JASNA GOLUBIĆ, D.Sc.
Fakultet prometnih znanosti
Vukelićeva 4, Zagreb

Traffic Safety and Ecology
Preliminary Communication
U. D. C. 656.25:504
Accepted: Oct. 17, 1997
Approved:Dec. 11, 1997

EVALUATION OF THE FAVOURABLE ECOLOGICAL IMPACT OF THE RAILWAY ON THE ENVIRONMENT

SUMMARY

The railway has advantages over other branches of long-distance transportation from the ecological, economic, safety, and technological point of view.

The paper gives an evaluation of the favourable influence of railway traffic on the environment reflected in the rational energy consumption, significantly reduced need of physical space, and reduced air pollution.

Having these data in mind, the railway is considered to have a negligible influence on environmental pollution. However, studying even such small amounts plays a significant role in the traffic safety and in the lives of people and nature itself.

1. INTRODUCTION

The environmental protection in UIC has since 1991 been the basis of the development regarding the role of the railway in the future traffic scene in Europe. Since the European roads and air routes are getting saturated, the railway with all its advantages has shifted into the centre of the discussions about the future of traffic.

The concept of high-speed railways, understood in the beginning as a technological challenge and daring economic venture, has been confirmed now as a new way of travelling. The examples thereof can be seen in Japan - with the highest-speed railways, and in the experience of high speeds in Germany, Italy, Spain, etc. The relation between the development of high-speed railways, and the increasing and justified care for the environmental protection can sometimes be contradictory. On one hand, the development of high-speed railways provides a clear alternative, especially in Europe, to the excessive development of roads and air traffic. At the same time it is obviously a form of traffic which has the least adverse effects on the environment, considering the consequences of medium or high pollution. On the other hand, the need for environmental protection includes the need of implementing strict conditions in the construction of new infrastructure, which is a process that could delay its development, or even prevent it in certain cases. What is needed, is a sane compromise between the environment and the results of extra costs in the construction of new lines in accordance with the acknowledged economic criterion.

The development of high-speed rail network is an extraordinary plan which could match our wishes for greater mobility with the higher quality of living, and so the emphasised protection factors should not overshadow the advantages:

- its efficiency in energy consumption, which can be even improved by gradual introduction of "double-deck" rolling stock,
- its efficiency in "land-take" conditions,
- advantages for the users by virtue of time saving,
- higher level of safety compared to roads,
- lower costs compared to air traffic,
- significantly lower air pollution by harmful substances.

The noise, however, is still a problem of high-speed trains, and therefore remains to be studied in order to be reduced. Taking all this in consideration, the mentioned advantages, the ecological advantages of the rail traffic also outweigh the drawbacks of new lines construction, the length of which is, especially in Europe, more or less faultless.

The aim of this paper is, therefore, to evaluate the mentioned ecological advantages of the railway in comparison to other means of transport, first of all in relation to the numerically superior road traffic.

2. THE RAILWAY TRAFFIC AND ENERGY

The first basic parameter of pollution is the energy consumption (Figure 1). The total traffic consumes about 25% of energy. The road and air traffic consume 100% of liquid fuels. In the European railway traffic with 3% of consumed energy, 23% of goods and 9% of passenger traffic is performed, whereas the road traffic consumes 85% of energy for 61% of goods and 84% of passenger traffic.

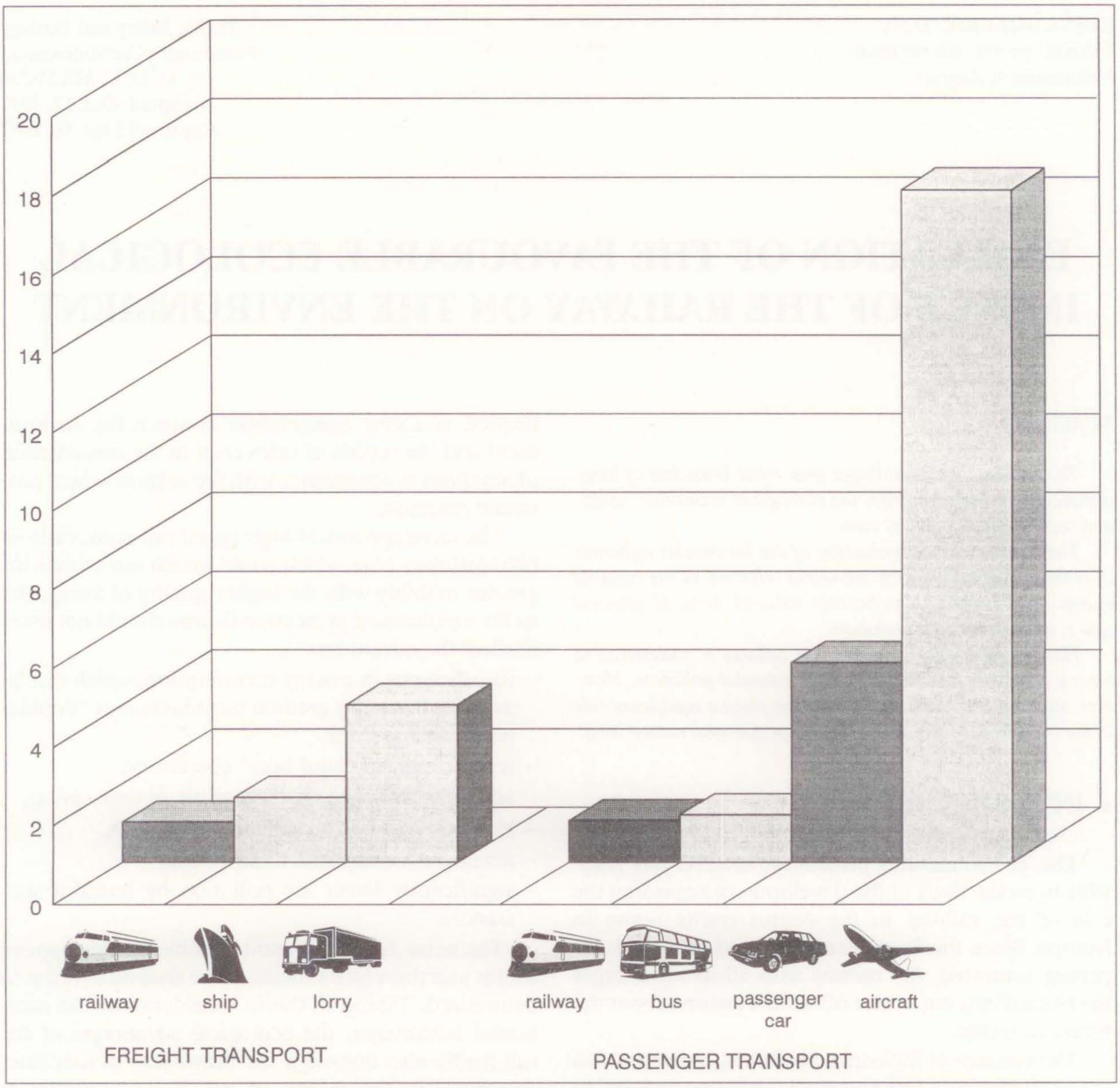

Figure 1 - The comparison of fuel consumption per work unit (NTKM, PKM) of the railway and other types of transport with 50% capacities

The railway uses three kinds of energy: electric energy, liquid fuels (gas oil), and coal. In railway traction vehicles the amount of consumed fuel depends on: the weight and type of the train, type, power, and construction characteristics of the diesel engine, its technical condition, type of the locomotive, technical condition of wagons, locomotive operating regime, and the duration of individual regimes. The skill of the personnel also has a great influence on the fuel consumption, the good knowledge of the track layout, skilfulness in managing the driving techniques, ground configuration, etc.

The structure of the fuel consumption of track motor vehicles in Croatia is presented in Table 2.[3] The diesel traction in Croatia started in 1938 when the first diesel train with mechanical transmitting gear was manufactured in Slavonski Brod. This type of traction is applied today on a big scale, due to the efficiency of 25 to 32%. In 1969 the electric locomotives for monophase electricity started to be manufactured in Zagreb in the "Rade Končar" factory. Great advantage of the electric traction is the higher overall efficiency compared to all the other kinds of traction, ranging from 32 to 36%. Turbine traction understands a vehicle propelled by gas turbine, and the first such locomotive was produced in 1941 in Switzerland. Gas turbine has certain advantages due to its low weight and small dimensions and high power, but its main drawback is the low overall efficiency (up to 18%).

Table 1 - Fuel consumption of track vehicles in Croatia[5]

Type of fuel	Unit	Type of traction	1960	1970	1980	1990
Pit-coal	t		200 275	105 824	7 231	–
Charcoal	t		515 765	256 959	50 241	–
Lignite	t	Steam	205 817	87 260	3 813	–
COAL - total	t		921 857	450 043	61 325	–
Masut	t		5679	1 968	negligible	–
Gas oil for motor vehicles	t		274	4 710	478	3 757
Gas oil for diesel locomotives - shunter	t	Diesel	269	4 104	6 102	5 105
Gas oil for diesel locomotives - transport engine	t		5870	32 407	61 958	44 869
GAS OIL - total	t		6414	41 223	68 538*	53 732**
Electric power for electric locomotives	MwH		12	126 042	196 965	225 355
Electric power for electric traction	MwH	Electric	0,177	13 592	58 298	37 113
ELECTRIC POWER - total	MwH		12,195	139 634	255 263	262 468

* – if the consumption of 2 320 t for railcars is added, the total sum is 70 858 t

** – the consumption of railcars is 1 135 t, so that the total sum is 54 868 t.

The world energy consumption uses still mostly coal (45%), oil (30%), gaseous fuels (about 14%), energy obtained from hydroelectric plants (11%) and from nuclear fuels (about 1%). The energy consumption per person per km in passenger cars compared to railway is 4.2 times greater, and compared to trams, the difference is ten times greater, (Figure 2), which only confirms the rational energy consumption in railway traffic.

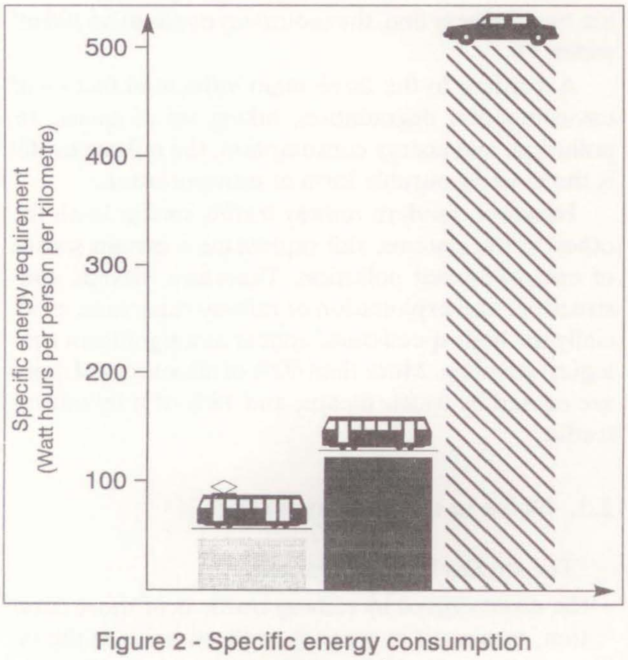

Figure 2 - Specific energy consumption per person per km

2.1. The railway and the exhaust gases emission

Regarding air pollution, steam and diesel track vehicles emit various harmful substances into the atmosphere: carbon monoxides, nitrogen oxides, hydrocarbons, sulphur dioxide, carbon - (IV) oxide, smoke containing various solid particles. Exhaust gases of railway traction vehicles are present in the atmosphere due to the used fuel. The exhaust gases system of a diesel locomotive is affected by the chemical composition of the fuel, regime of operation, and the engine type, its technical condition, etc. The highest level in all the exhaust gases components are H_20 and CO_2, with 98%, then about 2% of toxic components such as CO, CH, NO_x, SO_x, and about 0.8% solid particles. If these harmful substances emissions are compared to road traffic which is the main air polluter in urban centres with up to 80%, then again the advantages are on the side of the railway (Figure 3). So, e.g. in the carbon monoxide air pollution, road traffic participates with up to 98%, and railway only 1%. Road traffic measures nitrogen oxide emissions of up to 90%, and railway 4%. Hydrocarbons caused by road traffic amount to 95% in overall pollution, and caused by railway 1%. Therefore, compared to a passenger car, the railway emits 8.3 times less harmful substances into the environment, and 30 times less than a cargo vehicle for the same transport volume.

With electrical traction there is no chemical air pollution, though there is an increased concentration of ionised air particles. Biomedical research shows that ionised air particles in electrical traction have a significant effect on human health. The increase of positive ions in the atmosphere causes reduced concentration in humans, nervousness, migraines, aggressiveness, and all this may lead also to traffic accidents. Railway electrification contributes to the air protection and over 75% of tracks have been already electrified in the western Europe. In the Republic of Croatia, out of the total of 2974.4 km of railway tracks, 1228.3 km have been electrified. Regardless of the greater electrification, the diesel locomotives (83) still prevail on the Croatian railway tracks, as well as diesel motor trains (28) compared to electric ones (11). Comparing the pollution emission of carbon oxide (IV) caused by the railway (172 913 tons) in the year 1988, with road motor vehicles, the result is that the Croatian railways cause almost 35 times less pollution, that is, they participate with about 2.9% carbon (IV) oxide pollution caused by the road vehicles. In other words, their part in the overall world pollution of atmosphere with CO_2 is about 0.001 to 0.002%.(3)

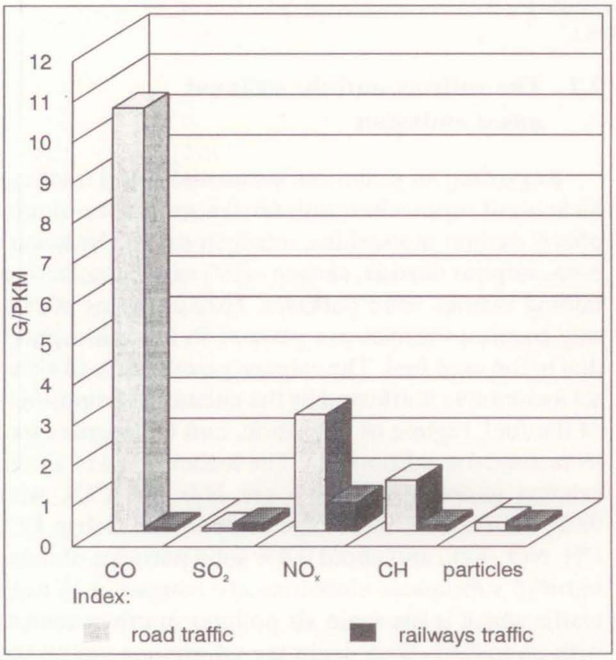

Figure 3 - Specific emission values in passenger traffic

According to the research carried out in Germany(6), the ratio of specific emission of harmful substances measured by the toxic factor in railway versus road amounts to as much as 1:30.

2.2. The railway and the physical space

The railway traffic requires three times less physical space than road traffic with approximately equal traffic capacity (the need for physical space of a double track railway is 3.2 ha/km, and a four-lane motorway 9.1 ha/km, with the railway line capacity 50% greater).(6)

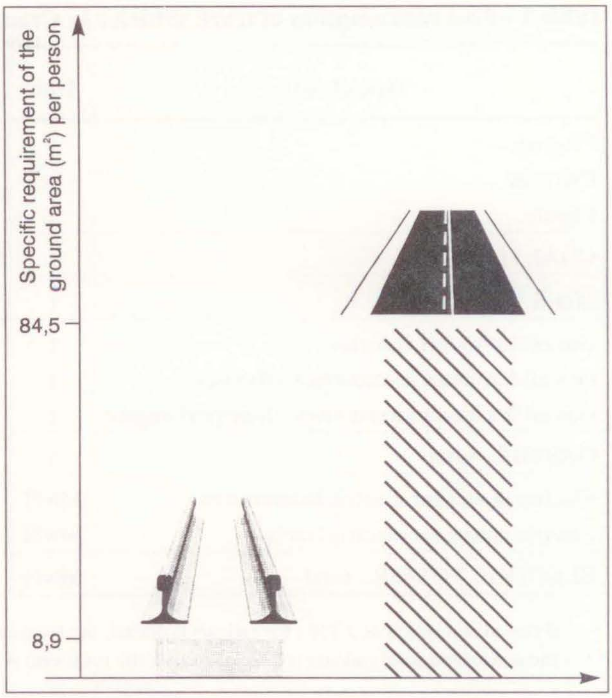

Figure 4 - Specific requirements of ground surface per person for railway and road traffic

Figure 4 indicates that road traffic has the greatest need for ground area per transported person. Thus, it is 9.5 times greater than in tram or railway traffic. Road traffic requires approximately 84.5 m^2 of ground per transported person, and the railway traffic 8.9 m^2.(4) The following data confirm also this fact: a double track railway line needs a space 13.7 m wide, whereas a motorway with 2x3 traffic lanes requires a width of 37.5 m. For the same traffic volume of a double track railway line, the motorway needs to be 100 m^3 wider. (4)

According to the three main influential factors of environmental degradation, taking up of space, air pollution, and energy consumption, the railway traffic is the most favourable form of transportation.

However, modern railway traffic, similar to all the other traffic systems, still represents a certain source of environmental pollution. Therefore, design, construction, and exploitation of railway capacities, especially the high-speed ones, appear as a significant ecological problem. More than 80% of all sources of noise are caused by traffic means, and 18% of it by railway traffic.

2.3. Noise in the railway traffic

The studies have shown that:

- the noise caused by railway traffic is of short duration, measured in seconds, with no noise in the interval between the passage of two trains,

Table 2 - Boundary values for noise caused by railway traffic

Sensitivity group	Typical purpose of the noise-affected region	Level of L_r in dBA					
		Imission		Planned		Alarm	
		day	night	day	night	day	night
I	Specially quiet zones	55	45	50	40	65	60
II	Mostly residential areas	60	50	55	45	70	65
III	Housing estates excessively affected by noise	65	55	60	50	70	65
IV	Industrial zones	70	60	70	60	75	70

where L_r is the estimated level of noise

- the noise depends on the fixed timetable, contrary to road traffic noise which does not depend on any rules, especially at night,
- the railway noise heard in a flat, is always of approximately same volume and same character, whereas in road traffic it depends on the make and type of the car and the way of driving.

Table 2 gives the boundary values for the railway traffic noise.

The noise is measured only during the passing of a train, and does not include other sources of noise. At the station, the measuring device is turned off in the interval between two trains. Measurements are carried out at the distance of 25 m from the railway tracks. The noise evaluation system has three boundary values: basic, emission boundary value and two additional - alarm and planned value.

Emission boundary value is the level of noise measured at the place that needs to be protected from the railway traffic noise.

Planned values are lower than the emission ones. They serve as guidelines in design and construction of new facilities, e.g. in determining the route of a new railway line.

Alarm value is the criterion for repair emergency.

Boundary values are different for the day and for the night, as well as for the areas depending on their purpose, e.g. related to the need for peace and rest. Therefore, the boundary values have been classified into four groups of noise sensitivity.

The impact of diesel locomotives on the human environment is a very complex one, and in the ecological sense the noise is one of the most adverse factors both for the workers, and for the environment. The noise level of 80 dB is known to cause disturbance in the human cardiovascular system due to hypoxia (low oxygen content in blood caused by noise), and therefore certain design requirements are set regarding the level of cabin noise. The basic objectives of these limitations are the following:

- the noise should not cause health disturbances,
- acoustic warnings need to be audible,
- verbal communication has to be undisturbed.

In order to fulfil these requirements, the allowed level of noise according to the European Economic Community (EEC) is 80 dB over a period of eight hours. In order to completely eliminate the risk, the recommendable level is 78 dB, very difficult to achieve in practice.

The highest level of noise in our railway network is caused by the diesel locomotives of the 661 series, and therefore the electric locomotives as the sources of noise have not even been studied here. The noise intensity in the cabin of the 661 type locomotive has been measured in normal operation of the power unit, as presented in Table 3. The level of noise was 93 dB.

The noise intensity is affected by the train speed and load, and also by the location of the cabin, characteristics and condition of the railway tracks, and the driving regime. The noise volume caused by the relation track/wheel depends on the condition wheel/track and the speed. The level of noise has been significantly reduced recently by welding the rails into continuous welded tracks, as well as by high-quality tracks maintenance (grinding etc.). Also, by replacing the conventional shoe-brakes by modern disc-brakes, the noise level has been reduced by up to 10 dB, which makes it almost twice as easy to endure for people.

Table 3 - Frequency analysis of the noise caused by the 661 locomotive

Frequency (dB)	31,5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	16 kHz
Measured noise level	104	94	102	97	90	87	84	74	65	50
Allowed noise level	106,5	94,7	87,2	81,7	77,9	75	72,6	70,8	69,2	–
Exceeded noise level	–	–	14,8	15,3	12,1	12	11,6	3,2	–	–

At low speeds the noise of the locomotive is dominant, not due to starting, and it is caused by the engine and the cooling fans.

The diesel locomotives produce rather low-frequency noise which is by far faster spreading and more disturbing.

The problem of noise is objectively the biggest problem in the relation humans-railway tracks-environment, and it is especially emphasised in high-speed tracks.

With high-speed railway tracks, the position of the route in relation to the grounds needs to be considered with special care, that is, whether the tracks have been laid on artificial facilities (tunnels, motors, viaducts, and elevated runways) or natural ground (passes and embankments). Table 4 gives the overview of certain types of construction works which can have a significant impact on the noise intensity and the amount of energy produced by trains. The majority of these measures have been studied through experiments, and some have even been applied to tracks in service. Considering the technical methods of protection, favourable results can be obtained by reducing the noise at the source, eliminating the noise transfer, and by reducing the noise at the point of reception. The expenses for the protection against the traffic noise and vibration depend on the desired level of reduction, method and technical solution, as well as whether an area surrounding an existing or a new designed railway tracks is to be protected. The data obtained by Prof. E.Janaček [5] can be taken as rough information. It says that for a noise reduction of 5-10 dB (A) the construction investments need to be increased by 20-35%, and for the reduction of 15-20 dB (A) the construction investments need to be increased by 55-70%. All this indicates that the traffic noise protection project needs to be implemented gradually, through phases, depending on the traffic and technological conditions, technical possibilities and available financial means. The noise protection is solved by constructing sound barriers in the form of walls (screens) covered by absorbing materials, shaping the protective barriers made of natural ground which combined with planted vegetation along the tracks and by forming a protective zone (200 m wide) can create a natural surrounding and provide good protection against noise and vibration. The scheme for noise protection is presented in Table 4.

INSTEAD OF A CONCLUSION

By comparing the railway traffic with other methods of transport, regarding air pollution, taking up of physical space, and energy consumption, it can be concluded that the railway is the most acceptable of all.

In order to achieve a balance between the individual methods of transport and the care for environmental protection to become imperative, the external damage related to environmental protection needs to be taken into consideration and built into the price paid by the user. The attitude of the Croatian Railways towards the environmental protection is not clearly defined, and therefore this practice is practically non-existent. The external transportation costs regarding the environmental protection would burden the infrastructure expenses most of all (according to an estimate by the CER experts - Community of European Railways) by even 60-70%.

Noise protection represents a high cost for the railway companies, which can also be included in the external transportation costs. Apart from the noise, there are some other basic ecological problems of

Table 4 - Noise protection in railway traffic

Route location / Type of protection	Tunnels Bridges Viaducts Elevated Runways	Embankments	Aisles (passages)	Stations
noise reduction at the source	insulation materials built into the upper tracks structure, covering the tunnel walls with noise absorption materials, protective facilities connecting neighbouring tunnels	insulation material built into the closed upper structure	upper structure of crushed stone aggregate	upper structure exclusively of crushed stone aggregate
prevention of noise transfer	protective walls, side tunnels, subtunnels, vertical pits, curtains of water droplets, artificial counterflow of air in the tunnel	Protective walls covered by absorption materials, plants	natural slopes, plants	protective walls along the whole station platform
noise reduction at the point of reception	acoustic barriers in front of housing estates, improved sound insulation	plants	plants	personal protective means for the personnel

high-speed trains such as: adverse effect of herbicides used to destroy the weeds along railway tracks, the ground under the railway tracks gets changed (green surfaces are destroyed, landslides formed), hydrotechnical works depending on the track route influence also the degradation of fauna and flora.

One should not, however, forget that every year about ten million of harmful substances are transported by the very railway without causing any dangerous incidents. The railway transportation technology is a safe one and well adapted to transportation of harmful matter, the fact which should be known to the users.

Since world wide the road and air traffic have almost reached the maximum of their exploitation possibilities, the railway has remained showing advantages over other long-distance traffic branches from the ecological, economic, safety and technological aspect.

In order to keep pace with Europe, Croatia needs to continue the electrification of railway tracks, that is to use the cleaner traction vehicles, which means higher investments.

Also, the air ionisation should be mentioned, as a side-effect of electric traction, but it should not be forgotten that in certain cases diesel traction is irreplaceable.

Having all this in mind, many people consider railway as playing a negligible role in environmental pollution. However, the study of even such a small amount is of utmost importance in the life of the nature and of the humans, as well as for the traffic safety.

SAŽETAK

PROCJENA POVOLJNOG EKOLOŠKOG UTJECAJA ŽELJEZNICE NA OKOLIŠ

S ekološkog, ekonomskog, sigurnosnog i tehnološkog gledišta željeznica ima prednosti pred ostalim granama prometa pri većim udaljenostima.

U radu se daje procjena povoljnog ekološkog utjecaja željezničkog prometa na okoliš koji se manifestira u racionalnom utrošku energije, znatno manjem zauzimanju površina i manjem onečišćenju zraka.

Imajući na umu te podatke, smatra se da željeznica ima zanemarujući udio pri onečišćenju okoline, no proučavanje i takve količine ima važnu ulogu za sigurnost prometa, život prirode i ljudi.

LITERATURE

[1] **Božičević, J.**: *Stanje i budućnost hrvatskih željeznica*, XI, 1996

[2] **Brkić, A.**: *Aspekti suvremenoga željezničkog prometa*, Proceedings

[3] **Džanić, H., Brkić, V.**: *Procjene emisije ugljik (IV) oksida i ispušnih plinova pružnih motornih vozila u Hrvatskoj*, SPIH '92, Proceedings, pp. 155-158

[4] **Golubić, J.**: *Humaniziranje prometa u gradu Zagrebu*, Znanstveni savjet za promet HAZU, 1990

[5] **Mihajlović, D.**: *Zaštita od buke kod željezničkih pruga za velike brzine*, Symposium ESPS '86, Proceedings, pp. 241-242

[6] **Richey, A.**: *Pilotvorhaben der Deutschen Bahn zur Verbesserung des Schienengüterverkehrs*, Umweltgerechter Verkehr, Springer-Verlag, Berlin, Heidelberg, 1996

[7] Željezničar, Croatian railway workers' journal, IX, 1997