# ISSUES OF HIGHWAY ROUTE DESIGN

**Željko Stepan, Ana Nikolić, Mario Njegovec**
*University of Zagreb, Faculty of Civil Engineering, Croatia*

## Abstract

The paper deals with a standard procedure of highways' corridors alignment. It presents the alignment stages and describes geometric parameters of the highways' designed route. The paper points to the justified highway demands on the basis of the traffic model. It addresses the impact of traffic load on the highway route characteristics, and the determination of construction phases. It indicates the complexity of route performance and solution selection with regard to the short time of 20 year planning period.

*Keywords: motorway, road alignment, geometric characteristics, traffic model*

## 1 Introduction

One of the most vital elements of roads' network concept in the Republic of Croatia is internal connecting of the space within Croatian boundaries, linking with neighbouring states and joining the European transportation system. The decisions on the roads' network have often been made without adequate construction and engineering documentation, without traffic- and cost-effect based analyses, and without sufficient data on the traffic volume and contents.

**Table 1** Review of the categorization of public roads [1]

| Road classification in Republic of Croatia | | | | | | | |
|---|---|---|---|---|---|---|---|
| Motorways | | State roads | | County roads | | Local roads | |
| km | % | km | % | km | % | km | % |
| 1.563 | 5,3% | 6.811 | 23,1% | 10.820 | 36,7% | 10.279,6 | 34,9% |
| ***29.472,5*** | | | | | | | |

According to the "Strategy of Sustainable Development of the Republic of Croatia" "Narodne novine", issue 30/09.), Croatia has a highly developed motorways network, whereas the network of state, counties and local roads should still be expanded. The public roads system in Croatia includes in total 29.472,5km (the status in November of 2009), the survey given in Table 1. Highways belong to the category of state roads. For the construction of highways in the period up to the year 2012 the Republic of Croatia plans to invest 1.435,35 mil. kunas [1].

## 2 Documentation needed for determining the highway corridor

To determine the route's corridor for the relevant area the following documentation should be prepared:
· Spatial development plans for counties, cities and municipalities,
· Geological, hydro geologic and geologic engineering data,
· Surveying data.

The highway route corridor is being determined on the basis of collected data and information on spatial limitations.
Figure 1. shows an example of the highway corridor Tromilja-Bosnia and Herzegovina boundary drawn into the Physical plain of Šibensko-kninska County.

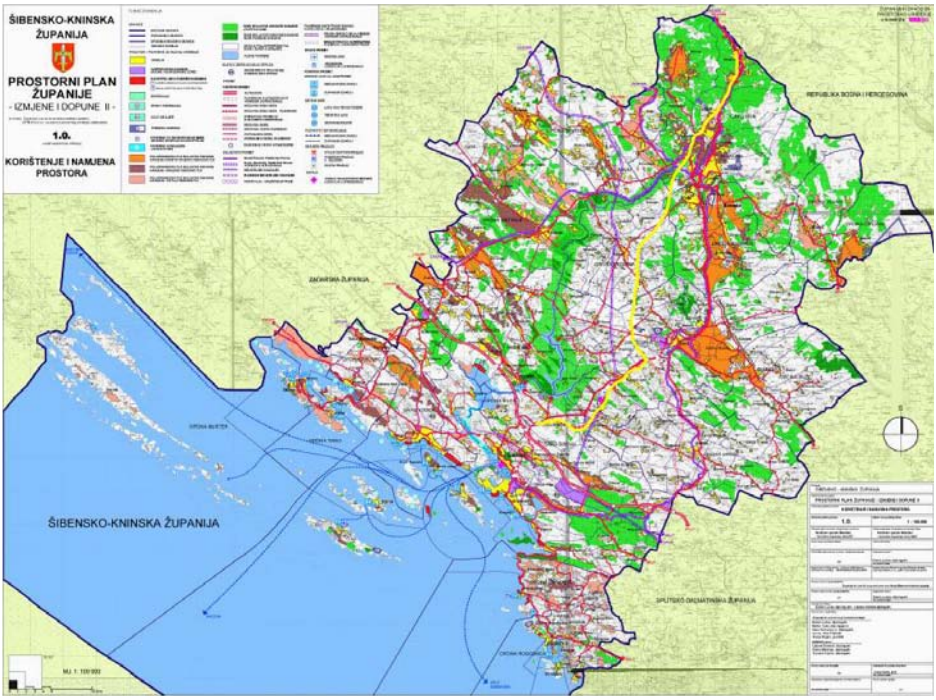


**Figure 1** Physical plan of Šibensko - kninska County with highway Tromilja - Bosnia and Herzegovina boundary.

Conceptual designs of the highway are being aligned on the basis of surveying data according to the Croatian Base Map (HOK) in scale 1:5000. In accordance with data sources underlying future Digital Model Terrain (DMR) the surveying documentation of mentioned precision can be divided into :

- DMR source data basing on photogrammetric restitution for HOK,
- DMR source data basing on photogrammetric restitution for TK25,
- Vectorization of contour lines, characteristic heights and structures from the existing HOK.

Surveying documentation including a digital ortophoto plan (DOF) is being used for the spatial valorization. DOF contains a large number of grid information on the space of future highway's corridor. A quality and updating of information depends on DOF's fabrication datum. Data are of considerably high quality as the cyclic mapping of the space in the Republic of Croatia was annually conducted from 2001 to 2007.

## 3 Valorization of the highway corridor

In the Republic of Croatia the roads corridors are determined through spatial plans without conducted procedure of traffic valorization and detailed defining of highway characteristics. In working out the conceptual design it is necessary to conduct traffic and economic valorization of the highway. The conceptual design should include the transportation model of individual traffic.

The following data should be collected for the investigation related to transportation model:
· Data on existing traffic network,
· Data on residents (residents' and working places number, number of employed residents).

Transportation model is worked out in four steps. Traffic model levels include
· Trip generation,
· Trip distribution,
· Mode choice,
· Route assignment.

Trip distribution is performed with gravity model, calibrated on the basis of permanent and temporary traffic counters. Graphic survey of trip matrix is illustrated through demands' lines. The characteristics of the future highway are being defined on the basis of completed transportation model through traffic valorization as follows:
· Construction priorities according to sections,
· Decision to construct one or two pavements.

Figure 2 shows the trip matrix for the Šibensko-kninska County
Corridor's valorization should include cost-benefit evaluation to determine optimal solution for the suggested corridor.
Cost-benefit analysis involves the benefits parameter, which is the difference of traffic effects between planned network and those on the existing network. Providing that there are several variants of one solution, the one that features most benefits, i.e. the one with the highest current net value has been put forward (NSV).

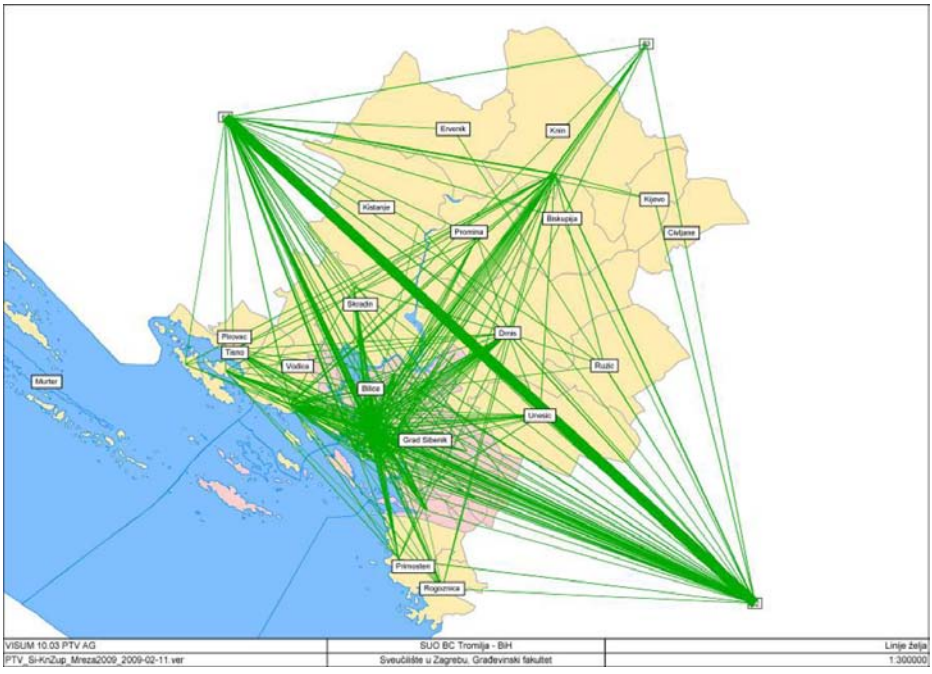


**Figure 2** Demand lines.

# 4 Geometric Parameters of the Highway's Designed Route

## 4.1 Horizontal alignment

Highway's plan design elements are determined in compliance with the "Regulations on Basic Conditions which public roads and their elements outside the settlements have to satisfy from the safety standpoint (NN 110/01)", for 100km/h design speed.
For Vp=100km/h design speed the following minimal horizontal elements equal [2]:
· Rmin=450m,
· Lmin=75m,
· Amin=184m.
In the case of "quiet" terrain morphology the highway alignment with elements higher than mentioned above are allowed. Operating speed calculated upon performed highway alignment can assume values exceeding 120km/h. The difference between operating speed and design speed can exceed 20km/h in this case.
This difference indicates that the design speed should be raised to 120 km/h. According to NN 110/01 for highways with one pavement the maximal allowed speed is set at 100km/h.
The reduction of operating speed requires alignment with higher curvature (Figure 3.).

**Figure 3** Compare of horizontal alignment with elements of the larger and less curvature

The alignment of the Tromilja – Bosnia and Herzegovina boundary highway features higher curvature due to required reduction of operating speed ($v_R$). The alignment effects were $v_R$ = 110km/h with route extension for 1.000m and earthwork increase for 5.700m³/km.
The maintaining of the original route is considered as a rational solution where the highest allowed speed should be administratively limited to 100km/h. The speed limit signs should be posted at every 2km [3].
In determining highway corridors the highway should be brought closer to cities, and with a regular grid nodes the highway should be as frequently as possible joined to the existing traffic network.

## 4.2 Vertical alignment

Vertical visibility for 100km/design speed is 190m, which corresponds to the minimal radius for 8700m convex curve and 5700m for the concave one. The inclinations of the route's level line should be within 0.3–5% limitations, whereas for the slopes bigger than 4% one should take into account the necessity of adding lanes for slow vehicles, the length of which should not be shorter than 800m.
As the design speeds for the highway are bigger than 80km/h, all the nodes should be designed at two levels.

### 4.3 Elements of cross section

Highway's cross section elements are shown in Figure 4.

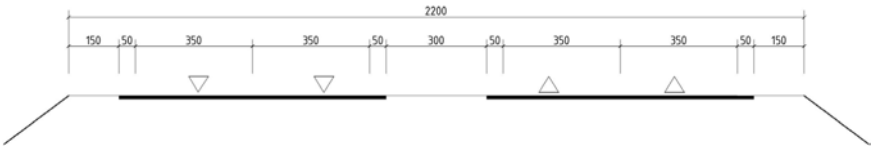


**Figure 4** Highway's Cross section

The cuts' slopes for the roadbed calculations, i.e. for the embankments' slopes in earth materials are constructed at 1:1.5 inclination, whereas in carbonate rocks slope is performed at 2:1 in the highway corridor defining phase. The maximal cut's height in uniform inclination should not exceed the height between 8 to 10m. In areas considered rocky from the geological point of view 3 to 5m wide berm is constructed at the depth of up to 3m in loose surface layer. The slope's loose surface layer is being excavated at 1:1.5 inclinations.

### 4.4 Facilities

Already in the corridor's investigation phase the conceptual design should foresee the facilities over spatial hindrances. For this purpose the sketches for bridges, viaducts, tunnels and culverts should be drawn.
Due to the fact that highways are designed for 100km/h speed, they should be wire fenced for the safety reasons. In this way natural fauna pathways would be broken. If there are no natural possibilities for animals' passage (tunnels, river canyons, valleys bridged by viaducts) the construction of "green bridges" should be planned on the highway.

## 5 Conclusion

In defining the highway corridor it is necessary to connect all design participants (urban planners, road designers, geologists, ecologists, local communities' representatives ...), and to avoid in this way potentially unwanted alignment errors at the early design stages.
Transportation and cost-benefit analyses obtained through transportation model, and cost-benefit evaluation significantly affect highway characteristics, particularly construction stages in cross section and priorities determination in construction of individual highway sections. Traffic projections will prove whether the only one highway pavement would be enough for the 20 year planning period.

## Reference

[1] Program construction and maintenance of public roads for the period from 2009. to 2012. The Croatian Government, 3.12.2009.

[2] Regulation of basic conditions that a public road outside the urban community and their elements must adhere to the security of transport (NN 110/01)

[3] Conceptual design of highway Šibenik-Drniš-Knin-Bosnia and Herzegovina boundary, section Tromilja-BiH, Faculty of Civil Engineering, Zagreb, November 2009.