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**DETERMINATION OF TRANSPORT AND TECHNICAL  
CHARACTERISTICS OF NEW MULTIPLE UNIT TRAINS  
FOR CROATIAN NETWORK**

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**Key words:** rolling stock, technical characteristics, multiple-unit trains

**Abstract:** *The Croatian Railways rolling stock is much characterized by diversity of types, models and series. This kind of system generates high maintenance costs and the most vehicles are obsolete and unavailable. Although Croatian Railways endeavored in the last few years in acquiring some new vehicles and modernizing some old series, the most of the rolling stock is more than 30 years old. The worldwide economic crisis has brought rail cargo transport to stagnation, but on the other hand passenger transport, especially in the urban-suburban service, offers much better perspective. Old, unreliable and uncomfortable rolling stock poses a strong set back to competitiveness towards other rail operators or even more, other modes of passenger transport. Therefore factors like quality of service, punctuality, price and comfortable journey will be the key for attracting passengers. These requirements are to be met by acquisition of new multiple-unit trains for urban-suburban and regional transport. The paper is analyzing the productivity of the old multiple unit trains in the past period. On the basis of transport demand and passenger transport prognosis for the next period the acquiring of new sets of multiple-unit trains is proposed. There are also determined the technical characteristics for the new multiple-units as well as the needed structure of the trains.*

## **1. INTRODUCTION**

The Croatian Railways rolling stock is rather diverse in type and obsolete. It consists of 18 series of traction vehicles alone, diesel and electric. Although the company acquired in the last few years several new vehicles and modernized few old ones, the average vehicle age is still over 30 years. Required maintenance technology and short intervals in between for old series of vehicles and general obsolescence are the main reasons for low availability. On average, 25 – 30% of diesel and electric locomotives are unavailable on the daily basis and also 20 – 25% of diesel and electric multiple units. According to current availability of classic passenger railcars and multiple units, there are, on average, 374 vehicles in daily use. These vehicles are used for running 715 various passenger services daily (most in both directions). Yearly, these trains perform 18.1 million train-kilometers (period 2011/12), 49.5% of that sum is realized by multiple unit trains.

## 2. CURRENT STATUS OF ROLLING STOCK

Despite general obsolescence, the current status of passenger railcars and multiple units is satisfactory from the safety point of view by virtue of several investment projects of restoration and modernization. Unfortunately, classic passenger railcars are not suitable for urban and suburban service and commuters. Classic railcars are fitted with too narrow entrance and too high floor for adequate passenger transfer in urban/suburban service, the passenger compartments are obstructing the passenger flow on short voyages and taking up the standing space.

On the other hand, using multiple unit trains in the local service is characterized by lower running costs, higher energy efficiency and lower environment impact. Nevertheless the general condition of the multiple unit trains used in Croatia is unsatisfactory for number of reasons:

- low availability,
- obsolete construction of EMUs is no longer adequate (narrow entrance, poor ventilation, low capacity, low running reliability),
- DMUs are too unreliable in service and have bad ventilation system.

Despite high regular maintenance costs (modernization not included), low availability is causing timetable disturbances, increases management costs and loses users' trust. The number and types of multiple unit trains used by Croatian Railways are shown in Table 1.

**Table 1: Available multiple units [2]**

Multiple unit type	Production year	Quantity	Active vehicles	Planned availability (2012/13)
DMU - local service (mono-unit)	1981	35	34	22
DMU – local service (dual-unit)	1980-1982	31	31	22
DMU - long distance (dual-unit, tilting)	2004	8	6	3
EMU - 25 kV 50 Hz (triple-unit)	1977-1978	21	21	15

When talking about rolling stock, especially vehicles designated to urban, local and regional area, operational cost must be also taken into account. Operational cost consists of:

- infrastructure costs (use of train paths) ,
- maintenance costs,
- traction cost (engine personnel, traction vehicle maintenance, propulsion energy, amortization)
- cleaning costs,
- shunting costs,
- inspection service costs,
- train and other personnel costs.

At present, infrastructure cost is not adequately rated cost category. The infrastructure manager is not charging realistically for infrastructure usage. Infrastructure costs must be charged properly to the operator. Currently, the infrastructure manager is charging 0.5€ per train-km, in 2007 that amount was almost 10 times smaller.

### 3. DEMAND PROGNOSIS FOR THE NEXT PERIOD

The best results in passenger transport for urban/suburban areas of service are shown in the city of Zagreb. Other cities are more or less at the beginning of organizing this kind of service and are showing more modest results. In Zagreb area, most of the trains used for urban/suburban service are EMUs 6111 series, 25 kV/50Hz, produced by Ganz Mavag, Hungary in 1977 and 1978. These trains were originally acquired for regional service and currently only half of the units are operating as regional trains. According to the Croatian rolling stock manager HŽ Vuča vlakova, only 15 out of 21 EMUs were available on daily average in 2012 [2], therefore the calculated availability was 71,65%. EMU 6111 is characterized by high failure percentage (3.04 failures per 100 000 km in 2012 [2]) which causes disruptions in daily service. Series 6111 are also known for low reliability during winter season and snow precipitation. Additional discomfort and dissatisfaction is caused by poor ventilation system and inexistence of air-conditioning system.

Estimated daily availability for EMU 6111 series for 2012/13 timetable is 15 trains, which is insufficient and they are often substituted by classic composition trains. There is similar situation concerning DMUs used on the non-electrified part of the network for regional and partially suburban transport.

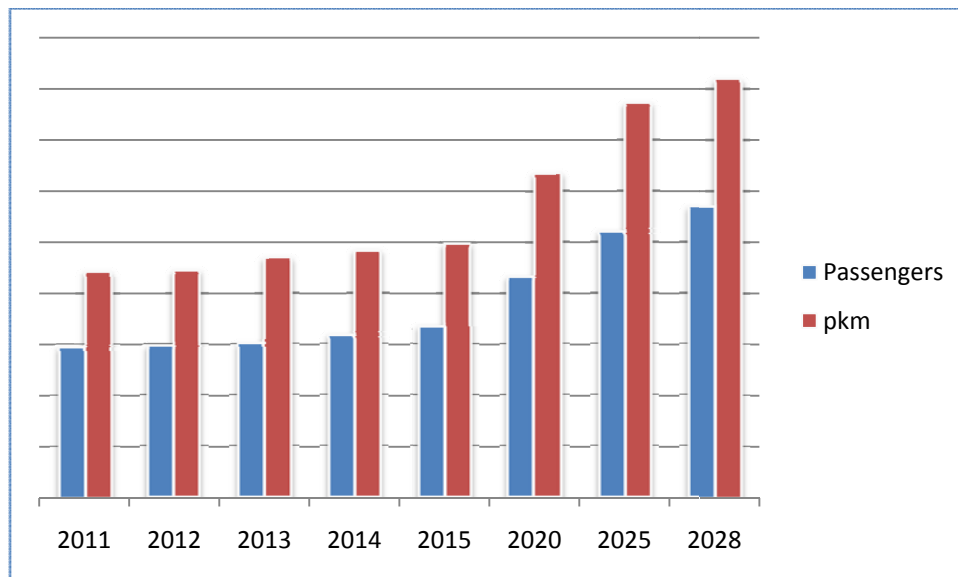


Figure 1: Prognosis of passenger increase [2]

In Figure 1 is shown the prognosis of passenger increase for the next period along with the past two years' average for the Zagreb urban/suburban area service. It also shows the estimated increase of passenger kilometers for the same service. Therefore, for the period from 2015 to 2020 it is estimated increase at 5.5%, from 2020 to 2025 at 4% and until 2028 at 3%. The aforementioned calculations were guided by several assumptions determined in the development studies of Croatian Railways for Zagreb area [1]:

- timetable reorganization,
- acquiring new EMU trains for urban/suburban service,
- implementation of new intermodal and integrated concept for urban/suburban service,
- realistic necessity for general improvement of the passenger transport quality, local and regional.

Similar to above, the reorganization should be made also in other major regional centers' services as well as integration of timetables locally and regionally. The concept of reorganization comprises:

- new categorization of local passenger service,
- turnover interval minimization by detecting optimum turnover station.

This organization of regional and suburban service should combine the complete supply into one uniform technological system. Therefore the categories like urban/suburban service should stop in all stations in given junction, but the local trains should service only the major stations of the junction. Outside the junction the local trains can stop in all stations connecting local centers. Regional service should be the real bearer of the provider quality in Croatia. Fast regional trains with more comfort and above all reliability and accuracy are essential to this concept. Dedicated regional service should offer high quality connections between region centers and not mix with local service.

#### 4. TECHNICAL CHARACTERISTICS FOR NEW MULTIPLE UNIT TRAINS

New multiple unit train for urban/suburban service should be designed with highest standards and modern attractive look. It also must meet expectations of potential passengers in way of speed, comfort and safety. It should provide good driving characteristics and traction in all conditions. The units should be with low-floor passenger area and entrance for 550 mm height of the platform. Also, the multiple unit composition should have double-door entrances for quick passenger transfer and at least two entrances per section, depending on the length. Ideal length for the whole composition for urban/suburban service would be 75 m so it could automatically couple in double composition and take advantage of 150 m long platforms if needed.



**Figure 2: Proposition for new multiple unit train**

Figure 2 presents a graphic proposition for new multiple unit trains. It should be built according to EN and UIC standards, offering long-term durability in usage with repeated stopping and starting and all that with much higher energy efficiency than presently used vehicles. For shortening the current travel time the train should offer much higher acceleration values (at least  $1.0 \text{ m/s}^2$ ). For the intended service and network, the train should provide at least 140 km/h of maximum speed. It should reach 120 km/h in less than one minute on horizontal track. If used for the regional service, it would have to provide up to 160 km/h of travelling speed.

The interior should be low-noise certified, light and spacy with translucent barriers where needed. Seats should be located in favorable positions, not to obstruct standing passengers and passenger flow inside the sections. The seats should be comfortable two-seaters without barriers. Different composition would be expected in the regional service trains, more suitable for longer rides and with business class sections.

All trains should have adapted areas for disabled persons including toilet facilities. The overall capacity of one composition for the urban/suburban service should be not less than 450 passengers. The number should go in favor of standing places in calculated ratio of 5 passengers per m<sup>2</sup>. High quality air-conditioning system should be a necessity. Video surveillance system for interior and exterior is a desirable safety feature. An important characteristic is attractive information system for passengers. Safety features like fire alarms and automatic extinguishers should be built in every unit.

## 5. CONCLUSION

The existing rolling stock of the Croatian Railways is not sufficient in terms of transport demand. Regardless of modernization of some series of multiple unit trains and classic railcars, more than 30 years old vehicles are still in use. Modernization of some series of vehicles is more than questionable considering now days' demands and criteria in passenger transport compared to the time when these vehicles were delivered. Another concern is the issue of maintenance costs which are increasing rapidly not just in terms of money but also time and very often leave the vehicle unavailable for service.

Another issue is railway passenger transport reorganization. Intermodal and integrated passenger transport is a new step forward in transport politics and must go hand to hand with new rolling stock acquisition. For Croatian railway passenger transport, in the next period, the strong points are urban/suburban service, especially in Zagreb City, local service and most of all regional service that needs to rise up with new rolling stock and high quality of service. The transport forecast shows constant increase in number of passengers. This potential can be harvested in only short period before some other operator takes his market share. The new multiple units must fulfill the given technical preconditions and safety measures and comply with given standards.

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# ОПРЕДЕЛЯНЕ НА ТРАНСПОРТНИТЕ И ТЕХНИЧЕСКИ ХАРАКТЕРИСТИКИ НА НОВИ МОТРИСНИ ВЛАКОВЕ ЗА ХЪРВАТСКАТА ЖЕЛЕЗОПЪТНА МРЕЖА

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**Ключови думи:** подвижен състав, технически характеристики, мотрисни влакове

**Резюме:** Подвижния състав на хърватската железница се отличава с разнообразие от видове, модели и серии. Тази система генерира високи разходи за поддръжка, а повечето возила са морално остарели и не работят. Въпреки че, хърватската железница в последните няколко години положи усилия да придобие нови превозни средства и да модернизира някои стари серии, подвижния състав в по-голямата си част е на повече от 30 години. Световната икономическа криза доведе железопътния превоз на товари до стегнация. От друга страна пътническият транспорт предлага много по-добра перспектива, особено при градските и крайградските услуги. Стар, ненадежден и некомфортен подвижния състав е поставен в неизгодна конкурентна позиция спрямо други железопътни оператори или дори други видове пътнически транспорт. Следователно фактори като качество на услугата, точност, цена и комфорт при пътуването ще бъдат ключови за привличането на пътници. Тези изисквания трябва да бъдат изпълнени чрез придобиване на нови мотрисни влакове за градски-крайградски и регионален транспорт. Статията анализира продуктивността на старите мотрисни влакове за минал период. Въз основа на търсето на транспортни услуги и прогнози за пътническият транспорт е предложено придобиване на нови мотрисни влакове. Също така е определена техническата характеристика на новите мотрисни влакове, както и необходимата структура на влаковете.