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## COMPARATIVE ANALYSIS OF EXTERNAL COSTS OF DIFFERENT MEANS OF TRANSPORT

### SUMMARY

*Owing to the European Union open borders, free movement of goods, services, people and capital has been enabled and the need for a fast, efficient and comfortable transport, with as low transport and external costs as possible, has necessarily increased. External costs, as transport-generated public costs, represent great threat to the environment and increasing attention has been engaged in fighting the negative impact of transport upon environment. According to the EU statistical forecasts, significant increase in transport activities may be expected within 2050, hence the adoption of the European Union Sustainable Development Strategy and a collection of Directives dealing with environmental protection from different means of transport within different traffic categories. Through various Action Programmes comprising a series of measures, the European Union Sustainable Development Strategy aims at decreasing external costs, protecting the environment and increasing traffic safety.*

*In this accordance, the paper deals with the analysis of external costs within each particular traffic category, taking into consideration the air, water and soil pollution, noise, vibrations and the impact of certain traffic categories upon landscape and animal and plant diversity.*

*Using the comparative analysis of external costs within different traffic categories, the research is aimed at highlighting the advantages and disadvantages of exploitation of different means of transport. The examined external cost indicators point to the complexity of examined issues and they should be systematically used for the purpose of development and continuous traffic redirection to more acceptable traffic categories in terms of environment protection, energy efficiency and safety enhancement.*

**Key words:** economy, energy efficiency, environmental protection, external costs, safety

## 1 INTRODUCTION

External Costs are transport-generated public costs which can be divided in three groups: Environment Pollution Prevention Costs, Safety Enhancing Costs and Congestion Reduction Costs.

It is very important for all these three groups of costs originating from transport to be reduced in order not only to achieve better economic efficiency but also to better safeguard the environment, reduce the number of traffic accidents and enable higher comfort (quality of transport). It is hard for all these interests to be reconciled, yet the European Union has strived to achieve these goals by adopting a number of Directives, Laws, Regulations and Strategies.

The European Union has strived to secure solid contribution towards the prevention of climate change through the reduction of greenhouse gas emissions (GHG) and has adopted the Transport Development Strategy aimed at sustainable development. The White Book 2011 encloses the policy based on defining the long term Transport Strategy aimed at transforming the transport system in line with the sustainable development policy by 2050.

Altogether, the reduction in emissions the EU should achieve by 2050 amounts to 80-95 % below the 1990 level, within the context of reductions required from developed countries as a group, in order to reach the target.

The general objective of the policy of the EU initiative is to define the long term Strategy that will transform the EU transport within the sustainable system by 2050. This general objective can be summarized into a number of specific objectives:

- a) Reduction in GHG emissions consistent with long term requirements for limiting the climate change magnitude up to 2 °C, where the EU overall target for emission reductions by 2050 amounts to 80 % as compared to 1990. Transport-related emissions of CO<sub>2</sub> should be reduced by approximately 60 % by 2050 as compared to 1990.
- b) Drastic decrease in the oil dependency ratio of transport-related activities by 2050 as required by the EU 2020 Strategy for transport, i.e. the so-called “decarbonised transport”
- c) Limitation of congestion increase

The first two objectives overlap to a large extent and one should take into consideration the absolute priority in accordance with the EU 2020 Resource Efficiency Flagship Strategy. However, the third objective synergies are also significant, which would typically call for a more intensive use of non-motorized and public transport, whereby both the use of space and the use of energy are also reduced.

Two thirds of total costs are generated from passenger transports and one third refers to public cargo transports.

The External Costs for each type of transport are displayed in Table 1.

**Table 1** External Costs for Each Type of Transport

Transport branch	External costs (%)
Road	83.7
Air	14.0
Railroad	1.9
Water	0.4

**Source:** UIC – Union International Union of railways; Press release no.198 – Brussels/Paris,6 October, 2004, p. 2

Traffic Safety is one of the most important factors in preserving human lives and as they go up, medical and rehabilitation costs go down, as well as the cost of remedies for environmental pollution from accidents.

Traffic congestions take place most commonly in road transport and its most significant consequences are increased external costs, inclusive of costs related to traffic accidents and detrimental impact upon the environment, in consequence of which congestion is to be characterized as a crisis situation.

## 2 AIR POLLUTION CAUSED BY PARTICULAR TRANSPORT SYSTEMS

Constant economic growth, brisk economy activity (consumer policy), production growth, and traffic intensification etc. cause an ever increasing environment pollution and exhaustion of renewable and particularly of non-renewable natural resources. Predictions in respect of traffic growth have become undisputed facts as shown in Table 2.

**Table 2** The EU anticipated traffic growth

Type of transport	Within 2030	Within 2050
cargo	40%	80%
Passenger	34%	51%

**Source:** Commission staff working document; Accompanying the White Paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, SEC(2011)359 final – Brussels, March 28, 2011, pp. 12

Table 2 shows that Cargo and Passenger Transport Increase could be expected within 2050, in accordance with the EU predictions, thus confirming from the aspects of external costs that transport strategy should be necessarily created.

### 2.1 Greenhouse Gas Emissions within Particular Transport Branches

Greenhouse Gas Emissions (GHG) create the greenhouse effect (through the ozone layer deterioration), thus bringing about global warming (climate changes). It is necessary therefore to introduce measures aimed at reducing environmental pollution in traffic, an issue that Europe has been seriously engaged in (having adopted the climate and energy package of measures aimed at reducing greenhouse gas emissions by 20 % as compared to 1990).

#### 2.1.1 Road Transport

Greenhouse gas emissions in traffic are attributable to fossil fuels and are most evident in road transport which shows a rapidly growing development rate and is most represented, leaving behind any other branch of transport. Motor fuels used in road transport are composed of carbon and hydrogen. Under the conditions of “ideal combustion”, only carbon (IV) oxide – (CO<sub>2</sub>) and water vapour would be released into the atmosphere. However, due to incomplete combustion within the engine, whereby a certain portion of combustion energy and harmful gases are lost into the atmosphere, any reduction in road traffic circulation bears great significance.

Table 3 shows that, among all harmful gases, carbon monoxide (CO) is most frequently present.

**Table 3** Particular harmful gas emissions by percentage

Harmful gases	Percentage (%)
Carbon monoxide (CO)	98.0
Nitric oxide (NOx)	90.5
Hydrocarbons	95.0
Sulphur dioxide (SO <sub>2</sub> )	74.0
Solids	85.0

**Source:** Golubić, J.: “Promet i okoliš”, Fakultet prometnih znanosti, Zagreb, 1999, p.17

It is a well known fact that air pollution has a harmful impact on human health, especially in cities where roads lead through residential and shopping areas where people are directly exposed to dangerous gas emissions.

Long high speed freight vehicles are more dangerous to the environment than passenger cars due to their large mass and load and consequently higher fuel consumption, thus leading to higher harmful gas emissions and to more significant environment pollution.

#### 2.1.2 Railroad Transport

In railroad traffic, diesel driven vehicles produce carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), nitric oxide (NOx), sulphur dioxide (SO<sub>2</sub>), hydrocarbons and smoke containing solid particles, which are all discharged into the atmosphere. Such a harmful emission is attributable to the type of fuel, engine operation and age of the vehicle. The air pollution generated from railroad transport is significantly lower in comparison with other branches of transport, with particular substance shares in total emissions, as presented in Table 4.

**Table 4** Shares of Harmful Gas / Substance Emissions in Railroad Transport

Harmful substances	Share (%)
CO	1
NOx	4
SOx	10
Hydrocarbons	1
Solids	5

**Source:** Golubić, J.: “Promet i okoliš”, Fakultet prometnih znanosti, Zagreb, 1999, p.17

In the case of railroad transport based on power driven vehicles, there has been no significant chemical air pollution detected. Yet, high amounts of ionizing particles in the air have negative impact on human health causing reduced concentration, aggressiveness and headaches.

### 2.1.3 Airborne Transport

Air transport has shown a continuously growing trend matched by the desire for crossing large distances in a fast, safe and comfortable way.

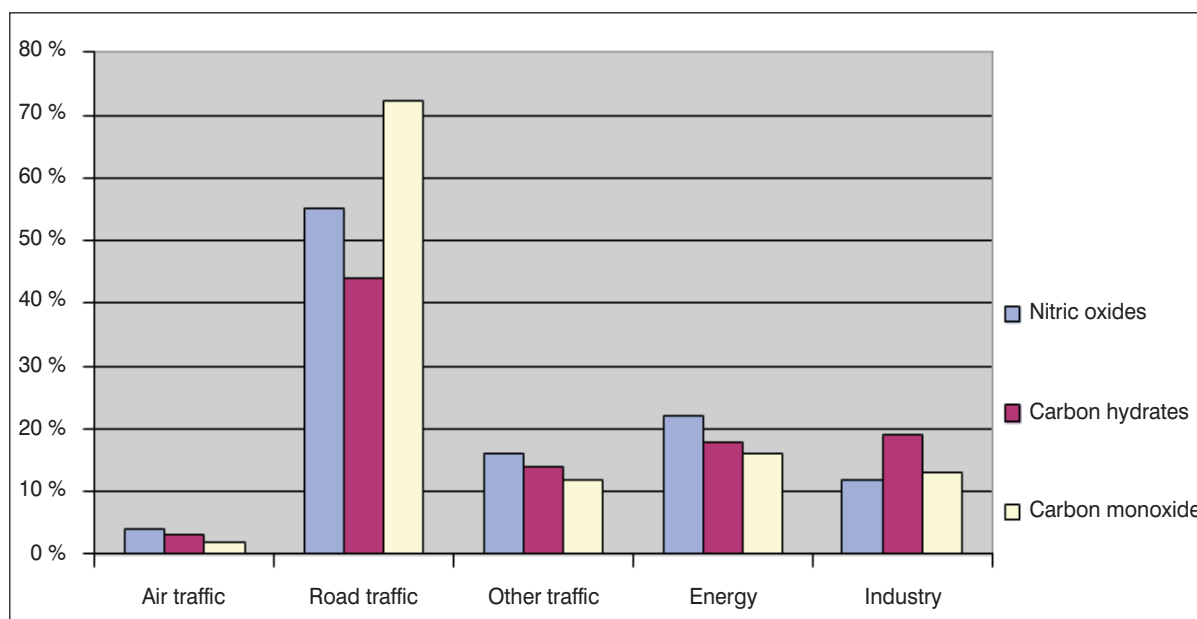
Even in case of short distances, there is a sore need for this transport branch because of the increasingly fast lifestyle. Owing to its features (fast and comfortable over long distances), air transport appears to be irreplaceable, and particularly so where military purposes are concerned. As such, air transport will certainly follow further development in future, but it is important to have its negative impact on the environment reduced. In pursuing reduced harmful impact of air transport on the environment, the EU strives to define an acceptable policy to be implemented with positive effects on the environment and on external costs of transport in general. One of the possibilities is seen in the introduction of an “Eco-Tax” to be

imposed upon airlines for the purpose of funding environmental protection using “tradable harmful gas quotas”, as confirmed by international treaties and already implemented in business strategies (Bozicevic, 2011, p. 11).

In evaluating harmful effects of particular branches of transport on the environment, and apart from the lowest share of harmful gases in total emissions of greenhouse gases (CO, CO<sub>2</sub>, CH<sub>4</sub> stainless steel) generated from air transport, air traffic is considered to be the greatest traffic polluter, due to its emission taking place at the altitude of 8 to 12 km (in the *tropopause* - between the troposphere and the stratosphere), where aircrafts are the only anthropogenic pollutants. Taking into account the density / frequency of this type of traffic which is rather low in Croatia as compared to road transport, the total emission rate may be lower, but still more harmful because of the altitude at which it takes place. In the total CO<sub>2</sub> emissions caused by fossil fuel combustion, air transport participates with 2 – 3 %. In the anthropogenic production of greenhouse gases affecting global climate changes, 3.5 % are attributable to air transport (Steiner et al. 2012, p. 33).

Graph 1 presents percentage shares of particular harmful gases (NO<sub>x</sub>, CH, CO) by the transport branch.

**Graph 1** Sources of greenhouse gases



**Source:** Modern Air Transport and Environment – ATR: The Optimum Choice for a Friendly Environment. CO/EM 467/00, ATR, 2000

**Table 5** Harmful Gas Emissions by the Transport branch

Transport branch	Harmful gas emission			
	Passenger Transport (gr/person/km)		Freight Transport (g/ton/km)	
	CO <sub>2</sub>	NO <sub>x</sub>	CO <sub>2</sub>	NO <sub>x</sub>
Railroad	3.00	0.01	2.80	0.01
Road	87.00	0.48	53.00	0.70
Air	243.00	1.63	-	-

Source: <http://www.casopis-gradjevinar.hr/dokumenti/200301/7.pdf>

The graph clearly shows that air transport has the lowest share in harmful gas emissions, whereas the road transport has the highest one. Table 5 shows harmful gas emission values by particular sectors of transport, in grams per kilometre.

Table 5 presents harmful gas emissions based on a research performed at the Swedish National Road and Transport Research Institute. Harmful gas emissions in air transport, according to total shares, does not appear to be the highest one, yet, taking into account the kilometres crossed under load, it results so. Taking into consideration the altitude where the harmful gas emission occurs, in addition to other consequences (the aircraft produced water vapour – the so called *tails* that can be seen behind it – forms ice crystals in the upper atmosphere which block the Earth warming process. Apart from the direct greenhouse effect, which results 10 times as strong as within the lower layers, emissions of water vapour generated from air transport additionally affect the activity of the climate because of condensation streaks which contribute to the creation of high, icy cirrus clouds. Within the border of *tropopause* and within the stratosphere lower zone (isothermal zone) with the temperature around -50 °C, water vapour is transformed into ice crystals (Steiner et al., 2012, p. 33).

#### 2.1.4 Air Pollution from Ships

Talking of air pollution from ships, we refer primarily to harmful gas emissions from diesel engine ships. In order to achieve the highest engine performance efficiency, the time of fuel combustion inside the cylinders is reduced, thus making the long stroke engine compression ratio higher. This leads to fuel combustion under

higher temperatures in the engine cylinder and causes harmful gas emissions (Milosevic-Puljo and Jurjevic, 2004, p. 178)

Harmful gas emissions in ships are emissions of different types of oxides (carbon, nitric, sulphur), substances participating in the ozone reduction (including halons), smoke and solids, evaporating organic compounds, and similar pollutants. Carbon dioxide (CO<sub>2</sub>) is not a toxic gas, but it calls for great attention due to its role in the greenhouse process. In case of ships, the emission of hydrocarbons and carbon monoxide is fairly low in comparison with other transport branches and industrial facilities. (Milosevic-Puljo and Jurjevic, 2004, p. 178–184)

Nitric oxide is among major air pollutants causing the greenhouse effect (increased radiation and higher temperatures). Nitric oxides (NO<sub>x</sub>) appear as nitrogen (II) oxide – NO and nitrogen (IV) oxide – NO<sub>2</sub>.

Nitrogen (IV) oxide – NO<sub>2</sub> is:

- harmful to human health (respiratory tract);
- harmful to flora;
- one of the causes of acid rain;
- affects the amount of ozone in the stratosphere and
- affects the ozone formation in the lower atmosphere (the troposphere) (Prelec, 2012, p. 4)

### 3 SOIL AND WATER POLLUTION CAUSED BY TRAFFIC SYSTEMS

Soil and water pollution occurs in all transport branches, thus increasing external costs. All efforts are directed towards the reduction of pollution and cutting of costs.

### 3.1 Road Traffic

Where road traffic is concerned, car tire wear (brakes, road friction) and surface layer depletion contribute significantly to the production of waste substances which are absorbed by the surrounding soil and water. (Građevinar, 2003, p. 51). The Program for the construction and maintenance of public roads for a period of four years is adopted by the Government upon proposal by the Croatian Ministry of the Sea, Transport and Infrastructure (Official Gazette, 2011, No. 84/11).

In cities, the transition to clean transportation prompted by higher population density is facilitated by lower requirements in respect of vehicles. Public transport choices are more widely acceptable, as well as walking and cycling options. Cities suffer from congestion, poor air quality and exposure to noise. Urban transport is responsible for about a quarter of transport generated CO<sub>2</sub> emissions, in addition to 69 % of road accidents occurring in cities. (EC-COM(2011)144 final, p. 8)

The objectives comprise: 'conventional fuel' driven cars within the urban traffic to be reduced by one half within 2030, this type of cars to be limited in cities by 2050. 30 % of road freight transport exceeding 300 km should be shifted to other modes such as rail or waterborne transport by 2030, and more than 50 % by 2050, facilitated by efficient and green freight corridors. To achieve these goals, it is also necessary to develop adequate infrastructure. (EC-COM(2011)144 final, p. 9)

### 3.2 Railroad Transport

In rail transport, soil and water pollution occurs in the maintenance of railroads, using various weed and vegetation fighting chemicals around tracks. Railway embankments are water permeable, rains rinse chemical agents and all toxic components run into the soil and on into the subterranean waters, thus polluting them. With a view to soil and water pollution, railway transport is as harmful as road transport. There is an open space for discussion and drawing the parallel between the occurrence of toxic components in railroad transport and heavy metal dust particles in road transport. (Zanzerovic and Savic, 2012, p. 1-6)

### 3.3 Inland Waterway and Maritime Transport

In waterborne transport, pollution affects waters and the sea (liquid medium) in many ways. Ships release huge quantities of waste (oil, oil derivatives, chemical agents, faeces, organic waste etc.) into water ecosystems and in accidental situations such waste runs into rivers and seas. (Bicanic, 2003, p. 5)

Particular problem has been seen in ballast waters recently. Ballast waters can transfer drainage waters, toxic seaweeds, pathogenic bacteria, viruses, sediments, plankton communities, jellyfish etc. into different aquatic media, which are not their natural habitat, thus producing negative consequences upon species naturally present in such new areas. Organisms carried through ballast waters can produce negative effects in terms of ecology (biological diversity), human health and economy. (Kurtela et al., 2007, p. 1-6)

In this connection, the International Convention for the Control and Management of Ships' Ballast Water and Sediments was adopted by the International Maritime Organization in 2004 as the first comprehensive international legal instrument for regulation of the issue. (Amizic Jelavic, 2008, p. 797-810)

## 4 IMPACT OF PARTICULAR TRANSPORT SECTORS ON LANDSCAPE AND ON THE FLORA AND FAUNA DIVERSITY

All transport branches have negative impact on the environment, inclusive of the flora and fauna. Such impact being unavoidable, it is very important to reduce it as far as possible, i.e. by opting for transport solutions with lowest negative consequences.

### 4.1 Road Transport

Traffic communication lines, motor ways in particular, require considerable space, thus leading to decrease in arable land, woods, recreational and housing zones etc. The construction of a 4-lane motor way requires approx. 9.1 ha (22 acres) of land, with the motor way area width of 37.1 m (121 ft.). Due to traffic communications lines passing across particular landscapes, changes occur in habitats of particular

animal species (despite specially designated crossing points for animals) and in some plant habitats (due to timber cutting leading to ground erosion and disappearance of certain species in such areas).

#### 4.2 Railroad Transport

Railroad construction requires less space than motor way construction, but problems involving deterioration of animal and plant habitats occur in such selected areas as well. For example, it takes 3.2 ha (7.4 acres) of land per kilometre for the construction of a two-railway track with the track area width of 13.7 m (approx. 43 ft). (Bosnjak, 2002, p.212) Even less space is occupied by high speed railways (hanging railways), the so called “levitating trains”.

Airborne and waterborne traffic systems cause landscape deterioration through the construction of airports and port terminals. Flora and fauna are threatened by noise, especially in case of airports, and by frequent aircraft flights in bird flock areas.

#### 4.3 Pipeline Transport

Pipeline transport is a specific mode of transport used exclusively for transfer of special types of freight (gas, liquids, plaster, sludge etc.). In terms of environment deterioration, pipeline transport contributes to landscape pollution by merely occupying a certain area, yet with the rate of pollution below any other transport sector. Pipeline transport is the most cost-effective and safest way of transport (provided regular pipeline maintenance). In addition, it appears to be the most acceptable one as compared with other factors with detrimental effect upon the environment (noise, vibrations). (Croatian Chamber of Economy Transport and Communications Department, 2010, p.1-8)

### 5 NOISE AND VIBRATION

Great significance has been attached to the protection from noise in the EU, primarily in order to achieve better life quality and human health protection. Noise affects human health by causing impaired hearing and reduction in concentration and labour productivity. Noise represents the major problem in road, air and railroad transports. Noise and vibrations are

constantly present in road transport, and only occasionally in air and railroad transport (train passing, aircraft landing or taking off). Furthermore, noise and vibrations in road traffic are even more noticeable because roads are situated closer to settlements and therefore their impact on population is stronger. High intensity of noise and vibrations in road traffic is attributable to movement of freight vehicles.

Increasing importance has been attached to this problem in the Republic of Croatia as well, through statutory regulations precisely defining noise levels (in dB), as well as places and time periods allowed for different types of noise. Railroads and motorways located near settlements are provided with noise dampeners made of either natural or artificial materials. As far as waterborne transport is concerned, noise and vibrations have no significant influence on humans owing to vast areas involved which are distant from settlements, but periodically they do affect the aquatic world.

### 6 ENERGY EFFICIENCY OF PARTICULAR TRANSPORT SECTORS

Energy consumption is the most important element of external costs. Significant quantities of energy are required for large cargo transfers in cases of road and air transport. The situation is quite opposite in waterborne and railroad transports where the energy efficiency rate has the highest value in comparison with other transport sectors, making it possible for largest quantities of cargo to be transported within the same distance at a lower energy consumption rate. (Table 6)

**Table 6** Harmful Gas Emission Ratio by the Transport Sector

Types of Transport (Transport means)	Distance (km)
Vessels	500
Rolling stock	330
Lorries	100
Aircrafts	6.6

**Source:** The Power of Inland Navigation; The social relevance of freight transport and inland shipping 2004-2005, Bueau Voorlichting Binnenvaart

Where freight transport is concerned, the importance is not only in the possibility to transfer huge quantities of goods with lower energy consumption, but also in the type of energy used.

## 7 SAFETY

Nowadays, expansion of urban areas, new lifestyle and the development of small communities seek for good, fast and efficient connecting. Higher traffic density itself requires stronger safety measures.

Through adjustments with EU traffic standards in all aspects, the Republic of Croatia has improved the operation of its own traffic system and has created the legal framework enabling further traffic safety improvement and better protection of passengers' rights. (Negotiations EU-RH, 2011) The European Commission is to supervise the correct usage of EU legislation in particular EU member states and to encourage bilateral cooperation, improve the data collection system and analysis by enhancing the role of ERSO (European Road Safety Observatory) and to consider the possibility of adopting common principles related with investigation of traffic accident causes. The EU road safety policy is aimed at raising the level of road safety and mobility of citizens across Europe. (EC – COM(2010)389final, p. 14-15). Other transport branches are featured by high level of safety, with accidents occurring less frequently, and by constant improvement of preventive measures. External costs are significantly lower where traffic safety is higher because there are no additional costs involved and human lives are preserved as most valuable in the first place, and there are no hospital and rehabilitation costs involved and no costs for damage repairs and protection of environment affected by the accident. (Galovic et al., 2007, p. 50-56)

### 7.1 Traffic Congestion Reduction

The most significant effects of congestion are increased external costs, including the cost of traffic accidents and harmful effects upon the environment, whereby traffic congestion must be characterized as crisis. (Galovic et al., 2007, p. 50-56)

In Croatia, the number of road accident victims is around 600 a year on the average, and

with the EU cost estimate ranging from 1 to 1.2 million per person this means a loss of 600 million euro yearly. With the cost of treatment and rehabilitation of the injured added, in addition to early disability pensions, the amount soon reaches 15 % of GDP in respect of total external costs of transport, according to estimates made in European countries in transition. (Galovic et al., 2007, p. 50-56)

Having established an efficient Helicopter Emergency Medical Care (HEMC) acting within the “golden hour”, EU countries have reduced the total number of fatalities in traffic accidents by one half. The “Golden hour” has been conceived on the fact that patients suffering from internal bleeding may only survive if help is provided within one hour. Major traffic congestions occur in road transport, thus creating “traffic jams”, and consequently leading to increased nervousness, anxiety, stress and greater exposure to accidents caused by drivers' condition. (Galovic et al., 2007, p. 50-56)

## 8 CONCLUSION

By adopting different Strategies, Directives, Guidelines and Regulations, the EU strives to direct traffic policies of its member states towards ecologically more acceptable transport branches, thus aiming towards sustainable development. The EU proposed packages of measures related with traffic are based on the reduction of greenhouse gas emissions (GHG), railroad revitalization, promotion of maritime and inland waterways usage, increasing safety and rights of passengers, traffic congestion reduction, planning of well balanced growth in all transport branches and controlled growth in air and road transport, promotion of ecologically acceptable fuel driven cars, and the like.

Comparing all transport sectors, it is evident that some of them deserve preference in comparison with other ones, where a specific type of pollution is concerned (eg. air pollution). On the other hand, some sectors are more acceptable with regard to some other types of pollution (eg. noise and vibrations). While all of them have detrimental impact on the environment, it is of essential importance to stimulate the development of those with less detrimental effect upon the environment. Railroad and inland water transport enjoy essentially significant comparative advantages (ecological acceptability,



energy efficiency and safety), which should be the basis for their preferential development aimed at improving all the above mentioned elements as well as the quality of services, comfort, delays, and the like. Road transport development should be fostered towards ecologically accepted fuels and education of the population towards minimized usage of cars on short distance routes, particularly in towns. Traffic congestions and delays would be reduced through revitalization of existing railroads and higher ecological consciousness in respect of road traffic effects. It is very important to increase safety and the issue has been dealt with a lot; however, persistence is here of essential importance. It is difficult to single out just one transport sector as most acceptable and with lowest external costs and to disregard other sectors. The intention of strategy of sustainable transport is to foster the development of every transport sector with the aim of

achieving lowest external costs possible and with particular care for environmental protection. The development of infrastructure is feasible and even dependent, so to say, on Structural Funds and Cohesive Policy.

Whereas transport and its future development will inevitably have continuous impact on further environment pollution, the development of transport policies should take the course towards implementing appropriate measures for the reduction of such detrimental effects upon environment. One step forward in this direction is the selection of an optimum and safe mode of passenger and freight transport. The Sustainable Transport Development Strategy is the right way towards the environmental protection and external cost cutting, provided its continuous upgrading in accordance with new traffic requirements arising in the course of time.

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