



CETRA²⁰¹²

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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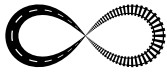
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FUTURE TRANSPORT NETWORK OF THE CITY OF DUBROVNIK

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Abstract

The paper presents the planned transport network of the city of Dubrovnik in the future. Being the Croatian tourist pearl Dubrovnik needs to deal with its transport problems through the contemporary transport modeling. An optimization model in solving crucial traffic problems for the functioning of the City in the future is presented. The tests of planned actions of the existing plan documentation and the introduction of new ideas are shown. The tests are based on the integral transport model of Dubrovnik. An estimation of transport effects of planned scenario for both the private transport and the public transport is elaborated. The method of evaluating planned scenarios is described. New transport solutions in the network of the city of Dubrovnik are discussed and the efficiency of the planned network is elaborated.

Keywords: private transport, public transport, transport modeling, transport planning, transport effects, evaluation and selection of solutions

1 Introduction

Tourism is the basic economic activity of Dubrovnik. 28% of its population is directly or indirectly involved in tourism. The number of tourist arrivals grows each year. In the year 2010 Dubrovnik was visited by 588.568 tourists with the total of a little bit less than 2,2 million overnight stays. Most tourists visit the City during summer months, which means that 2/3 of tourists come there in the period between June and September. Only in August 2010 there were 123.184 tourists with more than 515.000 overnight stays. Dubrovnik is one of the greatest Mediterranean destinations on the cruise market. In 2010 more than 915.000 cruise passengers visited Dubrovnik, 150.000 of them came in August only. On average in August 2010 more than 21.000 tourists a day stayed in Dubrovnik which means that the population of the city was increased by 50%. In spite of a significant increase in the number of tourists coming to Dubrovnik the transport infrastructure has not been upgraded. After the required traffic study report was made the city recognized the discrepancy between its value and the current transportation system. Therefore, an integral transport model of the current transportation system was conducted for the city of Dubrovnik. The model was used to locate the traffic problems within the existing transportation system and in the planned periods of its development. The model also served to propose different solutions the effects of which were tested.

2 Traffic model

The area covered by this traffic model includes the city of Dubrovnik with 32 settlements, municipality Župa dubrovačka with 16 settlements and municipality Konavle with 23 settlements (Figure 1).

For the purposes of the traffic model the area is divided into 105 zones. The city of Dubrovnik is divided into 57 zones or statistical circles while the surrounding area covers 48 zones based on the settlements. In order to define specific areas of the greatest assembling and tourist attractions within the research study we created additional zones of interest, the Dubrovnik airport, the Dubrovnik port, the center, the Old City and the County hospital. The three cordon zones are determined for the outside area representing important traffic corridors and providing transport connection between the research area and the surrounding area. All the zones are described by attributes serving for generating traffic demand (Table 1). The information used for demographic, migrational and economic attributes of the zones were obtained by the Croatian bureau of statistics, Dubrovnik tourist board and global urban plan of the Dubrovnik city.



Figure 1 Research area

Table 1 Zone attributes

Zone attributes		
number	number of citizens	high schools
code	number of employees	faculties
name	number of workplaces	allocation of space
type	tourist accommodation	

2.1 Model of demand

The transport model is developed as a four level transport model for the private and the public transport. The levels of the transport model are: trip generation, trip distribution, transport mode choice and transport assignment.

Trip generation was made for the following activities: home – workplace trip, home – high school trip, home – college trip, home – other places, not from home – other places, tourist

trip – accommodation and tourist trip – others, per personal groups as: active population, the employed, students, college students and tourists.

Trip attractions are workplaces, tourist accommodation, tourist attractions, school and college capacities and purpose of the areas (public, economic and mixed).

Activities and personal groups are connected by an attraction and a number of trips from one zone into another are calculated. Trip distribution was made by the gravity model and distribution matrices defining travels from one zone into another are calculated.

Trip matrices were calibrated on the basis of data obtained by traffic counts at 23 locations. The final level of transport modeling, the transport assignment was conducted for all transportation systems, i.e. car transportation, bus transportation and new metro transportation. The traffic is generated for four time terms: the base year 2011, short term from 2011 to 2016, medium term from 2016 to 2021 and long term from 2021 to 2031

Two scenarios of traffic growth, the conservative and the optimistic one, for the private transport are introduced. The growth in public transport travels is estimated to be 1% on. The growth factors for private and public transport are shown in the Table 2.

Table 2 Growth factors for private transport

Planning period	Yearly growth				
	Private transport				Public transport
	Optimistic scenario		Conservative scenario		
	1% in the narrow area of research	2% in the wider area of research	1% in the narrow area of research	1% in the wider area of research	1%
2016.	1,04	1,08	1,04	1,04	1,04
2021.	1,09	1,2	1,09	1,09	1,09
2031.	1,21	1,46	1,21	1,21	1,21

The introduction of the metro lines in the year 2031 in the zone of the new transportation system reduces the number of individual travels by 15% which are then added to the public transport.

2.2 Model of supply

The model of supply is described by the transport network. The total network includes 1.284 nodes, 3.525 links (192 one way links) and 804 connectors.

The roads are interpreted by links and their characteristics are described by link attributes. The basic link attributes are shown in the Table 3.

Table 3 Basic link attributes

Links attributes		
number	length	free flow speed
start node	number of lanes	longitudinal slope
end node	transport system	EWS-a parameters
link type	capacity per direction	

In the traffic model of private transport the network is organized into freeways, state roads, county roads and local roads, and in the city area the main city roads, city roads, collector roads and the other kinds of roads as well as pedestrian roads both for the existing and the planned network. Categories, free flow speed and the length of the existing and the planned network included in the transport model are shown in the Table 4.

Table 4 Road categories given in the transport model

Category	Lenght of road [km]				Free flow speed [km/h]	Capacity per road direction [voz/dan]
	City of Dubrovnik		Župa & Konavle			
	existing	planned	existing	planned		
Freeway	0,00	27,84	0,00	17,32	80	15.000
State road	34,89	7,83	55,58	0,00	60	8.000
County road	10,22	0,00	55,47	0,00	50	6.000
Local road	34,49	3,70	47,71	0,00	40	4.000
Main city road	17,43	4,84	-	-	60 / 50 / 40	7.200 / 8.000
City road	28,04	10,56	-	-	50 / 40	6.400 / 4.800
Collector road	8,92	1,06	-	-	30	4.800
Other roads	48,32	7,62	-	-	30	4.800
Pedestrian	34,40	0,24	-	-	-	-
Total	216,70	63,69	158,76	17,32	-	-

The modeled network of the public city and suburban bus transport include all the bus lines, stops and schedules. The new transportation system of light metro is introduced and precisely routed taking into consideration the location and the height. The stops are also determined.

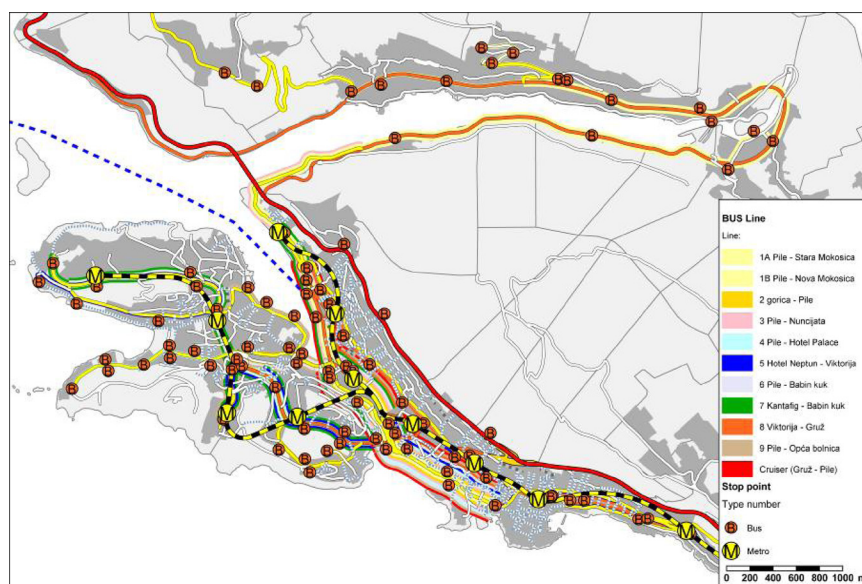


Figure 2 Network of city bus lines and light metro with stops

The light metro network analyzed by the transport model consists of 3 routes with the following working titles: M1 Gruž port – Viktorija, M2 Viktorija – Dubrovnik airport and M3 Babin kuk – Dubrovnik City. The network of city bus and light metro lines with stops is shown in the Figure 2. The passengers would get on and off each of the public transport systems at hierarchically structured stops:

- stop point,
- stop area,
- stop area for taking another transport mode.

Stops which belong to one area of changing transport mode will exchange passengers from different transportation systems. Thus, the designed integral transport model was used for the evaluation of the existing transport system and the planned scenarios of the total transportation system of the city of Dubrovnik.

3 Future road network in Dubrovnik

Being at the foot of Mountain Srđ, Dubrovnik was developed along very narrow belt (up to 500 m) between the coast and the steep mountain slopes. By the end of the 1960s the Adriatic Highway D8 was built beneath Srđ slopes. Fifty years later this highway is still the only connection between Dubrovnik and the other parts of Croatia. The state road D233 to Border crossing Gornji Brgat (BH border) – Dubac connects Dubrovnik with Bosnia and Herzegovina.

Plans for the future were analyzed through 18 scenarios of the network for 4 time periods (2011, 2016, 2021 and 2031) and include connecting Dubrovnik by freeway to the state system of freeways at Osojnik in the north. In the south Dubrovnik will be connected to freeway system Župa – Plat – Čilipi at Župa junction geographically located north of Donji Brgat.

The road network of the city is connected to the external system at three locations, Sustjepan in the northwest, the Ilijina Glavica node centrally and Orsula in the east. Entering Dubrovnik when compared to the existing road system will be different by introducing the east entrance into the city at the crossroad of D8 and the Frane Supila street.

The internal road network of Dubrovnik is determined by the principle of the private and city bus transport organization as one way transportation system. One way road system can be described with 7 internal road rings:

- 1 V. Nazora – A. Starčevića – Put Republike – Splitski put,
- 2 Vukovarska – connector road Vukovarska – A. Starčevića,
- 3 tunnel 'Radeljević' – Obala S. Radića,
- 4 Od Batale – Od Svetog Mihajla,
- 5 Zagrebačka – Iza grada – tunnel 'Minčeta' – Splitski put – V. Nazora,
- 6 Tunel 'Minčeta' – Brsalje – Put branitelja – Splitski put,
- 7 P. Krešimira IV – Viktorija – F. Supila – Iza grada – Zagrebačka.

The Dubrovnik link to the system of freeways and one way road system inside the city is shown in the Figure 3.

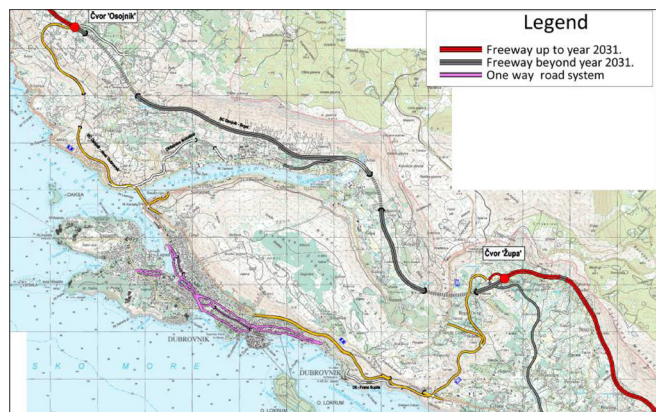


Figure 3 City link to the system of freeways

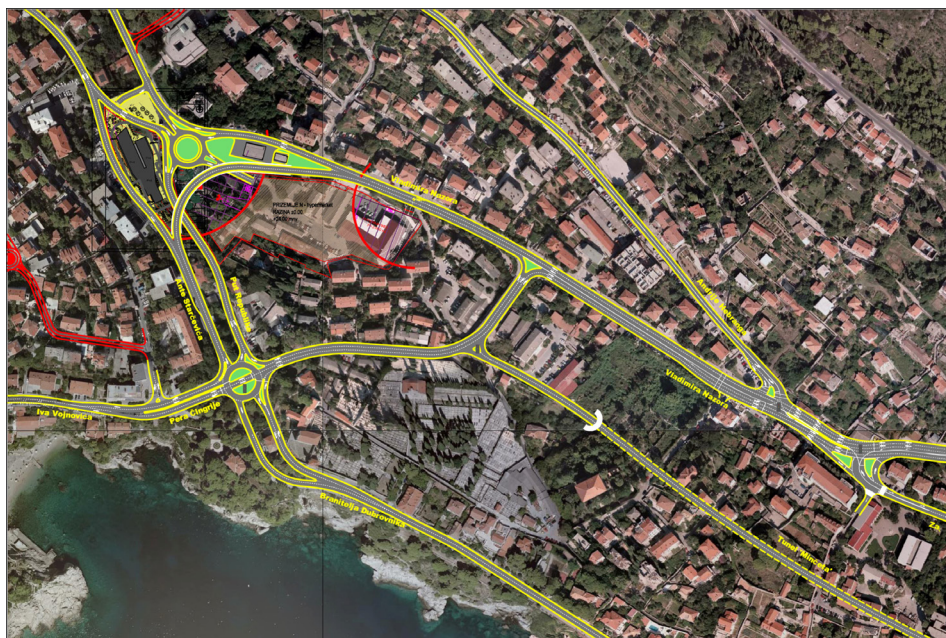


Figure 4 Dubrovnik City

The road ring consisting of the streets of Vladimir Nazor – Ante Starčević – Put Republike – Splitski put (under the working title 'Dubrovnik City') is the busiest part of the inner road network (Figure 4). The Dom zdravlja roundabout, intersection of the streets Put Republike, Ante Starčevića, Pera Čingrije, Branitelja Dubrovnika and Splitski put, is an integral part of the Dubrovnik City road ring and the busiest roundabout in Dubrovnik.

4 Evaluation

The newly proposed technical solutions of the Dubrovnik road network derived from the conceptual design to present the validity of the system. The technical solutions were tested on the basis of DOF 1:5.000, DOF 1:2.000 and a digital relief model 1:25.000. The calculation of investment value includes the price of land. The evaluation was performed for the following time periods:

- 2016 – short term period,
- 2021 – medium term period and
- 2031 – long term period.

The costs and economic indicators were calculated through the savings in the traffic system, the net present value (NPV) in the year of starting the investment, the internal rental rate (IRR) and the cost–benefit factor (C/B factor). The net present value is calculated with the discount rate of 8%. The indirect benefits were not taken into consideration. The Table 5 shows the scenarios of road transport network for particular periods with specific cost calculations and economic indicators.

Table 5 Overview of costs and economic indicators by each scenario for the private transport

Period	Scenario	New segments (* investment not included)	Investment [€]	Saving [€]	NPV [€]	B/C	IRR
2012. - 2016.	S-2016_PSD_R	- Ilijina glavica - 'Dubrovnik City', jednosmjerni sistem Nazorova - Starčevićeva - Splitski put - Pile - D8 - Frana Supila - N.Tesle - A.Starčevića (2 lanes)	15.583.302	1,758	-0,49	0,974	7,62%
2016. - 2021.	S-2021_PSD_R1	- Tunnel 'Minčeta' - Tunnel 'Radeljević'	17.364.039	1,417	-6,07	0,704	-
2021. - 2031.	S-2031_PSD_R1	- Od Batale & Od Sv. Mihajla - N.Tesle - A.Starčevića (4 lanes) - BC Osojnik - bridge 'Dubrovnik' * - BC Župa - Plat * - Ilijina glavica - Dubac (4 lanes) - Dubac - čvor Brgat - Mokošica detour	70.232.627	4,170	-46,95	0,475	-

The transport system for each scenario for the medium term and long term periods provides the traffic without congestion which will require certain financial sacrifices.

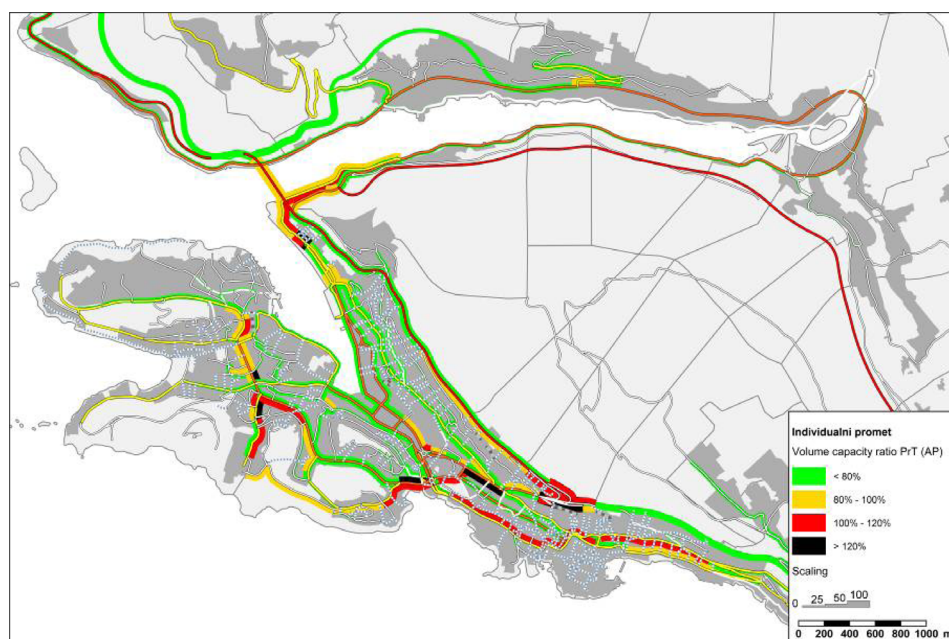


Figure 5 Saturation of planned transport network in 2031 (S-2031_PSD_R1)



Figure 6 Dubrovnik City, traffic flow simulation

The evidence of the traffic without congestion of the planned Dubrovnik transport network by the year 2031 in the scenario S-2031_PSD_R1 is shown in the Figure 5 with the saturation of transport network.

5 An evidence of validity of the technical solution

Based on the planned development of road network from the scenario S-2021_PSD_R1 as a resultant scenario for the year 2021 traffic flow simulation (microscopic traffic model) for the Dubrovnik City area as an evidence of validity of the technical solution (Figure 6) is designed. Signalization plans for the Ilijina Glavica junction and the Dom zdravlja roundabout with traffic lights are calculated for the purpose of the simulation.

Functioning of road transportation system without congestion is indicated by a visual mark. Road indicators shown in the Table 6 demonstrate the authenticity of the proposed transport solution for the Dubrovnik city area.

Table 6 Road indicators

		Dom zdravlja	INA roundabout	Splitski put	Ilijina glavica
Average Delay	s/veh	16	0	4	14
Emmision CO	g/h	287	84	135	230
Emmision NOx	g/h	56	16	26	45
Fuel consumption	l/h	302,60	89	142	243
LOS	-	B	A	A	B

6 Conclusion

The narrow coastal strip by the Adriatic Highway is completely built. There is hardly any possibility of building new infrastructure corridors in that area. Thus, planning new road corridors can be provided by the use of the underground. The plan is to build the road tunnels 'Minčeta' and 'Radeljević' by 2021 and to introduce the new public transportation system of light metro by 2031.

The problem of congestion of main road routes in Dubrovnik is solved by introducing a one way road system in the narrower area of the city by 2016. Consequently, parking lots by the roads are eliminated or a number of parking lots is reduced. Parking lots need to be substituted by new parking space away from the main roads or new garage facilities.

With the system of freeways by the year 2031 the city will be connected at Osojnik (Osojnik junction) in the north and at Donji Brgat (Župa junction) in the east regardless of potential freeway system behind Srđ. The technical procedure for finding the quality solution of the future transport network is described in 4 steps:

- 1 designing the integral transport model (macroscopic or mesoscopic) which includes all the transportation systems (pedestrian, road, bus, railway, ship, air,...),
- 2 designing the technical solutions (more versions)
- 3 evaluating the proposed technical solutions, i.e. scenarios of the future development of the transport network,
- 4 designing the microscopic transport model as an evidence of validity of proposed technical solutions.

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- [1] Prometna studija grada Dubrovnika, Promel projekt d.o.o. i Građevinski fakultet Sveučilišta u Zagrebu, siječanj 2011