

ALOJZ BRKIĆ, D.Sc.  
Fakultet prometnih znanosti  
IVAN ŠVALJEK, B.Eng.  
HŽ - Hrvatske željeznice, Direkcija, Zagreb  
VINKO JENIĆ, B.Eng.  
Fakultet prometnih znanosti

Technology and Management of Traffic  
Review  
U. D. C. 656.223.1:625.45  
Accepted: Feb. 18, 1998  
Approved: Jun. 1, 1999

## ORGANISATION OF SUBURBAN AND URBAN RAILWAY TRAFFIC IN THE KRAPINA-ZAGORJE COUNTY AND THE CITY OF ZAGREB

### ABSTRACT

*Numerous inhabitants of the Krapina-Zagorje county fulfil their needs (work, education, trade) in the City of Zagreb. The main passenger streams are related to railway transportation which, due to insufficient investments in the infrastructure and transportation means, shows decrease in the service quality. A model is proposed for organising suburban and urban railway transportation in the Krapina-Zagorje county and the City of Zagreb, which would offer better quality in transportation services, increase economic efficiency of railway transportation, and thus eliminate the risk of having to close down certain railroads in the county.*

### KEY WORDS

*Krapina-Zagorje county, passenger railway transport, railway infrastructure, reconstruction, modernisation*

### 1. INTRODUCTION

Krapina-Zagorje County is located Northwest of the city of Zagreb, i.e. from Medvednica mountain to Strahinjčica and Macelj mountains, along the Krapina valley all the way to the Sutla.

The city of Zagreb, as the administrative, trading and business centre exerts strong gravitation power towards its surroundings, mainly towards the whole Krapina-Zagorje county. According to its urban and demographic development trend, Zagreb is also the origin of strong transportation demand and internal mobility of the inhabitants. This mobility of the urban and suburban inhabitants is, unfortunately, to the great extent realised through passenger car transportation.

In the Krapina-Zagorje county region the public transport is carried out by two traffic subsystems (bus and railway), whereas the Zagreb public transport uses three subsystems (tram, bus and railway).

The specific characteristic of transport in the Krapina-Zagorje county lies in the fact that many functions (work, education, trade) of its inhabitants

are realised daily in Zagreb. This means in fact that the transport problems within the Zagreb county, i.e. the city of Zagreb and the Krapina-Zagorje county, have to be to a great extent jointly planned and implemented.

More than 152,000 inhabitants of the Krapina-Zagorje county live in 422 towns and villages. Their everyday needs for travelling can be realised if the mentioned system is designed and developed integrally in accordance with the passengers' interests. The main passenger streams are related to railway traffic. This is precisely the reason why individual transport needs to be connected to public road and railway transport.

Over the recent dozen years, we have witnessed very little investments in the Croatian Railways (HŽ) infrastructure, even worse, current maintenance has been neglected. It is no wonder then, that the speed on the Krapina-Zagorje county railway lines is almost the lowest in HŽ (20 km/h), and timetables are being changed every year, reducing the number of lines. Many call this "quiet closing down of the lines".

In order to stop this negative trend, it is necessary to organise a rational traffic railway system in the whole gravitation region so as to enable quick entrance into and quick exit from Zagreb, and to relieve the unnecessary and everyday congestion in the Zagreb streets.

### 2. STATE-OF-THE-ART ANALYSIS

#### 2.1. Passenger railway transport

152,598 inhabitants (1991 census) live in the region of Krapina-Zagorje county, covering an area of 126.3 km<sup>2</sup>. The average population density of this region is 120.8 inhabitants per square kilometre, which makes it the most densely populated areas in Croatia, excluding the city agglomerations. About 85,000 inhabitants live in the wider gravitational region of the railway lines in the county, in 150 settlements out of which

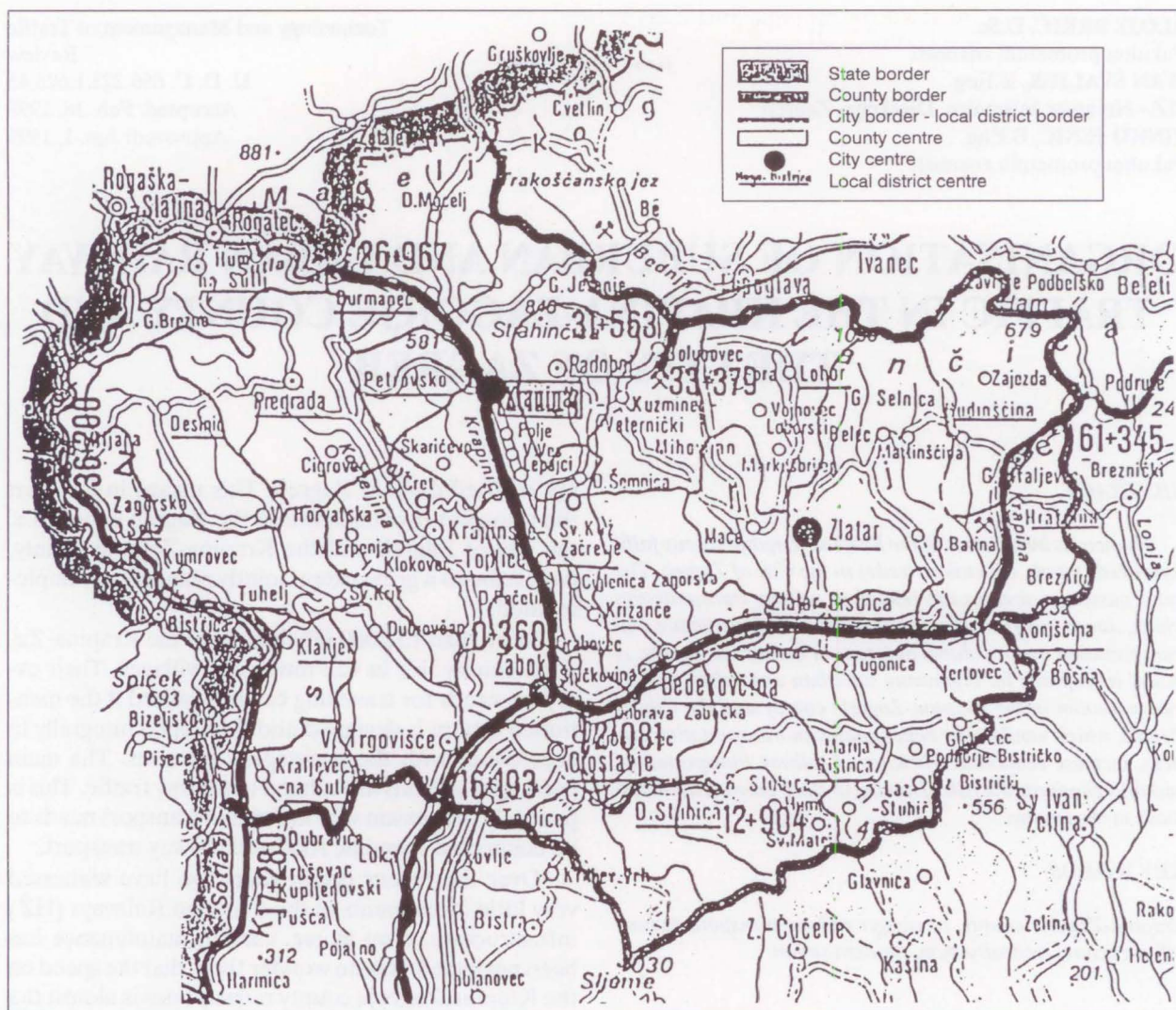


Figure 1 - Krapina-zagorje county

nine are towns. Almost 55% of the county inhabitants live in the wider area of the railway line. The data that Krapina-Zagorje county has 103,318 km of railway lines, and that the traffic is carried out at 36 official locations, indicate that the average distance between the railway official locations is 2.87 km, and the minimum distance is 1.8 km, and the maximum 6.8 km. Obviously, such small interstation distances indicate the good serviceability of the county by railway traffic, and on the other hand they substantially reduce the commercial speed of transport and their quality.

There are several towns in the Krapina-Zagorje county region with very strong correspondent relations, as well as the relations of these towns and other places on one hand and places in Zagreb and the Zagreb county on the other. Besides, out of the total number of travelling by railway of the Krapina-Zagorje county, about 80% refer to the suburban travelling. Therefore, in order to solve the problematic of the passenger transport related precisely to organising

of the railway suburban transport of passengers as a supplement and upgrading of the suburban transport in Zagreb and its environment. The number of transported passengers in the Krapina-Zagorje county is at the very top of the Republic of Croatia, i.e. at the third place (data of ERC HŽ in the last ten years). During 1997, about 1,800,000 passengers were transported, and an amount of about 20% passengers needs to be added who could not pay for the tickets, for various financial reasons.

The average commercial speed of passenger transport along railway lines amounts to:

- a) Zaprešić - Podrute 40 km/h
- b) Zabok - Đurmanec 36 km/h
- c) Zabok - Gornja Stubica 30 km/h
- d) Savski Marof - Kumrovec 41 km/h

Naturally, such low commercial speeds result from the great number of stops, bad condition of railway lines, inadequate insurance of railway stations and inadequate and obsolete means of transport. As an ex-

**Table 1 - number of seats occupied regarding railway line**

Railway line	number of trains	seats offered	number of passengers	seats occupied
Zagreb - Zabok	34	11,128	5,426	0.49
stright Zagreb - Budinščina	39	9,712	4,450	0.46
Zabok - Đurmanec	26	4,320	2,712	0.62
Zabok - Gornja Stubica	21	2,880	1,000	0.35
Savski Marof - Kumrovec	16	2,304	296	0.13

ample, let us compare this with the commercial speed of an IC train on Zabok - Zagreb relation, which is 62 km/h, which shows that possibilities for increasing the commercial speed of trains do exist.

The changing of trains has very adverse impact on the commercial speed of transport, so that the transportation speed from several towns towards Zagreb amounts to:

- a) Krapina - Zagreb 38 km/h
- b) Gornja Stubica - Zagreb 34 km/h
- c) Kumrovec - Zagreb 38 km/h

When changing trains in Zabok arriving from Gornja Stubica, on the average 13 minutes are needed, and when changing trains arriving from Krapina, 8 minutes are lost approximately. When changing trains in Savski Marof arriving from Kumrovec, 6 minutes are lost on the average.

The current timetable is planned on the basis of the available means of transport and mainly meets the demands for commuting to and from work, as well as to schools. Thus, during the considered period from 4 a.m. to 10 p.m. (18 hours), the following number of trains travel the following lines:

- a) Zagreb - Zabok 34 trains
- b) Zabok - Podrute 29 trains
- c) Zabok - Đurmanec 26 trains
- d) Zabok - G. Stubica 21 trains
- e) Savski Marof - Kumrovec 16 trains

If average frequency of railway traffic is considered, it is concluded that it is satisfactory and amounts to 1 - 2 hours. However, since the timetable is designed to meet primarily the travelling to work and school, a completely different scheme is obtained when considering the sequence of trains in peak intervals. Thus there are seven departures from Zabok to Zagreb between 4.31 a.m. to 6.56 a.m., with trains leaving every 37 minutes. Similarly, there are five departures of trains from Zagreb between 2.20 p.m. and 4.22 p.m., so that the average interval between the trains is 25 minutes. Such frequency of trains in the morning and in the afternoon peak hours results in a decrease of frequency during other parts of the day, so that the frequency of trains outside peak hours amounts to between 2 and 4 hours.

Of course, such low train frequency makes the railway less attractive and passengers decide to use other means of transport.

When looking at the occupancy of seats on certain trains (Table 1), one can see that it is much higher than the average of HŽ, which indicates that the trains are well filled. Further, if this occupancy is regarded per single trains, it is 5 to 250% which is highly inconvenient from the aspect of service quality, since trains in peak hours are occupied to a level much higher than the offered capacity.

## 2.2. Railway infrastructure

The total length of railway network in the Krapina-Zagorje county region amounts to 103,318 km, and is divided among the following lines:

- Zaprešić - Čakovec (section Žeinci - Podrute in the length of 45,173 km)
- Varaždin - Golubovec (section Očura - Golubovec in the length of 2,449 km)
- Savski Marof - Kumrovec - D.G. (section Prosinec - D.G. in the length of 16,783 km)
- Zabok - Đurmanec - D.G. (length of 27,187 km)
- Hum/Lug branch - Gornja Stubica (length 10,823 km)

No main railway lines pass through the county. The section Žeinci - Podrute has the status of the 1<sup>st</sup> order line, and all the others are of the 2<sup>nd</sup> order.

It is interesting that all the five railway sections in the Krapina-Zagorje county, have organised areas and constructed asphalt low platforms at the official locations planned for passenger handling, except the Gornja Stubica railway station, and this is one of the major prerequisites in structuring the suburban traffic.

## 3. FORECASTS REGARDING RAILWAY PASSENGER STREAMS

The assessment of the number of passengers is based on the data of the formal statistical method of the interviewed passengers, and the expert method, (15 experts, out of which 10 from HŽ and 5 from out-

**Table 2 - Forecast daily number of railway passengers in 1998**

Railway line	Passenger transport within the county	Passenger transport towards Zagreb	Passenger transport towards Varaždin	Passenger transport towards Slovenia	Passenger transport in transit Zagreb-Varaždin	Total
Zaprešić - Varaždin	3996	3090	218		828	8140
Zabok - Đurmanec	3334	1758		116		5208
Zabok - G.Stubica	846	634				1480
S.Marof - Kumrovec	62	338				400
Total	8238	5820	218	116	828	15228

**Table 3 - Forecast daily number of railway passengers in 2000**

Railway Line	Passenger transport within the county	Passenger transport towards Zagreb	Passenger transport towards Varaždin	Passenger transport towards Slovenia	Passenger transport in transit Zagreb-Varaždin	Total
Zaprešić - Varaždin	4408	3409	249		914	8980
Zabok - Đurmanec	3687	1944		129		5760
Zabok - G.Stubica	969	726				1695
S.Marof - Kumrovec	79	429				508
Total	9143	6508	249	129	914	16943

side HŽ). The forecast of railway transportation demand in the county region is based on the last pre-war year (1990), and the last war year (1995). [1] [2]

In the forecast we used as the basis the real forecast input and official transport forecast by HŽ by the year 2000, and the opinion of the interviewed experts. The year 1998 was identified as the year of likely return to the pre-war state. The forecast number of transported passengers in 1998 is presented in Table 2, and for the year 2000, in Table 3.

#### 4. PROPOSAL OF MODEL FOR ORGANISING RAILWAY PASSENGER TRANSPORT

For suburban travelling the directions, relations and approximate duration of travelling are mainly known, so that the organisation of train traffic needs to be planned in such a way as to meet the passenger demands regarding frequency, safety, speed and the appropriate capacity.

Among a number of aims included in organising railway suburban traffic, the ecological reasons are highlighted, according to which it is much more suitable (cleaner, healthier, causes less environmental pollution, less noise, etc.) to enter the very centre of the town, than for example car traffic.

One of the major principles of the passenger sub-urban transport is the so-called combined transport: PASSENGER CAR - BUS - TRAIN. In this kind of transport, the road carriers gather and concentrate passenger streams in the initial phase from a wider region surrounding the railway stops, who are then taken over by the railway and who are then again disposed by the road carriers in the final phase of travelling.

Therefore, it is necessary to equip the railway stops with bus terminals, as well as parking spaces for passenger cars and bicycles, and with all the other accompanying facilities so as to satisfy the comfort of passengers.

It is well known that the backbone of railway passenger traffic in the county is the Zagreb - Varaždin line, not only from the aspect of the main-line region, but also from the aspect of connecting lines.

There are three means of transport (three ranks) available on this main line, such as passenger, fast and IC trains, which require the highest possible concentration of traffic, in several major railway stations. Model [1] assumes that the passenger concentration at major railway stations is carried out by buses and passenger cars from near and farther surrounding, and also by train, by lighter and more mobile railcars. It needs to be mentioned that the supply of fast and IC trains is met by 4-axle carriages which provide greater comfort to passengers on longer journeys. In the remaining, i.e. passenger, and all the other trains on

other lines, the services are supplied in adequate types of railcars, which have to be very mobile due to frequent stopping.

The design of the model needs to take into account the lack of uniformity, i.e. the distribution of passenger demand during the day, which is in our case divided into three time periods, i.e. into three daily peak intervals of the highest traffic density. It is perfectly logical that the highest demand is concentrated in the early morning hours, with the start of all the activities which have to be reached from more remote places of residence, and in the afternoon when people are returning home. This, of course, is true for other places and urban concentrations as well, but Zagreb is the most prominent. At issue is, therefore, the phenomenon of mass demand over a relatively short period, and this can be met by the railway, since it is best suited to such a demand due to its technical and technological structure.

Apart from fulfilling the needs by supplying the trains on the *Zagreb - Varaždin* relation, with direct transport to Zagreb, without changing trains, such service is proposed also for the lines *Zagreb - Gornja Stubica* and *Zagreb - Krapina (Đurmanec)*. For this supply, adequate railcars are planned with easy manoeuvrability and speed. No great comfort is needed because the journeys are short. Here, it is important that passenger handling (changes) is carried out quickly (wide exit and entrance doors, high platforms) and that if necessary several sets can be joined into one composition (Diesel railcars). Connecting of these trains into larger units is important because they need to "collect" the largest possible number of passengers in the shortest time, and in the minimum number of major railway stations, in order to make the best use of the infrastructure capacity of the most critical section *Zagreb - Zaprešić* and the Main (West) Railway Station, i.e. to transport as many passengers as possible in the minimum number of larger units (trains).

The supply of trains on other lines is planned only up to adequate connecting railway stations i.e. *Zabok* for the line from *Đurmanec, Gornja Stubica* and *Sutla* or *Savski Marof* for the *Kumrovec* line. On these lines, except for the *Krapina* line, which is somewhat better supplied by the planned offer of direct trains, there is no greater demand concentration, so that adequate connections to the connecting stations can meet not only identified but also latent needs. As the connection to the *Zagorje* main line at the *Zabok* junction has already been explicated in this context, it may be concluded that the *Kumrovec* line as well (if necessary) may have strong and fast connections towards *Zagreb*, even with changing trains in *Sutla* or *Savski Marof*.

Since the demand for railway services on the lines of lesser intensity has been for the moment substituted

by road traffic, considering the dilemma between supply of larger train capacities, and lower frequency, we are in favour of a better flexibility in supplying smaller transport units with substantially higher commercial speed.

Although, organising of passenger railway traffic is of primary importance within this thesis, the passenger road transport has been considered also, at least implicitly to a certain extent, which includes a complex of interrelations between railway and road. Since the road network is much denser in the county than the railway network, it is easy to understand that road transport is so much more direct and more accessible to users, both in direct transport as well as in co-operation with railway. Therefore, the model took into account the ranking of certain transport carriers regarding their inertness on the transport market, so that we would like to stress the need for the carriers of more flexible characteristics to adapt to those of more permanent but less flexible ones. Respecting these characteristics in the reactions of transport carriers of the former ones adapting to the latter ones, here is the appropriate order: passenger car, bus, train. This order is imposed also by the economic justification (expenses) regarding the distance (the shortest in passenger cars, the greatest in railway), so that tendencies to engage railway as much as possible for mass transportation and for greater distances are perfectly understandable.

Instead of closing down the railway lines, it is necessary to improve and modernise railway transport in the *Krapina-Zagorje* county, that could become the main organiser of the passenger and cargo transport. In order to make the railway transport influence the economic and tourist development of the *Krapina-Zagorje* county, the started activities leading to improvement of the railway transport need to be continued, and the existing infrastructure needs to be most urgently reconstructed.

## 5. DYNAMICS OF REALISING URBAN AND SUBURBAN PASSENGER RAILWAY TRANSPORT

The phased implementation of the set organisation of urban and suburban passenger railway transport in the *Krapina-Zagorje* county, has been determined on the basis of two average time intervals which reflect the commuting state supported by the economic development plans in the region.

**First phase** (short-term) of the railway transport organisation relies on the possibilities of railway regarding the condition of vehicles and infrastructure, with necessary adaptation and repair of travelling capacities and infrastructure components, as well as the

new adequate traffic organisation. It is urgent to purchase by the end of this year (1998) 4 Diesel railcar units, which would provide 6 new lines on the Zabok - Krapina relation and 8 lines Zabok - G.Stubica.

**Second phase** (medium-term) of the railway transport organisation according to the set transport tasks needs to be carried out based on the technical and financial project as the basis for adequately solving the urban and suburban railway traffic, taking into account the optimal solutions for vehicles, infrastructure and traffic organisation. The following is needed:

- purchase of 10 new Diesel railcars
- reconstruction of railway stations with a substantial passenger capacity with road - railway design (parking spaces for passenger cars and buses, and adequate access to passenger platforms), e.g. at railway stations in Zaprešić, Zabok and Krapina, where there is the greatest frequency of passengers and all the conditions for designing of modern terminals exist.

**Long-term phase** of the realisation of urban and suburban transport in the Krapina-Zagorje county and the City of Zagreb plans the construction of new infrastructure facilities (lines and their electrification, provision of SS and TC devices, platforms) and purchase of modern means of transport.

## 6. CONCLUSION

The Krapina-Zagorje county has been realising many of its daily needs (education, work, medical care, etc), travelling by railway to Zagreb, and this provides also an aspect which makes it important whether to decide for the risk of closing down certain railway lines in the county.

The unsatisfactory condition in the development of the Krapina-Zagorje county, difficult internal traffic connections, and especially inadequate railway infrastructure hinder and slow down the better quality of connecting the county with Zagreb.

Low travelling speed by railway, disorganised stops, not reconstructed lines, inadequately organised road accesses and obsolete SS devices, along with the lack of railway vehicles, make the passenger railway transport difficult. This is particularly the problem in connecting Krapina, Zlatar Bistrica and Stubica with Zaprešić and Zagreb, as well as Kumrovec (and the settlements along the line) with Zaprešić and Zagreb.

It is extremely important in the future development, realising it over a long term as a feasible and rational objective, to realise those phases (infrastructure, vehicles, organisation) which will efficiently and directly increase the frequency and quality of transport and will not disturb the planned vision and development goals.

Therefore, it is important to design the terminals joining the road and railway transport as a unique transport and urban whole. Of course, the fact needs to be taken into account, that substantial participation in the integrated passenger travelling will be provided by the travelling: passenger car - bus - train and vice versa. In order to make such travelling competitive, apart from comfortable ride, also convenient transfer is needed (waiting rooms, shelters, areas for passenger entrance and exit, organised parking spaces at all the official locations etc.).

For the total traffic system, and especially the passenger transport system, to develop efficiently, it is necessary to gradually construct and reconstruct the existing road network. Within the frame of this basic and general objective, it is necessary to work on the reconstruction of intersections and dangerous points, as well as the design of bus stops. One of the important elements is also the organisation of pedestrian paths and pavements i.e. side-spaces.

At the government level, and also at the level of local authorities (counties, city, local districts) for the consistency and efficiency of development, it is necessary to search for stimulating measures, even co-funding, especially of the public and suburban traffic, as well as inter-city traffic, particularly to the extent in which inter-city traffic has the characteristics of the suburban one (daily commuting from the Krapina-Zagorje county to Zagreb). This means high quality infrastructure (roads, railway lines, terminals), which will be primarily developed by the government and local authorities, whereas the vehicles and the transport organisation itself can be funded and carried out by various investors on the basis of contracts signed with the government, i.e. local authorities.

This proposal of suburban and urban railway traffic organisation of the Krapina-Zagorje county and the City of Zagreb has the objective of stimulating first of all the authorised county, city and local district authorities, as well as transport experts to consider and not to question any single section of the railway lines for closing down, but to urgently reconstruct the existing mobile and stable facilities i.e. to improve the traffic (1<sup>st</sup> phase), which is in the interest of all the inhabitants in the Krapina-Zagorje county.

### SAŽETAK

#### PRIJEDLOG ORGANIZACIJE PRIGRADSKOG I GRADSKOG ŽELJEZNIČKOG PROMETA KRAPINSKO-ZAGORSKE ŽUPANIJE I GRADA ZAGREBA

*Mnogobrojni žitelji Krapinsko-zagorske županije svakodnevno svoje potrebe (posao, škola, trgovina) ostvaruju u gradu Zagrebu. Glavni tokovi putnika vezani su za željeznički promet koji zbog nedovoljnog ulaganja u infrastrukturu i prijevozna sredstva postupno sve manje zadovoljava potrebe.*

*Predlaže se model organizacije prigradskog i gradskog željezničkog prometa Krapinsko-zagorske županije i grada Zagreba koji bi dao kvalitetniju ponudu prometnih usluga, povećao rentabilnost željezničkog prometa, te time otklonio rizik od ukidanja pojedinih pruga u županiji.*

## LITERATURE

- [1] *Project of the model of organising passenger transport in the Krapina-Zagorje county.* Prometni institut Zagreb, Zagreb, May 1996
- [2] *Long-term ŽTP - Zagreb development program for the time period until 2000.* Centar za razvoj, ŽTP, Zagreb, 1974
- [3] *Work group. Study of the social and economic suitability and justification of founding the "Gradske željeznice" group* (Eng: Urban railways), Zagreb, April, 1998
- [4] **J. Božičević**, *Stanje i budućnost Hrvatskih željeznica.* Fakultet prometnih znanosti, Zagreb, November 1992.