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Traffic and Human Environment
Review
U. D. C.: 656:339.9:504.06(497.5)
Accepted: Feb. 12, 2001
Approved: Feb. 26, 2001

TRAFFIC – CROATIA FACING THE GLOBAL ISSUES

ABSTRACT

Traffic today is an indispensable part of our lives and one of the basic preconditions of what is called social progress. Like blood in our body it circulates across the whole globe and allows for the necessary flow of people and materials. This work considers the impact of traffic on the lives of people and on the environment, analyses the available energy sources and vehicle propulsion systems and illustrates global climatic issues. The paper presents the methodology created by EU for monitoring of harmful emissions at the national level and gives data on differences in emissions of individual transport modes. The traffic condition in the Republic of Croatia is analysed and a thesis is given regarding possible solution of the stated problems.

KEY WORDS

transport of passengers and goods, environmental issues, alternative fuels, global impact

1 INTRODUCTION

Heavy burden on the environment, constant depletion of energy supplies and piled up ecological problems are becoming an ever increasing burden for the whole human society. At the 1992 UN Conference on Climate, held in Rio de Janeiro, the leading world countries did not accept the recommendations stated then. In the meantime, a concrete target has been set: to reduce the emission of carbon dioxide to 50% of the 1987 level (Fig. 10). Unfortunately, all attempts to arrive at a joint agreement in realising this objective have remained in vain. The richest country in the world and the biggest producer of carbon dioxide is simply not willing to reduce the production, the personal standard of living and the appetite for profit.

Although environmental and transport problems go far beyond the borders of small countries such as Croatia, making of right or wrong decisions will have an even greater impact on their further development, especially if it relies to a great extent on tourism. The desire to join the European Union will require also adaptation of the traffic system, in turn including the implementation of transparent standard methods for its analysis and control. The aim of this paper is a general analysis of the road traffic technology and its influence on people and the environment, as well as the situation in Croatia. As the final result, an assumption is given regarding the immediate tasks that would contribute in this field to the creation of the necessary conditions to solve the mutually conflicting requirements for maximally efficient and inexpensive traffic on the one hand, and for preserving the still intact environment on the other.

2 TRAFFIC AS A COMPONENT OF OUR LIVES

Transport is a very valuable and necessary part of modern society but, increasingly, its widespread and escalating existence is recognised as a major contributor to an extensive range of undesirable side effects. Traffic congestion makes cities less pleasant and reduces the efficiency of transport system by increasing journey time, fuel consumption and driver stress. The infrastructure used for transport activity must sometimes be built on agriculturally useful land or at locations that are sensitive for ecological, historic, aesthetic or other reasons. Thus environmentally, economically and politically, it is important that the transport system is designed in the most effective way so that it satisfies the needs for personal and goods transport without creating unacceptable conditions. Its costs must be kept in check and its adverse effects on the natural and anthropological environment should be minimised.

If in 1999 in Croatia, daily, 20,000 passengers were transported by ships, 50,000 passengers by train, 180,000 by bus, and as many as 290,000 passengers used public transport, then there are certainly good reasons for that. The need to go to work, to school, shopping, on holidays, are closely related to higher material prosperity and the living quality of individuals. The necessity of traffic and the distances that need to be travelled in everyday lives depend to a great extent on the structure of settlements. Compared to the medieval man, today people move across a much wider area. Mass production of transportation means and the building of roads have enabled dispersion of population over greater areas. The Man of today regards transport as integral part of their lives, and decides on the usage of various types of traffic means on the basis of the distances travelled, Figure 1.

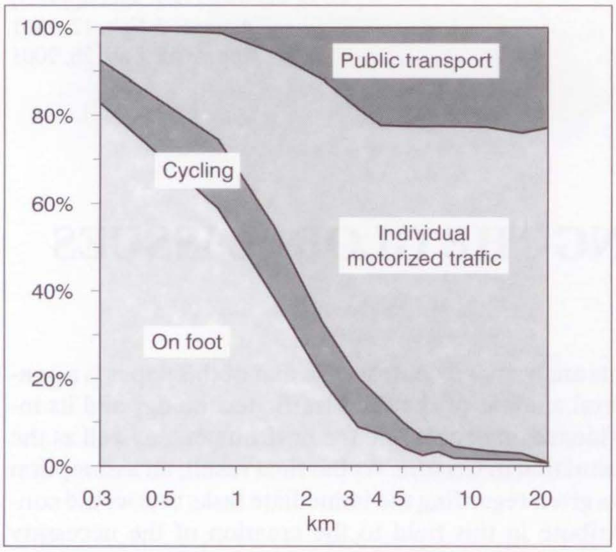


Figure 1 - Utilisation of transportation means depending on the travelled distance. [Braess–Frank]

Of all the transportation means, the passenger car is certainly the one that has the greatest impact on the life of a modern Man. This miraculous machine creates an illusion of freedom to go *where* and *when* the desire to do so might arise, and it is equally preferred in urban and interurban traffic. Today's traveller, spoiled by the amenities of materialistic civilisation, has a whole series of criteria at their disposal to evaluate the quality of traffic, Figure 2. In a merciless competition against time, the only thing that cannot be bought, one of the key parameters of every traffic system is the travelling time, expressed by the so-called travelling speed. And this is precisely where the advantages of public urban transportation lie, particularly if it is well integrated in the global traffic system, Table 1.

Similar principles are valid also for all the other transportation means for people and goods. Thus, wa-

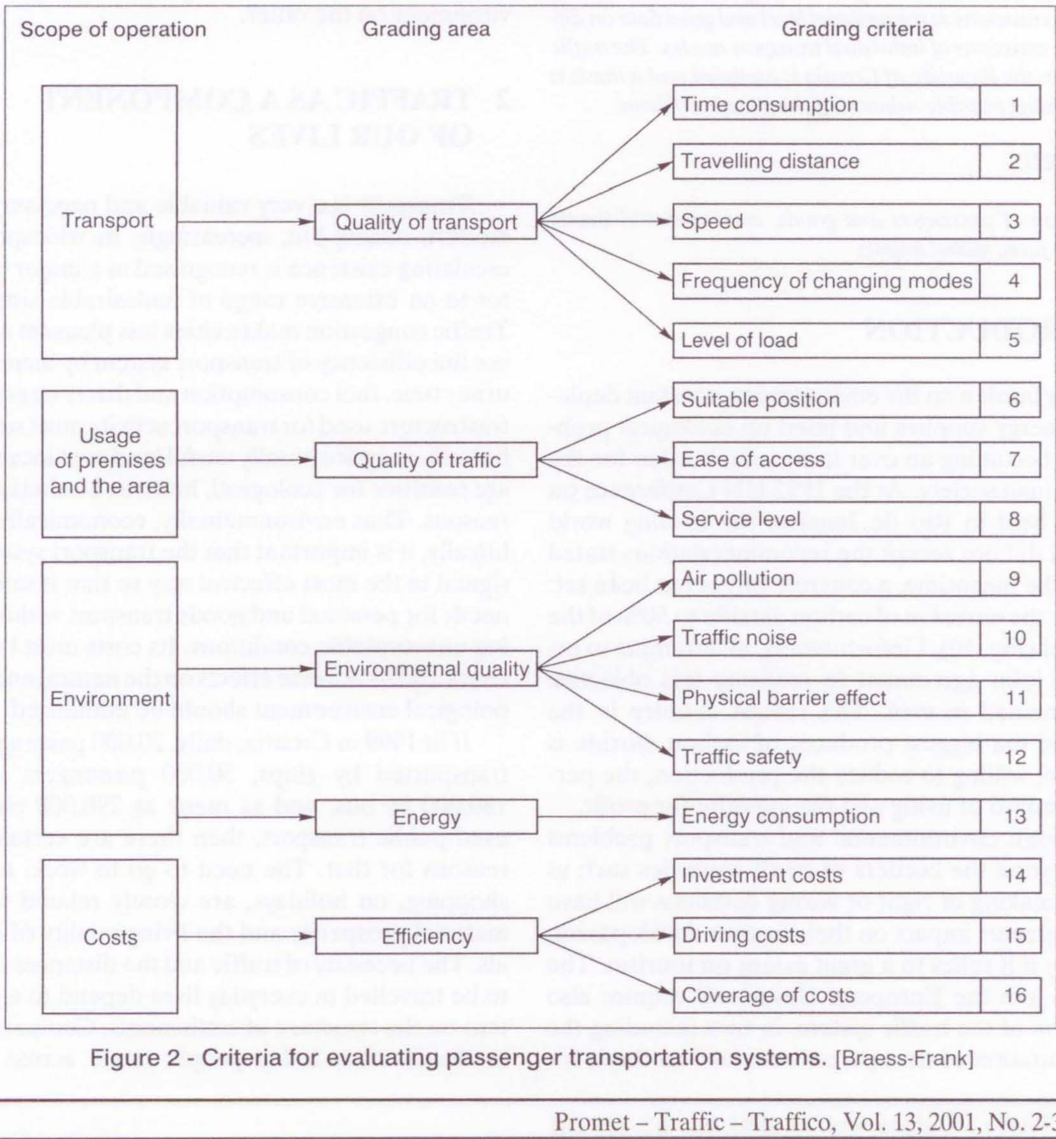


Figure 2 - Criteria for evaluating passenger transportation systems. [Braess-Frank]

Table 1: Advantages and disadvantages of using a passenger car instead of public means of transportation.

Advantages of private passenger car	Advantages of public transportation
– availability does not depend on place and time – minimal walking, no waiting, no changing – usually favourable travelling time – personal ambient, comfort, protection from bad weather – easy transport of luggage, possibility of having it stored in the parked car – reduction of costs when taking riders – pleasure in driving – pleasure in the nice car	– passengers can ride who cannot or do not want to drive a car (children, senior persons, disabled persons) – direct costs arise only from direct use – during the ride, a passenger can have a rest or e.g. read – no need to look for a parking space – in railway, arrival on time even in case of very bad weather

ter transport will be preferred if huge amounts of heavy freight need to be transported, and air transport in case of transportation on great distances. Only good harmonisation of various transport modes provides at the same time a good solution for the Man as part of the society.

3 ENERGY SOURCES AND VEHICLE DRIVING SYSTEMS

Requirements to reduce the CO_2 emissions overlap greatly with the requirements to reduce energy consumption in traffic. Also, the use of primary low carbon content energy carriers such as natural gas, and considered over a long run the use of renewable energy forms have this same objective in mind. The reduction of emission of certain harmful substances that act locally (NO_x, HC, particulates) can be achieved by reducing the fuel consumption and by improvement of catalysts. If local emission needs to tend towards zero, then electric propulsion is one of the possible replacements for the common internal combustion engine. Figure 3 represents relevant relations between primary energy carriers and driving engines. The choice

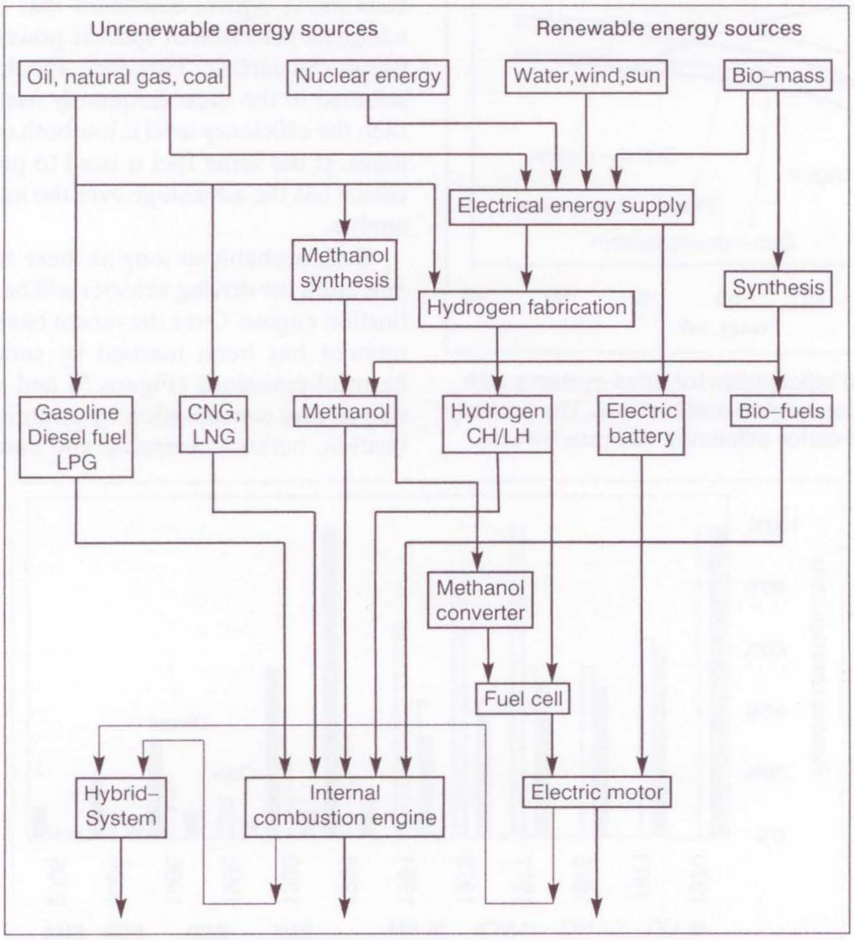


Figure 3 - Connection between primary energy sources and driving systems. [Carpetis-Nietsch]

of driving engines is limited: it can be an internal combustion engine or an electric motor, or hybrid propelling system using both of these engines. A great number of possible alternative solutions develops partly due to various primary energy carriers (oil, natural gas, biomass, etc.), but they have mostly resulted as consequence of the multitude of possible fuels: petrol, Diesel-fuel, LPG, CNG, methanol, electricity, hydrogen and various bio-fuels. The internal combustion engine may operate on any of these fuels. Even the renewable sources of energy may be used by means of

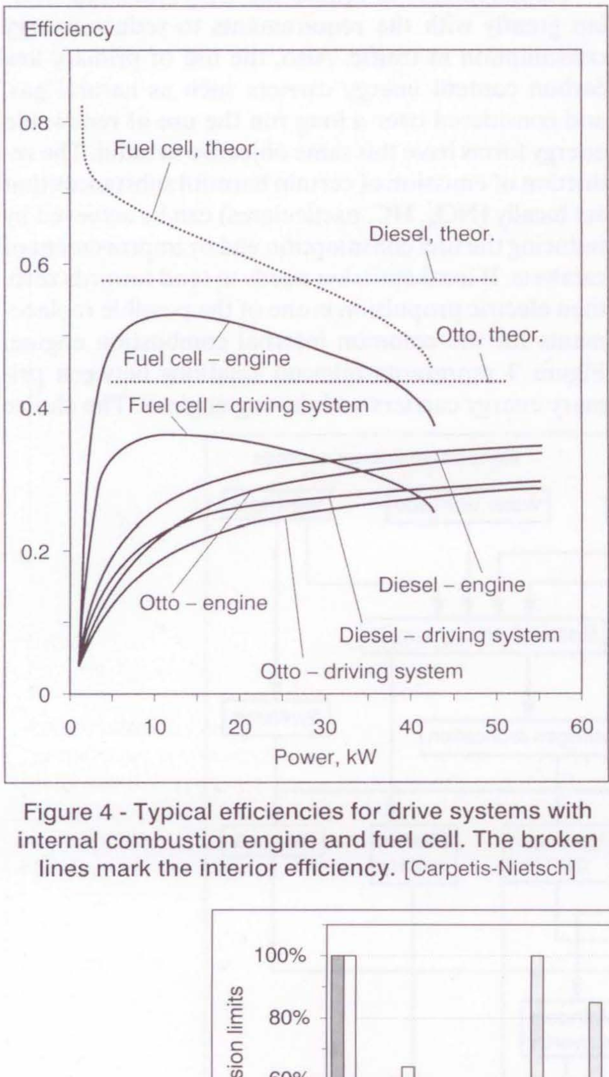


Figure 4 - Typical efficiencies for drive systems with internal combustion engine and fuel cell. The broken lines mark the interior efficiency. [Carpetis-Nietsch]

hydrogen as propelling fuels for driving engines. However, the implementation of these engines leads to local harmful emission. Should local traffic be required free of harmful emission (Zero Emission Vehicle), then electricity comes to the fore. It allows this requirement to be realised with every source of energy. However, due to the still unresolved problems of storing electricity, the range of these vehicles is far below the standards usual today.

The use of fuel cells to propel vehicles solves the problem of storing electrical power since it is generated in the vehicle, practically free of harmful emissions. As seen in Figure 3, when using fuel cells, the battery is replaced by a chemical energy tank and converter. Electricity is generated in the cell itself by mixing hydrogen with oxygen. The fuel cell vehicles should therefore be supplied with hydrogen. Since such supply does not exist yet, methanol is used as fuel, which is then converted into hydrogen in the vehicle itself. Figure 4 represents the efficiency level of various driving systems of a small urban car. It may be seen that the internal combustion engine is most efficient under full load, so that due to low loads in urban traffic strong engines operate with low efficiency. On the other hand, the efficiency level of fuel cells shows typical maximum that may be shifted by adequate selection of specific power in W per cm^2 of useful cell surface. However, should the optimum be selected in the most frequently used area of loading, then the efficiency level is low both under high and low loads. If the same fuel is used to propel the fuel cell, then it has the advantage over the internal combustion engine.

Still, probably as long as there is oil, the main engine used for driving vehicles will be the internal combustion engine. Over the recent twenty years its development has been marked by sudden reduction of harmful emissions (Figure 5) and substantial reduction in fuel consumption by optimising cylinder combustion, better scavenging and continuous improve-

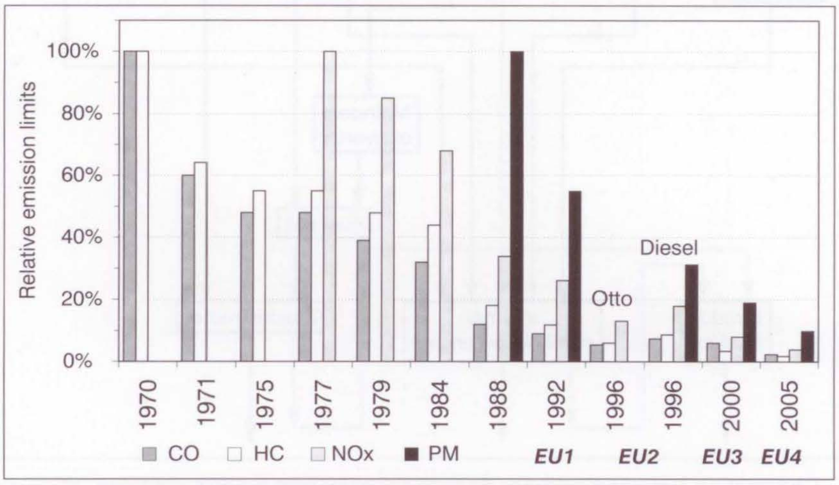


Figure 5 - Restricting limits of harmful emissions in the EC countries

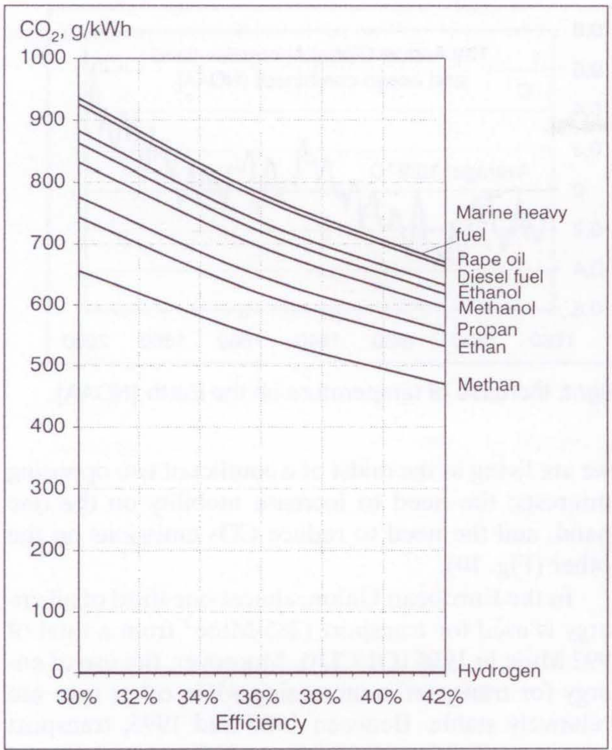


Figure 6 - Influence of the type of fuel and efficiency on CO_2 emissions. [Dietrich]

ment in the quality of fuel (e.g. reduction of sulphur content). The drag of passenger vehicles has also been significantly reduced. However, advances are not easy, because concurrent tendencies to improve vehicle safety, reduce energy consumption and harmful emissions result in conflicts regarding technical solutions. New vehicles are indeed less of a burden to the environment than the old ones, but the total number of vehicles in the world is continuously growing so that the overall harmful emissions are still rising, since old vehicles die slowly (the average age in Croatia is 11 years). After a hundred years of development, stimulated by depletion of oil reserves and earthquakes on the fuel market, the Diesel engine is forcing its way into the most numerous population of vehicles, the passenger cars. Owing to the better level of efficiency, especially in part loading, it has the advantage over the Otto engine not only regarding energy consumption but also regarding CO_2 emissions.

Regarding fuels, the significance of alternative fuels is growing steadily, Figure 6. The most attractive one is hydrogen. However, it contains little energy per volume unit (Fig. 7) which requires big fuel tanks in vehicles. Of other fuels, the most interesting are those that are biologically renewable (biomass) since their use does not increase the share of atmospheric CO_2. Approximately the same amount that is generated by engine combustion is re-used by the plants for the generation of fuel thus closing up the cycle.

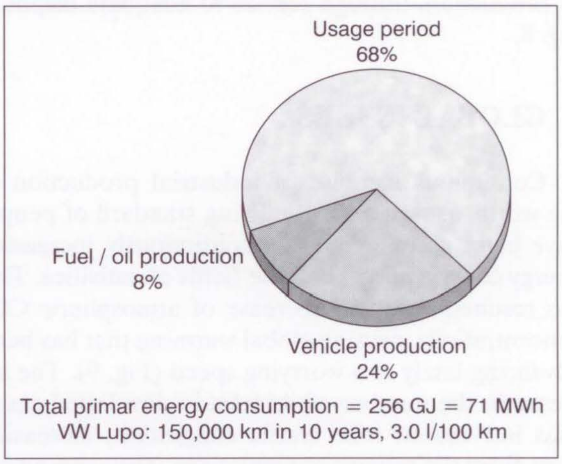


Fig. 8: The assessment of the environmental friendliness of a vehicle should include energy consumption during the whole vehicle life cycle. [Winterkorn]

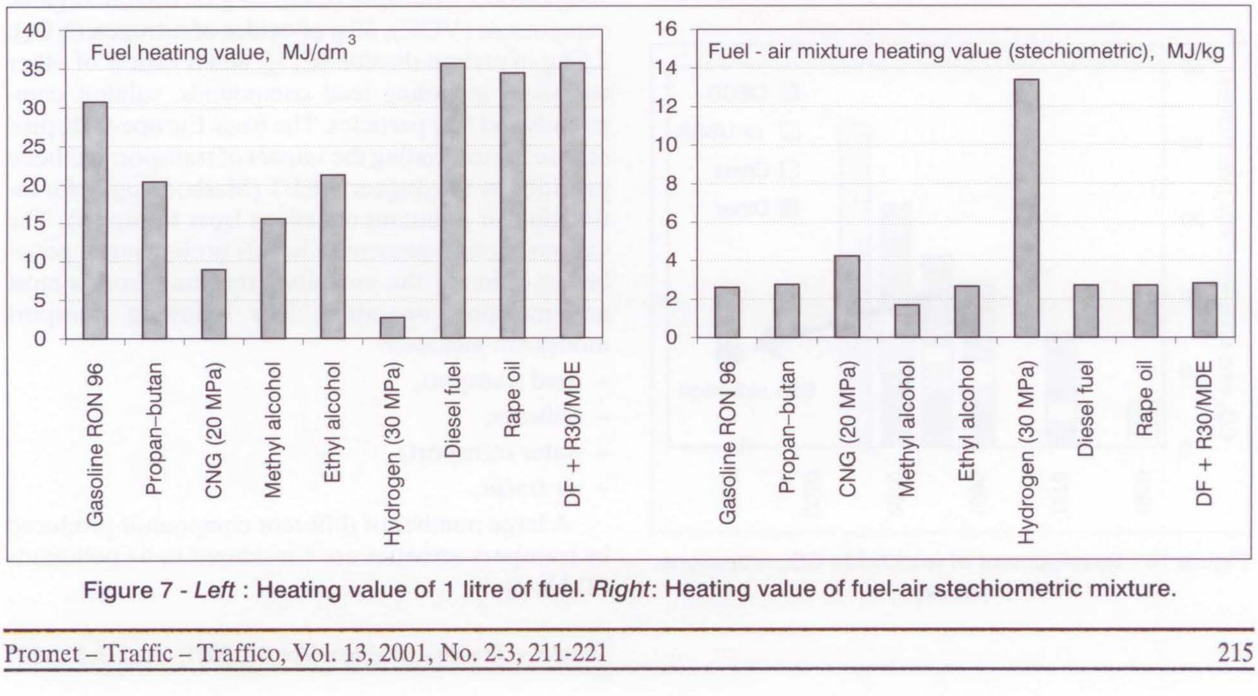


Figure 7 - *Left* : Heating value of 1 litre of fuel. *Right*: Heating value of fuel-air stechiometric mixture.

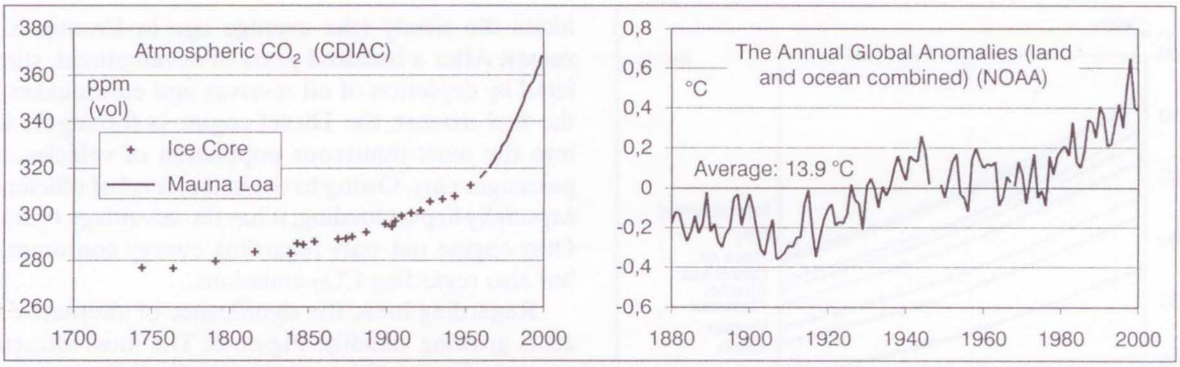


Figure 9 - *Left*: increase of atmospheric CO_2 [CDIAC]. *Right*: increase of temperature on the Earth [NOAA].

The implementation of environmental protection measures and the respective comprehensive energy savings in all the fields of human activities will be impossible without collecting data on the overall consumption of energy of single products from the start of its production, through service to adequate disposal, Fig. 8.

4 GLOBAL ISSUES

Continuous increase of industrial production in the world, as well as of the living standard of people have been accompanied by continuously increasing energy consumption in all the fields of activities. This has resulted in steady increase of atmospheric CO_2 concentrations, causing global warming that has been advancing lately at a worrying speed (Fig. 9). The increase in the number of vehicles in developed countries has caused road traffic congestion, increasing even more the exhaust gas emissions. Thus, the whole system of human activities becomes a generator of negative global changes on the Earth. The forecasts made by the leading world institutions show that today we are living in the midst of a conflict of two opposing interests: the need to increase mobility on the one hand, and the need to reduce CO_2 emissions on the other (Fig. 10).

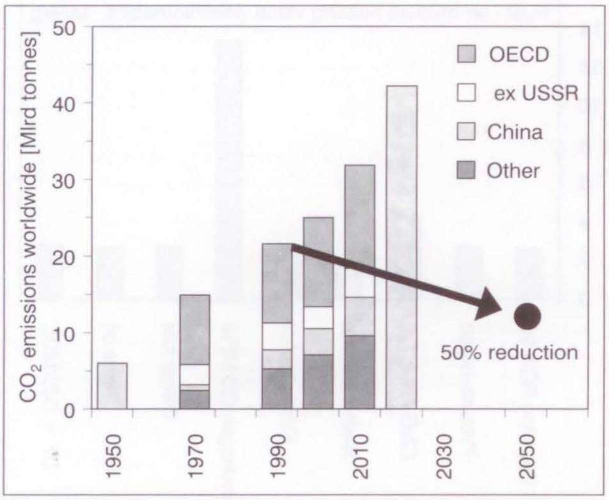


Figure 10 - Development of worldwide CO_2 emissions. [Weule]

In the European Union, almost one third of all energy is used for transport (285 Mtoe[1] from a total of 992 Mtoe in 1995 [OECD]). Moreover, the use of energy for transport is increasing while other uses are relatively stable. Between 1980 and 1995, transport energy usage increased by about 45%, while that used for industry and other purposes declined very slightly (0.5%). Various studies [Schäfer - van Basshuysen, p. 155] contain estimates that the internal combustion engines produce about 20% of the total world emission of carbon dioxide (CO_2).

5 EMISSIONS BY VARIOUS TRANSPORT MODES

One important environmental effect of transport is its contribution to atmospheric pollution. Each litre of fuel that is burnt produces, in very approximate terms, 100g carbon monoxide (CO), 20 g of volatile organic compounds (VOC), 30 g of oxides of nitrogen (NO_x), 2.5 kg of carbon dioxide (CO_2) and a variety of other emissions including lead compounds, sulphur compounds and fine particles. The basic Europe-wide procedure for evaluating the impact of transport has been provided by the project MEET (Methodologies for estimating air pollutant emissions from transport). The various models presented in this project make possible to estimate the emissions resulting from almost any transport operation. The following transport modes are included:

- road transport,
- railways,
- water transport,
- air traffic.

A large number of different compounds produced by transport activities are considered to be pollutants (Table 2).

Table 2: Pollutant categories according to the present knowledge of emission factors.

Level	Pollutant	Knowledge level
1	Energy consumption, CO_2, CO, VOC, NO_x, PM, SO_2, Pb	emission factor
2	N_2O, CH_4, NMVOC, VOC species (*e.g.* PAH, benzene)	magnitude
3	PM size distribution, NH_3, H_2S, NO_2, heavy metals	very few data

The calculation methods for energy consumption and emissions are grouped into four classes: *based on transport activities, based on energy consumption*, *carbon balance calculations* and *pollutant specific calculations*.

As an example, let us consider road transport. The main source of emissions are the exhaust gases and hydrocarbons produced by evaporation of the fuel. When an engine is started below its normal operating temperature, it uses fuel inefficiently, and the amount of pollution (E_{start}) is higher than when it is hot (E_{hot}). The total emission (E) is obtained from:

$$E = \sum_x E_x = E_{hot} + E_{start} + E_{evaporative}. \quad (1)$$

Each of these contributions (E_x) to the total emission (E) depends on an emission factor (e_x) and one or more parameters related to the operation of the vehicle:

$$E_x = e_x \cdot a, \quad (2)$$

where:

a – the amount of traffic activity relevant to this type of emissions.

The parameters (e_x) and (a) are themselves functions of other variables.

The calculation of hot emission ($E_{k,hot}$) of each pollutant (k) depends on a variety of different parameters:

$$E_{k,hot} = e_k \cdot m = \sum_{i=1}^{categories} n_i \cdot l_i \cdot \sum_{j=1}^{roadtypes} p_{i,j} \cdot e_{i,j,k},$$

(unit of mass per unit of time) (3)

where:

i – the number of vehicle categories;

j – the number of road types;

n_i – the number of vehicles in category i;

l_i – the average annual distance travelled by the vehicle of category i;

$p_{i,j}$ – the percentage of annual distance travelled on the road type j by vehicle type i;

$e_{i,j,k}$ – the emission factor of pollutant k corresponding to the average speed on the road type j, for vehicle category i.

The engine start-related excess emission ($E_{c,k}$) of each pollutant (k) is calculated according to the following formula:

$$E_{c,k} = \omega \cdot [f(V) + g(T) - 1] \cdot h(d), \text{ g/km} \quad (4)$$

where:

V, km/h – the mean speed during the trip;

T, °C – the temperature (ambient temperature for cold start, engine start temperature for starts at an intermediate temperature);

d, km – the distance travelled;

ω, g/km – the reference excess emission.

Evaporative losses (VOC emissions) for each vehicle category (j) are calculated as follows:

$$E_{eva,voc,j} = 365 \cdot a_j \cdot (e^d + S^c + S^{fi}) + R,$$

(unit of mass per year) (5)

where:

a_j – the number of gasoline vehicles of category j;

e^d – the emission factor for diurnal losses of gasoline powered vehicles;

S^c – the average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor;

S^{fi} – the average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection;

R – the hot and warm running losses.

The necessary data required for the calculations of emissions from road transport are: structure of fuel consumption, structure of the transport fleet (fleet spectrum including engine pollution classes

Table 3: Definition of scenarios.

Example		Current fleet (1995)	Best available technology (1995)	Future fleet (2010)
1	Modal split traditional[2]	Scenario A	Scenario B	Scenario C
	Modal split green commute[2]	Scenario D	Scenario E	Scenario F
2	Maximum load factors	Scenario A	Scenario B	Scenario C
	Average load factors	Scenario D	Scenario E	Scenario F
3	Maximum load factors	Scenario A		Scenario B
	Moderate load factors	Scenario C		Scenario D

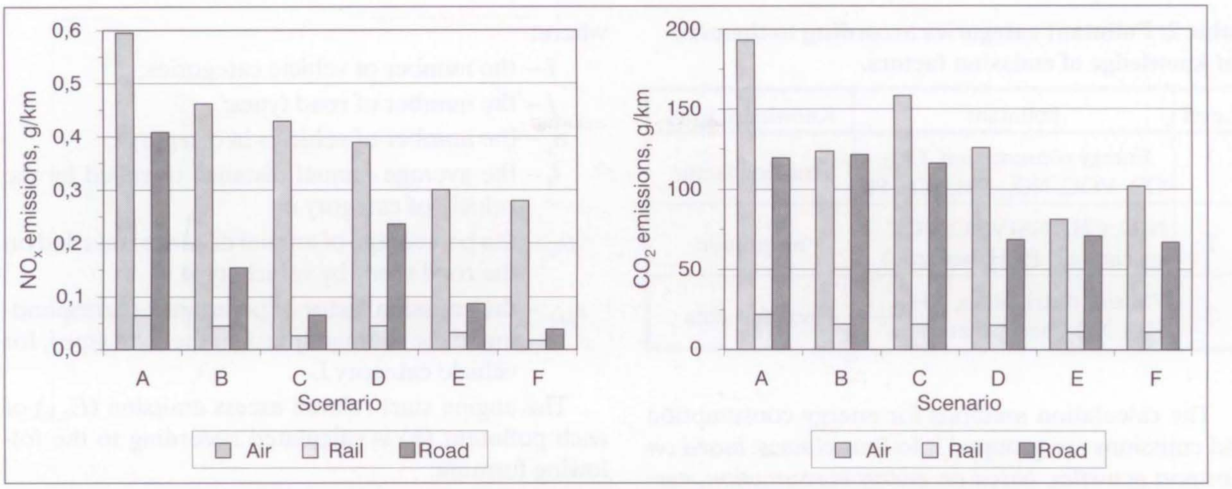


Figure 11 - Long distance passenger transport. *Left*: comparison of nitrogen oxide emissions (grams per passenger-kilometre) for the six scenarios. *Right*: comparison of carbon dioxide emissions. [Meet]

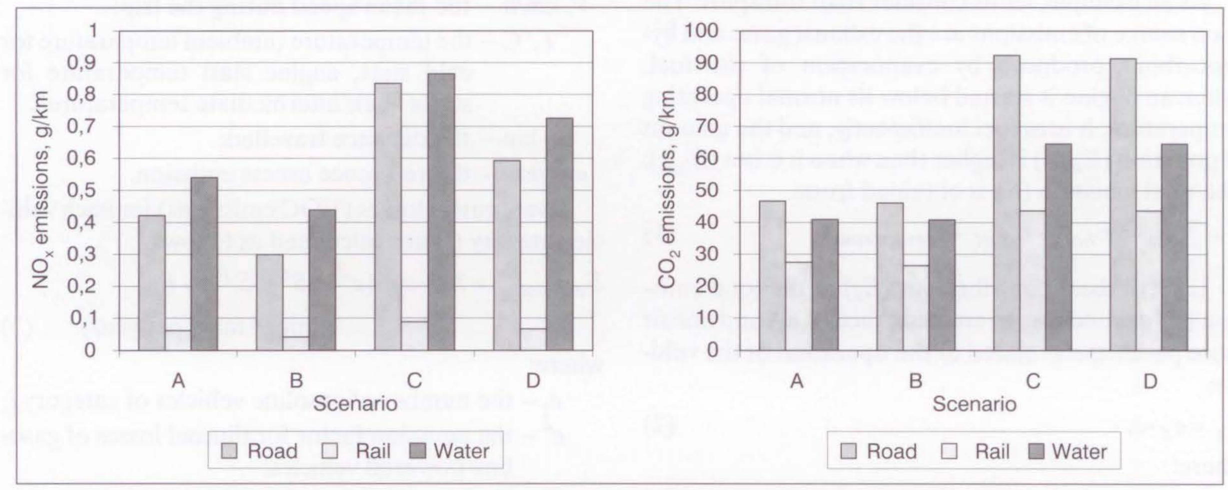


Figure 12 - Long distance cargo transport. *Left*: comparison of nitrogen oxide emissions (grams per tonne-kilometre) for the four scenarios. *Right*: comparison of carbon dioxide emissions. [Meet]

(Euro 0/1/2/3), load sets, road types, average speeds, annual distances (in urban/rural areas, on highways) etc.

Also the methods of calculating harmful emissions in railway transport, sea and river transport as well as air transport are based on similar principles.

Three characteristic examples analysed within project MEET show well today's mutual differences in harmful emissions in different transport modes.

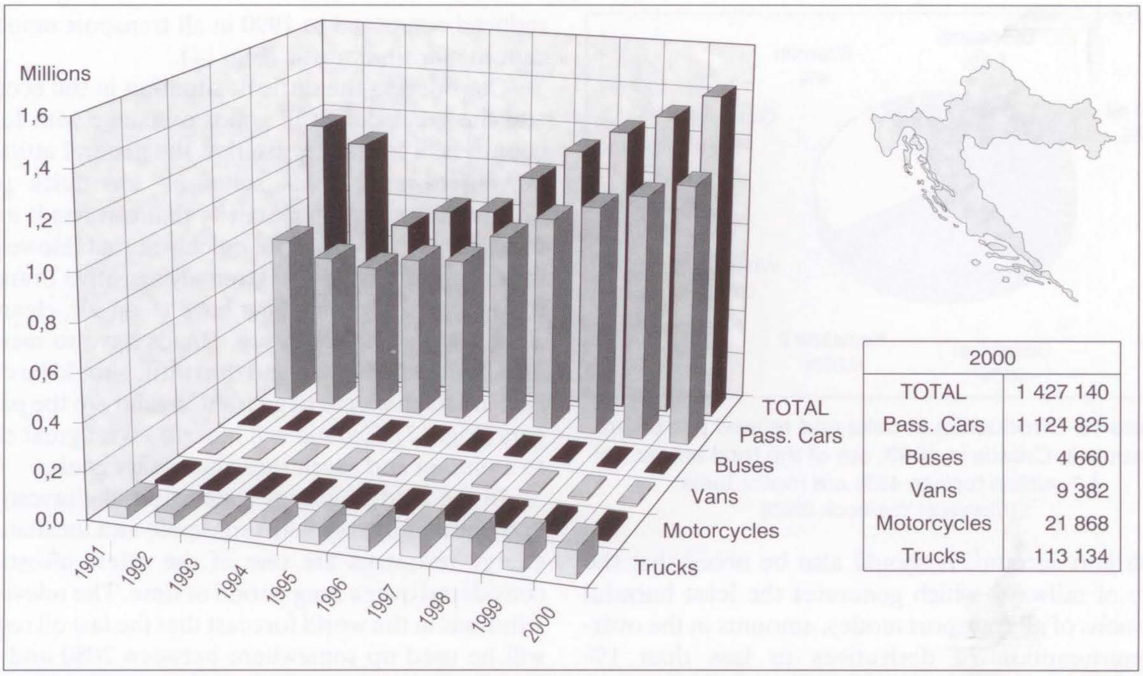
- example 1: commuting in big cities (Brussels)
- example 2: long distance passenger transport (Vienna – Rome)
- example 3: cargo transport (Rotterdam – Zurich)

Six different scenarios were examined for each example (Table 3). The results are shown in Figures 11 and 12.

In all the cases the advantages of railway are obvious. For both NO_x and CO_2 emissions, the train clearly is the least polluting form of transport.

6 CROATIA – SITUATION, AIMS AND TASKS

The Republic of Croatia covers an area of 56,000 km^2 and has about 4,800,000 inhabitants. The greatest share in passenger transport belongs to road transport (72%), and in the goods transport the greatest share is covered by sea transport (57%), Fig. 16. Out of the total of 1,430,000 registered motor vehicles, by far the highest share is that of passenger cars (79%), Fig. 13. The average age of all the vehicles is approximately 11 years so that the harmful emissions from road traffic are very high. Improvement in this respect is provided by the vehicle approval system that started to be implemented in September 1997. The Vehicle Approval Service was established in 1993 within the Department for Quality of the State Institute for Standardisation and Metrology. Croatia was the 25th country to participate in the Agreement on adoption of uniform conditions for approval and reciprocal recognition of



2000	
TOTAL	1 427 140
Pass. Cars	1 124 825
Buses	4 660
Vans	9 382
Motorcycles	21 868
Trucks	113 134

Figure 13 - The vehicle population in Croatia. [Monthly statistical report]

motor vehicle approval of equipment and parts, which was developed in Geneva on March 20, 1958. Presently, about 70 out of the total number of 110 regulations are in force in Croatia, and a considerable increase in their number is expected soon. Let us briefly analyse the effects of introducing the approval system on the reduction of harmful emissions generated by road vehicles over the last three years. According to data provided by the Croatian Vehicle Centre), during that period a total of 20,282 cargo vehicles had their first registration and their total number amounted to 113,134 on Dec. 31, 2000. All these newly imported trucks meet the Euro 1 and Euro 2 (Euro 2 is much stricter) requirements. As may be seen in Figure 5,

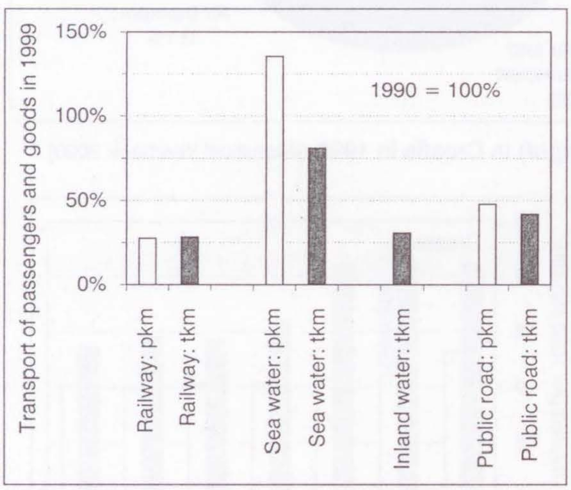


Figure 14 - The transport of passengers and goods in Croatia in 1999 (pkm = passenger-kilometres tkm = tonne-kilometres). [Monthly statistical report]

harmful emission of these vehicles is on the average by 1/3 lesser than the emission up to 1988 which corresponds to the average age of the vehicles in Croatia. Therefore, the reduction of harmful emissions ΔE of truck fleet amounts to approximately:

$$\Delta E = \frac{n_{new} \cdot (E_{old} - E_{new})}{(n_{all} - n_{new}) \cdot E_{old} + n_{new} \cdot E_{new}} = 0.136 = 13.6\% \quad (6)$$

where:

$n_{new} = 20282$ is the number of imported new vehicles,

$n_{all} = 113134$ is the number of all vehicles in Croatia,

$E_{old} = 3$ are the total relative emissions of old vehicles,

$E_{new} = 1$ are the total relative emissions of new vehicles.

In passenger vehicles as well, the results obtained are encouraging. Whereas before the introduction of the vehicle approval system the ratio of used versus imported new vehicles was 4:1, already during the first six and a half months it was reduced to 1.9:1 thus achieving a relative reduction of harmful emissions of $\Delta E = 4.9\%$ [Mahalec - Bjelovučić - Jeras - Lulić]. In 2000 the ratio was almost reverse: there were only 0.85 used vehicles to every imported new vehicle.

Considering the distribution of oil derivatives consumption in Croatia (Fig. 15), it may be seen that the greatest consumer of course is transport (46%). However, almost the same share is accounted for by heating oil (44%), so that the efforts to reduce harmful emissions from vehicles alone will not improve the general air quality if these other consumers are not

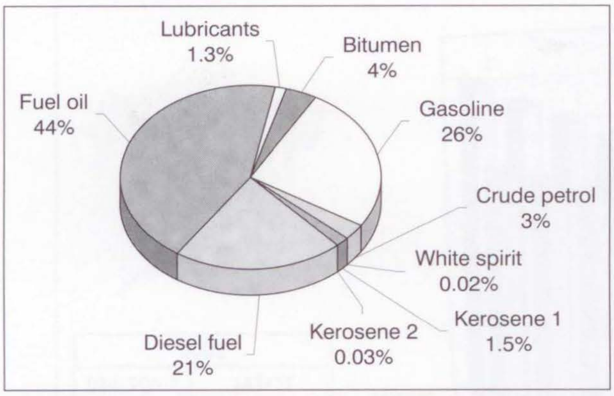


Figure 15 - Production of coke and refined petroleum products in Croatia in 1999: out of the total amount of 4.7 million tonnes 47% are motor fuels.
[Statistical Yearbook 2000]

taken into account. It should also be noted that the share of railways, which generates the least harmful emissions of all transport modes, amounts in the overall consumption of derivatives to less than 1% (29,800t). It is evident that the potentials of this most favourable transport mode are insufficiently used, although in comparison to road traffic, repair and maintenance of railway lines is cheaper than building motorways, and the sensitivity to snow in winter is much lower. Total volume of goods transport has been reduced compared to 1990 in all transport modes except in maritime traffic (Fig. 14).

Considering the difficult situation in the economy and the great deficit in goods exchange with foreign countries, it is no surprise that the general attitude is moving towards quick solutions and quick profit. Tourism appears as an activity that can result in high financial effects and quite quickly at that. However, it is at the same time an extremely sensitive branch. A tourist country today must have clean air, clean soil, clean waters and clean sea. Roads have to meet the usual world standards, and the traffic should be organised in such a way as to guarantee safety to the passengers (Fig. 17). Croatia will have to invest great efforts to maintain and reach these necessary goals.

In the field of energy generation, the investments in the use of biologically renewable and inexhaustible energy resources are one of the safest investments considered over a long period of time. The relevant institutions in the world forecast that the last oil reserves will be used up somewhere between 2050 and 2060. Waiting for others to solve the issue of energy supplies seems too risky. The government would most certainly lose little or almost nothing if they e.g. completely tax-exempted rape oil (RME) used as engine fuel. Moreover, this could be an incentive to re-settling and reviving of quite large, almost extinct areas of Croatia.

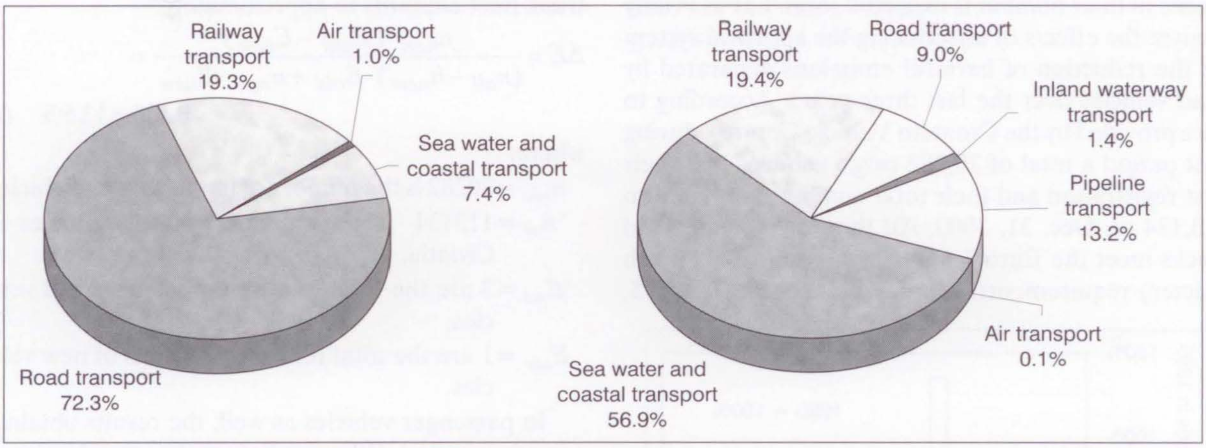


Figure 16 - Transport of passengers (*left*) and goods (*right*) in Croatia in 1999. [Statistical Yearbook 2000]

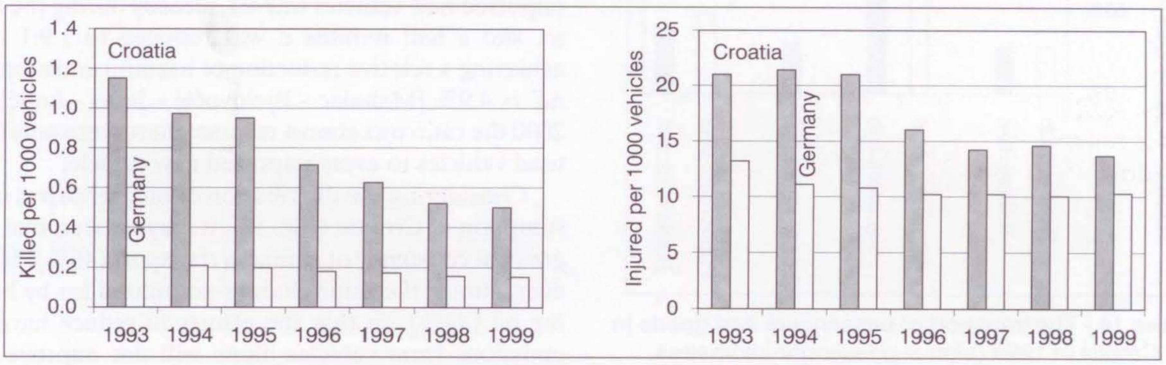


Figure 17 - Traffic accidents in Croatia compared to Germany. [Statistical Yearbook 2000, Statistisches Jahrbuch 2000]

This would also alleviate the burden on towns, reduce unemployment, and in these regions the today neglected and once cultivated farmland would be saved from further decay.

In this sense, the following theses are set:

- It is necessary to start immediately with building of a system of statistical traffic monitoring which will provide high-quality and transparent production of binding reports (CLRTAP, UNFCC, 93/389/ /EEC) to the authorised European institutions (EEA, ETC/AE)[3]. The current systems do not make this possible.
- The precise plan of measures for the reduction and use of biologically clean sources and insistent education of the whole population can stop the negative trends and improve environmental preservation. Actions directed towards this goal should become one of the most important priorities at the government level. Regardless of all the accepted international conventions, current regulations on environmental protection in Croatia remain a dead letter, and the database about the efficiency level of energy processes simply does not exist.
- Tax reductions in Croatia can stimulate development of new technologies using biologically clean energy sources and reduction of energy consumption.
- Modernisation of railway would be a valuable contribution to improving the traffic as integral system and to reducing the harmful emissions.
- We are not so poor that these solutions would be too expensive for us. On the contrary, we are not rich enough to afford any more failures.
- We have to act fast and we need to keep the planned deadlines!

7 DOUBT – INSTEAD OF A CONCLUSION

Traffic today is simply a part of our lives and one of the basic preconditions of what is called social progress. Like blood in our body it circulates across the whole globe and provides the necessary flow of people and material goods. However, Man has started so many thermal and other processes on Earth, that he is losing control over them and is dangerously increasing the world entropy. Damages done by humans to the nature are practically irrecoverable, and the global issues of the change of climate do not know of any borders on the geographical maps, but rather involve every single individual. We are at the threshold of an age that requires smart, intelligent and above all fast and decisive actions in order to stop the negative trends. One of the most significant roles belongs to transport. Are we able to gather enough strength to resist racing after profit and to preserve this wonderful planet?

NOTES

1. Mtoe - = megatonnes of oil equivalent energy.
2. *Traditional*: urban trains 20 %, buses 20 %, private cars 60 %. *Green Commute*: urban trains 30 %, buses 25 %, private cars 45 %.
3. EEA – European Environmental Agency, ETC/AE – European Topic Centre on Air Emissions, CLRTAP – UNECE Convention on Long Range Transboundary Air Pollution, UNFCCC – UN Framework Convention on Climate Change, 93/389/EEC – EC Monitoring Mechanism of Community CO_2 and Greenhous Gas Emissions.

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13. CDIAC - Carbon Dioxide Information Analysis Center, Oak Ridge, USA
14. NOAA - National Oceanic and Atmospheric Administration, U.S. Department of Commerce
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