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STUDY AND EVALUATION OF THE SPLIT RING-ROAD TRAFFIC FLOWS

ABSTRACT

For the needs of the traffic model of the Feasibility Study of the Split ring-road, a traffic survey was carried out at 15 places. The result of this research is a travel matrix that contains 93,885 trips in the base year. The analysis of the data and distribution of trips was done by the program package Visum. The traffic forecast was done for the period from 2001 to 2028 by the method of equal growth factors. The output results were used for the economic evaluation of the project.

KEY WORDS

traffic model, traffic forecast, travel matrix

1. INTRODUCTION

This work presents the traffic model of the Split ring-road, for the needs of the road construction feasibility study. The model, generally, presents the procedures for complete description of the existing and forecast of the future traffic flows, within the scope of the road project. Three basic input data are necessary for such a description: first, in order to obtain the data on the origin-destination, purpose of the trip and goods flows the surveys (interviews) are necessary on the very roads; second, in order to implement the data from the survey sample to a wider base the counts per vehicle types are necessary, and third, in order to adapt the data obtained through surveys (interviews) to the average annual daily traffic, factors are necessary that have been deduced from the existing permanent or periodic traffic counts.

One of the most burdened sections of state roads is the Split ring-road. The ratio between the throughput capacity and the offered capacities is least favourable on the section of this road from Stobreč to Omiš. Unfortunately, the research and distribution of traffic flows do not offer the alternative route from Stobreč via Žrnovnica and Gat with tunnel connections below Perun between the new section and the section of the existing state road Stobreč – Podstrana – Dugi Rat – Omiš. This would lower the cost of the construction of this section, and the sun-exposed side of Perun could be used for the residential high-quality tourism.

2. TRAFFIC RESEARCH

Only those trips will be analysed that have been surveyed during the recording. Therefore, the surveys should encompass the main seasonal movements. Maximum accuracy can be achieved by carrying out the survey at times when all the trip purposes are widely represented.

All the data of traffic research have to be adapted to the average annual flow per vehicle types.

Within the feasibility study of the project it is necessary to determine only the traffic which will be affected by the designed road. Therefore, the locations of recording will be based on the subjective evaluation of the road network for closer determination of those road sections on which this influence occurs. This will encompass the entire traffic that can be diverted from other roads to this road because of design improvements.

The selection of the recording places (survey locations) should be such as to enable the inclusion of all or a satisfactory number of trips. All the movements that are not included will be estimated or eliminated from further analysis. The not-included trips can be estimated as the difference between the average annual daily traffic (AADT) and volume of the traffic distributed to this section. The survey locations should be distributed along road routes affected by the road design, between all the main origins of traffic flows and intersections of traffic flows.

Table 1 - Traffic research time

Day	Date	Duration
Thursday	23 Aug. 2001	7 - 18h
Thursday	25 Aug. 2001	7 - 18h
Tuesday	9 Oct. 2001	7 - 17h
Thursday	10 Oct. 2001	7 - 17h
Saturday	13 Oct. 2001	7 - 17h
Sunday	14 Oct. 2001	7 - 17h

The traffic flow volumes during an average day will be the same in both directions. This would assume that there is no constant or periodic migration of vehicles. In the extreme case, this would assume that the tourist traffic volume is the same in both directions. However, goods flows are not equal per flow directions. Therefore, it is necessary to carry out the surveys in both directions of travelling. If it is sufficient on the main road to survey only in one direction the vehicle trips, that do not carry goods, then the summary tables of trips in the analysis of traffic recording have to be adjusted in such a way as to encompass both directions. However, in order to increase the sample size, it is better to carry out the survey in both travel directions.

The survey locations need to be set in such a manner as to present minimal danger to the safety of the traffic participants. The access from the road to the survey locations has to insure good distance of visibility with huge warning signs. At these locations there should be adequate carriageway and shoulders of such a width that the queuing time is reduced to minimum.

2.1. Traffic zones

Data about the origin and destination are closer determined per traffic zones. Since the accuracy of obtained data and the success of the invested efforts depend to a great extent on the number of zones in the studied area, great attention should be paid to their choice. The most direct procedure is to use the survey to make a better determination of single locations of trip origin and destination. These data can then be observed and combined in a suitable manner into single zones for analysis.

In preparing the traffic zone maps, the following three measures need to be considered:

1. Each zone has to be the origin and create significant traffic volume. If the number of recorded origins or trip destinations of a certain area is small, then this area should be combined with others in order to form one traffic zone.
2. Every zone should have one or several determined connections with the road system (network).
3. One or several zones should be entirely located within the borders of the social and political community (administrative units) which has available social and economic data. In this respect, it should be noted that the district is the smallest social and political community with available basic social and economic data.

These three mentioned measures are sufficient for determining of the minimal number of zones required for the traffic analysis. Better, complete zone map can be the result of the higher invested analytic effort. The collected social and economic data for each zone, however, will be averages for these zones, so that the size of these zones will depend also on these considerations.

After having marked the traffic borders more narrowly, the road network is established by connecting the main activity centres of every zone including, when necessary, the border crossings. The main centre of activity is almost always the biggest town in the zone. It should be noted that thus closely determined (identified) network includes both those roads which accommodate the existing traffic under consideration, and the roads from which traffic could be diverted, as result of the proposed road improvement.

2.2. Data expansion

All the data from the survey are adapted to the average annual daily flow. The adapting of data to AADT includes: adjustment (expansion) of the samples of hourly surveys, adapting to the 24-hour period and adapting to the average annual daily traffic – AADT. In order to perform the adapting usually the data on continuous traffic count are necessary.

These counts can be representative for various counting locations or strictly related to every single counting locations. Besides, the required data can be deduced from the available data on counts performed in previous years, or from the counts done during the traffic survey. Obviously, the data on monthly variations can be obtained only on the basis of the data from previous counts (so-called history data).

If the sample surveys are done per hours, these counts per hours should exist for every counting location (because of different sizes of collected samples at different counting locations, the representative variations cannot be determined).

Adjusting of data to 25-hour period can be done by the application of representative counts. However, this procedure is enormous, except when, within every representative group, the survey periods are constant.

Seasonal variations of traffic have to be done from continuous counts from previous years. This requires the pilot, i. e. orientation counts.

All the data on traffic counts should be classified according to types of vehicles. When counting is done

by automatic counters (which register only the total number of vehicles, and not the number of vehicles per single types), then the structure of vehicles can be determined only by orientation manual counts and therefore such counts have to be performed.

The representative counts basically mean that the traffic characteristics have been determined at orientation count locations, they are representative for these same traffic characteristics at those count locations to which these variations are applied. The representative count locations are classified into urban or suburban ones, tourist or non-tourist ones, as well as according to different volume of traffic or significance of the road.

For those survey locations at which surveying was done several days in a week (e. g. the middle of the week and on Sunday), the average annual daily traffic may be calculated by applying the factors on the obtained data.

Monthly variations per individual types of vehicles are obtained from continuous counts on representative roads. These data can be classified per types of vehicles on the basis of periodic manual counts.

3. DATA ANALYSIS

Full overview of the procedures used in the analysis of survey data has been presented in the processing flowchart. The computer-processing of the analysis has been programmed in a package which consists of a program for database processing (Access, Excel).

The recommendation is to eliminate random, minor errors from further analysis. However, if the error includes an entire block of data, e. g. all the data of a one-hour survey, then these data need to be corrected and then re-included in the program.

In making the travel table, further analytical processing is necessary in order to eliminate multiple counts of the recorded same vehicles.

In the influencing area of the future road improvement, over a certain period of time, traffic surveys will be carried out at many locations. Therefore, vehicles that pass by two or several survey locations will be double-counted (this expression includes also multiple counts). This may happen regardless of whether sample surveys are done or 100-percent surveys, that is, whether the survey is done in one day or the survey takes several days. In order to eliminate double-counts, the use of stickers on the vehicles is not recommended, since such method may result in errors, especially in adjustment (expansion) of data from the sample. Apart from that, stickers are not suitable for surveys of more than one day.

The best estimate of the travel characteristics between two zones will be obtained, therefore, from the averages of the data collected at all survey locations, at which these travels have been recorded. In this way, the survey data can include the factors that show the number of surveyed locations through which such a vehicle has passed.

All the recorded data on the number of travels between arbitrary pairs of zones will be divided by adequate double-count factor.

The simplest way of calculating the double-count factor is to analyse the data lists per origins and destinations of trips and the number of survey locations, which is obtained by the Visum program. If necessary, this analysis can be done per types of vehicles, regarding the possible choice of different traffic route of each type of vehicle.

When traffic between two zones flows along different, numerous routes passing by a different number of count locations, then the double-count factors have to be determined by weighting the traffic volume on certain sections (road routes), thus calculating various double-count factors for each survey location.

4. SAMPLE SIZE

Traffic sample surveys need to be done on the main roads during every hour. In that case, the data obtained by surveys are adjusted (expanded) to daily averages by using the data from the previous, i. e. current counting hours.

The sample sizes can be different and need to be random ones. The adjustment (expansion) of data

Table 2 - Size of the survey sample

Survey location	Surveyed	Counted	% of survey sample
1	230	681	34%
2	635	1355	47%
3	589	5134	11%
4	260	576	45%
5	978	7459	13%
6	674	1604	42%
7	1396	5307	26%
8	468	1943	24%
9	1138	8193	14%
10	475	2339	20%
11	990	4721	21%
12	1039	4666	22%
13	353	564	63%
14	186	319	58%
15	839	3400	25%
Average	683	3217	21%

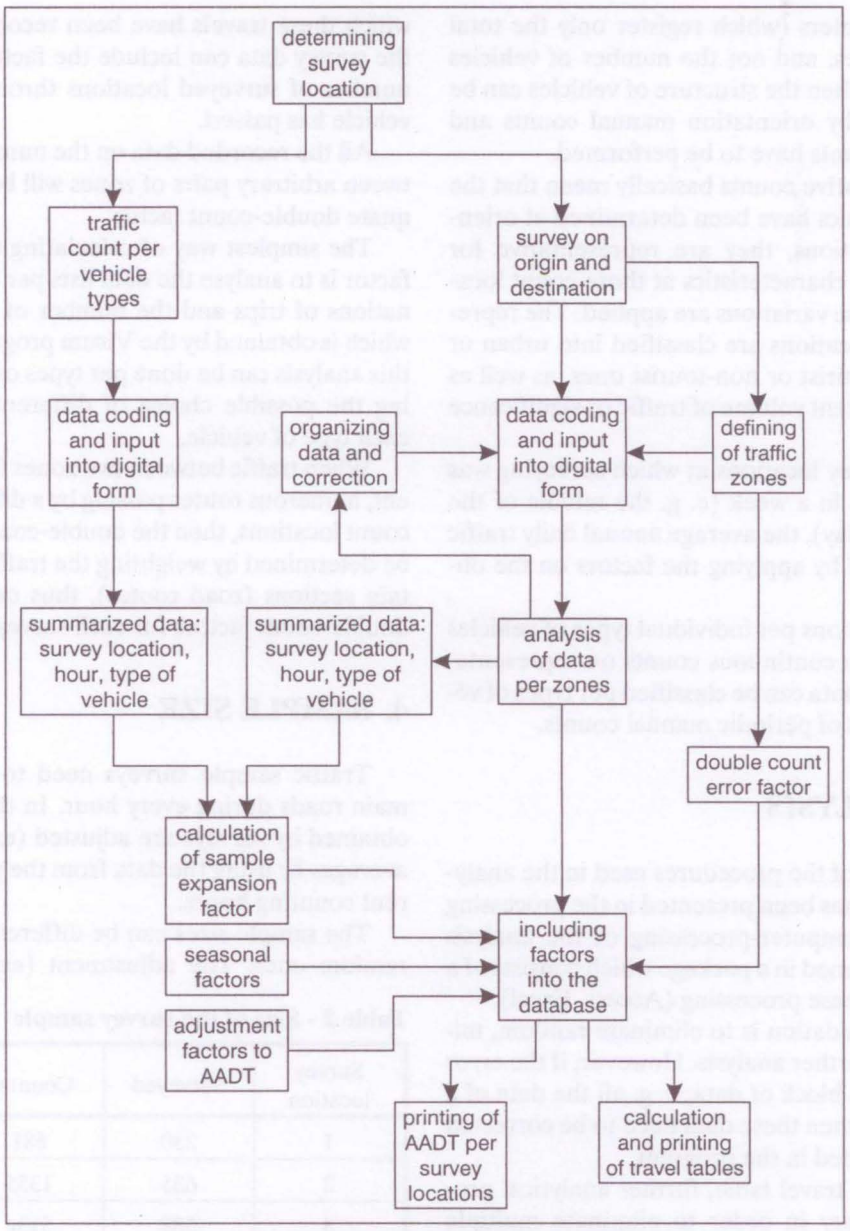

Figure 1 - Data processing flowchart

need to be per hour and type of vehicle for every single survey location.

Minimal size of the sample depends on the level of required accuracy, entire traffic volume and size of the used traffic categories. The latter parameter refers to the number of inter-zone movements at any survey location and to the level of data analysis according to vehicle types, types of goods, purposes of travelling, etc.

Since it is impossible to monitor the multiplication of possible errors during the development of the entire feasibility study, the category-definition regarding the selection of minimal required sample size of the survey data is of no use. However, the fact is the bigger the sample the more accurate the data.

5. TRAFFIC FORECAST

Future traffic forecasts are necessary in order to determine the technical elements of road construction (route), to estimate future road maintenance costs as well as future cost flows for the road users.

Total traffic on the designed road consists of the existing traffic and its normal growth, additional traffic redirected from other roads and other transport modes, as well as traffic which is newly created (induced) exclusively thanks to the reduction in transportation costs caused by road improvement. Although the construction project and maintenance costs require estimate of the total traffic, the analysis of users' costs requires the setting of the difference between var-

ious traffic growth categories. The reason lies in the fact that the benefits from the redirected traffic have to be deduced from the difference between travel costs on the old road or transport mode and new travel costs per designed road, as well as the fact that the resulting benefits from the newly created (induced) traffic should be deduced from the analysis of the economic excess.

The traffic growth on the travel network depends directly on the demand for the transport of passengers and goods. This demand is created in the dependence of economic characteristics of the area at the beginning (origin) and end (destination) of travel, and the traffic flows depend on the physical distribution of these economic characteristics in the entire region.

Therefore, in order to forecast the future flows and traffic movements, it is necessary to forecast the traffic growth at origins where this traffic originates. Depending on the available data and the level of required accuracy, numerous assumptions are possible. These assumptions refer to the similarity of the growth per areas and/or per types of goods. The level and analysis processing, therefore, may be various – ranging from very detailed analysis of cargo traffic growth per types of goods and sub-zones of the region to very generalized and rough analysis which starts from the assumption of similar growth of all goods within the entire area.

For the projection (forecasting) of traffic there are two basic procedures: simulation technique, which encompasses calibration of the set model according to data on the existing traffic and social and economic movements, and growth factor techniques, with these growth factors applied to the existing traffic.

6. MODELS OF GROWTH

In implementing the growth factor techniques, the basic assumption lies in the fact that the growth of traffic (travel) from zone "i" to zone "j" id proportional to travel creation in zone "i" and increase of attractiveness of travel in zone "j".

The method of equal travel growth factor is the oldest one and at the same time the simplest method for forecasting the future travel distribution. It assumes the application of growth factors equal for all the zones of the observed area. The amount of each of the current inter-zone flows is multiplied by this factor, determined on the basis of the social and economic analysis. The obtained product yields the size of the future inter-zone flows. This is symbolically written as:

$$T_{ij} = t_{ij} \cdot F$$

$$F = \frac{T}{t}$$

T_{ij} = future trips between zone "i" and zone "j",

t_{ij} = current trips between zone "i" and zone "j",

F = traffic growth factors for the entire area,

T = total number of projected trips in the observed area,

t = current number of trips in the observed area.

Table 3 - Projections of traffic for the selected time cross-sections

Year	Travel matrix
2001	93,885
2007	121,678
2009	131,607
2026	230,509
2028	224,547

7. TRAFFIC DISTRIBUTION

The tables of future trips of a certain traffic volume per vehicle types have been calculated in the traffic forecast, that are based on the social and economic development and on the increase of goods flows. These tables of trips can be made for the last year of the analysed period as well as for every inter-period. The ta-

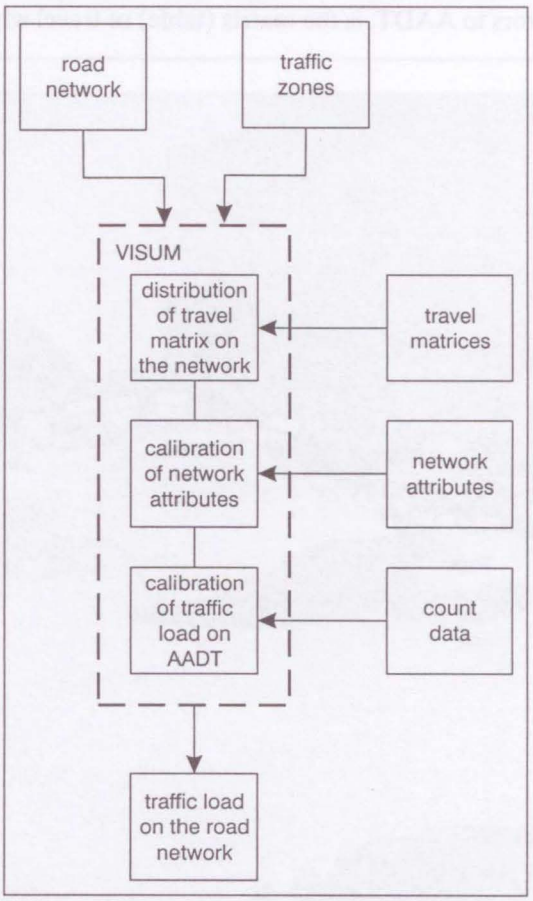

Figure 2 - Model calibration flowchart in Visum program package

bles have the form of matrices which contain inter-zone traffic flows, per vehicle types, between all the zones in the analysed area.

In order to estimate the traffic volume per road sections, these trip tables are distributed on the road network. This is repeated for every proposed change in the travel network. Annual growth rates for every section can be deduced from the traffic distribution in the beginning (base) year and the traffic of the following years.

The traffic distribution process essentially means that between every pair of zones one or several travel routes are determined, and then the number of trips between each pair of zones are allocated to this travel route or group of routes. Once all the inter-zone trips are assigned, then the total traffic volume on every section of the road network is determined (collected).

8. RESULTS

After having completed the surveying at 15 locations, on two occasions (summer and fall), all the data have been entered into a unique database which contains 40,056 surveys. The results from the processing of the database, after having included the adjustment factors to AADT, is the matrix (table) of travel which contains a total of 68,940 trips. After adjusting the single-way and two-way survey locations, the double-count solutions, calibrations to count values a matrix with 93,885 trips has been obtained, divided into three types vehicles.

The projection of the trip matrix through selected time period cross-sections has been presented in the previous table.

The loads on the existing and planned road network have been presented in the following figures.

The structure of the purpose of travelling and the occupancy rate of vehicles and the carried number of passengers have been given in the following tables.

Table 4 - Distribution of purpose of travel and passenger car occupancy rate

Purpose		Share of Purpose	PAX Carried	Occupancy Rate (PAX/Vehicle)
1	Business	21.53%	19,513.20	1.57
2	Work	10.93%	10,255.29	1.62
3	Tourist	6.39%	10,294.96	2.79
4	Other	61.15%	71,448.03	2.02
Total:		100.00%	111,511.48	1.93

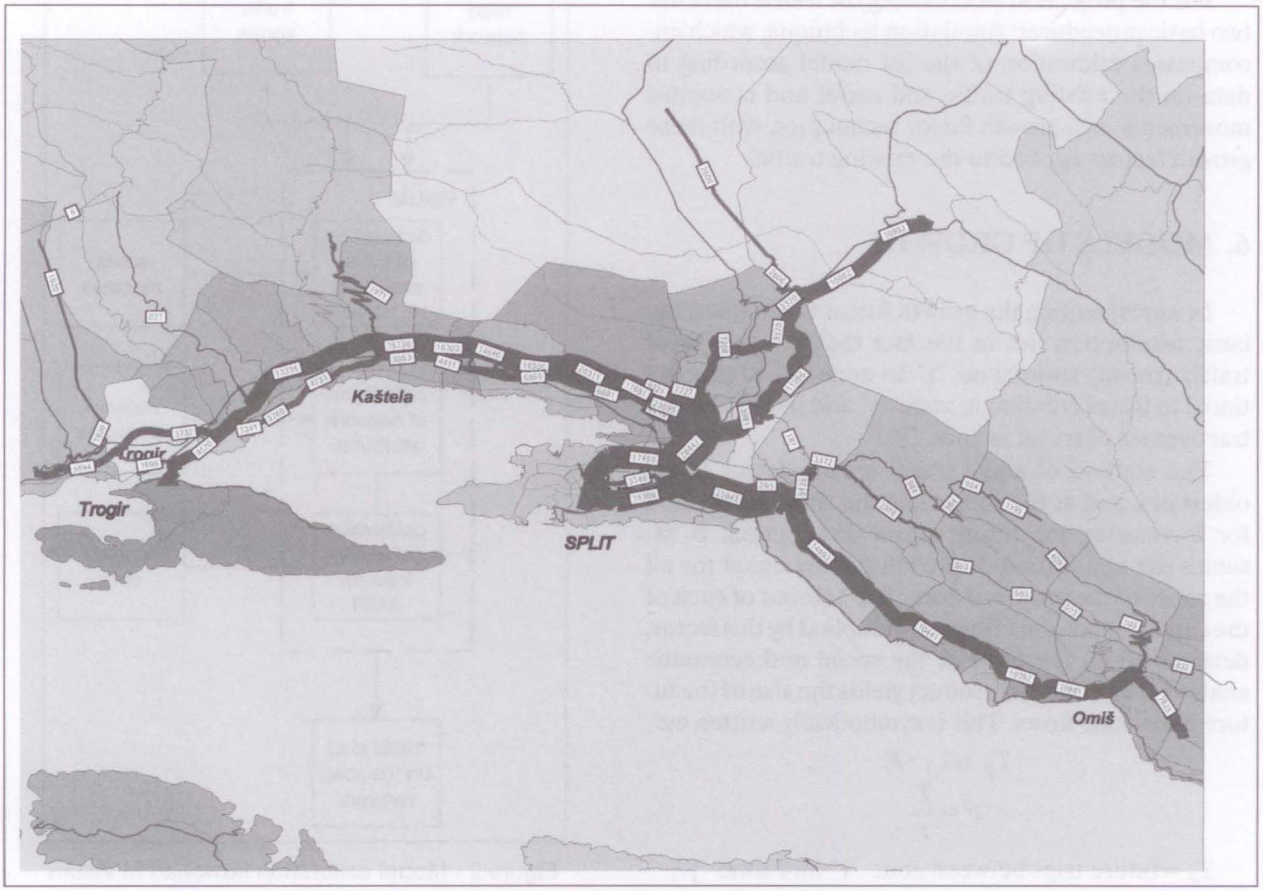

Figure 3 - Traffic load in the base year 2001

Figure 4 - Traffic load at the end of the project period – the year 2028

Table 5 - Distribution of types and occupancy rate of buses

	Type	Share of Purpose	PAX Carried	Occupancy Rate (PAX/Vehicle)
1	Line	79.69%	27,447	24.01
2	Work	7.64%	946	8.66
3	Tourist	7.95%	4,083	35.94
4	Other	4.45%	1,786	28.06
Total:		100.00%	34,262	23.97

9. CONCLUSION

For the needs of the road construction feasibility study i. e. the estimate of the project, the results obtained in this work are entirely satisfactory. If compared with the previous and similar research, they can be reduced to the frames of the expected results.

The most sensitive part of the traffic planning represents a part of the traffic forecast, i. e. growth factors of individual zones. To improve this segment of traffic planning, more detailed social and economic analyses are necessary, which should be continuously researched.

This research of the traffic flows does not include also the Split ring-road route variant from Stobreč via Žrnovnička dolina (valley) and Gat by tunnel connections below Perun for the connection with the existing road from Stobreč to Omiš. Therefore, this variant should also be studied and evaluated.

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SAŽETAK

ISTRAŽIVANJE I VREDNOVANJE PROMETNIH TOKOVA OBILAZNICE SPLITA

Za potrebu prometnog modela Studije opravdanosti obilaznice Splita, izvršeno je anketiranje prometa na 15 mjesta. Rezultat ovog istraživanja je matrica putovanja koja sadrži

93.885 putovanja u baznoj godini. Analiza podataka i raspodjela putovanja napravljena je u programskom paketu Visum. Prognoza prometa je rađena za vremenski period od 2001. do 2028. g. metodom jednakih faktora rasta. Izlazni rezultati su upotrijebljeni za ekonomsko vrednovanje projekta.

KLJUČNE RIJEČI

prometni model, prognoza prometa, matrica putovanja

LITERATURE

[1] Dorsch Consult, Louis Berger Inc.: *Uputstva za izradu studije o izvodljivosti puteva*, Ljubljana, 1974.

[2] Institut građevinarstva Hrvatske: *Studija opravdanosti obilaznice Splita*, Zagreb, 2004.

[3] Padjen, J.: *Osnove prometnog planiranja*, Zagreb, 1986.

[4] PTV AG: *Visum User Manual*, Karlshruhe, 2004.

[5] **Ortúzar, Willumsen**: *Modelling Transport*, England, 2004