CETRA 2012

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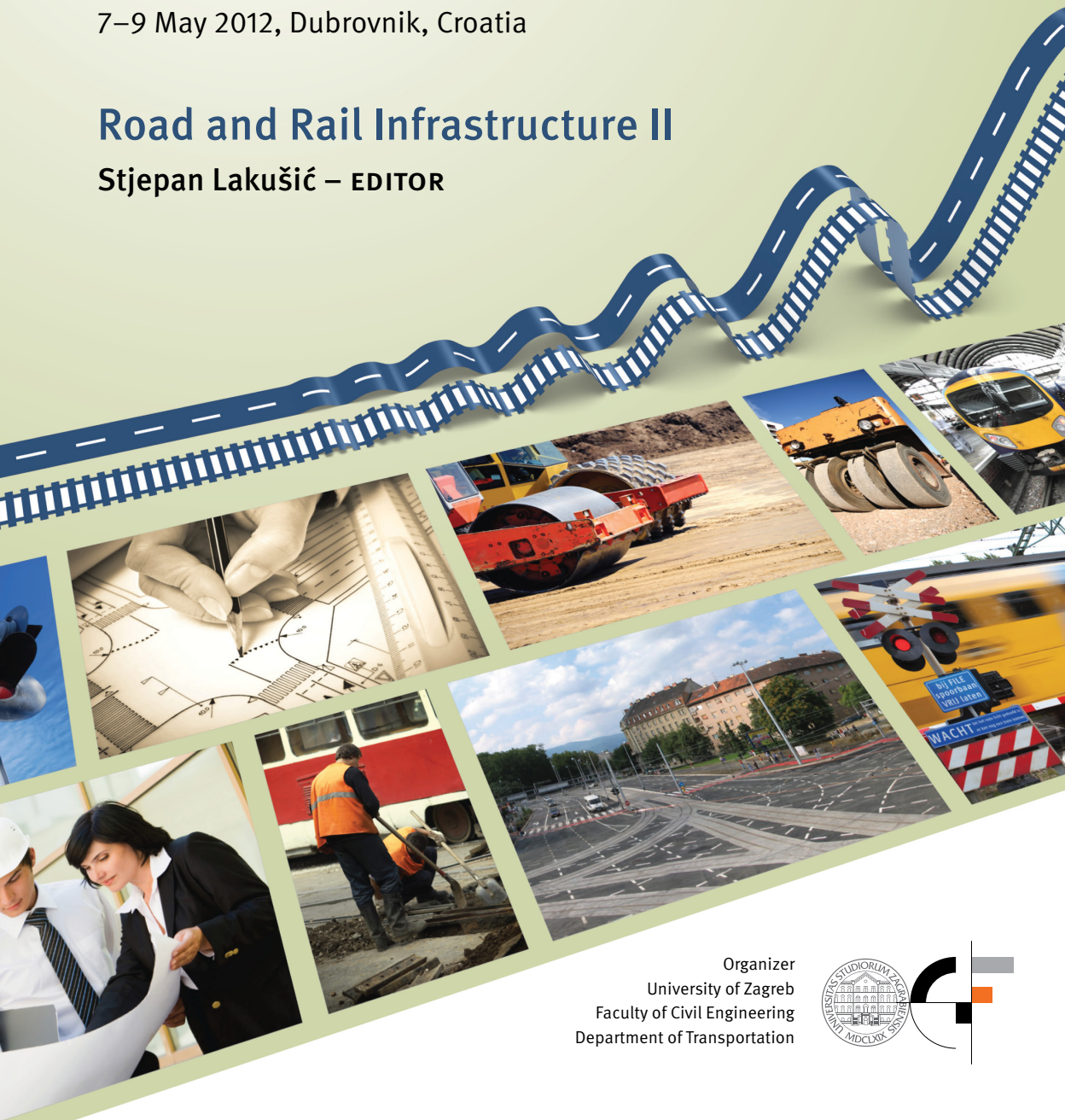
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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NEW TRANSPORTATION SYSTEM OF THE CITY OF DUBROVNIK

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Abstract

The paper presents the idea of introducing a new transportation system in the city of Dubrovnik. The efficient solution of the problem of fast public mass transport connecting the port of Gruž and the Čilipi airport with the old center of Dubrovnik could be found in the metro system. The need of introducing the metro system based on the integral transport model of Dubrovnik is discussed. The paper analyzes the evaluation of the planned scenario by comparing transport effects of the new system through savings in the system and investments of the new integral transport system. The evaluation results proving the purposefulness of the idea of new transportation system design in the city of Dubrovnik in the future are discussed.

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

1 Introduction

The transportation system of the city of Dubrovnik as a world tourist destination confirms its inefficiency with traffic congestions during summer, the period with the greatest number of tourists. The problem of fast and mass transport cannot be solved by reorganizing and reconstructing the main roads for the private transport. Within the current public transportation system including bus and taxi services there is no solution in finding the fast transport connection between the Gruž port, the old City and the Dubrovnik airport which are points with the busiest traffic. The paper presents the idea of introducing a new transportation system of the public transport improving the efficiency of the integral transport model of the city of Dubrovnik. The evaluation of the scenario by introducing a new transportation system which entirely redesigns the traffic in the City based on calculations of transport and economical effects confirms the purposefulness and justification of the idea.

2 Traffic model and methodological approach

The traffic model observing the idea of the new transportation system is a contemporary traffic model of integral transport for the area of the city of Dubrovnik. The traffic model was performed by the software package VISUM. Both models of the existing and the future transportation systems were made. The model includes the transportation systems of private transport, public bus transport as well as track transport system.
The model is made for the base year 2011 and the following three periods:
· the phase up to 2016
· the phase from 2016 to 2021
· the phase from 2021 to 2031

In the traffic model of private transport the network is organized into motorways, state roads, county roads and local roads, and in the City area the main city roads, city roads, collector roads and the other kinds including pedestrian roads.
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 precisely routed taking into consideration the location and the height. The stops are also included into the model. The overview of the public transport network in the model is shown in the Table 1.

Table 1 The overview of public transport network

	BUS	Metro
Number of lines	10	4
Routes length [km]	718,1	75,5
Network length [km]	424,5	26,1
Number of stop points	120	18

The trip distribution by trip modes for the base year 2011 and the planned year 2021 is shown in the Table 2. :

Table 2 Trip distribution by trip modes

Distribution of trips by mode	Number of trips			
	2011		2021	
Public transport	66.264	27,85%	73.988	26,89%
Private transport	101.705	42,74%	117.170	42,58%
Pedestrian transport	70.000	29,42%	84.000	30,53%
Total	**237.969**		**275.158**	

3 Solution description and characteristics of the new transportation system

There have been two recent suggestions for connecting the city of Dubrovnik with the Dubrovnik airport with a track system.
The first idea was to connect Dubrovnik with the airport through Cavtat by a single track electrified railway 21,8 km long. The facilities (tunnels and viaducts) make 60 % of this route [1].
Another idea is to build the track system connecting the Gruž port and the Dubrovnik airport. This proposal sees the solution in the double track light railway 24,1 km long, which makes 73% of the total route in the terrain [2].
Both of these suggestions deal with construction possibilities disregarding the quality of the built environment which does not allow the implementation of the new infrastructure corridor.
The new track system described here includes a double track light metro from the Gruž port to Viktorija and a single track light metro from Viktorija to the Dubrovnik airport as well as from the Dubrovnik City to Babin kuk. The plan is to construct two tracks at the metro stops.
The technical solution derived from the conceptual design to present the validity of the light metro. The project was based on DOF 1:5.000, DOF 1:2.000 and a digital model of terrain 1:25.000. It shows that a sector in the Srebreno area allows and requires the route above the terrain (partly as an embankment, mostly as a viaduct) while other parts of metro would be under the terrain. The sector above the terrain covers 7,3 % of the total metro route. Since the rock mass characteristics are made of limestone deposits the plan is to excavate one tube for a single track and a double track metro system.
The cross-sections of a single track and a double track light metro are shown in the Figure 1.

The lines of the new track system are marked with geometric characteristics of a light metro, i.e. with the horizontal radius of more than 100m and the maximum longitudinal slope of 4%. The route of light metro is shown in the Figure 2.

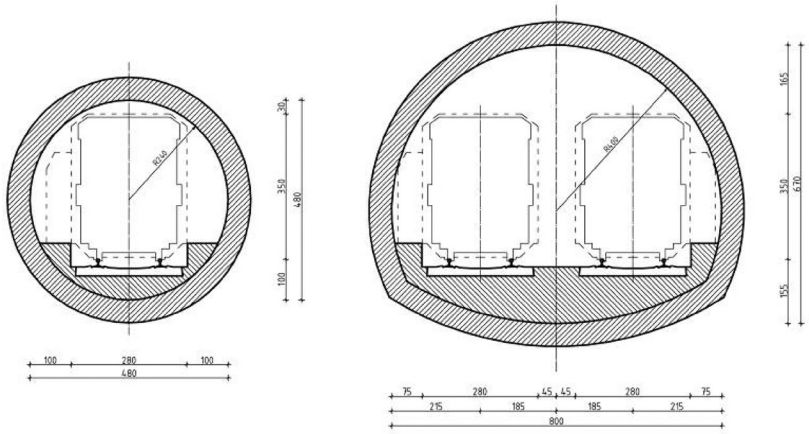

Figure 1 Cross-sections of a single and a double track light metro

Figure 2 The route of light metro in the Dubrovnik area

Table 3 Length characteristics of the metro routes

Route	No.	Stop area			
		Name	Chainage	Distance	Altitude
M1 Luka Gruž - Viktorija	1	Gruž	0+020		-13,09
	2	Tržnica	0+952	932	-12,85
	3	Gruško polje	1+572	620	-11,90
	4	Dubrovnik " City"	2+248	676	-1,29
	5	Stara bolnica-kampus	2+877	629	8,51
	6	Iza grada (Buža)	3+511	634	0,86
	7	Viktorija	4+881	1.370	38,94
	Total		**4.901**		
M2 Viktorija - Zračna luka Dubrovnik	8	Hotel Belvedere	5+865	984	68,52
	9	Dubac (P&R)	8+199	2.335	107,63
	10	Čibaća	9+102	903	71,51
	11	Srebreno	11+321	2.219	12,14
	12	Mlini	13+300	1.979	66,16
	13	Plat	15+756	2.457	66,85
	14	Cavtat	18+504	2.747	19,52
	15	Čilipi	22+480	3.976	139,42
	Total		**16.655**		
M3 Babin kuk - Dubrovnik City	1	Babin kuk	0+020		35,90
	2	Lapad pošta	1+232	1.212	3,95
	3	Bolnica	2+054	823	31,64
	4	Čokolino	2+797	743	18,06
	5	Dubrovnik City	4+006	1.209	-1,29
	Total		**4.026**		
	Total		***25.582***		

The solution includes 3 metro routes with the following working titles:
· M1 Luka Gruž – Viktorija,
· M2 Viktorija – Dubrovnik Airport,
· M3 Babin kuk – Dubrovnik City.
The length characteristics and stop points are shown in the Table 3. The new metro system provides the solution for the mass public transport in the City zone (route M1) as the double track system, for connecting the City with the Dubrovnik airport (route M2) and with Babin Kuk (route M3) as a single track metro system. The route is set in the way that it connects all the tourist attractions of the City and all the stop areas for taking another transport mode, and it also connects the City with the planned Park&Ride system in the Dubac area.

4 Evaluation of the new transportation system

The evaluation of the new transportation system was conducted by determining the efficiency of the future transport network valuated within the integral transport model. The efficiency of the light metro was determined by the calculation of effects of the transportation system and the costs of its construction throughout particular time periods.
The efficiency calculations include transport indicators both for the public and private transport which were transformed into money values in the analysis of benefits and costs.
For public transport:
· Transport indicators
  · Duration of travel (number of people - hours/year)
  · Vehicle costs without energy (millions euro /year)
  · Energy expenses
· Investment indicators:
  · Infrastructure maintenance costs
  · Investment costs including:
    · price of land

- construction of roads
- equipment for roads
- other appliances

For private transport:

- Transport indicators
  - Time costs (millions euro /year)
  - Vehicle costs (millions euro /year)
- Investment indicators:
  - Infrastructure maintenance costs
  - Investment costs including:
    - price of land
    - construction of roads
    - equipment for roads
    - other appliances

The efficiency of this idea is based on the cost-benefit analysis of the performed action in the transport system (the planned situation - doing something/moving forward) in comparison with the costs in the case the planned action is not performed (keeping the status quo – the minimum).
Apart from the public transport scenario, the scenario of the needed actions in the private transport was analyzed in the evaluation process.
The introduction of the light metro in the zone of the new transportation system reduces the number of private travels by 15% and it consequently increases the public transport for that number of travels.
The Table 4 shows the efficiency list of introducing the light metro in the public transportation system.

The success of the planned action in the public transport is shown in the display of traffic load in the transport network in the city of Dubrovnik (see Figure 3.) There are several times more passengers on the route M1 of the metro in comparison with the number of passengers in the public bus transport.
The economic and financial analysis included the calculations of: savings in the traffic system, the net present value (NPV) in the year of starting the investments, the internal rental rate (IRR) and the cost-benefit factor (C/B factor). All the indicators present the criteria for the justification mark of a specific investment implementation, a specific action in the infrastructure system. The net present value being higher than zero proves the acceptability of the planned action.
Inlet parameters for the calculation of economic and financial indicators are discount rate of 5%, and the indirect benefits were not taken into consideration.
The calculations of the indicators for each scenario of the light metro network are shown in the Table 5.
The calculations show that the route M1 Luka Gruž – Viktorija in the scenario S-2031_PSD_METRO-04 is profitable with IRR of 17,42% and positive NPV of 76,75 It needs to be emphasized that the savings in the transportation system of this scenario are prevailing in comparison with other scenarios. The saving is 10,38 million € per year. The proven justification of the metro route M1 Luka Gruž-Viktorija indicates the need to intensify all the activities included in the implementation of this idea.

Table 4 Overview of service kilometers and travel duration by rotes of light metro

Route	Component		Base	Scenario		Diference
			BUS	BUS	METRO	
M1 + M2 + M3 (without crusing)	Cost component	Length of infrastructure [km]	341,000	341,000	26,446	-26,446
	Benefit component	Vehicle service kilometres [km/day]	8.957	8.654	6.816	-6.513
		Duration of trip [hour/day]	10.588	5.163	3.732	1.693
M1 + M2 + M3 (with cruising)	Cost component	Length of infrastructure [km]	341,000	341,000	26,446	-26,446
	Benefit component	Vehicle service kilometres [km/day]	8.957	8.654	6.816	-6.513
		Duration of trip [hour/day]	12.076	5.450	4.809	1.817
M1 + M3 (with crusing)	Cost component	Length of infrastructure [km]	341,000	341,000	8,847	-8,847
	Benefit component	Vehicle service kilometres [km/day]	8.957	8.654	1.683	-1.380
		Duration of trip [hour/day]	12.076	10.381	1.886	-191
M1 (with crusing)	Cost component	Length of infrastructure [km]	341,000	341,000	4,860	-4,860
	Benefit component	Vehicle service kilometres [km/day]	8.957	8.957	713	-713
		Duration of trip [hour/day]	12.076	10.924	1.481	-329
M1 (without cruising)	Cost component	Length of infrastructure [km]	341,000	341,000	4,860	-4,860
	Benefit component	Vehicle service kilometres [km/day]	8.957	8.654	713	-410
		Duration of trip [hour/day]	10.588	10.811	414	-637

Table 5 Economic and financial indicators for the proposed scenarios of the light metro network

No.	Scenario	Network of scenario	Included in the network (segments)	INVESTMENT (EUR)	BENEFIT (Mio. €)	NPV (Mio. €)	B/C	IRR
1	S-2031_PSD_METRO-01M1+M2+M3	network Years 2031. *	Luka Gruž - Viktorija Vikotrija - Zračna luka Dubrovnik Babin kuk - Dubrovnik City	380.468.256	7,563	-201,17	0,357	-
2	S-2031_PSD_METRO-02M1+M2+M3	network Years 2031. **	Luka Gruž - Viktorija Vikotrija - Zračna luka Dubrovnik Babin kuk - Dubrovnik City	380.468.256	7,870	-196,62	0,372	-
3	S-2031_PSD_METRO-03M1+M3	network Years 2031. **	Luka Gruž - Viktorija Babin kuk - Dubrovnik City	149.795.477	9,649	20,08	1,164	6,05%
4	**S-2031_PSD_METRO-04M1**	**network Years 2031. ** **	**Luka Gruž - Viktorija**	**94.106.254**	**10,380**	**76,75**	**2,000**	**17,58%**
5	**S-2031_PSD_METRO-04M1**	**network Years 2031. ***	**Luka Gruž - Viktorija**	**94.106.254**	**9,820**	**68,47**	**1,892**	**16,32%**

** without cruising*
*** with cruising*

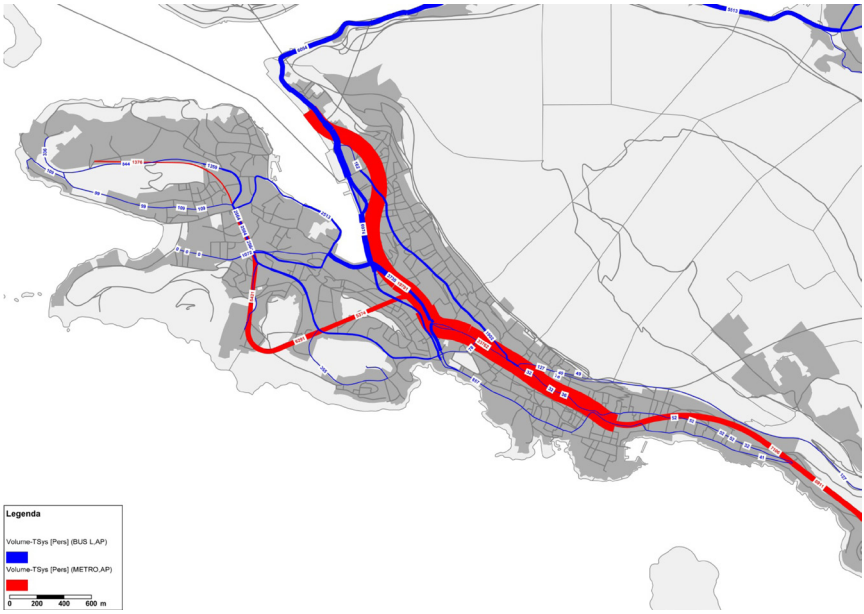

Figure 3 Traffic load in the public BUS and METRO network

5 Conclusion

The introduction of any kind of a new transportation system into the traffic system of an area or a city has to be based on a contemporary traffic modeling of integral transport and economically justified and not only on the analysis of project feasibility and its technical characteristics.

The paper presents the introduction of light metro in the traffic system of the city of Dubrovnik which are based on the basic principles of modern traffic planning which deals with issues such as the use of space, integration of transport systems, traffic safety, sustainability, reduced traffic congestion, reducing the harmful substances emissions, innovative technologies, convenience for users, innovative financing as well as modern construction technologies.

The results show that the planned underground transport network in Dubrovnik offers positive economic indicators based on which further elaboration of technical solutions can be made. Consequently, the ideas from the organization and implementation aspects could be realized by the year 2021 which is an assurance of the sustainable development of traffic in the city of Dubrovnik.

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