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## Road and Rail Infrastructure IV

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## ROUTE GUIDANCE OF TRAM TRAFFIC IN CITIES: PARTICULARITIES OF TRAM TRAFFIC IN THE CITY OF OSIJEK

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### Abstract

An important part of the urban public transport system consists of a network of tramways which effectively connects parts of the city and / or suburban areas. Tram is suitable for the entire metropolitan area, in particular for wider central zone, and the transport capacity ranges from 4000 to 15,000 passengers per direction and per track per hour, depending on the method of running the tracks. Tracks can run as integrated or segregated on-street tramways or as off-street tramways wholly separated from pavement. The construction of the tram tracks on road surfaces is more expensive, traffic is slower, and special attention should be given to measures for traffic regulation due to frequent conflicts with other road users. Commonly, tracks are built separated for each direction of travel, but due to the lack of possibility for such traffic management, a single track can be performed for both directions of travel. The planning and construction of bi-directional single track is specific because of facilities like passing loops, signaling, etc., but also for presence and frequency of conflicts of tram with other types of traffic. The paper will describe solutions for tram traffic in the city of Osijek, with special emphasis on the tram traffic on by-directional single track tramway and increase of safety measures for conducting traffic.

*Keywords: tram infrastructure, by-directional single track tramway, conflicts, safety measures*

### 1 Introduction

Classic urban public transport system consists of two subsystems: road and rail, which differ from each other according to subsystem type, types of management and guidance of transportation device. An important part of the urban rail system is a network of tramways. The tram system consists of one or more electrical vehicles running on tracks along other modes of road traffic or as off-street tracks, while driver's only job is to control the riding speed of vehicle. This traffic mode allows minimum route width, higher travel quality and greater stability. Trams have good dynamic characteristics and provide a comfortable ride, but their reliability and speed depend on the conditions of the route. If the tram line passes through the narrow streets with heavy traffic, together with other traffic participants, speeds will be lower, and traffic delays greater. The best effect is achieved with off-street tracks completely separated from pavement. Thus, capacity of tram traffic driven on off-street tracks is 180 vehicles/h/direction, while capacity of trams driven in mixed traffic flow is 144 vehicles/h/direction [1].

#### 1.1 The position of the tram tracks in the cross-section of urban roads

Tram lines can be guided along pavement, as integrated or segregated on-street tramways, or as off-street tramways, embedded into concrete, ballast or grass turf. Typically tracks are built as two tramways, separated for each travel direction. However, in cross-section of urban roads

a single tramway line intended for two-way traffic can be built and in this case it is necessary to perform passing loops. Construction of the tram tracks on the pavements of urban streets is more expensive than the off-street routes, and special attention should be given to traffic regulation measures without which the tram movement becomes more difficult, and conflicts with other road users are very common. Conflicts of tram traffic with other types of traffic can be reduced by measures of traffic techniques, such as [1]:

- Prohibition of left turn at smaller intersections and their regulation with traffic lights at major intersections,
- Prohibition of traffic from minor streets to the unmarked intersections – allowed only right turns,
- The introduction of “signal island” at tramstop to prevent the entry of cars in the station zone,
- Activation of signals at intersections that allow the tram departure before other vehicles,
- Special signal phase for tram traffic diversion that allow the movement of trams without excessive delay,
- The prohibition of parking of vehicles,
- Labelling traffic lanes reserved for public transport – marking or installing specific elements on the roadway,
- Asymmetrical railway position and movement in opposite direction (especially useful for one-way streets).

These applications of traffic techniques have been introduced in many European cities in the mid-sixties and give very good results. With respect to the traffic safety, off-street guidance of tramlines is the best solution, it allows faster flow of vehicles and easier transit through intersections.

In this paper tramway system of the city of Osijek is described, as well as a specifics of route guidance solution in Divaltova street where tram traffic for both directions is driven on single tramway, while a part of the tramway route runs on pavement along road vehicles.

## 2 Tram system in the city of Osijek

### 2.1 Development of tramway system

Tram traffic in city of Osijek has been ongoing for many years. 132 years ago, precisely, on September 10th of 1884, a horse drawn tram started to operate (in that time called horse railroad). This was the first such form of urban transport in Croatia and south-eastern Europe. Launching the tram transport was extremely important step in connecting and modernizing the city and a key step in integration of still unconnected city parts, a role that has been kept throughout history [2].

Electrification of the city in 1926, created the preconditions for the start of operation of electric trams and it has been officially opened to traffic on December 17, 1926. The length of the tram tracks for electric trams in Osijek was around 10 km, including all branches and depot/ car house area [3].

Extension of the tram network of Osijek took place on several occasions: in the 60s (Retfala – Višnjevac), 2006. (Đakovština – Mačkamama), 2009. (Bosutsko – Divaltova – Jug II) and 2014. (Višnjevac) (Fig. 1.).

Length of tram tracks today is approximately 29.2 kilometres (in city and outbound tracks in front of the depot). Tram line is fully operational and reliable for conducting tram traffic. It consists of 41 shunts and 5 crossovers. Tram line is for the most part embedded in concrete, approximately 25,3 km, while approximately 3,8 km is embedded in ballast [4].



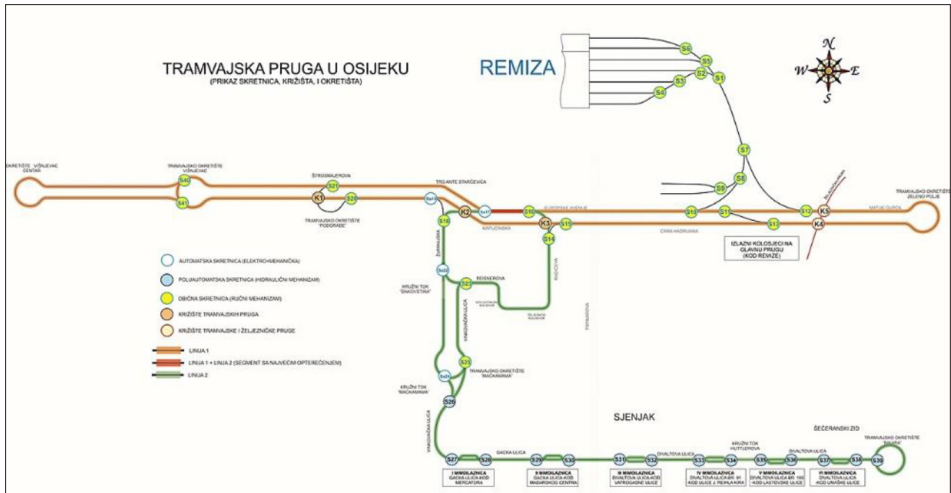


Figure 1 Tram network in Osijek today [4]

## 2.2 Single tram line – particularities of tram traffic guidance in Divaltova street

In the city of Osijek in 2009 a single bi-directional tram line was built as part of construction and reconstruction of important city road in Divaltova street. The tram track consists of: 6 passing loop, 13 shunts, 9 tram stops and 1 U-turn at Velebitska street (Fig. 2). The tram track is 4 413m long and split into 3 sections: section 1 – from Vinkovačka street to Kneza Trpimira street – 1 283m, section 2 – from Kneza Trpimira street to Srijemska street – 1 536m, section 3 – from Srijemska to Velebitska street – 1 594m [5]. Each section is shown on Fig. 2, differentiated by colour according to the type of route guidance. From route beginning in Vinkovačka street to Svilajska street tramway is segregated, running along left side of the road. In roundabout at intersection of Hutlerova and Divaltova street tram line crosses the pavement in an S shaped curve and than continues along the middle of the roadway until U-turn at the intersection of Divaltova with Velebitska St.

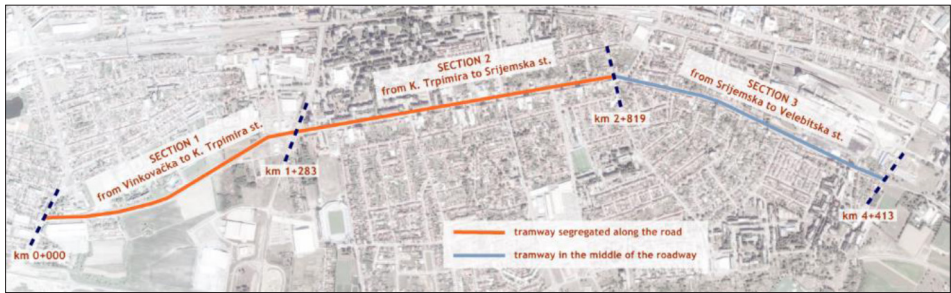


Figure 2 General layout with sections 1, 2, 3

Type of filling material dependeds on the location. From Vinkovačka street to Hutlerova street, where the track is in it own lane, the track is embedded into crushed stone ballast 30/50, while at level crossings and tramstops it is embedded into concrete and asphalt layer. Tramstop platforms are performed as elevated islands (+20 cm from rail) both along the edge of the pavement on sections 1 and 2 where the tracks are separated in the special lane (Fig. 3a), and also on section 3 where tram traffic takes place in middle of pavement (Fig. 3b).



Figure 3 Tram stops: a) along the edge of the pavement, b) in the middle of pavement

### 2.3 Conflict of road and rail traffic on the considered section

Along the route at Divaltova street tram line passes and crosses 14 intersections, 8 of which 8 are tree-legged, 5 four-legged and 1 is roundabout at Huttlerova street. Because of the specific mode of traffic these are potentially dangerous places for drivers, pedestrians and cyclists. Especially dangerous place are pedestrian crossings at the end of the promenade Sjenjak and in front of the school Fran Krsto Frankopan, regulated only by traffic sign.

#### 2.3.1 Accident record

Accident data [4] for the bi-directional single track in Divaltova Street in the 5 year period shows there has been a total of 80 accidents involving tram traffic. In figure 4. it can be seen there is a steady decline in number of accidents in the given period from 2011 to 2015. This means that drivers and other participants in traffic have gotten more aware of the risk for accident and thus more accustomed to this kind of traffic situation. Contribution to drivers awareness and decrease in occurrence of accidents can be also found in recently marked horizontal “tram” signs on pavement of some minor streets in proximity of intersection with Divaltova St. A closer look at distribution of accidents per location can give more insight into problematic situations and design.

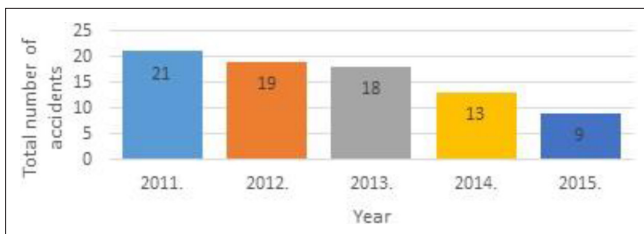


Figure 4 Total number of accidents per year [4]

#### 2.3.2 Route critical locations – increased number of accidents

Figure 5. shows locations with the highest number of accidents in 5 year period. A great number of this accidents occurred on smaller intersection without traffic lights, where only a few



of them have left turn lanes. Those are intersections of Divaltova Street with minor streets at Sjenjak area, Gacka, Reihl Kirova and Krbavska Street. It should be noted that Sjenjak includes several smaller streets connected to Divaltova Street, not an isolated intersection.

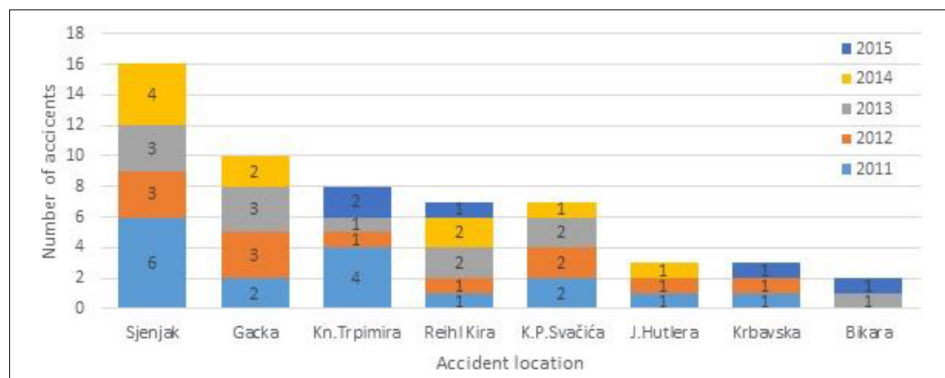


Figure 5 Distribution of accidents per location [4]

At intersections with Trpimirova St and Svačićeva St a high number of accidents was also recorded even though they are regulated by traffic lights. But this is intersection of streets with high average daily traffic, which is a possible cause of increased number of traffic accidents. Other instances of accident are isolated events distributed on the whole stretch of tram line.

### 2.3.3 Suggestions for possible improvements

Improvements of traffic safety, without major reconstructions, can be obtained through different measures of traffic techniques. Horizontal and vertical traffic signalization is an example of such measures that does not require large financial means and can be easily installed in short time period. Decision on solution type should be based on each location specificities, exiting signalization and occurring problems. On a given route two groups of solutions can be implemented depending whether it is a minor intersection or major one regulated by traffic lights. In major intersections that are already regulated with traffic lights a synchronization of left turning road traffic and passing trams should be done. The greatest safety issue here are permitted left turns governed by traffic lights coinciding with oncoming trams behind them. A simple signal phase that would allow tram departure before other vehicles could improve safety. At minor intersections there is a need for placing additional horizontal and vertical signalization that would emphasize the presence of the tram on the paths that would intersect with it. On the pavement of left turn lanes in Divaltova St. it is advisable to mark horizontal “tram” sign. Oncoming trams intersecting with the right turns in Divaltova St. could be emphasize with vertical signalization in form of blinking yellow lights. Vehicles approaching Divaltova St. from minor roads should have both horizontal and vertical signs warning them on intersecting with tramway. On certain locations yield signs should be replaces by stop signs due to questionable sight distance and reaction time of drivers.

## 3 Conclusion

Tram traffic in Osijek takes place on a network approximately 29,2 km long, of which 4,4 km is bi-directional single tramway in Divaltova St. Construction of single tramway in 2009 is significant for connection of southern city districts and also as modernization of transit in those neighbourhoods. However, in addition to the benefits of connecting parts of the city, specific two-way traffic results with higher number of traffic accidents than in the rest of the tram network where two-way traffic is separated on special tracks for each direction of travel.

The reasons are (other than the usual: negligence), primarily in the fact that motorists, cyclists and pedestrians do not expect the emergence of a tram in the west-east direction, a direction that is opposite to the movement of road vehicles on traffic lanes next to it. When the single track line opened to traffic, accidents were frequent, as confirmed by the official statistical data, but there was also a number of “conflict” that were avoided at the last minute and were not recorded. Road users that are daily driving, biking or walking along Divaltova St can testify to this. Certainly it is encouraging that over time the number of accidents decreased. It took time for all traffic participants to accept the bi-directional tram traffic on single tramway and adjust their behavior in traffic accordingly. Still, additional traffic technique measures can be made at different intersection as a measure of precaution to increase traffic safety. Installation of additional horizontal and vertical signalization, solutions that depend on location specificities, doesn't require large financial means or major reconstruction works but could have great benefits on traffic safety.

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