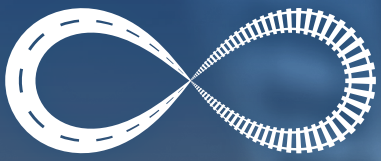

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

# Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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Organizer
University of Zagreb
Faculty of Civil Engineering
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# Road and Rail Infrastructure V

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# CONCEPTUAL DESIGN FOR ESTABLISHING TRAM IN THE PUBLIC TRANSPORT IN SKOPJE

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## Abstract

Skopje is capital of Rep. of Macedonian with more than half million residents and the region of Skopje include more than six hundred thousand inhabitants. The demographic and socio-economic characteristics of this region require a good-quality and well-organized public transport systems that will accommodate a growing traffic demand and meet the criteria and objectives of sustainable urban development. The existing public transport in Skopje takes place only by buses managed by three operators. One of them is the property of City of Skopje, and two other represent associations of private bus companies operating smaller part of public transport. From an environmental sustainability point of view the City of Skopje and its surroundings is in a very vulnerable position considering its inland location surrounded by mountain ridges and strong seismic activities. Seasonal variations in climate and inversion phenomena reinforce the pollution from not always up to standard industrial emissions and an increasing traffic volume contributes heavily thereto. The socio-economic characteristics of the area are also typical for an urban area in transition with strong in-migration and daily commuting to jobs or for job seeking. All these specifics require introduction of a new environmentally sustainable public transport system in the city like a tramway (or light rail system). This paper provides a comprehensive elaboration of conceptual design of tram infrastructure solutions in Skopje in several phases and alternatives for future development of this public transport system.

*Keywords: transport planning, conceptual design, public transport, tram track, evaluation of alternatives*

## 1 Introduction

This paper provides a comprehensive elaboration of conceptual design of tram infrastructure solution in Skopje in several alternatives for future development of this public transport system. The conceptual design of the new tram line in Skopje is carried out in collaboration with the Faculty of Civil Enginnering at the University of Zagreb, Croatia.

## 2 Geographic, administrative, demographic, socio-economic and traffic data for Skopje

Skopje is a capital city of Republic of Macedonia located in the North part of the country (Fig. 1) where live more than half million residents. In the Region of Skopje dwelling more than six hundred thousand inhabitants. City of Skopje is constituted with then municipalities, and the Region of Skopje has additional seven municipalities.


**Figure 1** Location map of Skopje

The urban development of the city is carried out along the riverbed of Varadar. Skopje covers an area of 1818 km$^2$, 23 km in longitude and 9km in latitude and is situated on altitude of 245 metres. City of Skopje and its surroundings is in a very vulnerable position considering its inland location surrounded by mountain ridges and strong seismic activities. The mountain Vodno (altitude of 1066 metres) is located to the southwest of the city.
The dominant transport mode in the city is private cars with about 32 % of all trips in 2009, while the share of public transport drops from 34 % in 1999 to about 27 % in 2009 [1]. The rate of motorization increases regularly and it was 239 private cars per 1000 inhabitant in 2009 and 256 private cars per 1000 inhabitant in 2016 [2].

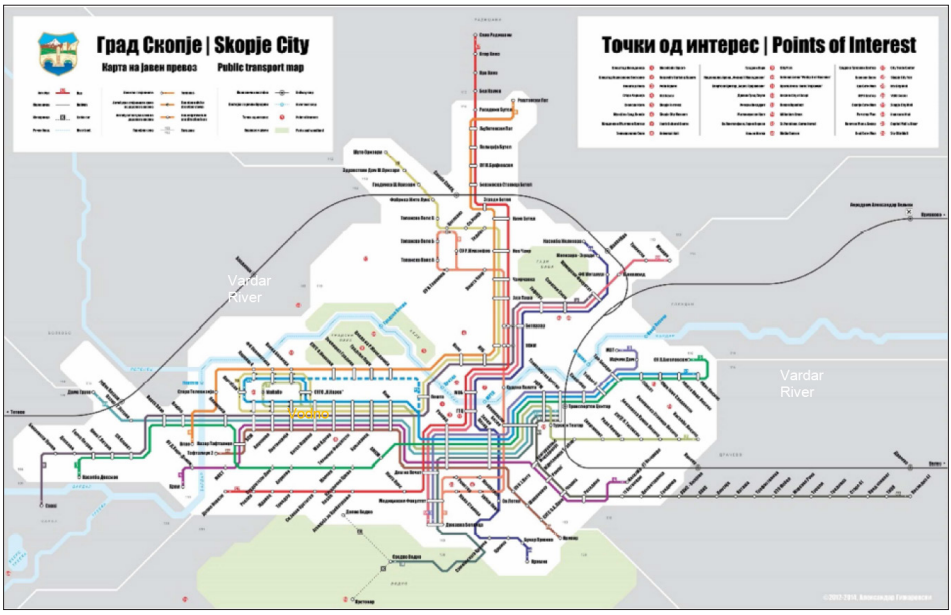


**Figure 2** Public transport in the region of Skopje

The existing public transport in Skopje takes place only by buses managed by three operators. One of them is the property of City of Skopje – JSP, and two other represent associations of private bus companies operating smaller part of public transport. About 84 % of bus lines are owned by JSP, and 16 % by private carriers. The JSP dispoes with 430 buses which average age is 10,1 years. In 2015 the JSP transported 52 milion passengers and in 2016 it was about 46 milion passengers [3].

## 3 New tram network in existing planning documents

The most important document concerning traffic issues is Transport Master Plan (TMP) which is produced for the needs of Skopje's Spatial Urban Plan (GUP); the latest was carried out in 2010. The planned tram network is designed in the Feasibility Study of Tram in Skopje made in 2007 (Fig. 3). The concession potential of project for development and introduction of tramway system (or LRS) for passenger transport in the area of the City of Skopje was assessed in the Feasibility Study (FS) made in December 2010 [4]. The assessed passenger flow in 2010 in peak hour along the tram network is shown on the next picture (Fig. 4).

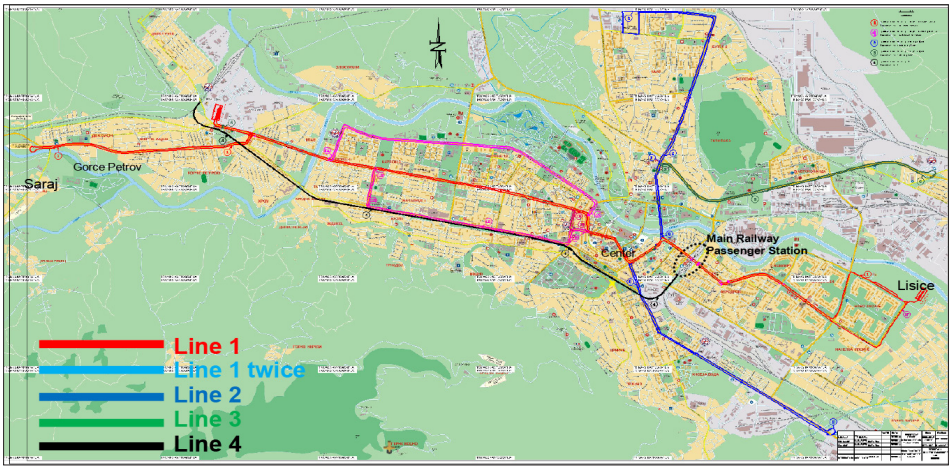


**Figure 3** Planned tram network in Skopje in 2007

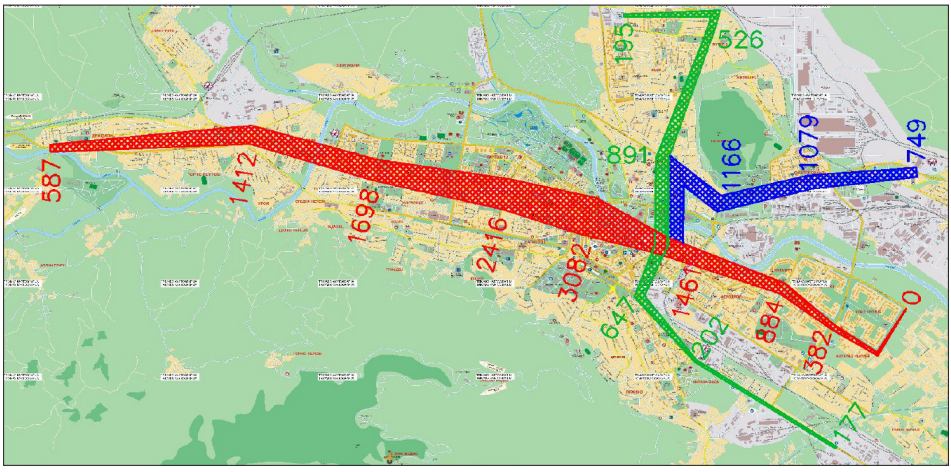


**Figure 4** Estimated passenger flow in peak hour in 2010

The estimated infrastructure construction cost in this FS for about 24 km tram track with catenary and depot is 75 mill.euro, for tram vehicles is 42 mill.euro, or in total is 117 mill.euro. The estimeted operational cost per year is about 8 mill.euro/year. According to the traffic assessments, it is evident that the first stage of development of Tram network (or LRS) in the City of Skopje should be foreseen along the route of Line 1 (Fig. 3).

## 4 Conceptual design of tram system

The Faculty of Civil Engineering Zagreb – University of Zagreb, Croatia and the Faculty of Civil Engineering Skopje – University St. Cyril and Methodius, Macedonia, have cooperated and studied development of this very important project for Skopje. The development of tram network in Skopje is envisaged to be built successively in four stages (Fig. 5). The conceptual design solutions of two variants of the construction of two-lane tramway tracks of Stage 1 are made according to the TMP and GUP of Skopje, located in the corridors of existing streets [5].

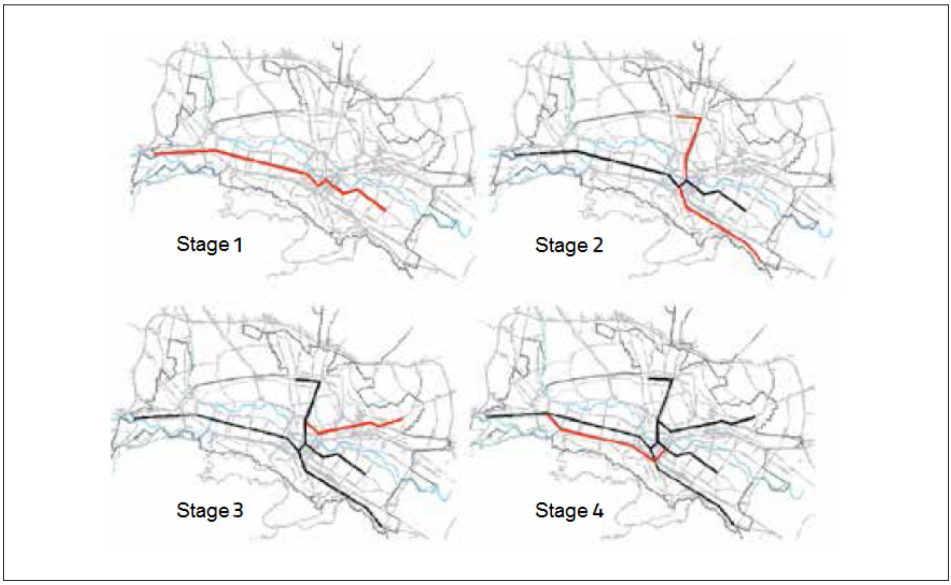


**Figure 5** Development of urban railway public transport in Skopje in 4 stages

The tramway Line 1 extends from western to eastern part of the town (Fig. 3) starting in Saraj toward Lisice. Although the new tram infrastructure is preferable to locate them in a separate traffic corridor, the tramway tracks in Skopje are planned along the edge of the pedestrian corridor on the right carriageway of streets (Fig. 6). The reason for this is that the central part of the traffic corridor has been already occupied by underground installations and infrastructure. This layout of the track reduces the operational speed of the trams to an average of 14 km/h due to frequent conflicts in intersection zones. Therefore, in the elaboration of the conceptual solutions, it was considered the possibility of separating the tram tracks from the rest of the motorized traffic. Thus, in the first two variants (A and B) the tracks are guided at the terrain level and the difference between them is just on the location of terminals at Lisice, while the third variant (C) foresees their placement in tunnel along the wider centre area. This design solution would increase the operating speed of tram at 40 km/h. The excavation of tunnels is planned to be made at a maximum depth of 20 m, taking in consideration the soil characteristics and depth of the existing pipelines and installations. The tramway depot with 2 transit tracks, 8 service tracks and 8 garage tracks is designed in Gorce Petrov near to the existing railway station. The applied horizontal curves are determined according to the projected speed of the city roads within which the tramway route is foreseen, while the minimum applied radius in the intersection zones is 25 m.

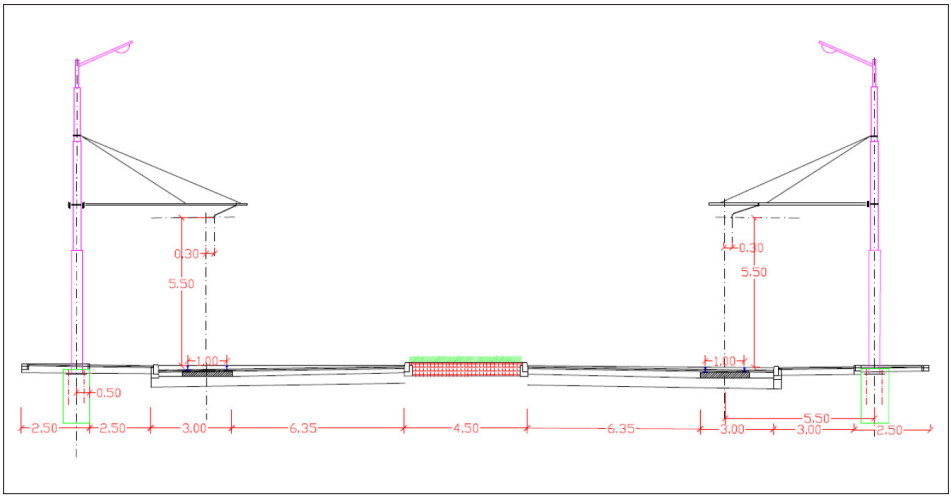


**Figure 6** Cross section of tram lines at the street level

The minimum lengths of the transition curves – clothoid are defined according to the minimum length of the super-elevation ramp that meets the required safety and comfort requirements. The transition curves are not applied in the case where a radii curve are greater than 2000 m, the S-curve, the curve with a small angular angle and the cross-curve. All applied tram switches are designed with an angle of $\alpha = 5.81°$ and a radius of R = 50 m. The ramps for entry and exit from the tunnel have longitudinal gradient of 35 ‰ (length 575 m) and 55 ‰ (length 365 m).

**Table 1** Characteristics of variants analysed in conceptual design

| Characteristics | Variant | |
|---|---|---|
| | A and B | C |
| Total track length (km) | 30 | 30 |
| Total track length in tunnels (km) | 0 | 17 |
| Number of stops (one direction) | 24 | 17 |
| Commercial speed (km/h) | 14 | 22 |
| Travel time (one direction) (min.) | 65 | 40 |
| Construction cost of tunnels (mill. euro) | 0 | 261 |
| Total construction cost (mill. euro) | 77 | 338 |
| Number of tram vehicles traveling per day | 26 | 18 |
| Cost for tram vehicles (mill. euro) | 52 | 36 |

The data shown in the table above give a good figure for the studied conceptual design solutions for tram Line 1. The variant C is more expensive because there are important portion of track in tunnels (more than 50 % of length), while the variants A and B need more tram vehicles because the travel time is higher than this in variant C. However, the construction cost of tunnel is very important and the reduction of number of vehicles is not compensating for the disparity between the costs of construction.

## 5 Conclusion

The demographic and socio-economic characteristics of Skopje City require a good-quality and well-organized public transport systems that will accommodate a growing traffic demand and meet the criteria and objectives of sustainable urban development. The socio-economic characteristics of the area are also typical for an urban area in transition with strong in-migration and daily commuting to jobs or for job seeking. All these specifics require introduction of a new environmentally sustainable public transport system in the city like a tramway.
The conceptual designs of tramway Line 1 are made for three variants A, B and C. The alignments of tram line in the variants A and B are on the street level, while this one in variant C has more than 50 % of length in tunnel which increases considerably construction costs. The number of vehicles in variant A and B is less important of this in variant C, but the disparity of construction costs remains to be very significant. Hence, the optimisation of vertical alignment design in variant C in longitudinal profile should be proceeded to reduce construction costs like the solution for the Light Rail System LRS line Metro Ouest in Lausanne [6].

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