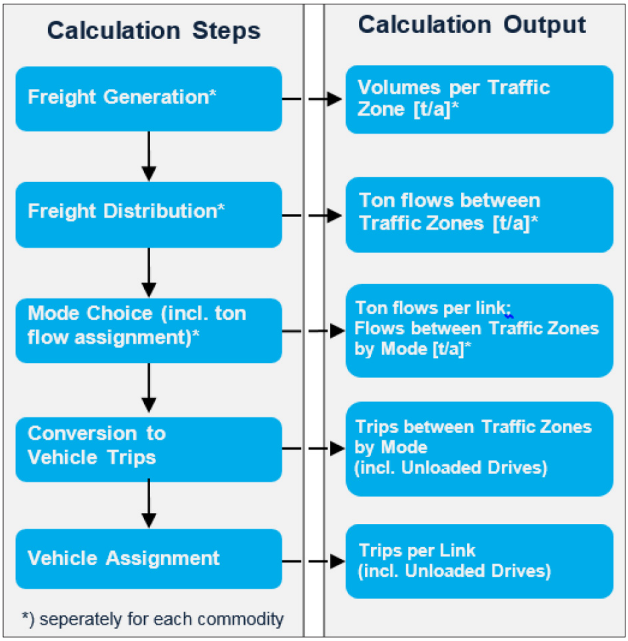

Figure 1 Freight Model Calculation Steps

Freight Generation

In practice, the reasons for the transport of goods are the different locations of production and consumption of a certain good and the resulting need of exchange. Hence, as a first step of the demand calculation, the generated volumes per traffic zone are determined for each commodity. This is done both for the production side (also referred to as origin side) and the consumption side (also referred to as destination side). In general, the determination of origin and destination vectors is conducted in 2 steps:

1) Determine production and consumption volumes on national level for Croatia and the countries of the region
2) Break down of these national volumes to traffic zone level

On national level, there is the constraint that the total generated volume of all origin zones must equal the total generated volume of all destination zones. While the origin volumes consist of local production volumes and import volumes, destination volumes are the sum of local consumption and export.

$$\sum_i \text{FreightVolumes}_O = \sum_j \text{FreightVolumes}_D \tag{1}$$

$$\sum_i (\text{Local Production} + \text{Import}) = \sum_j (\text{LocalConsumption} + \text{Export}) \tag{2}$$

Where:

O; D – origin; destination;
i – index for origin traffic zone;
j – index for destination traffic zone.

The production and consumption volumes on national level are broken down to traffic zone level by the distribution of the decisive land uses for each commodity. Depending on the type of commodity, decisive land uses can be for example population, employees by economic sector as well output/ production capacities of production facilities. Thus, calculating the local production and consumption per zone and adding the import/ export volumes, for each commodity two vectors are generated. One includes the generated origin volumes per zone, the other vector the attracted destination volumes.

Freight Distribution

Like traffic generation, distribution calculation is applied successively and separately for each commodity. Using a gravity model, the generated origin and destination volumes per zone are distributed, resulting in yearly ton flows between the traffic zones. The trip distribution calculation is carried out in 2 steps:

1) Calculation of evaluation matrix based on a skim matrix including the impedances between traffic zones
2) Calculation of trip matrix (yearly ton flows) based on the evaluation matrix and the origin and destination volumes

A monetary impedance matrix calculated from the VISUM network model is used as skim matrix. The matrix values in [€] are calculated with the following impedance function.

$$w_{ij} = \sum C_{handling} + \sum (Length \cdot c_{km}) + \sum (Time \cdot c_h) \quad (3)$$

where:

w_{ij} – impedance between traffic zone i and traffic zone j [€];
$C_{handling}$ – handling costs [€];
c_{km} – distance cost rate [€/km];
c_h – time cost rate [€/h].

For all commodities, different impedances (costs) result from:

• different cost rates for required logistic system (e.g. bulk, container) and
• different requirements for transport speeds due to varying urgencies (loss of value)

Mode Choice

The route and mode choice are conducted simultaneously in an interim assignment step for the ton flows. The ton flow matrices of each commodity are assigned to the multi-modal network with an equilibrium assignment procedure.

The mode choice decision for a certain commodity and origin-destination relation is based on the transport costs. It is always the most cost efficient route and transport mode that is chosen. This can be either a direct transport with one transport system or a multimodal chain with a combination of transport modes and transhipments in between. As illustrated in Figure 2, the total transport costs, which are the determining factors for the route and mode choice during the assignment, consist of:

• Time costs (mode specific time costs + commodity specific loss in value)
• Distance costs (mode specific distance related transport costs)
• Handling costs (costs for loading/ unloading and transhipment)

The modal transport costs are allocated to all network links. Different sets of transport costs consider:

• The link attributes (permitted transport mode; transfer link) and
• The logistic system, the commodity is allocated to

As noted before, the ton flow matrices of each commodity are assigned to the multi-modal network with an iterative equilibrium assigning procedure, resulting in the most cost-efficient route and mode choice for each OD relation. From the multi-modal ton flow assigment, ton flow matrices by mode can be derived.

Conversion to vehicle trips and vehicle assignment
The modal ton flow matrices are converted to vehicle trip matrices by average loading factors (depending on distance classes) and a factor for the unloaded drives. Finally, the generated HGV and LGV trip matrices are assigned to the PTV Visum network together with the trip matrices from the passenger demand model.

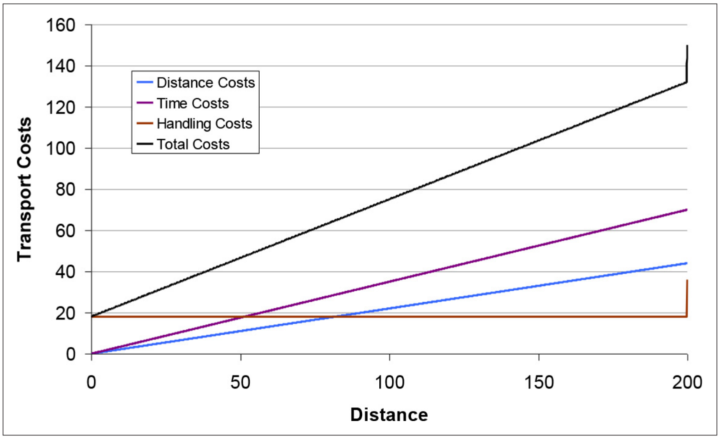

Figure 2 Composition of total transport costs

3.2 Input Data

The main input data of the freight demand model is listed below:
- Socio-economic data, i.e. population and employment data, disaggregated to traffic zone level,
- Data on national production (production volumes, location of major production facilities) for each commodity,
- Import / export data from trade statistics, aggregated to about 50 freight model commodities,
- Transit data from UN COMTRADE statistics in, aggregated to the freight model commodities,
- Transport cost parameters (distance related; time related; transhipment costs) per transport mode for the route and mode choice calculation,
- Operational parameters (e.g. average loading factors and share of empty trips by commodity and vehicle type),
- Growth rates and macro-economic parameters are required for forecasting internal and external freight flows.

4 Results

The main results of the multi-modal freight model are summarized below:
- Generated and attracted volumes per commodity and traffic zone in tonnes per year (see Figure 3),
- Yearly ton flow matrices by transport mode (rail, road, ship),
- Daily trip matrices (HGV, LGV),
- Link volumes in tonnes per year (see Figure 4) and HGV / LGV trips per day.

4.1 Base Year Results

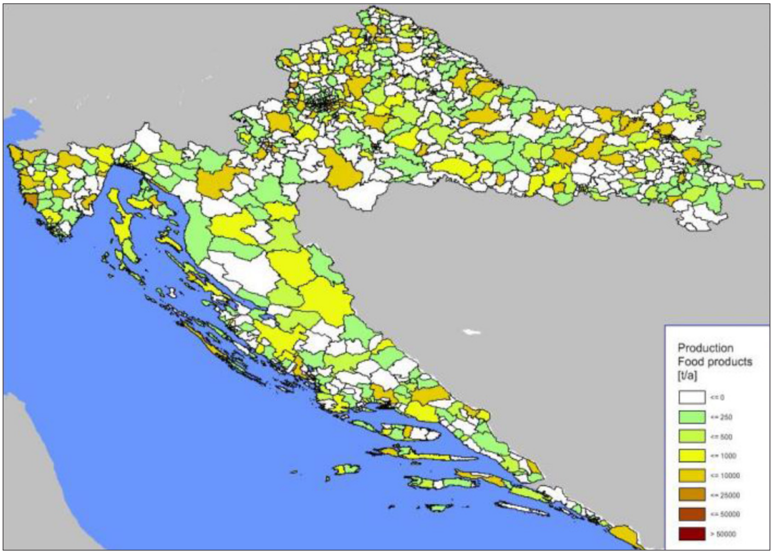

Figure 3 Production / attraction volumes per zone for each commodity

Figure 4 Link volumes by transport mode in tonnes per year

4.2 Model calibration and validation

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 proven by the validation.

Validation procedure for the verification of the adequacy of the national transport model of Croatia (NTMC) is based on internationally recognized guidelines:
• JASPERS Appraisal Guidance (Transport) [1]
• Design Manual for Roads and Bridges, Volume 12 [2]
• Variable Demand Modelling – Convergence Realism and Sensitivity [3]

Critical opinions on these documents and examples of good practice have also been taken into account. Considering all above mentioned guidelines and recommendations the following validation criteria have been settled:
• R2 › 0.9
• 65% of GEH ‹ 5
• 85% of GEH ‹ 10

For the freight model, the calibration and validation process comprises three levels:
• total national freight volumes by mode [tonnes]
• port and border crossing volumes [tonnes]
• freight vehicle volumes at 480 count locations

For all validation levels, a satisfying model quality is achieved. Figure 5 presents the correlation between observed and modelled HGV volumes at the count locations. The correlation factor R2 is 0.92 and 95 percent of the count locations have a GEH ‹ 5.

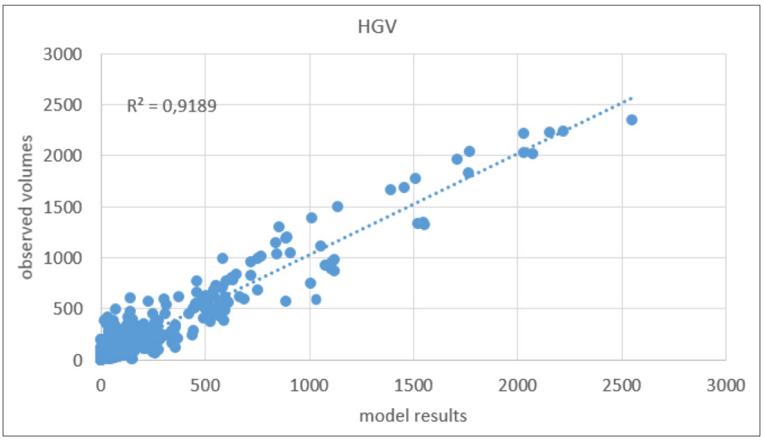

Figure 5 Correlation between observed and modelled HGV volumes

4.3 Forecast results

currently, the reference scenarios for the forecast horizon years 2020, 2030 and 2040 have been finalized.
Forecasting political and (macro-) economic developments, in turn effecting production, consumption and hence transport, were beyond the scope of the NTMC study. Therefore, established growth factors published in several EU studies were used to calculate the expected freight flows for the respective forecast horizons.
The do-something scenarios are under development. From the results of the reference scenarios, the total development of import, export and transit traffic by commodity groups can be analysed as presented in Figure 6.

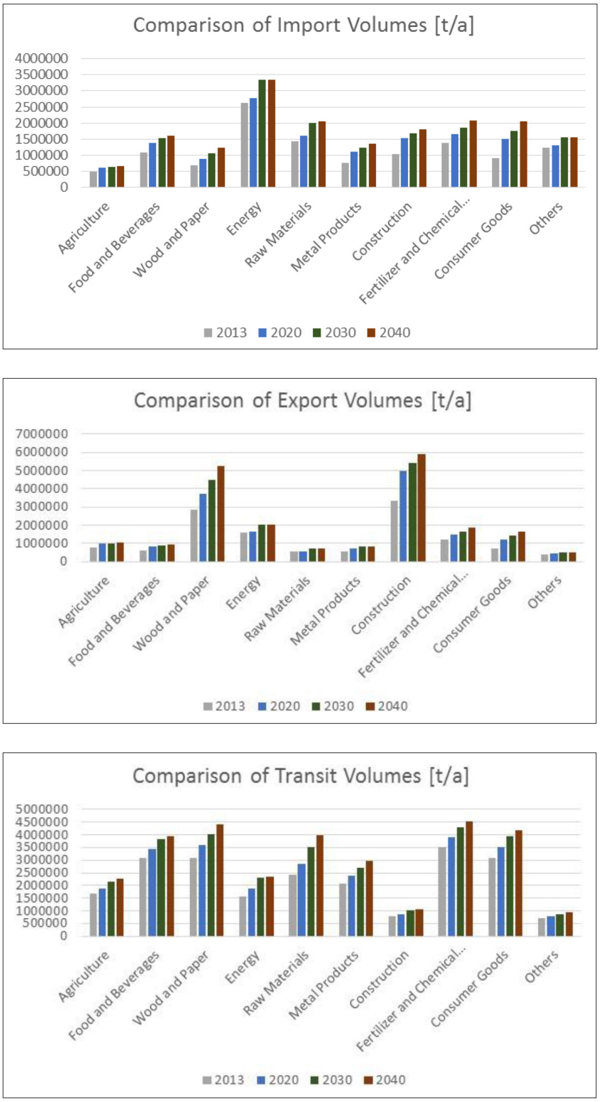

Figure 6 Comparison of import, export and transit volumes by commodity group between base year 2013 and forecast horizon years

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