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Environmental Effects and Externalities from the Transport Sector and Sustainable Transportation Planning – A Review

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ABSTRACT: A literature review of the environmental effects and externalities of the transport sector and the concerns in sustainable transport planning is presented in this paper. The relation between air pollution and transport, considering that transport is an important air pollution emitter, is initially analyzed. The causal relationship between per capita GDP and individual consumption for transport, annual growth of global GDP and CO_2 emissions and changes in CO_2 emissions from fuel combustion by the various transport modes is then explained. Furthermore, energy consumption of transport modes for the EU countries is illustrated, as well as the relation between traffic flow and noise emissions and the implications of transport infrastructure to the landscape and environmental aesthetics. The increase in passenger mobility has caused traffic congestion, constituting an effect which is also quantified. Furthermore, the impact of accidents in terms of injuries, impairments and fatalities is a global social and public health issue. Moreover, the transport policies and the impact on economic and urban development, health, environmental protection and energy, focusing also on possible conflicts and convergence between safety and environmental policies are discussed. Finally, transport sector externalities, quantification in monetary units and possible effects of eventual internalization of these external costs are presented.

Keywords: Environmental effects; Externalities; Internalization; Sustainable; Transportation planning
JEL Classifications: H23; O44; Q53; R4

1. Introduction

Actions towards accessibility present an important task of improving citizens' well-being and prosperity in modern societies. Raising the ability of individuals, entrepreneurs and firms to exchange goods and services, to be where activities are being carried out and to interact and communicate with people on a systematic basis is significant not only to the economy but also to the quality of life. With the growth of economic and social networks and the spatial dispersion of activities, transportation has become the backbone of accessibility systems.

The rapid growth of the transport sector results in significant environmental impacts (Table 1). The excessive consumption of energy resources, the excessively high levels of pollutants and noise in the environment combined with longer standing problems of congestion, while accidents have been also at high levels, attenuate the importance of transport growth in order to raise standards of living.

The increase of human and freight mobility could not have been achieved without environmental implications. However, these repercussions could have been minimized, if in the early stages the necessity had been realized that the transport system (in regard to its infrastructure, as well as its operation) should be developed in a rational manner. It must be provided that the properly developed various transport infrastructure networks and transport systems would cooperate efficiently in order to serve any emerging demand. They should compete on equal terms and would be organized in an environmental-friendly way, thus securing better environmental conditions, lower energy consumption and less congestion and traffic accidents, (Tricker, 2007).

Table 1. Environmental impact due to the development of transport, (compiled by the authors).

Type of impact	Local and Regional environmental impact	Wider environmental impact
Impact on the environment	Air pollution, The emissions of carbon oxides, sulphur dioxide and hydrocarbons contribute to the formation of smog acid rain. Expropriation of areas for transport infrastructure needs, Marine pollution	Air pollution, The emissions of carbon dioxide contribute to the change of the climatic conditions, Halogen compounds destroying the ozone layer, fossil fuel reserves reducing.
Impact on the society	Changes in land use and separation of residential units / built-up areas, Mobility restrictions for persons not owning cars, Accidents, Delays	

The transport sector has together with the industrial, tertiary and household activities sectors a number of harmful effects on the environment, such as air and noise pollution, consumption of energy, accidents and safety, land occupancy. However, within the transport sector, railways are the least harmful transport mode to the environment and this could prove a critical element for the development of railways in the distant future.

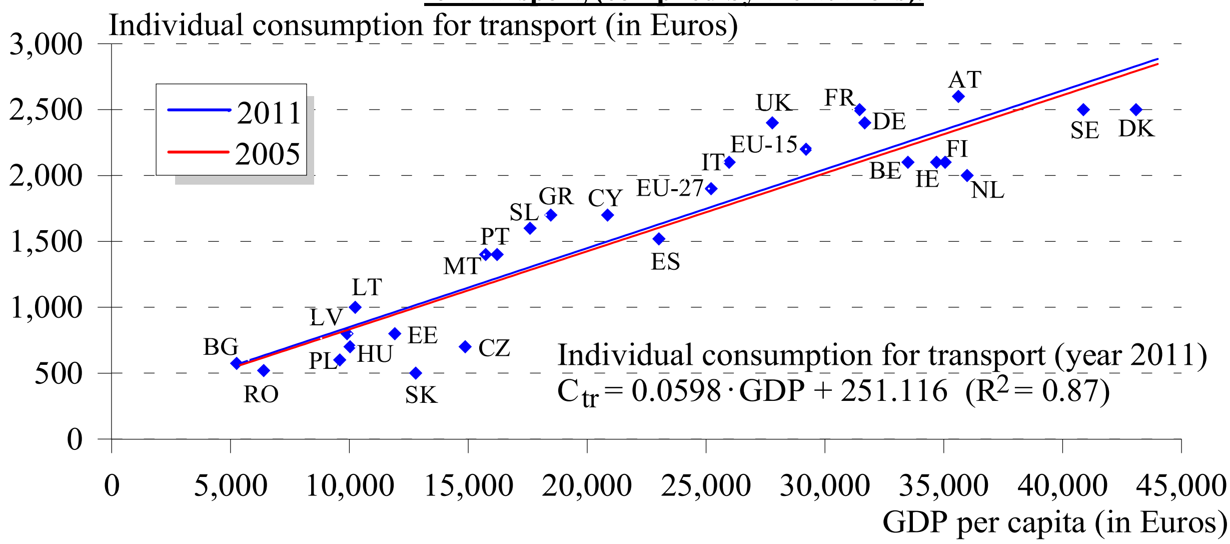
The environmental effects of each transport mode (road, rail, air, sea) include passenger and freight traffic and may refer to the following, (Chapman, 2007):

- construction and maintenance of infrastructure,
- manufacture, maintenance and disposal of rail and road vehicles, airplanes, ships,
- operation.

The consumption of transport by individuals is affected by their income and the GDP of the specific country. A causal relationship can be established between the individual consumption for transport C_{tr} and the GDP for various countries, as illustrated in Figure 1.

Conclusive evidence suggests that for many decades worldwide the amount of time that people are willing to spend on travel has remained remarkably constant at approximately 1.1 hours per day, (Smith, 1998). This means that as people have an increased income, they make use of faster modes of transport, a fact leading to more harm to the environment.

Figure 1. A causal relationship between per capita GDP and individual consumption for transport, (compiled by the authors).



Legend: AT: Austria, BE: Belgium, BG: Bulgaria, CY: Cyprus, CZ: Czech Republic, DK: Denmark, EE: Estonia, FI: Finland, FR: France, DE: Germany, GR: Greece, HU: Hungary, IE: Ireland, IT: Italy, LT: Lithuania, LV: Latvia, MT: Malta, PL: Poland, PT: Portugal, RO: Romania, ES: Spain, SE: Sweden, SK: Slovakia, SL: Slovenia, NL: The Netherlands, UK: United Kingdom, EU-27: European Union of 27 countries.

2. Air Pollution and Transport

Trends in energy-related CO_2 emissions continue to be bound closely to those of the global economy, (Figure 2), with the few declines observed in the last decades being associated with events such as the oil price crises, terrorism attacks and the recent global recession, (Li et al., 2011; Dritsaki and Dritsaki, 2014).

Transport is an important air pollution emitter, accounting for 90÷95% of carbon monoxide (CO) emissions, 60÷70% of nitrogen oxides (NO_x), 40÷50% of hydrocarbons (HC) and volatile organic compounds (VOC), 30% of carbon dioxide (CO_2) emissions, 5% of sulfur dioxide (SO_2) and 25% of suspended materials, (IEA-UIC, 2013). Figure 3 presents the emissions of some air pollutants provoked by the various transport modes for passenger and freight transport.

In 2010, the transport sector was responsible for the 27 EU countries for a 30.9% of total CO_2 emissions, the other sectors contributing electricity and heat 38.4%, the manufacturing sector 13.2%, the residential sector 11.2%, the agriculture sector 1.4% and the other sectors 4.9%, (EU, 2013). Within the transport sector, contribution of the various transport modes in CO_2 emissions was for the year 2010 as follows: roads 72.1%, navigation 14.1%, aviation 12.4%, railways 0.6%, other (non-specified) 0.8%, (EU, 2013). However, changes between 1990 and 2010 in CO_2 emissions from fuel combustion for the various transport modes are illustrated for the 27 EU countries in Figure 4.

Figure 2. Annual growth of global GDP and CO_2 emissions, (compiled by the authors).

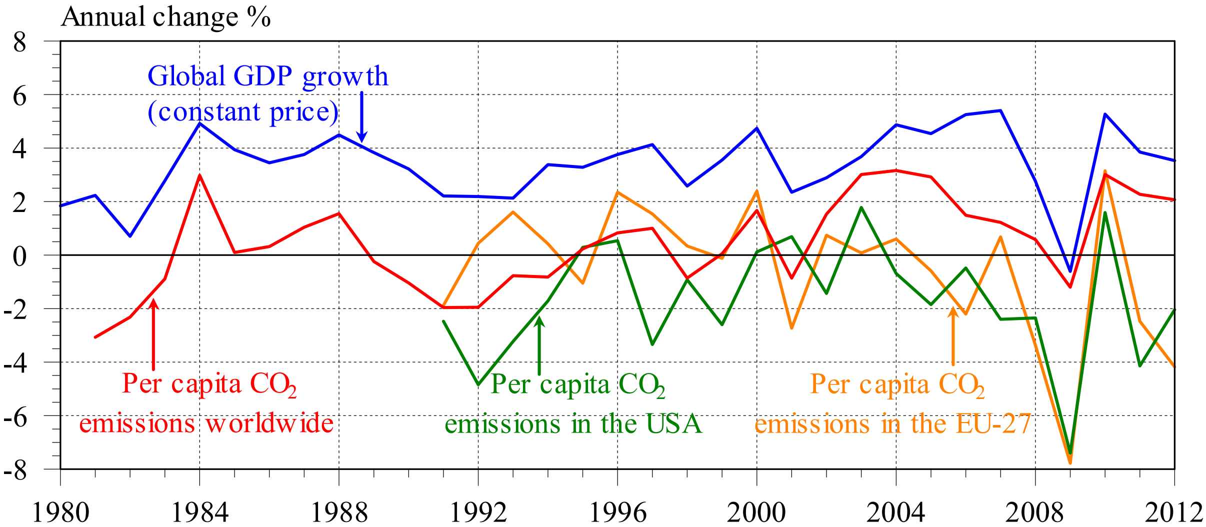


Figure 3. Emissions of pollutants provoked by various transport modes, (Profillidis, 2014).

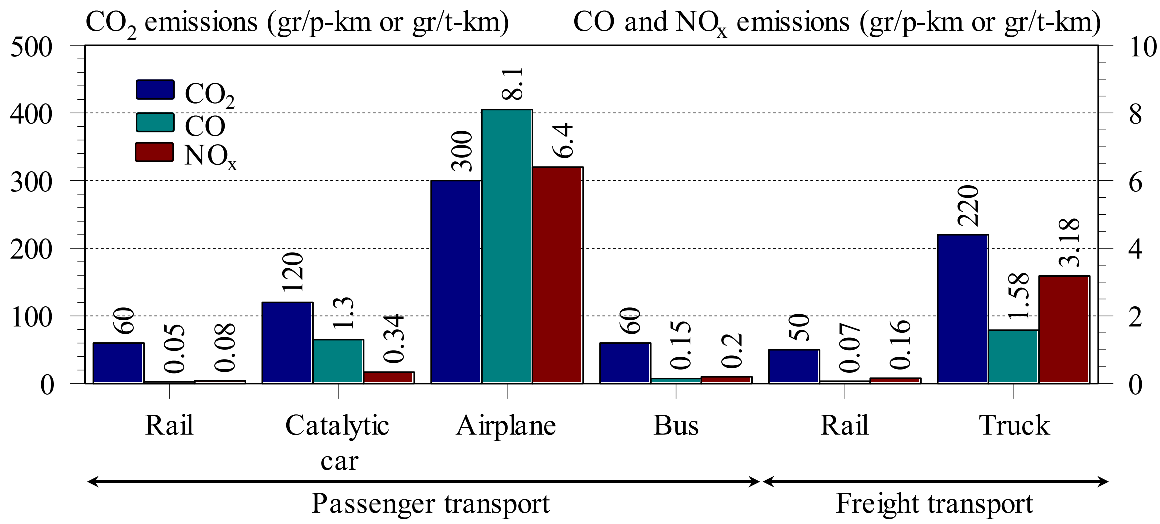
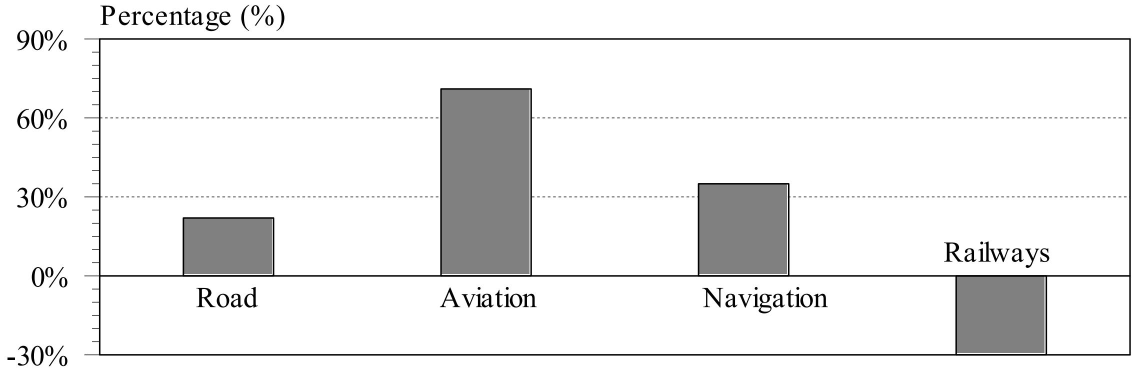


Figure 4. Changes in CO_2 emissions from fuel combustion by the various transport modes for the 27 EU countries between 1990 and 2010, (IEA-UIC, 2013).

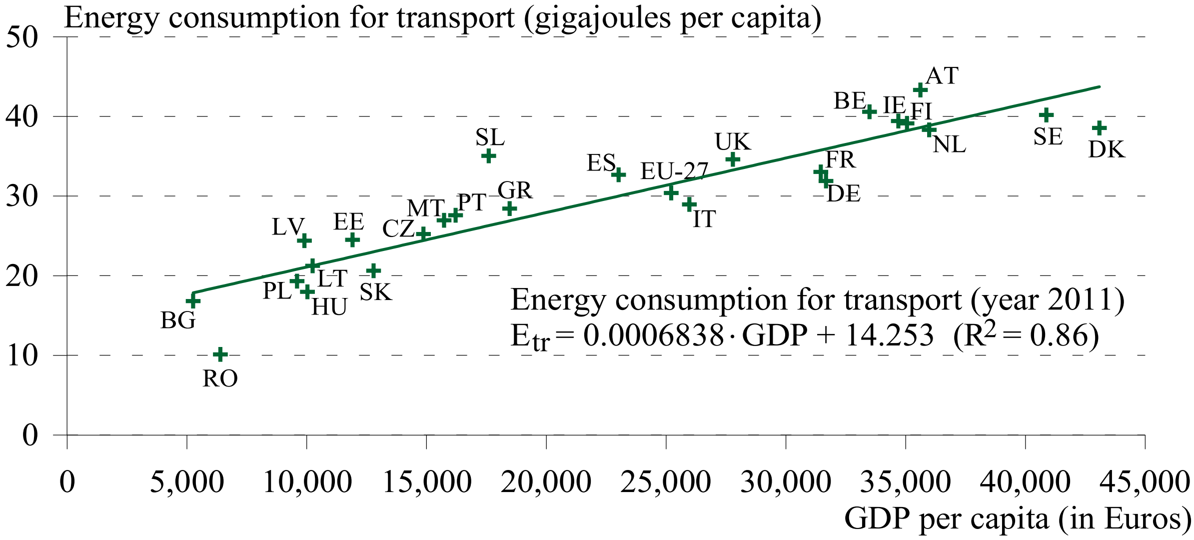


3. Energy Consumption

The energy consumption by individuals is affected from their income and the GDP of the specific country (Chen et al., 2007; Ozturk, 2010; Lau et al., 2011; Ucan et al., 2014; Naser, 2014; Profillidis, 2014). A causal relationship can be established between the energy consumption for transport E_{tr} and the GDP for various countries, as illustrated in Figure 5.

For the 27 EU countries in the year 2011, the transport sector consumed 33.0% of total energy, households 24.7%, industry 26.0%, agriculture 2.2%, services and other activities 14.1%, (EU, 2013). Percentages of the energy consumption at the world level were for the year 2010 as follows: transport 27.3%, industry 27.8%, domestic and tertiary sector 36.0%., whereas world energy demand was satisfied from five main sources: oil 37.8%, gas 23.8%, coal 25.6%, nuclear 8.1%, hydroelectric 6.1%, alternative 0.9% (Profillidis, 2014). While a global oil shortage should be expected around 2050÷2060, known gas reserves will continue to serve the planet and satisfy world demand without expecting excessive prices at least until 2100÷2150 (Bently and Boyle, 2008; Owen et al., 2010; Profillidis, 2014).

Figure 5. A causal relationship between per capita GDP and energy consumption per capita for transport, (compiled by the authors).



Within the transport sector for the 27 EU countries in the year 2012, railways consumed 1.2% of total energy for transport activities, road transport 73.3%, navigation and pipelines 10.0%, and air transport 13.4% (IEA-UIC, 2013). Figure 6 illustrates the evolution of energy consumption by transport mode from 1990 to 2012 for the 27 EU countries, whereas Figure 7 illustrates specific energy consumption per unit transported (passenger-km, ton-km).

Figure 6. Energy consumption of transport modes for the 27 EU countries, (EU, 2013).

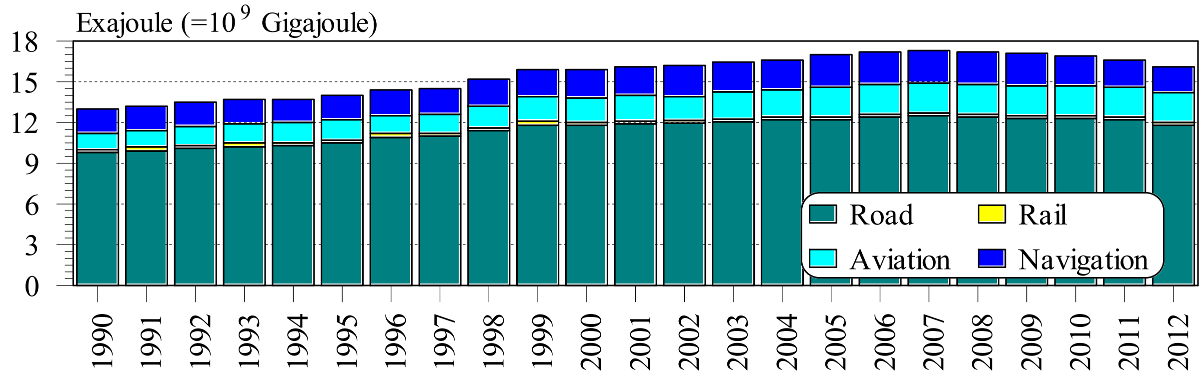
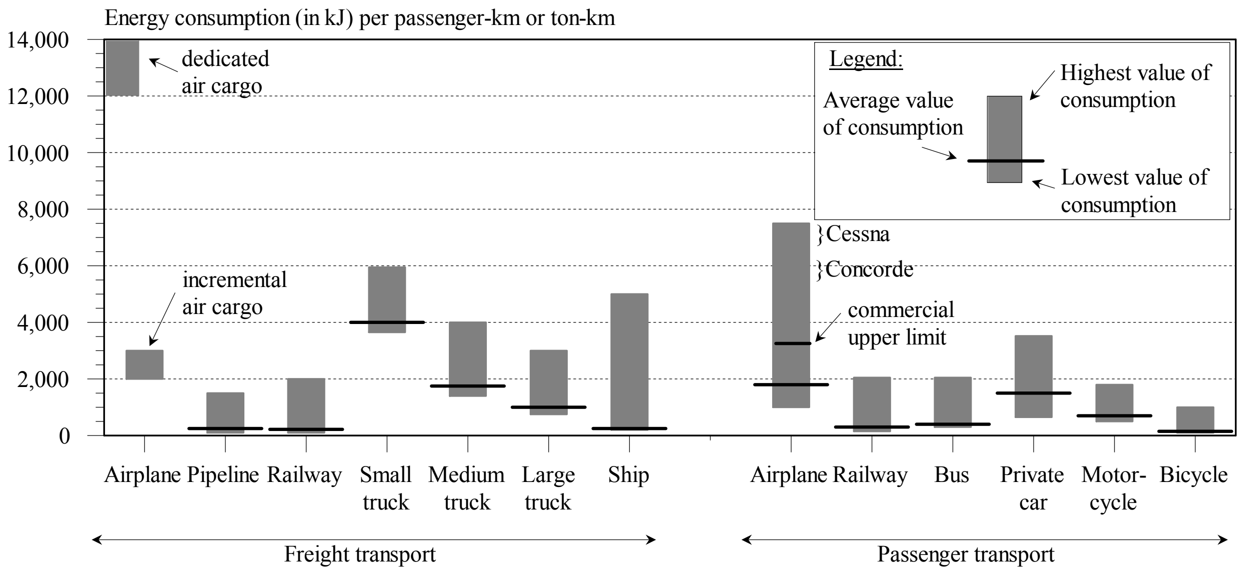
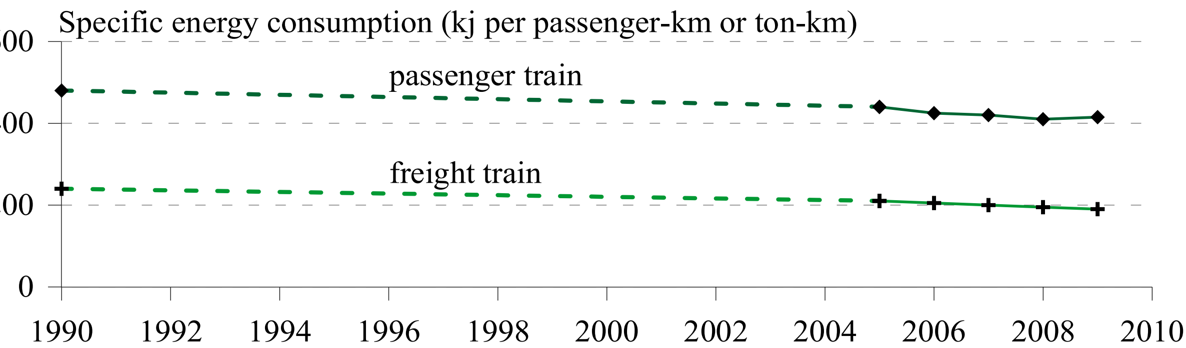


Figure 7. Specific energy consumption of transport modes, (Profillidis, 2014).



During recent years, the presence of technical innovations has substantially reduced specific energy consumption of railways, as is illustrated for the 27 EU countries (Figure 8). In other parts of the world, the reduction of the specific energy consumption of railways between 1990 and 2009 was indicated as follows: USA 50%, China 63%, India 71%, Russia 17%, (IEA-UIC, 2013).

Figure 8. Evolution of the specific energy consumption of railways for the 27 EU countries, (UIC, 2011).



Specific energy consumption for both conventional and high-speed trains is in the range of 28÷39 Wh/seat-km (1kWh=3,600kJ) and is not significantly affected by speed (Figure 9), but is strongly affected by longitudinal track gradient. Figure 10 illustrates what distance can be traveled for 1 ton of freight when using 1 kWh of energy for various freight transport modes.

Figure 9. Energy consumption of passenger trains in relation to speed, (UIC, 2011).

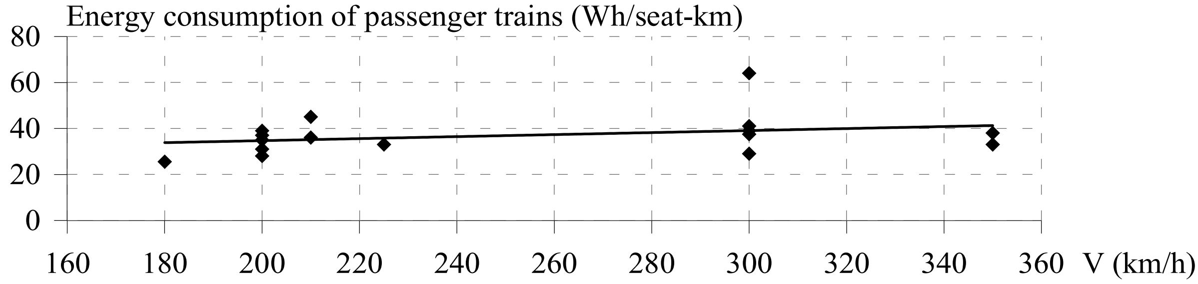
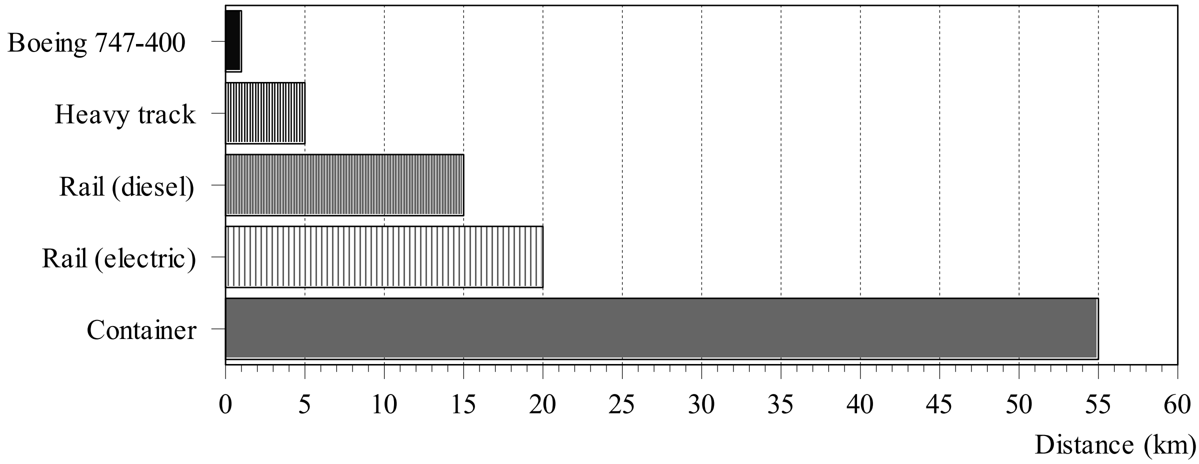


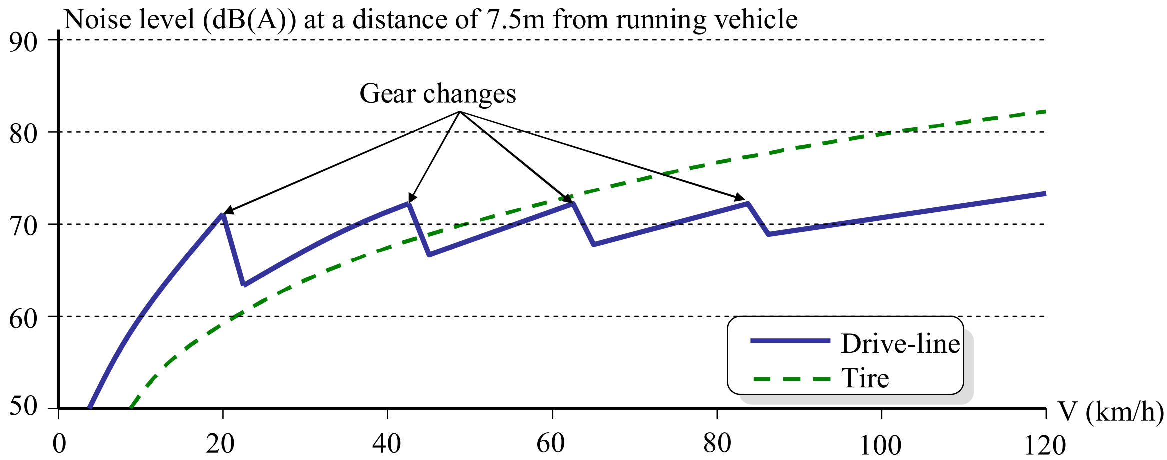
Figure 10. Distance traveled for 1 tonne of freight when using 1 kWh of energy, (IEA-UIC, 2013).



4. Noise Exposure

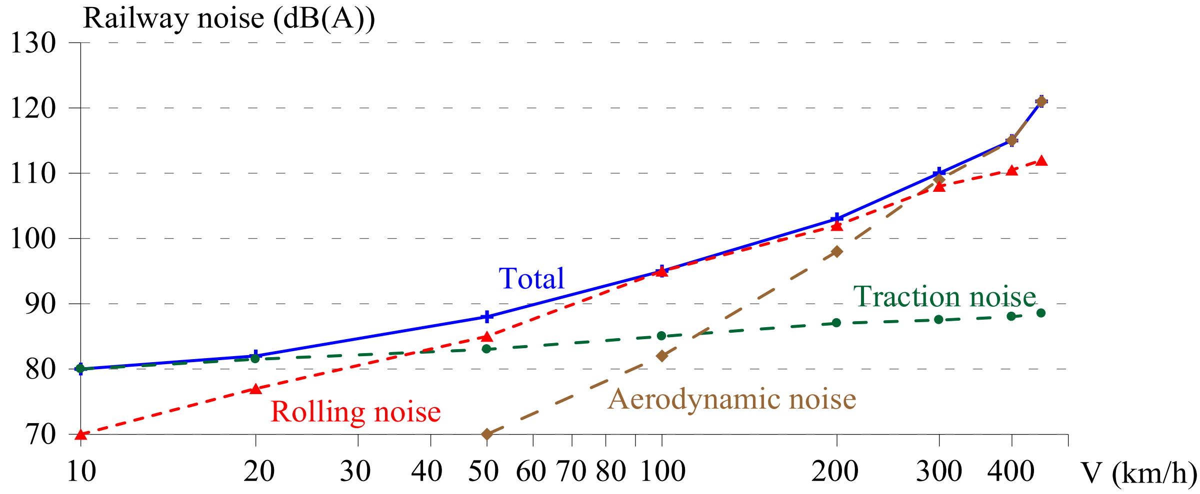
Noise emissions have significantly increased in the recent decades, due to the increasing levels of urbanization, mobility and continuous industrialization of human activities. Noise, according to its loudness and nature can have various effects on humans, starting as a simple annoyance up to pathological reactions. Noise emissions and their effects are differently depending on the respective transport modes. The noise level of road transport results from the overlapping of the engine noise, the rolling noise (the contact of tires to the road surface) and other recurring noises, (Figure 11), while the main noise emissions of railway transport are resulting from the contact of the wheel with the rails, the motor operation, the aerodynamic effect and the vibrations of the above-ground railway structures, (Figure 12). The main noise source of airplanes are engines, their noise level sometimes exceeds 120 dB(A). It is estimated that noise becomes annoying for humans when the noise level exceeds the limit of 55÷65 dB(A), (Moliner et al., 2013).

Figure 11. Noise levels of the various sources of passenger car noise, (de Boer and Schroten, 2007).



During 2010, about 44.3% of the residents in 25 countries of the European Union plus Norway and Switzerland were exposed to noise levels exceeding 55 dB(A), a level that although officially tolerable, is yet unpleasant and undesirable. These noises were produced to 35.8% by road transports and to 5.4% and 3.1% by railways and airplanes respectively. The situation is dramatic in urban agglomerations were 11% of the population are exposed to a noise level of 70 dB. It has been estimated that for the EU countries the willingness to pay, per person disturbed by noise in order to avoid noise exposure, has been increased by almost 0.11% of per capita income per unit of dB(A) when noise level exceed the value of 55 dB(A), (Profillidis and Botzoris, 2010).

Figure 12. Noise levels of the various sources of railway noise, (UIC, 2008).



5. Land Occupancy

Transport infrastructure occupies space that can have other uses in urban and non-urban areas. Awareness of this effect is more apparent in densely populated countries, such as The Netherlands, Belgium, etc. If the carrying capacity of all transport modes is compared to their land occupancy, then railways have a clear advantage, since the space required by a private car passenger is 22 times higher compared to rail, and by a bus passenger 1.7 times compared to rail, (Profillidis and Botzoris, 2010).

In addition, all transport infrastructure cause a minor or major effect to the landscape and environmental aesthetics. Railways are more easily inserted into the environment, particularly if layout design has the maximum number of sections in cut as opposed to embankment.

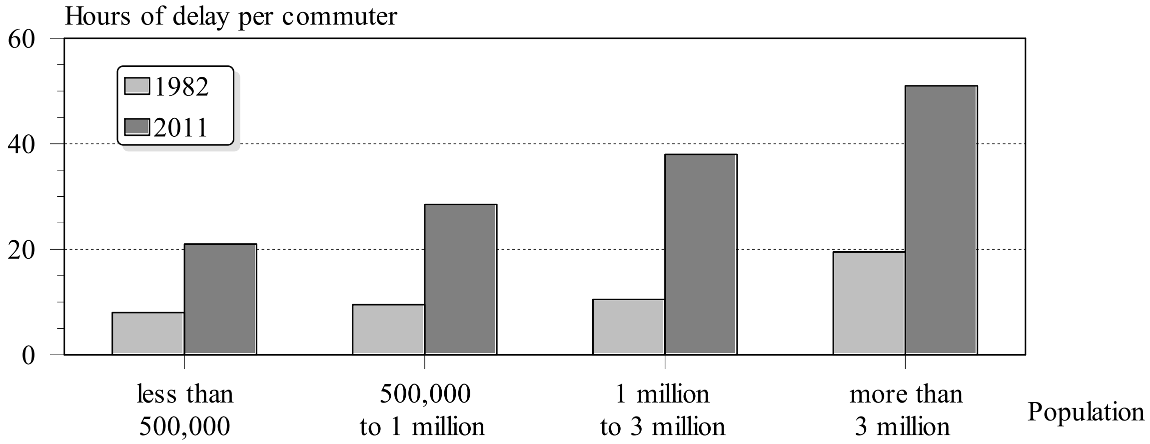
6. Congestion

Traffic congestion constitutes a significant effect of transport evolution. The transport infrastructure in certain cases has already reached its limit. The base differentiation of congestion is that while all other categories of effects (i.e. air pollution, noise, accidents, etc.) considered previously reflect the effect imposed by evolution of transport on the whole society, including people not participating in transport process, the congestion and its effects considered a phenomenon mainly within the transport sector. Users of various transport modes mutually disturb each other, provoking in some cases significant delays, but do not impose external effects on the rest of society. However, delays in transportation entail additional production costs to certain industries and in some cases rescheduling of path allocation or of timetables.

The total annual congestion cost has been evaluated for the 25 countries of the European Union + Norway + Switzerland at approximately 200 billion € (1.6% of GDP, values of year 2011) (Profillidis, 2014). Congestion cost is the sum of time losses by passengers and the increase of operation cost, due to low speeds.

Congestion is worse in areas of every size; it is not just a big city problem, (Figure 13). The growing delays also hit residents of smaller cities. Big towns and small cities alike cannot implement enough projects, programs and policies to meet the demands of growing population and jobs.

Figure 13. Congestion growth trend in relation to the population, (Schrank et al., 2012).



7. Accidents

The impact of transportation (and especially road traffic) accidents in terms of injuries, impairments and fatalities is a global social and a public health challenge. In absolute figures the number of fatalities globally well exceeds half a million and is increasing every year. In motorized countries, at least one in twenty is killed or impaired in accidents within a year and one in two persons is hospitalized due to an injury at least once during his life time. It is estimated that life expectancy is shortened by at least six months due to traffic accidents and the economic effects of accidents in all transport modes amount for the 27 EU countries to 2% of their GDP, (van Essen et al., 2011).

Figure 14 presents the risk for somebody having a fatal accident using various transport modes. Concerning road traffic, Figure 15 represents the number of road fatalities per 100,000 inhabitants, per 100,000 motor vehicles (motorcycles included) and per billion vehicle-km in various countries of European Union and worldwide.

Table 2 illustrates the effects of railway accidents on the 27 EU countries for the year 2011, during which 2,685 significant rail accidents occurred with 2,325 persons killed or seriously injured, (EU, 2013). Railway accidents include the following types: collisions, derailments, accidents involving level crossings, accidents to persons caused by rolling stock in motion, and fires in rolling stock. In the total number of deaths occurring in railway accidents, fatalities of passengers account for 5%, of employees for 2%, of level crossing users for 29%, of unauthorized persons for 60% and others for 4%.

Aviation accidents attract the attention of media and the public, as they are spectacular events. Figure 16 represents the evolution since 1970 of lives lost over European Union territory and by EU-27 air operators anywhere worldwide. Data includes onboard fatalities from commercial air transport (passenger, cargo, air taxi, etc.) and fatalities from general aviation.

Figure 14. Risk of death by distance traveled for the various transport modes, (Profillidis, 2014).

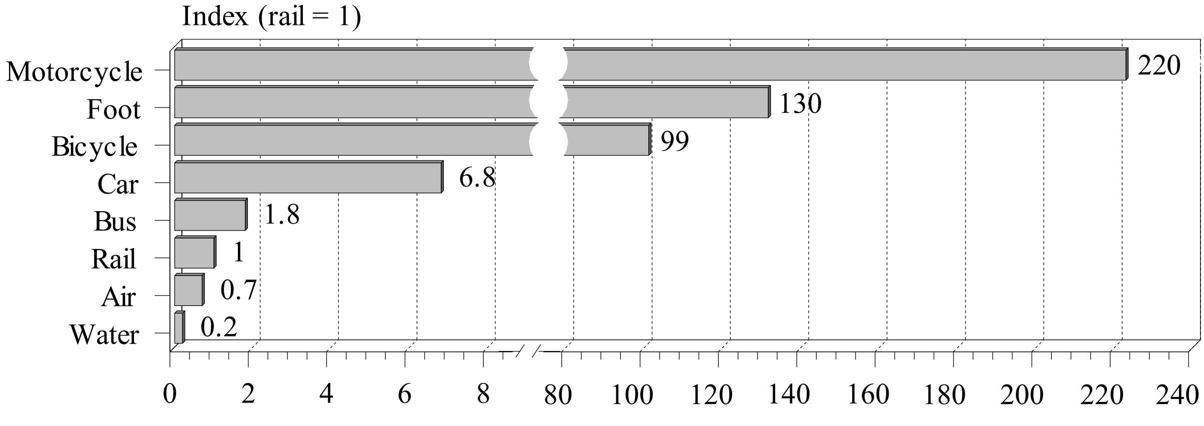


Figure 15. Road fatalities for the year 2010 in various countries of European Union and worldwide, (compiled by the authors).

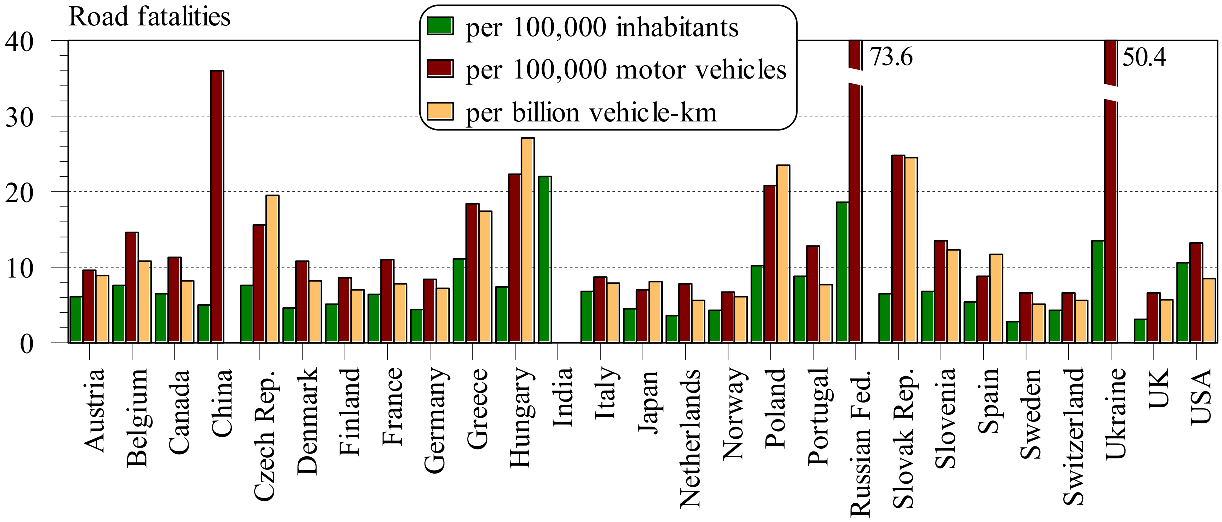
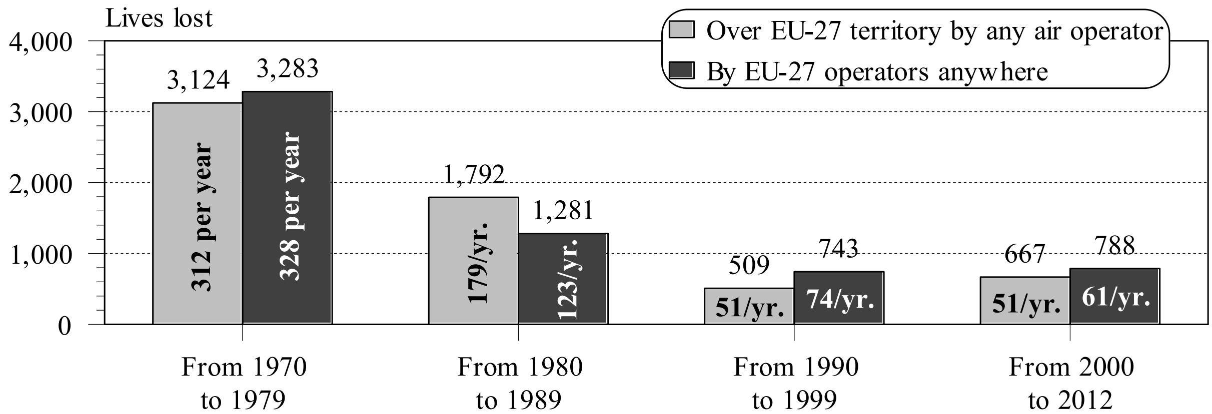


Table 2. Effects of railway accidents in the 27 EU countries for the year 2011, (Profillidis 2014).

	Number of persons killed				Number of persons seriously injured				Total			
	passengers	employees	other	Total	passengers	employees	other	total	passengers	employees	other	total
Collisions	9	3	3	15	33	11	5	49	42	14	8	64
Derailments	2	2	0	4	43	2	0	45	45	4	0	49
Accidents involving level crossings	6	0	311	317	24	14	291	329	30	14	602	646
Accidents to persons caused by rolling stock in motion	22	25	856	903	123	36	453	612	145	61	1,309	1,515
Other	0	1	2	3	6	20	22	48	6	21	24	51
Total	39	31	1,172	1,242	229	83	771	1,083	268	114	1,943	2,325

Figure 16. Aviation-related fatalities, (EU, 2013).



8. Transport Policies and Impact on Safety and Environment

Traffic accidents, air pollution and noise are closely linked to common factors, such as: traffic flow, traffic speed, vehicles' engine power and traffic composition. The policies aiming to prevent accidents, air pollution and noise are based on the same principles: travel demand management, improving both of safety and environmental performance of vehicles, strengthening, encouraging and promoting the use of modes that perform better as far as the safety and environmental protection is concerned, (such is railways, public transport modes, etc.), (Chapman, 2007; Proost and van Dender, 2012; Galanis and Eliou, 2014). However, it has not been ensured that a measure taken to improve traffic safety will automatically have the same possible impact on the environment and vice-versa. Some examples of this conflict are, (Chapman, 2007; Proost and van Dender, 2012, Profillidis, 2014):

- the use of electric or hybrid vehicles will prove beneficial as far as the reduction of air and noise pollution and the fuel consumption is concerned, but the silence of an electric engine will increase the risk of safety of pedestrians and bicyclists, as they may not be aware of the moving vehicle until it is too late,
- the construction of noise barriers will reduce the noise level of the surrounding areas but could have a negative impact if the visibility of the drivers or the pedestrian is affected, etc.

Table 3 illustrates a synthesis of the possible safety and environmental related conflicts and convergences of various policies. Furthermore, Table 4 illustrates the impact of transport policies on economic and urban development, health, environment protection and energy.

Table 3. Possible conflicts and convergence between safety and environmental policies, (Hasson, 1998; Profillidis, 2014).

		Energy conservation	CO_2 reduction	Air quality	Noise reduction	Landscape	Safety
Road vehicles	Vehicle weight reduction	+	+	×	?	×	–
	Power reduction	+	+	+	?	×	+
	Limiting maximum speed	+	+	+	+	×	+
	Electrified vehicle	?	+/–	+	+	×	+/–
	Vehicle check	+	+	+	+	×	+
	Driver training	+	+	+	+	+	+
Transport policy	Transfer to rail	+	+	+	+	+/–	+
	Strengthening public transport	+	+	+	+	×	+
Road infrastructure	By-passes	+/–	+/–	+	+/–	–	+
	Noise barriers	×	×	+	+	–	+
	Porous asphalt	×	×	×	+	×	+/–
	De-icing salt	?	×	×	–	–	+/–
Traffic	Reduction in speed limits	+	+	+	+	×	+
	Control of speed	+	+	+	+	×	+
	Traffic calming	+/–	+/–	×/+	+	+	+
	Congestion management	+	+	+	–	×	–

+ positive effect × no effect – negative effect ? uncertain effect +/– effect may be either way

Table 4. Transport policies and impact on economic and urban development, health, environment protection and energy, (Figueroa and Ribeiro, 2013).

System goal	Category related to sustainable transport goals	Example of indicative approach for assessing progress	Reduce Need to Use Car and Expand Mobility Options and Services							Improve Vehicles		Promote - Uptake Alternative fuels		
			Promote compact, transit oriented, mixed land use development	Build-upgrade non-motorized transport infrastructure	Adopt pricing policies over car ownership, distance based tariff	Adopt strict parking regulation and pricing	Promote and upgrade public transport options	Innovate and expand mobility services	Use of Information Technology Systems (ITS)	Adopt efficiency and emission reduction standards for conventional technology vehicles	Incentives supporting research and development	Adopt standards (e.g. low carbon fuel, renewable fuel)	Incentives to increase advance electric drive technology vehicles	Information campaigns - Promotions campaigns and artnerships
Economic Development	Functionality and Efficiency	Reduced travel time, travel cost and trip uncertainty	Essential	Essential	Limited	Limited	Essential	Essential	Essential	Uncertain	Limited	Uncertain	Uncertain	Limited
	Operation	Quality of system condition. Percent of lane-kms by pavement conditions. Infrastructure maintenance expenses.	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Limited	Limited	Limited
	Support General Economy	Cost/benefit new facilities. Indirect jobs supported (created). Lost time due to congestion	Limited	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Essential	Limited	Limited	Limited
Urban Development and Equity	Accessibility	Ease of reaching opportunities. Reduced access time from origin to destination. Good conditions for biking-walking	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain
	Affordability	Passenger trips per household. % of income used to pay for transport services (<20%)	Essential	Essential	Uncertain	Uncertain	Essential	Essential	Essential	Limited	Limited	Limited	Essential	Limited
	Acceptability	Public acceptability. Participation in decision-making progress	Limited	Limited	Uncertain	Uncertain	Essential	Limited	Limited	Uncertain	Uncertain	Uncertain	Essential	Essential
Health and Environment Protection	Traffic Safety	Reduction of road traffic deaths and injuries	Limited	Essential	Essential	Limited	Limited	Limited	Limited	Uncertain	Limited	Uncertain	Uncertain	Limited
	Universal Access	Access provided for the elderly, very young and people wit disabilities	Essential	Essential	Uncertain	Uncertain	Essential	Essential	Essential	Uncertain	Essential	Uncertain	Limited	Limited
	Physical Activity	Public health benefits from increased physical activity	Essential	Essential	Limited	Limited	Limited	Limited	Limited	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain
	Air Pollution	Air pollution level reduction	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Essential	Limited
	Noise	Noise level reduction	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Limited	Limited	Limited	Limited
	Ecosystem Impacts	Land use area - Sprawl: % suburban dwelling - Biodiversity protection	Essential	Limited	Limited	Limited	Limited	Limited	Limited	Uncertain	Limited	Uncertain	Uncertain	Limited
GHG	Green House Gas emissions	Green House Gas emissions reduction	Essential	Essential	Essential	Essential	Essential	Essential	Limited	Essential	Essential	Limited	Limited	Essential
Energy security	Diversification of Energy Sources	Alternative fuel consumption per vehicle and passenger km	Essential	Essential	Limited	Limited	Essential	Essential	Limited	Uncertain	Limited	Essential	Essential	Essential
	Resilience	Sector is secure from, ready for and resilient to threats and hazards	Essential	Essential	Limited	Limited	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential
	Independence from Fossil Fuels	Percentage reduction in use of fossil fuels	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential

Essential: academic agreement, positive examples of implementation

Uncertain: academic dissent, of lack of substantive evidence

Limited / potential opposite: academic agreement and evidence of limited or opposite effect

9. External Cost of Transport

9.1. Externalities and quantification of external cost

For many decades, a crucial issue concerning the various components of external effects was their accurate and objective quantification in monetary values. This work has been conducted and applied to data of the year 2008, and refers to the 25 EU countries (Malta and Cyprus do not have railways) plus Norway and Switzerland, (van Essen et al., 2011). The various components of external costs under study are: accidents, noise, air pollution, climate change, nature and landscape, additional costs in urban areas, up- and down- stream processes. Congestion costs are usually presented separately.

Total external costs (excluding congestion costs) amount for the year 2008 to more than 500 billion €, which is 4.0% of the GDP of the 27 countries taken into account (25 EU countries + Norway + Switzerland). Climate change is the most important cost category, with 29% of the total costs. Air pollution amounts to 10.4% and accident costs amount to 43% of the total costs. The costs of noise and up- and down- stream processes amount to 9.6% of total costs. The costs for nature, landscape and undesired urban effects amount to 1.0% of total costs, (Figure 17).

Road transport is the mode with the highest share (93%) in total external costs, followed by air transport (5%). It should be stressed that in the calculation of external costs of air transport, only flights within EU have been taken into account, something that explains the low share (5%) of air transport in total external costs. On the contrary, railways have a small share (less than 2%) in total external costs and waterways even smaller (0.3%). Two thirds of external costs are caused by passenger transport and one third by freight transport, (van Essen et al., 2011).

Figure 17. Average external costs for passenger and freight transport for the various transport modes, (25 EU countries+Norway+Switzerland), (van Essen et al., 2011).

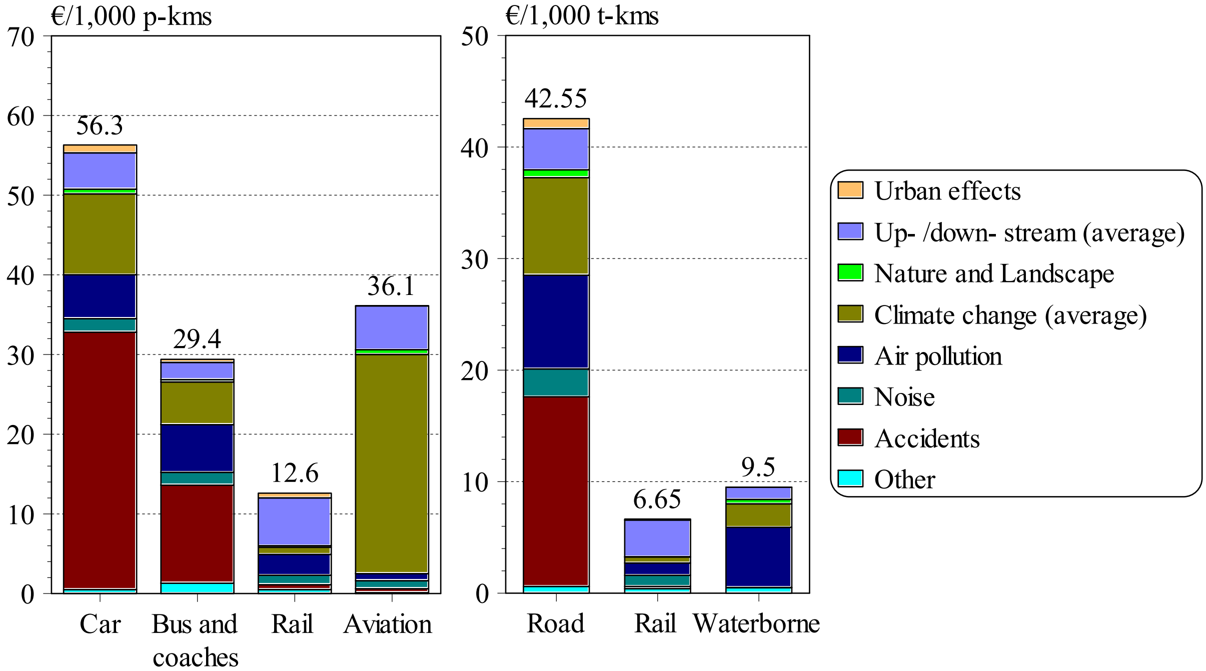
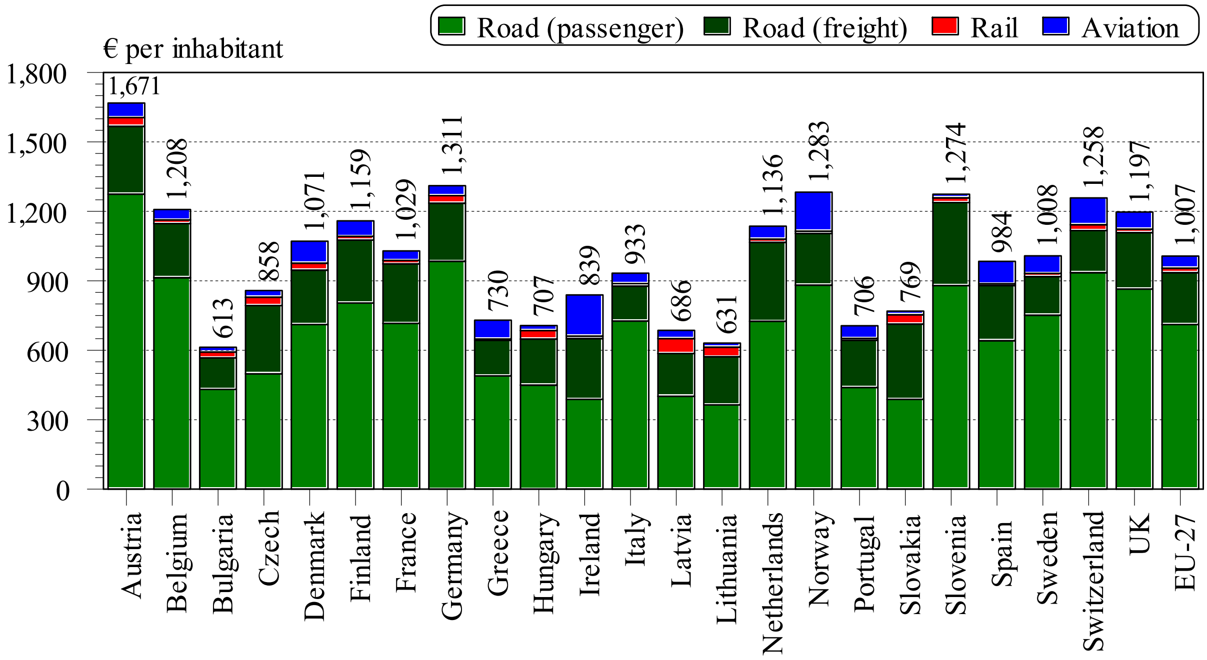


Figure 18 illustrates average external costs for passenger and freight transport for the 25 EU countries + Norway + Switzerland. The various aspects of transport offer, such as load factor, vehicle stock, population densities, share of diesel and electric train traction and other, have been taken into account.

Figure 18. External costs per inhabitant and transport mode and year for various European Union countries (excluding congestion), (van Essen et al., 2011).



9.2. Internalization of external cost

Many efforts to internalize (that is to ask each transport mode to pay the external costs it causes) external costs have failed to establish the appropriate legislation instruments. In order to properly internalize the external costs, the following action strategies are appropriate (Crozet, 2004; Macharis et al., 2010):

- application of road pricing schemes for passenger cars (i.e. by mean of tolls), especially in urban areas, in order to confront capacity problems. A differentiation of charges could be applied, depending upon the net weight and the power of cars as well as the emission of pollutants,
- introduction of road pricing schemes for freight vehicles. The applied charges must consider both accident cost and environmental costs, like air pollution, noise, etc.,
- introduction of a fuel price scheme for all transport modes, which takes into account the external costs of each transport mode. The inclusion in this measure of international air transport is necessary in order to avoid tax distortions among transport modes.

A priority must be given to the internalization of external costs caused by road and air transport, because these transport sectors are responsible for a huge amount of the total external costs. A study on the internalization of external costs for the 25 European Union countries + Norway + Switzerland was based on the increase of operation costs that will result and on cross-elasticities between rail and other transport modes. If internalization is conducted according to medium external costs, expected shift of traffic to the railways would be on the order of 12÷15% for passenger and up to 24% for freight. However, if internalization is conducted according to the marginal social cost, the expected shift of traffic for passenger and freight would be on the order of only 6% (Profillidis and Botzoris, 2010; Profillidis, 2014).

Many efforts to internalize external costs (that is to expect each transport mode to pay the external costs it causes) have failed to be approved as legislation. Among the various scenarios of internalization, the most efficient one should be fuel pricing, which takes into account all external effects for each transport mode, (Profillidis, 2014).

An eventual internalization of external costs and harmonization of infrastructure user charges to the market prices of various transport modes would have the following effects (Verhoef, 1994; Crozet, 2004; Macharis et al., 2010; van Dender, 2013):

- the internalization of average external cost would change tariffs of rail and road transport. In passenger transport the effect would vary between 20÷30% in favor of railways whereas in freight transport the effect would be even more significant (40%),

- the charging of infrastructure for rail, road and airport on equal basis and eventual internalization of external costs may change current terms of competition. If infrastructure expenses are covered from charges paid by rail operators, this will be detrimental for railways. If all external costs are internalized, with airports having far higher external costs compared to rail and road services, this will be detrimental for air transport,
- the harmonization of infrastructure charges would have significant effects on cost structure of rail freight transport and on waterway transport which pays today no infrastructure charges.

10. Conclusion

The transport sector presents unfortunately a significantly negative impact on the natural and built environment. The fossil fuel combustion associated with transportation, results in emissions of pollutants that cause damage to human health and sensitive ecosystems. Transportation can also contribute to the degradation of urban environments, with remarkable reduction of quality of life and financial productivity.

Political decisions to significantly reduce CO_2 emissions and their resulting climate change effects push forward to the adoption of efficient measures, among them in transport sector. Additionally, the need for a sustainable transport mobility plan requires the implementation of the appropriate legislation instruments. The overall goal is each transport mode to pay the external costs it causes, a procedure known as internalization of external costs.

In the present paper it is discussed and quantified the effects of an eventual internalization of external costs in the transport sector, and in particular the expected shift of traffic and the increase in transport costs. Policy measures towards more rational energy consumption, reduction of noise and environmentally friendly land occupancy are also suggested. Finally, this paper concludes that transport sector should focus on reducing the environmental, social and economic impacts, presenting a higher sustainability footprint.

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