International Master's Programme in Environmental Science

Reducing environmental impacts of freight transport sector: The case of the Czech Republic

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Abstract

A well-organized freight transport system is essential for economic development and it offers a wide range of benefits such as accessibility to goods and services. However, it is obvious that it also causes serious problems in form of negative impacts on environment and human health. Motor vehicles emit a large amount of pollutants and freight transport sector is a significant contributor to air pollution at local as well as regional and global levels. In addition, transport is a major source of noise, and gives rise to other environmental problems, such as water pollution and fragmentation of land.

The transport system in the Czech Republic has gone through substantial changes since 1990, mostly due to political and economical changes in the country. During this period, the environmental performance of many sectors, such as industry and energy has improved; however it is not so in the case of freight transport. The demand for freight transport in the Czech Republic has been steadily increasing during the latest years and demand is expected to continue growing. Furthermore, the most polluting road transport sector has become overwhelmingly dominant. There are several reasons for this development, such as currant trends in production and logistics and slow adoption of the railway sector to competition from more flexible and reliable road sector. Moreover, the external costs of the road sector are significantly higher then external costs of the rail sector, which makes the road favored at the expense of rail.

The analysis of transport related air emissions has shown that the contribution of this sector to the total of air emissions is small compared to OECD average. The reason for this is the high emission intensity of energy and industry sectors. However, freight transport related emissions of carbon dioxide have been increasing fast during the studied period and so have emissions of nitrogen oxides. Furthermore, the situation concerning the exceeding of air pollution concentration limit values in urban areas in the CR is serious. This shows that the current trends in freight transport performance would lead to negative effects on human health and environmental degradation and there is urgent need for measures in order to reduce these effects.

For the reduction of environmental damage caused by road freight transport, there is a need for strong emission regulations, implementation of new technologies as well as solutions in order to reduce the demand for transport. Those measures are important in working towards sustainable transport, however, they are unlikely to divert the currant development in emission trends. In order to attain a sustainable freight transport sector it is necessary to increase the share of railways on the freight transport market. Measures aiming at improving efficiency and opening up the freight railway market to competition will make this sector more competitive in comparison to the road freight sector. However, because the forces driving the modal slant towards road transport are powerful, more efficient policy instruments internalizing the external costs of road transport need to be implemented.

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1. Introduction

The development of transport networks has played an essential role in the economic development in all countries. Freight transport, in all its forms, provides access to materials, food and goods, enables export and import and is of high importance for virtually all industries and activities. It is has been well established that economic development requires a well-functioning transport system (OECD 2003), however, it is also known that freight transport, especially the road transport sector is a significant contributor to a wide range of environmental and social problems. Road transport gives rise to various forms of air, water and land pollution, noise pollution, contributes to global warming and causes accidents as well as congestion (UNEP 2000).

Freight transport is strongly linked to economic development. Consequently, following economic growth, freight transport has increased by an average of 2-3 % annually in OECD countries during the last decades (OECD 2003). Since the political changes in 1989, the Czech Republic (CR) as well as the whole Central and Eastern Europe has experienced a tremendous increase in freight transport by road. In contrast, rail freight transport, which is considered more environmentally sound experienced a substantial decline (OECD 2000). A projection of current transport trends in Central European countries from 1994 to 2030 shows a large increase in road traffic, road freight transport would be four times the volume of 1994. The consequences of this growth of road traffic would result in unacceptable environmental and social effects and there is an urgent need for efficient policy measures changing this trend (CEI 1999).

1.1 Objectives

The main objective of this study is to focus on the different ways of reducing the environmental impact of freight transport in the Czech Republic and thus, make this sector more sustainable. Existing policy measures for reduction of environmental impacts of transport currently applied in the Czech Republic will be analyzed. This analysis will asses a question if those measures are powerful enough to divert the current trend of increasing road freight transport. The possibility of enhancing rail transport and thus, stabilizing and successively decreasing freight transport by roads will be the main focus of this paper.

The main objectives are:

- Analyzing the development of the freight transport system performance in the Czech Republic since the beginning of the transition period in 1990. The focus of the analysis is on rail and road modes.
- Identifying the main driving forces for the increasing share of road transport in the CR
- Establishing the relationship between increasing road freight transport and its effects on air pollution

- Analyzing policy instruments used by the Czech government for achieving its targets
- Proposing improvements for solutions for reduction of the negative environmental effects of freight transport sector

1.2 Methods

In order to achieve a better understanding of the studied system and relationships between all its elements a mental model in form of Causal Loop Diagram (CLD) was developed (see figure 1). In this mental model, it is hypothesized that economic growth increases the demand for freight transport. At the same time a well functioning freight infrastructure is necessary for economic development, thus investments in infrastructure will increase economic growth. With increasing demand for freight transport, roads get congested and the traffic flow will decelerate. The governments will increase its investments in new infrastructure and at the same time, better infrastructure will make it easier and faster to transport goods thus, increase the demand for freight transport. This shows that increasing transport demand and investments in infrastructure are reinforcing one another.

This model is simplified, thus showing that freight transport can be conveyed either by rail or road transport (while in reality air and inland waterway can also be used). Those two variables balance each other, thus more road transport means less rail transport and less road transport will to certain extend increase road transport.

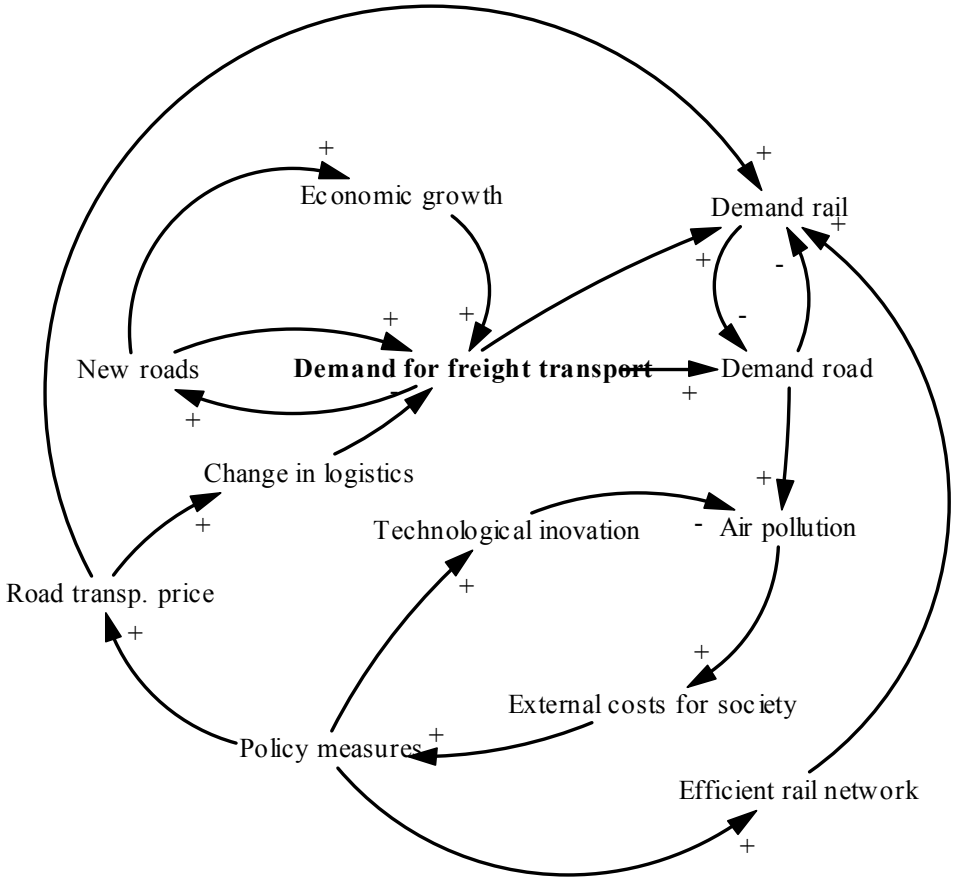
The higher demand for road transport will increase air pollution and thus increase external costs for society. This is also very simplified as rail transport is considered in this model not to cause any air pollution, which of course is not true. Rail transport also gives rise to air pollution and this varies according to whether the locomotive is driven by diesel or electricity. However, the air pollution caused by road freight transport is much higher thus, the only link between road transport and air pollution is considered in this CLD.

It is further hypothesized that with increasing external costs for society, more efficient policy measures leading to better use of technological innovations, improved efficiency of rail network and increased prices for road transport will have to be implemented in order to change the current trends of increasing the share of road transport and thus reducing air pollution. Increased prices for road transport will bring changes in the logistic organization of production and distribution of goods which would reduce the total demand for freight transport. At the same time, increased prices for road transport can also divert the modal from road to rail, to some extent.

To fulfill the objectives of this thesis a literature review of scientific journals and policy documents in the field of freight transport was conducted. For the analysis of transport performance and air emissions, secondary quantitative data was collected and analyzed. Statistical data was largely retrieved from studies conducted by the Ministry of Transport

of the CR, The Transport Yearbook of the CR and The Environmental Yearbook of the CR. However, additional data from articles published in Czech scientific journals were used.

Figure 1: CLD The relation between freight transport demand, air pollution and policy measures



In order to support the information retrieved from literature, five qualitative interviews were conducted with representatives of university and governmental institutions dealing with transport questions as well as an interview with a representative of a private haulage company. The qualitative research interview is more appropriate for this study as it allows more flexibility and gives more factual data, which is difficult to obtain from other sources. The persons interviewed work with transport questions and have good knowledge of the freight transport system in the Czech Republic. Their opinions and views on the problem and potential solutions were of great importance to this study.

There are certain ethical rules which are important to follow before and during a research interview. The researcher must inform the persons that will be interviewed about the purpose of the interview as well as about the risks the interview can cause. Another important rule is to protect the privacy of the interviewed persons and inform them in case this data will be published (Kvale 1997). Those ethical rules were followed and persons who were participating in the interviews were informed of all those facts prior to the interviews. The person representing of the haulage company did not wish to be named or the name of the company to be used, thus an aliases will be given to him and the company. Names, institutions and date of interview are in table 1.

Table 1: Information about persons participating in interviews

Number	Name	Institution	Date for interview
1	Zeman, Jan	The Czech Ecological Institute, Prague	September 14, 2004
2	Bendl, Jiri	The Ministry of Environment of the CR, Prague	September 22, 2004
3	Dufek, Jiri	Transport Research Center, Brno	September 8, 2004
4	Straka, Ivo	College of Business Studies, Prague	September 17, 2004
5	Petera, Jan	Haulage Company, Prague	September 21, 2004

The questions were carefully prepared before the interview and given in a structured way. All interviews were taped. Additional email interviews were conducted with several employees of Transport department and Czech Statistical Office in order to achieve additional information not published in statistical yearbooks.

1.3 Limitations

The issue this paper deals with is complex and the coverage is by necessity far from complete. In order to address the objectives, a broad and multidisciplinary approach is used in this study. This approach makes it impossible to go into depth in any of the many subjects dealt with in this thesis and gives the big picture of the whole situation. Road transport creates many environmental problems such as air pollution as well as to soil and water pollution and waste generation. However, the focus of this paper is only on the most significant air pollutants from freight transport sector.

Although the freight transport in the CR consists of 5 modes: railways, road, inland waterway, air and pipe-lines, only road and rail will be considered this thesis, the two overwhelmingly dominant modes in the Czech freight transport sector.

1.4 Study area

As stated in the title of the thesis, the focus area of this study is the Czech Republic (CR). The country was founded in 1993, when Czechoslovakia split into two independent states: the Czech Republic and the Slovak Republic. The area of the CR is 78,864 km^2 with around 10.3 million inhabitants. 1.2 million people live in Prague, the capital (OECD 2000). The country is located in central Europe, bordering with Germany, Austria, Poland and The Slovak Republic (see figure 2).

The Czech Republic is a locked country, thus the modes used for the freight transport are road transport, railway, air and inland waterways. However, road and railway are the overwhelmingly dominant modes with the share more then 99 % in 2003 (CDV 2004).

Figure 2: Map of the Czech Republic

The Czech Republic has gone through a radical political and economical transformation during the past decade. In 1989, the communist one party political system was abolished and replaced by multiparty parliamentary democracy. During the transition period, all sectors, thus even freight transport sector, had gone through the process of privatization and liberalization. Most of the work in this field has been finalized, much due to preparations for accession to the EU, which occurred in May 2004.

Since the beginning of the transition period, the improvement of the degraded environment was among the main issues in the CR and the country has experienced a fundamental decrease and stabilization in the air pollution level in all the main indicators (CHI 2003). However, during this period air pollution related to the freight transport sector increased considerably, mainly due to uncontrolled growth of road freight sector.

2. Freight transport and environment

2.1. Sustainable transport

There are many definitions and ideas associated with sustainability. This term became popularized by release of the Brundtland Report, where the concept of sustainable development in its broader version is defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987, 43). This vision has become a framework for policy debates at all levels. The United Nations Document from 1992, *Agenda 21*, contains 40 chapters that define the more specific objectives and strategies for practical application of those targets. An important outcome of Agenda 21 is the notion of three dimensions of sustainability: the economical, social and ecological. Those three dimensions are not seen as contradictory; on the contrary, all these conditions for development must be taken into account (SOU 1997).

Since release of the Brundtlnd Report, the world's governments and policies have increasingly been oriented towards sustainable development. A central feature of sustainable development is the notion that sustainability requires a complex process of trading off social, economical and environmental priorities. Development is a transformation process, which by combining economic growth with broader social and cultural changes, helps individuals to realize their potential. The dimension of sustainability brings the recognition that the development must respect the limits imposed by ecosystems and that environmental considerations must be embedded in all sectors and policy areas (Carter 2001).

Sustainability is a relevant issue for transport, because on one hand transport is connected to economic growth while at the same time it puts enormous pressure on the environment. Consequently, there have been many attempts to define sustainable transport. Black (1996, 151) suggests a definition of environmentally sustainable transport as "*satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs.*" He gives reasons for why the current transport system is not sustainable. Those include the fact that petroleum reserves are finite and their emissions have impact on urban air quality and as well as on global environment. Also injuries, fatalities and congestions are issues making transport non-sustainable. Other, short terms problems such as noise pollution or water pollution due to runoff from streets are considered as important, however not preempting the future generations from meeting their transportation needs and thus not considered as creating long term problems of sustainability (Black 1996).

OECD has defined environmentally sustainable transport as "*Transport that does not endanger public health or ecosystem and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non –renewable resources at below the rates of development of renewable substitutes"* (CEI 1999, 20). More specifically, a sustainable transport system is one that:

- "allows generally accepted objectives for health and environmental quality to be met, for example, those concerning air pollutants and noise proposed by the World Health Organization" (OECD 2002, 16)
- "is consistent with ecosystem integrity, for example, it does not contribute to exceedence of critical loads and levels as defined by WHO for acidification, eutrophication and ground level ozone; and" (ibid, 16)
- "does not result in worsening of adverse global phenomena such as climate change and stratospheric ozone depletion" (ibid, 16)

OECD defined six criteria for the attainment of environmentally sustainable transport: reduction of particulates, nitrogen oxides (NO_x) and volatile organic compounds (VOCs) emissions, use of land for transportation, climate change and noise pollution. For each of those criteria, a long term objectives were defined (OECD 1997 (a)). When referred to sustainable transport in this thesis, the definition of OECD is carried in mind.

Thus, there are various definitions and explanations of sustainable transport. However, the exact definition of sustainability does not change the fact that the current transport patterns contradict the objectives of sustainable development. The conclusion of the majority is that fundamental changes in technology, design and financing of transport system are needed (Greene and Wegener 1997).

2.2 Environmental impacts of freight transport

A well-organized freight transport system is essential for economic development and social well-being. It enables trade and offers a wide range of benefits such as accessibility to goods and services (UNEP 2000, 4-6). However, transport is also identified as one of the main consumers of fossil fuels and thus a major contributor to serious problems in form of negative impact on environment and human health (Alvarsson and Andersson 1995). Motor vehicles emit a large amount of pollutants and transport sector is a significant contributor to air pollution at the local as well as regional and global levels (Westerholm 1996). Besides air pollution transport gives rise to other environmental problems such as water pollution, uptake and fragmentation of land, noise pollution, and generation of waste and risk of accidents (UNEP 2000).

2 .2. 1 Road and railway transport modes

Current transport sector is mostly based on fossil fuels and its energy consumption is seen as having a major effect on environment (OECD 2001 (a)). Because oil consumption can be directly related to air emissions a key factor in determining transport related environmental impacts is energy intensity of different transport modes. While rail freight transport requires approximately 0.09 kWh / tonne-kilometer, truck distribution requires 0.65 kWh / tonne-kilometer (Holmberg 2004). Freight transport section is an important element concerning energy use as it accounts for one third of the total transport energy

demand in OECD countries. Motor vehicles are by far the most important concerning intensity of use and environmental impacts (UNEP 2000).

Thus, different transport modes have varying degrees of impact on the environment. Railway is considered to be an environmentally friendly transport mode, mostly due to lower energy consumption compared to a lorry with the some freight capacity. However railway demands more energy when accelerating and demands at least two reloading stages before reaching the final customer. Also, its environmental effects depend on whether the train uses electric or diesel power. While emissions caused by electrified railways are largely determined by the source of power generation, diesel locomotives emit the same pollutants as road transport (Alvarsson and Andersson 1995).

Most widely used engine in heavy duty vehicles is diesel engine. In comparison to petrol engines, diesel engine has better fuel economy and higher combustion temperatures. Because of the fact that the combustion is almost complete the diesel engine gives rise to low hydrocarbons (HC). Also the fact, that diesel engines work with access to air ensuring efficient combustion and thus eliminating emissions of carbon monoxide (CO). However, the same factors that support the low emissions of HC and CO, high combustion temperatures and access of air are the same factors that cause the formation of high emissions of NO_x to the air. Thus, in comparison with petrol engines, diesel engines contribute very little to CO and HC emissions but at the some time their contribution to NO_x emissions is high. The emissions of carbon dioxide (CO_2) are directly related to the fuel consumption (Alvarsson and Andersson 1995).

2.2.2 Air pollution

Car emissions are the combined effects of 10 000 – 15 000 different chemicals, a fraction of which have been identified and quantified (Westerholm 1996). The main pollutants emitted from transport are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOC) and sulphur dioxide (SO_2) (OECD 2001 (a)). The following paragraphs will discuss the most significant environmental and health effects of these pollutants.

Emissions of CO_2, HC (mostly methane) and nitrous oxide (N_2O) contribute to global climate change (OECD 1997) and thus contribute to pollution on global level. These gases accumulate in the atmosphere and absorb and trap some of the infrared radiation radiated by the Earth's surface. This is called greenhouse effect and it is a natural process. However, increasing concentrations of greenhouse gases in the atmosphere enhance the Earth's natural greenhouse effect and thus raise the average global temperature. This effect is also called global warming (Miller 2004).

Nitrogen oxides (NOx) are chemical species containing nitrogen (N) and oxygen (O), particularly the reactive form nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide is colorless gas that occurs in extremely low quantities in the atmosphere, but which is nevertheless regarded as a significant pollutant and contributor to acid rain. Human

health effects of NO_2 are causing concern, especially in urban areas. NO_2 can cause lung irritation, asthma and chronic bronchitis and at high concentrations even pulmonary edema. Epidemiological studies have shown an increased frequency of respiratory diseases at children younger then 12 years exposed to high levels of NO_2. Also, repeated respiratory diseases at childhood are considered as risk factor for high inclination to lung diseases at adult age (Adamec et al. 2002).

Sulphur dioxide (SO_2) is a colorless gas that is soluble in water. At higher concentrations in the air, SO_2 gives rise to effects in the form irritation of the mouth and eyes, coughing and breathing difficulties. SO_2 is one of main contributors to acid rain which causes damages on buildings, statues and metals (Alvarsson and Andersson 1995)

Carbon monoxide (CO) is a poisonous gas, reacting with hemoglobin receptors, and competes with oxygen. This reduces the ability of blood to transport oxygen to the cells. This has numerous effects on humans and animals such as dizziness, headaches, impairing perception and thinking. In extreme cases of high level and bad ventilation, it can cause a coma, irreversible brain damage and even death (Miller 2004).

Suspended particular matter (SPM) is a range of small particles and droplets, which remain suspended in the atmosphere and create dust, smoke and haze. Diesel engines are the main emitters. SPM can cause various health effects such as lung damage, bronchitis or asthma. Toxic particulates such as lead, dioxins or PCB can cause cancer and damage to reproductive systems (Miller 2004). In addition, particulates can accumulate in the atmosphere and deposition on leafs may reduce photosynthesis and thus the growth of plants (Rodrigue 2004).

Volatile organic compounds (VOCs) are organic compounds which include pure hydrocarbons and organic compounds containing chlorine, sulfur, or nitrogen. Some of VOCs are highly toxic and are considered human carcinogens. The compounds causing most concern are benzene, polycyclic aromatic hydrocarbons (PAHs) and aldehydes. Benzene can cause dizziness, headaches and at high concentrations even unconsciousness in humans. Repeated exposure to high levels, benzene increases incidence of leukemia and US EPA has classified benzene as human carcinogen. Animal studies carried on pregnant animals have showed adverse effects on the fetus, such as low birth weight, delayed bone formation, and bone marrow damage (U.S. EPA 2004 (a)). Also some of PAHs are considered as possible human carcinogens as many animal studies have shown its carcinogenic effects. Formaldehyde (CH_2O) a form of aldehyde, which is another compound belonging to VOCs is also carcinogenic and highly toxic to human health (Adamec et al. 2002).

Some chemicals emitted by vehicles can react with one another and have additional impacts beyond the problems caused by each individually. An example is photochemical smog formed through several chain reactions. When nitrogen dioxide (NO_2) is exposed to ultraviolet radiation from the sun, it is converted to nitric oxide (NO) and oxygen (O) atoms. Being highly reactive, oxygen atoms react with O_2 to produce ozone (O_3) (Miller

2004). Breathing ozone causes various health problems including chest pain, coughing or throat irritation. It can also worsen bronchitis and asthma and reduce lung function. Furthermore, ozone also damages vegetation and ecosystems (U.S. EPA 2004(b)). In addition, oxygen atoms and ozone also react with VOCs (mostly hydrocarbons) and produce aldehydes. Also hydrocarbons, oxygen and nitrogen dioxide react and produce peroxyacyl nitrates (PANs). Collectively, NO_2, O_3 and PANs are called photochemical oxidants and create photochemical smog (Miller 2004).

2.2.3 Local, regional and global air pollution

As mentioned above, the effects of transport related to air pollution can be seen at three different levels: local, regional and global. At the local level, effects on human health caused by nitrogen oxides, VOCs and particles emitted by diesel vehicles are of the highest concern (OECD 2001). Furthermore, degrading the urban environment in form of discolored and damaged buildings and other objects is also of a concern (Miller 2004).

Regional impacts of car emissions include acidification, eutrofication and formation of ozone and photochemical smog. Sulphur dioxide and nitrogen oxides are major pollutants that lead to human - caused acid rain, which has various impacts such as soil acidification. Decreased pH of soils has negative impact on forests and ecosystems. Nitrogen oxides also contribute to eutrofication of lakes and coastal areas. One of the major effects of eutrofication is the stimulation of algal growth in water. The decomposition of dead algae depletes oxygen in the water, with killed fish and other aquatic animals as a result (Miller 2004).

Enhancing of Earth's greenhouse effect and rise in the Earth's temperature, caused mostly by emissions of CO_2, CH_4 (methane) and nitrous oxide (N_20), is environmental problem at global level. International Panel on Climate Change (IPCC) has stated that, "*climate change is likely to have numerous negative effects on human development and wellbeing*" (McCarthy et al. 2001, 84). Even though the warmer climate might have some positive effects, such as more precipitation and increased food production in some areas, the negative effects are a big threat for the whole planet. The possible negative effects are changes in water distribution, with a risk of expanding of desert in certain areas and heavy precipitation in others. Raised temperatures will facilitate for some animal and plant species to spread and at the same time threaten species with specialized niches. Also, rising of sea level and thus flooding low-lying costal regions is an expected consequence of increased global temperatures (Miller 2004).

2.2.4 Noise pollution

Traffic creates a major source of noise, especially in urban areas. Noise can be described as unpleasant and it is affecting wellbeing of people. At higher levels noise pollution contributes to various health problems such as stress, sleep disturbances, cardio-vascular disease and hearing loss. There are surveys showing that people perceive noise pollution as more affecting than any other source of pollution (OECD 1997 (b)). Road transport

accounts for approximately 70 % of total transport related noise emissions, while noise caused by rail contributes by 10 %. Main sources of noise are the engine and the friction of the wheels over the road surface. Also travel speed can be directly linked to the intensity of noise (Rodrigue 2004). According to WHO, the outdoor noise levels in residential areas should not exceed 55 dB(A) during daytime and 45 dB(A) during night-time. However, to reach such levels would require both significant reductions in traffic activity and development of noise protection measures (CEI 1999).

2.2.5 Land use and habitat fragmentation

The existence of infrastructure requires land for roads and land transportation systems are one of the main causes for habitat fragmentation, the division of ecosystem into smaller, partially isolated units. This can result in destruction of habitats, injury or killing of animals, disturbance and other negative effects on animals due to noise or movement. These impacts can reduce the chance of survival of populations of individual species and thus influence essential processes of the whole ecosystem (Bohemen 1998). Furthermore, the diversity of species in ecosystems is a function of the total size of the area of habitat, thus dividing this area by a road can cut diversity in half rather than reducing it only by the actual area used by the infrastructure (OECD 1997(b)).

3. Driving forces for freight transport

The phenomenon of increasing demand for freight transport can be observed in all industrialized countries. Furthermore, the most polluting road freight transport has become the overwhelmingly dominant mode. In order to understand this unfavorable trend, it is necessary to identify the driving forces behind the demand for freight transport as well as driving forces for increasing share of road transport.

3.1 Driving forces for transport demand

Freight transport can be defined as a system used for movement of goods in space and time. This service is integrated in the production and distribution processes and it must match the requirements made by the nature of the goods moved, such as complexity, speed or precision. Freight transport system does not operate independently of the surrounding systems; on the contrary it is highly dependent on economic, political or spatial systems (Chapuis et al 1993). Thus, any changes in governmental policies, the level of economic activity or investments in infrastructure will have impact on a countries freight transport performance.

Historically, there has been a strong correlation between the growth in economic activity (measured in GDP) and the demand for freight transport in all OECD countries. With growing economy and increasing incomes it can generally be assumed that demand for freight transport would increase and the majority of road freight traffic forecasts assume that these variables will remain closely correlated for the foreseeable future (OECD 2003). In Europe, each 1 per cent growth in GDP has given rise to 0.9 per cent increase in freight transport. These figures are even higher for road transport where 1 per cent growth in GDP was accompanied by a 1.7 per cent growth in traffic (Short 1995) while on the other hand the share of rail continued to decrease and the statistical correlation of this mode with GDP is quite low. Consequently, it is often argued that the demand for freight transport is a derived demand from productive activities and transport using sectors (OECD 2003).

However, at the same time a well functioning transport system is essential for economic growth and investments in transportation systems have stimulated economic development in various regions of the world (OECD 2003). Consequently, investments in transport infrastructure are also a driving force for freight transport. Also, when the roads get congested, policy-makers argue for building new roads to meet an increasing demand for transport. It is often argued that improvement of road infrastructure both contributes to economic progress and help the environment by relieving congestion-related air pollution. However, decreasing congestions and improving the attractiveness of transport system will increase traffic and therefore lead to more traffic-related pollution. There is a close connection between the improvement of transport infrastructure and economic globalization. Thus, with improving infrastructure, goods are being shipped over longer distances (Pfleiderer and Dietrich 2003).

When discussing the problem of rising goods transport one must also stress the importance of increasing globalization of the world's economy as one of the most important driving forces. Jandele defines globalization as "*the increasing geographical scale of economic, social, and political interactions*" (Jandele 1997, 199). This refers to increasing international trade, investment transactions and growing mobility of capital. Also changing patterns of institutional organization and structural changes in the basic rules of economic order are characteristics of globalization (Jandele 1997). Many countries have adopted free market principles and lowered the barriers to import of goods and services. This has speeded their economic growth and integration into the global economy. With this fact in mind, it is not surprising that during the last decades the world has experienced a steady increase in international trade. World export increased from 7 % in 1950 to 14 % in 1992 (Veen-Groot 1999).

Another important driver behind the growth in freight transport is the reduction in transport costs for companies. Freight transport has become cheaper over the last centuries, partially due to decreasing fuel and vehicle prices (OECD 2003). Manufacturing companies want, for a defined level of quality, to minimize all their production, storage and transport costs and thus reach optimum total costs (Chapius at al. 1993). Consequently, when transport becomes cheaper, companies seeking to minimize their total costs will weight the economic benefits of using more transport and thus saving money on warehousing and production costs (Bleijenberg 2002). The low transportation prices increase transports and lead to what Short (1995) calls "irrational" transports. These refer to the cases such as when almost completed garments are sent by trucks from United Kingdom to Morocco for the addition of buttons and zips and then back by truck to England. Even though Short calls those transport irrational, those are completely rational from the point of view of the company seeking to minimize all its costs. However, this development is influenced by the fact that transport users do not pay full costs of their activities and cause negative externalities to society. The main negative externalities linked to road transport will be discussed later in this thesis.

Logistical organisation of production and distribution of goods also highly influences transport volumes and the current trends in logistics and production can be considered as drivers for freight transport demand as well as for increasing share of road transport. Contemporary production and distribution activities are not organized by single firm, but more and more practiced in networks of suppliers and subcontractors (Hesse and Rodrigue 2004). The competition of the global market force companies to be highly flexible and at the same time more and more firms concentrate only on the main skills they can offer in order to be able to withstand world competition. Those trends of high degree of specialisation and differentiation result in reduction of the level of in-house production. Taking into consideration this trend together with the policies of deregulation and liberalization this gives rise to significant increase in the volume of traffic and frequency of consignments and at the some time reduce the size of consignments (Stabenau 1996).

A trend that has emerged simultaneously with reducing of in-house production is the strategy of reducing the stocks and feeding production lines with products delivered "Just

in time" (Council of Logistical Management 2004). Applying JIT production means that producers have no more inventories on the production line then is needed for the production cycle. This implies deliveries in much smaller sizes but more frequently. Furthermore, the experience from U. S. automobile industry accommodating JIT production system caused modal shift from the traditional 50 / 50 truck / rail to as much as 80-90 per cent truck (Whitford 1987). Thus, the current trends in production system and logistics with demand of flexibility, frequent deliveries in smaller volumes are not only increasing the freight transport demand but also influence the modal split in favor to road freight transport.

3.2 External costs of transportation

Above, it has been stated that low transportation prices increase the transport demand. The price of transports is determined by supply and demand, but transport is causing significant environmental and social costs that are not included in its prices. Neglecting those costs makes a distorted picture of reality (Harris 2002) and contributes to increasing transports. Thus, transport costs can be divided into internal and external costs. Internal costs are the costs borne by the person using transport in form of for example time, taxes or road tolls. On the other hand, when a transport user affects others well-being without paying for it, then those costs are external for him. The most significant external costs caused by transport are costs caused by traffic accidents, air and noise emissions and congestions. The sum of external and internal costs is also called social costs and table 2 shows examples on different external and internal costs of transport. Thus, transport externalities refer to situations in which transport user does not pay for the full cost of his / her activity, or does not receive the full benefits from it (European Commission 1995).

Table 2: The costs of transport

Cost Categories	Social Costs	
	Internal/Private Costs	**External Costs**
Transport Expenditure	- fuel and vehicle costs; tickets/fares	- costs paid by others (e.g. free provision of parking spaces)
Infrastructure Costs	- user charges, vehicle taxes and fuel excises	- uncovered infrastructure costs
Accident Costs	- costs covered by insurance, own accident costs	- uncovered accident costs (e.g. pain and suffering imposed on others)
Environmental Costs	- own disbenefits	- uncovered environmental costs (e.g. noise disturbance to others)
Congestion Costs	- own-time costs	- delays/time costs imposed on others

Source: European Commission 1995

There are countless studies evaluating external costs of transport, but quantification of external costs is difficult and the results of different studies vary according to the methodology used. Some external effects can be directly measured in monetary terms, such as hospital care, or production losses due to air pollution. However, external effects of transportation affect us more as welfare effects then as monetary costs and there are different ways for their evaluation. Welfare effects can be transferred to monetary values as willingness to pay for increased safety or quality of life, or willingness to accept, thus what would be an adequate compensation for deteriorated quality of life (Hansson and Markham 1992). The willingness to pay method has been used for decades; however it has also received severe critique for not being morally acceptable or for overestimating the values. That's why new, improved techniques for this method have been continuously developed. Another problem associated with this method is that not all countries use this method to the some extends, thus comparing of the results is difficult (CDV 2002, 10).

However, despite the problems concerning the methods, the fact that transport sector causes significant external costs is well acknowledged and the need of their internalizing is generally accepted. According to a review of existing literature carried out by the European Commission (1995), the rough estimates of external costs for accidents, noise and air pollution and climate were in 1995 33.2 ECU per 1000 tonne-km for road freight transport and 5.3 ECU per 1000 tonne-km rail freight transport. Although the evaluation methods vary, those numbers show that the external costs of freight transport are large and that the external costs of road freight transport are much higher then those of rail freight transport. This fact gives advantage to the road transport because, according to (Hansson and Markham 1992), in case that there are different external costs for different transport modes, the modes with large external effects will be favoured at the expense of modes with relatively little external costs.

4. Infrastructure and organization of transport in the Czech Republic

4.1. Road freight sector

As all other enterprises, even road freight transport sector was owned by the state until the downfall of communist regime in 1989. The liberalization of this sector started at 1991 and it can be considered to be successful, from free market point of view. Privatization started at 1991 and the governmental price regulations were abolished the same year. Today there are no numerical restrictions on entry to this business and prices are not controlled. The responsible authority for regulation of the road freight transport sector is the Ministry of Transport and Communications of the CR (OECD 2001(b)).

The data on freight prices is not collected systematically in the CR, however the prices have fallen substantially compared to general price level and the degree of competition on the road market is very high (ibid.). The competition has increased even further since the CR joined European Union in May of 2004. The reason for this is that before entering the EU, trucks often waited at the borders for many hours for custom clearance. Unused vehicles and drivers were causing economic losses on a big scale. After entering the EU, the custom clearance was abolished and the trucks pass through the borders within a few minutes. This means that the traffic goes much faster and the trucks which used to stand at the borders can be utilized today. Thus, the supply is much higher then demand, which is further pressing down the prices (Interview person 5).

4.2 Rail freight sector

The rail freight sector in the CR has also gone through substantial changes since 1990; however the transformation process of this sector has been more difficult then in the case of road sector. At 1995, the competition was introduced in the Czech rail sector. The access to rail sector is regulated by The Railway Authority, an independent governmental office, ensuring safety by licensing operators and drivers and giving technical approval to rolling stock. Since 1995 some private entry has occurred, however mostly on dedicated short haul high weight routes. The problem is that the 1994 Railway act ensures free access to track, but not to the terminals, rolling stock or other equipment. Thus, Czech railways can forestall some entry to the sector. However, it can not forestall entry by operators having own necessary equipment, e. g. coal mining company shifting coal to power station owning its own equipment (OECD 2001(b)).

The organization of the rail freight sector has changed radically by adopting the Czech Railway Transformation Act in January 2003. This resulted in the division of the 100 % state owned governmental organization Czech Railways into Railway Routes, the owner and responsible authority for rail infrastructure and Czech Railways join stock company, responsible for rail operations (Logistika a Doprava 2002).

Czech Republic has more then 160 years of tradition by railway transport with the density of railway infrastructure 0.12 km /km^2, which is much higher then EU average. The density of electrified rail is much less, 0.036 km/km^2, which nevertheless is also a little bit higher then EU average (Kasltlová et al. 2003). The density of railway network is highest at industrial and densely populated areas in the central and northern parts of the country (see figure 3). At more then 90 % of the area of the CR, the distance to closest railway is less then 10 km. With 29 crossing points, the Czech railway network is well connected to networks in neighboring countries (Kloutvor et al 2001).

Thus, the high density of railway network shows that there is a potential for higher use of railways on the freight market. However, it is also necessary to emphasize that the quality of the railway infrastructure is not good, so the possibility of its utilization in freight transport, with high demand on speed and time accuracy are limited. According to Kloutvor et al (2001) only 10 % of the tracks are able to keep the speed of 120-160 km / h. Furthermore, only 28 % of the tracks comply with international standards for axel load (22.5 t) which is an important factor for freight transport. Poor maintenance of the infrastructure causes that the speed needs to be reduced on many parts of the railway net, which is causing time delays. This poor condition of the infrastructure is naturally caused by lack of money for necessary reparations and investments. Almost all investments are used for building of the corridors connecting to the Trans European Network (see railway transit corridors in figure 3), so the rest of the trucks receive minimum financial support, resulting in further deterioration (Interview person 1).

Figure 3: Railway net in the CR

5. Performance of freight transport sector in the CR

As was discussed in the previous chapter, the transport sector in the Czech Republic has gone through vast changes since 1990, mostly due to political and economical changes in the country. During this period, the environmental performance of many sectors, such as industry or energy has been improving. However, it is not the case of the transport sector, which is showing the opposite trend. In this chapter, the performance of freight transport sector as well as modal split in the Czech Republic during the period 1990 – 2003 will be analyzed. Also, technical condition of vehicle fleet, which is an important factor determining environmental impact of transport sector, will be shown.

5.1 Transport performance

The demand for freight transport has been increasing in almost all industrial countries. In OECD countries, the overall freight transport increased by an average of 2-3 % annually since 1970 (UNEP 2000). The development of freight transport performance in the CR, divided into different transport modes is shown in table 3. Transport performance in this table is measured in tonne-km and is the amount of the transport (measured in tonnes) for a certain period multiplied by the average distance traveled of the goods transported (measured in km). There are several other ways to measure transport performance, such as in tonnes or in value of the goods. The data on total volume of goods does not say anything about the distances the goods is transported. The distances, however is important for showing the environmental impact of the transport sector. Neither the information about the value of goods transported can give any information about the distances the goods has been transported. Thus, transport performance measured on tonne – km basis was chosen as it was assumed to give an adequate picture of transports environmental impact.

Table 3 shows that the total freight transport performance had decreased between 1990 and 1994. As discussed in the previous chapter, transport demand is strongly linked to economic activity in the country. Thus, this decline in transport performance can be explained by economic recession and a decrease in the GDP that occurred after the collapse of the communist regime in 1989. Furthermore, in the beginning of 1990s, the Czech economy experienced large changes in the structure of industry with a decrease in the share of heavy industry, reorientation on the import of iron ore with higher content of iron and reduction of coal use. All those factors contributed to the decline of transport volumes (Interview person 4). However, in 1993 transport demand, following economic recovery, started to grow again and basically followed the development of GDP. The linkage between GDP and transport performance in the Czech Republic is shown in figure 4. On graph y-axis, there is transport performance in billion tonne-km and GDP in billion USD. It shows clearly that transport performance is following the development of GDP. The graph also shows that both transport performance and GDP had been steadily increasing since 1998.

According to interview person 4, the GDP in the Czech Republic can be expected to grow at a rate around three per cent annually. Taking into consideration this and the fact that none of the changes in the industrial and energy sectors that occurred at the beginning of 1990s is going to be repeated, it can be assumed that the demand for freight transport will continue grow in the future. The only way to divert this is to introduce efficient policy measures for decoupling economic growth and the growth of transport demand.

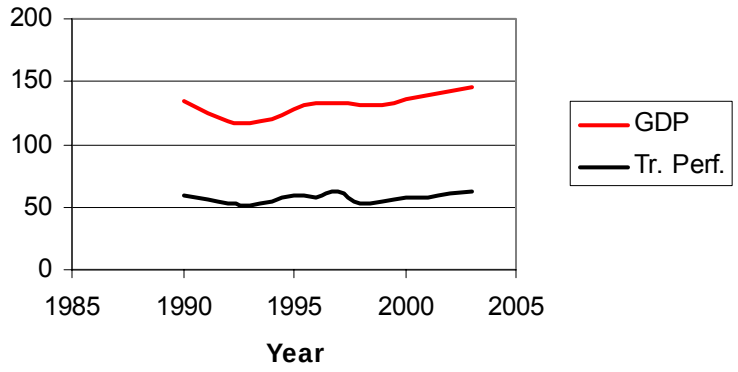
Table 3: Transport performance in freight transport 1990 - 2003 [billion tonne-km]

Transport Mode	Year												
	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Road total	16,82	20,25	25,26	29,81	32,50	34,55	40,64	33,91	36,96	39,03	40,26	45,06	46,56
Railway	41,14	31,11	25,14	22,70	25,50	22,46	20,97	18,76	16,71	17,30	16,88	15,77	15,85
Electric traction	34,81	26,48	21,59	19,43	20,66	19,10	18,68	16,90	14,37	15,57	14,91	13,91	14,12
Motor traction	6,33	4,63	3,55	3,27	4,84	3,36	2,29	2,63	2,34	1,73	1,97	1,86	1,72
Air	0,06	0,08	0,03	0,03	0,03	0,03	0,05	0,06	0,03	0,04	0,03	0,03	0,04
Inland Waterways	1,41	1,34	1,22	1,18	1,23	1,35	0,70	0,82	0,91	0,77	0,61	0,54	0,52
Total	**59,43**	**52,78**	**51,65**	**53,72**	**59,26**	**58,39**	**62,36**	**53,55**	**54,61**	**57,14**	**57,78**	**61,4**	**62,97**

Source: CDV (2004)

Another factor influencing the transport performance in the CR is the transit transport. The Czech Republic is situated in the centre of Europe with Germany, Austria and Slovakia as neighbors, and consequently a part of those countries export goes through the Czech Republic. Transit freight transport has increased substantially since 1990, from 4.7 mill tonnes in 1990 to 12 mill tonnes in 2003 (Codlova 2004, email). In addition, the transit freight transport has been increasing rapidly since the CR joined the EU. Because of the short time period, there is no available official statistical data, but according to preliminary estimations, the number of heavy duty vehicles has increased by up to 40 % on the Czech roads due to transit. The reasons for this are that it is easier to cross the borders and also the road tolls are very cheap in the CR in comparison to Germany and Austria. Consequently, it is economically profitable to drive through the Czech Republic (Interview person 5). Thus, as stated there is no official statistic yet, however even in case that the preliminary estimations are too high, the transit transport is increasing and this shows the need of policy measures regulating this phenomenon.

Figure4: Development of GDP and freight transport performance between 1990 and 2003 in the CR



Source: CDV (2004)

5.2 Modal split

The intensity of use of different modes of transport is an important factor in showing transport related environmental and social impacts of transport sector. Diagram 5 shows the share of different transport modes on total freight transport performance in the Czech Republic for the period of 1990 - 2003. It shows clearly that railways have been losing share on total transport performance. While in 1990 the share of railways on total goods transport was 69 %, this has dropped down to 25 % in 2003. On the other hand, the share of road transport has been steadily increasing from 28 % in 1990 to 74 % in 2003.

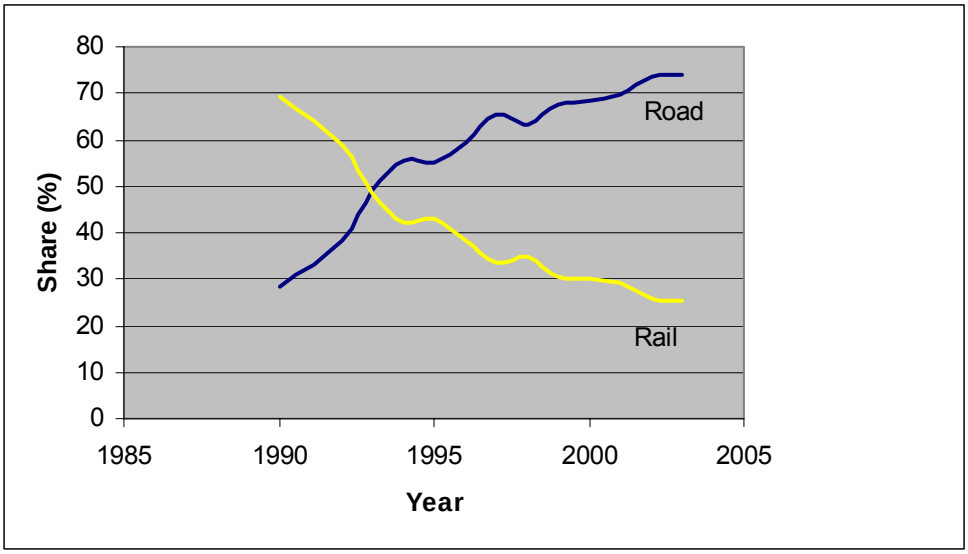
Increasing demand for freight transport as well as increasing share of road on total freight transport is a phenomenon that can be observed in almost all industrial countries. Within EU[1], most of goods traffic goes by road, and road's share of goods market has been growing continuously, from 41 % in 1990 to 44 % in 1998. On the other hand, goods carried by rail fell from 21 to 8 % between 1970 and 1998. Projections with business as usual scenarios are showing increase of road traffic to 47 % in 2010 (European Commission 2001). This comparison must be considered with the fact that Czech Republic is an in locked country, consequently has no sea transport. However, Czech railways are going through similar development as railways in other European countries. The clear difference is only that this development lasted for several decades in Europe, but just for a few years in the CR.

There are several reasons for this unfavorable development it the CR. Generally, railway has comparative advantage in transport of bulk commodities as coal, iron ore, construction materials and forestry products. Here the price advantage can outweigh speed and reliability offered by road transport (OECD 2001 (b)). During the last decade,

[1] EU before enlargement in May 2004

the volume of goods suitable for transport by railways has decreased in the Czech Republic due to structural changes in industry, with declining share of heavy industry and metallurgy. Also the structure of electricity production has changed, since 1989 several coal fired power plants have been shut down and replaced by gas or nuclear power stations, thus less coal is transported (Interview person 4). At the same time the volume of lighter goods with higher value that is more suitable for road transport is increasing (MDCR 2000). However, here must be pointed out that during the latest years the road sector takes a share even in bulk commodities. Sedimbursky and Vichta (2003 (a)) argue that practically all new transport volumes are taken by road transport, which furthermore takes shares on goods previously transported by other modes.

Figure 5: Share of transport performance in freight transport [%]



Source: CDV (2004)

The general trends in the current organisation of production and logistics with high requirement on flexibility and time accuracy were discussed in chapter 3. Also companies enterprising in the Czech Republic are adjusting to a global market and naturally, the haulers need to meet their customers' requirements. According to interview person 5 the criteria that are considered for the choice of transport mode are "*we have to fulfil what the customer requires: quality, keeping the time limits and of course the price. Our offer is the compromise of those three requirements. Thus, it is not the question of for example just speed, but that the goods must be delivered at exact time and we have to keep it…..Road transport in the Czech Republic is much more reliable considering the time of delivery, and in ability to keep the terms".* Also the safety of the goods is considered as higher when transported by road. There is no need for reloading and the risk for damaging the goods is therefore minimized. Also, according to interview person 4, there are companies complaining about the thefts on railways in the CR, so it is more convenient for them to pay more and transport the goods by road in stead. Thus, safety,

flexibility and reliability of road transport are clearly overweighing the advantages of railways.

The low ability of Czech railways, the biggest operator on the Czech rail market, to meet customers demand is accompanied by poor organisation of the whole company. While road sector has adapted to marked demands quickly, it is not possible to say the same about the railway sector. Slow changes and lack of business policy makes railways to lose even more customers. The decline of transport volumes on the Czech Railways logically caused reduced incomes from freight transport. Despite this large decline, the offered transport capacity was reduced only by one third during the last decade. Thus, the company keeps too many freight wagons resulting in poor maintenance and delaying of necessary reconstructions. This leads to situation where one third of wagons are not technically good enough for using for export and many exporting companies are reacting by going over to road transport, which enables them to keep the delivery times (Kloutvor et al 2001).

Nevertheless, it is also necessary to emphasize the fact that the railway and road sectors are for several reasons not competing at the same conditions. The need of improving and building new road infrastructure is taken as a matter of course and nobody questions this. The same can not be stated about the railway infrastructure. This because the capacity of road infrastructure is overused while the capacity of rail infrastructure is not fully used and the decisions for development of the infrastructure are based on current transport volumes. But the fact that the railway infrastructure is deprived and in many cases can not offer the quality that would be required is not taken into consideration (Sedimbursky and Vit 2003 (a)).

Another fact that makes the competition between railway and road sectors not equal is the case of externalities. There is no standard methodology for evaluation of external costs in the Czech Republic, however the studies over the external costs of transport carried out indicate that the external costs of road transport are significantly higher then external costs of rail. As explained earlier in this paper this favours the road transport at the expense of railways.

Zeman (2003) made, according to own methodology, calculations for external costs from different modes of transport. The results shows that external costs for road transport were year 2001 40 billion Kč [2], while this was only 18.6 billion Kč for rail. Thus, according to this study, the external costs of road traffic were 21.4 billion Kč more then external costs of rail. Another study, carried out by Transport Research Centrum (CDV 2001) has evaluated external costs of road transport. The study focuses on three different areas: Evaluation of external costs of traffic accidents, evaluation of costs for air pollution and evaluation of costs for emissions of greenhouse gases. Methodology for this study varies from the one used in Zeman's study and the estimations of road transport external costs is approximately 56.1 billion Kč. However, it can be concluded that external costs of road transport are significantly higher then external costs of rail transport, which favours road transport.

[2] 1 € = 29 Kč

5.3 Vehicle fleet

The technical condition of the vehicle fleet and the rate of its renewal is an important factor determining the environmental impact of transport sector. The European Union sets standards for new heavy duty vehicles engines and their emissions. They are also referred to as EURO I – V. First regulation EURO I was introduced in 1992, EURO II was introduced in 1996, EURO III in 1999. European Parliament also adopted EURO IV and V standards for years 2005 /2008. The limit values are for emissions of carbon monoxide, hydro carbons, nitrogen oxides and particulate matter (DieselNet 2004). Total number of lorries divided into different categories according to age is shown in table 4 below. Total number of lorries has increased considerably since 1995, from 202 929 in 1995 to 323 434 in 2002. Furthermore, vehicles older then 10 years and thus not fulfilling EURO I standards create the largest part of vehicle fleet. However, the positive fact is that the share of vehicles older then 10 years has been decreasing, it has dropped down from 44 % in 1995 down to 37 % in 2002.

Table4: Lorries registered in the Czech Republic

	1995	**1998**	**1999**	**2000**	**2001**	**2002**
Total number	***202 929***	***260 276***	***268 259***	***275 617***	***296 412***	***323 434***
by age category						
Up to 2 years	33 398	36 482	30 289	33 762	39 562	42 517
2 - 5 years	32 090	57 952	68 249	66 925	61 381	62 302
5 - 10 years	47 552	55 175	59 973	69 223	86 349	98 331
Over 10 years	89 889	110 667	109 748	105 707	109 120	120 284

Source: MDCR 2004

6. Air emissions from freight transport sector- the trends and the targets

The analysis carried out in the pervious chapter showed that the demand for transport can be expected to increase in the CR and that the dominant mode is the road transport. In this chapter the contribution of freight transport sector to the total air emissions, divided between road, rail electric traction and rail motor traction, will be analyzed. The trends of the most significant pollutants from road freight sector are presented and put into relation with governmental targets and emission limits expressed in Regulation No. 351 / 2002 Coll., setting air pollution limit values for emissions of NO_x, CO, VOC and SO_2 for the whole country. In addition, the quality of air, regarding the concentration of pollutants will be discussed.

6.1 Energy consumption by freight transport sector

In chapter 2, environmental effects caused by transport related energy consumption were discussed. As shown in table 3 the share of the transport sector on the total energy consumption has an increasing tendency. Between 1990 and 2003 both absolute consumption of energy by transport sector and the share of the transport sector on total energy consumption had increased. At the same time, the countries total energy consumption under this period had decreased. The growth of transport share is considerable, between 1990 and 2002 it has increased from 10 to 18 %. Within the transport sector, road freight transport was the second most energy consuming after individual car transport with almost 32 % of total transport sector energy consumption in 2003 (CDV 2004).

Table 5: Share of transport in the total energy consumption in CR [%]

	Unit	*Year*											
		1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total consumption	PJ[3]	1 303,2	1 124,7	1 056,2	1 038,2	1 091,3	1 151,5	1 098,1	1 054,6	1 052,1	1 018,2	1 056,6	1 049,8
Consumption by transport	PJ	131,4	120,0	113,2	121,7	138,5	158,0	164,6	160,1	171,8	176,4	187,1	189,9
Share of transport	*%*	10,1	10,7	10,7	11,7	12,7	13,7	15,0	15,2	16,3	17,3	17,7	18,1

Source: ČSÚ, CDV

[3] 1 PJ = 10^{15} J

6.2 Air emissions from freight transport sector

To find the data for air emissions created by freight transport sector itself in the Czech Republic is problematic. The data for emissions for different modes of transport are accessible in the Transport Yearbook of the CR and emissions created by road transport are divided into passenger and freight transport. However, emissions from the railway sector are not further divided into passenger and freight sectors. Furthermore the emissions from rail electric traction are not followed. Consequently, in order to find out the emission intensity of the railway freight sector, it is necessary to obtain further data from other sources.

Zeman (2004) deals with this problem and he has estimated air emissions for freight transport sector in 2002. In his study, he has calculated emissions from electricity production (in ton/GWh) in the CR and required further data concerning energy consumption of railway electric traction from Czech Railways. The data for air emissions from rail electric and motor tractions are taken from Zeman's study and used in this paper for further analysis. In 6 table total air emissions of most significant pollutants from road, rail electric and rail motor tractions, emitted by freight transport. Shares of respective mode on total emissions in the CR are also shown in the table.

Table 6: Freight transport related emissions of CO_2, VOC and NO_x and their contribution to total emissions in the CR

Type of emission	Road	Rail electric traction	Rail motor traction
CO_2 total (tonnes)	4 485 000	605 801	300 505
CO_2 % of total	4%	< 0.1%	< 0.1%
VOC (tonnes)	16 400	70	434
VOC % of total	8 %	< 0.1%	< 1%
NO_x (tonnes)	46200	Not available	Not available
NO_x % of total	15 %	Not available	Not available
SO_2 (tonnes)	1 288	1 087	96
SO_2 % of total	1 %	< 1 %	< 0.1 %

Source: MZP (2004), Zeman (2004), MDCR (2004)

Regarding CO_2, the most important greenhouse gas, the share of both rail tractions is below 0.1 per cent of total emissions in the country. On the other hand, the share of road is quite considerable, counting for 4 % of countries total CO_2 emissions. The share of the whole transport sector on CO_2 emissions in 2002 was approximately 12 %. This is quite low in comparison to other OECD countries, where transport sector contributes to total emissions by approximately 20 % (OECD 2001 (b)). This can be explained by the fact that the CR has high energy-intensity and the energy production is to large extent based on fossil fuels. Energy and industry sectors contribute with 70 % to total emissions of CO_2 (MZP 2000, 37). However, while total emissions of CO_2 in the whole country decreased by 27 % since 1990, transport emitted CO_2 emissions have been increasing (Brusik 2004). Emissions of CO_2 from road freight transport for the period of 1990 –

2003 are shown in figure 6. It shows that these emissions have increased considerably under the studied period and they have an increasing tendency.

As discussed in a previous chapter, the demand for road freight transport can be expected to grow in the future. Because CO_2 emissions are directly linked to the consumption of fossil fuels, an increasing share of railways on the freight market would slow down the fast increase in those emissions. Also increased share of vehicles with low, or none fossil fuel consumption in the vehicle fleet would decrease those emissions.

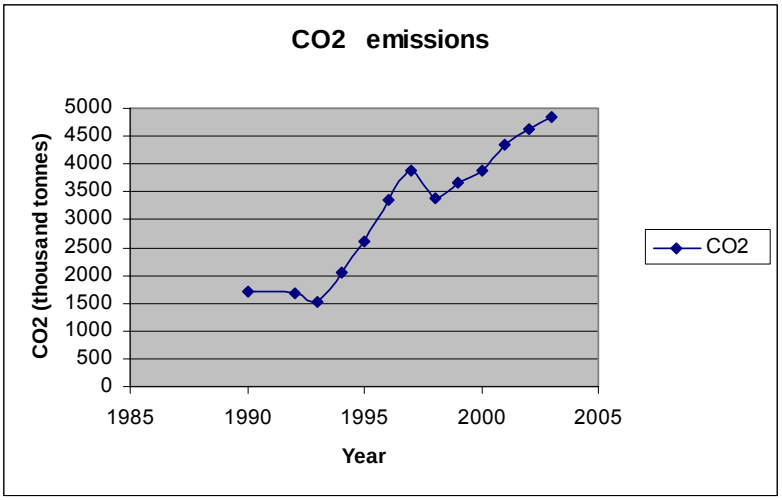


Figure 6: Emissions of CO_2 from road freight transport for period 1990 - 2003

The contribution of nitrogen oxides (NO_x) to total emissions is available only for road freight transport, which contributes with 15 % of the countries total emissions (see table 6). This is approximately 43 % of total transport sector contribution. As in case of CO_2, the contribution of NO_x to countries total emissions is lower then average in OECD countries, where transport sector contributed by 52 % to total emissions (OECD 2001 (b)).This can be explained by the some factors as for CO_2 emissions, e. g. high energy intensity and high share of fossil fuels on energy production. According to Directive No. 351 / 2002 Coll., setting emission limits for NO_x, CO, VOC and SO_2 for the Czech Republic, total emissions of NO_x must not exceed 286 000 tonnes in 2010 (ASPI). At 2002, total NO_x emissions for the whole country were 318 230 tonnes (MZP and CSU 2004) thus, this limit was exceeded by more then 32 000 tonnes.

The development of NO_x emissions in period 1990-2003 for the road freight transport sector is shown in diagram. The rapidly increasing trend of those emissions during the 1990s had slowed down since year 2000. This change has occurred due to lower emissions of NO_x from new vehicles. As mentioned earlier in this paper, NO_x belong to regulated emissions and all new vehicles must fulfil the emission standards. However, the increasing transport demand and number of vehicles is partially taking out the decreasing contribution of vehicles and NO_x are not likely to decrease rapidly in the nearest future due to technological improvements.

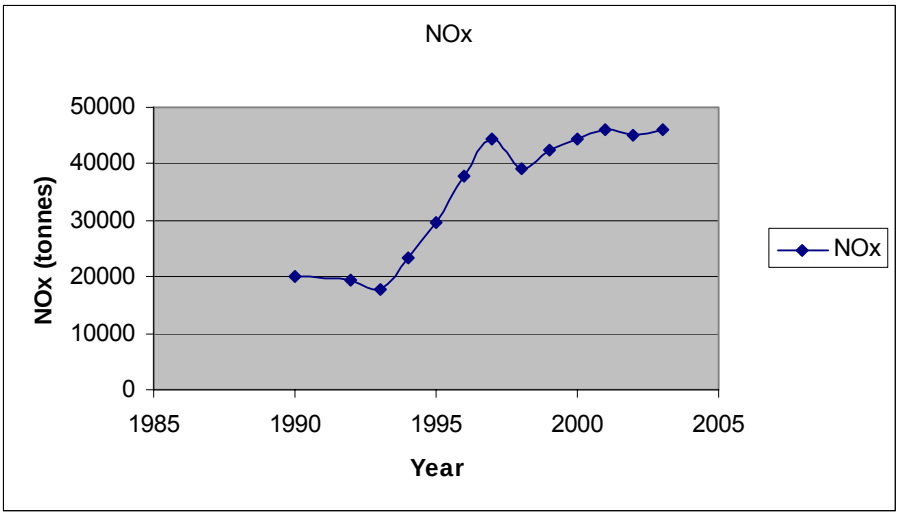


Figure 7: Emissions of NOx from road freight transport for period 1990 - 2003

Directive No. 351 / 2002 Coll. also regulates emissions of VOC. The target for VOC is 200 000 tonnes in 2010 for the whole CR. Current emissions in the CR are 200 000 tonnes (CEU 2004), thus very close to the targeted limit. As shown in the table 6, the contribution of both tractions of rail freight sector was under 1 % while freight road sector contributed by 8 % to the total emissions. After a rapid growth during the 1990s, those emissions changed the trend (see figure 8) and started to decrease year 2000. As in the case of NO_x this change occurred due to improved technology and implementation of tighter regulations, thus a rapid increase in number of vehicles can change this trend.

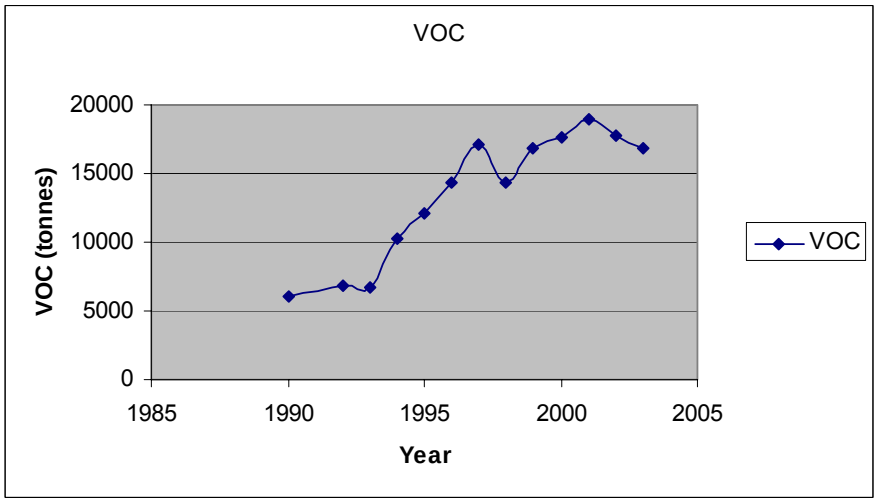


Figure 8: Emissions of VOC from road freight transport for period 1990 - 2003

Table 6 also shows the contribution of freight transport sector to total emissions of sulphur dioxide SO_2. Their contribution to countries total emissions is very low, 1 % for road transport and less then that for both tractions of railway. The development of SO_2

emissions from road freight sector is shown graphically in figure 9. After a substantial increase during 1990s, those emissions had decreased significantly between 2002 and 2003. This occurred due to implementation of new limits for sulphur content in diesel oil. This trend of decreasing of those emissions can be expected to continue as during 2005 the limits for sulphur content in diesel will be further lowered (CDV 2004).

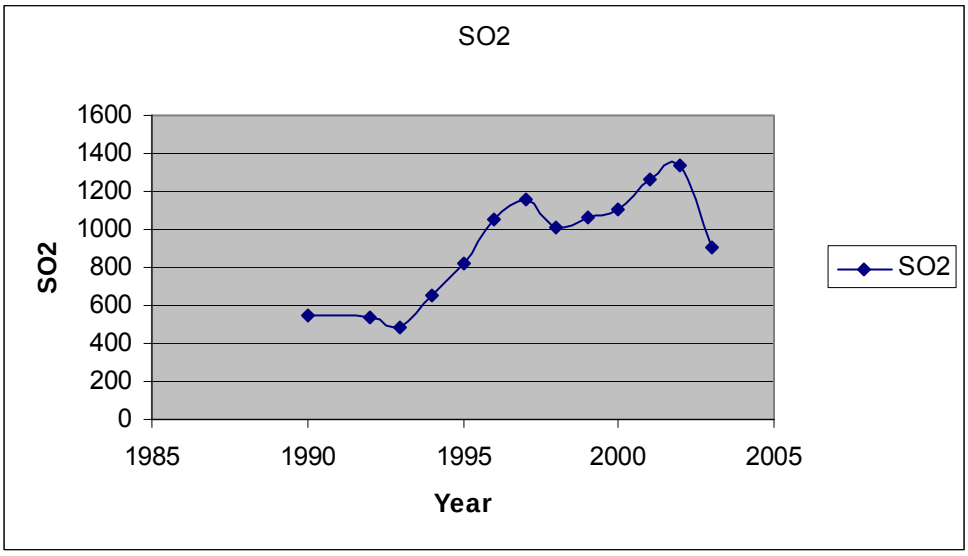


Figure 9: Emissions of SO_2 from road freight transport for period 1990 - 2003

However, one can not only consider the total volume of pollutants emitted as a guideline for pollution abatement policy. The data for total volume of pollutants do not show if the concentration of pollutants in the air is acceptable, or if it is exceeding the limits and thus endangering human health at specific areas. In chapter 2, various health effects caused by vehicle emissions in urban areas were discussed. As will be shown in the next paragraph, ssituation regarding the quality of air in urban areas in the CR can be considered as serious.

The quality of air, regarding pollutant's concentration in the ground layer of atmosphere in the Czech Republic is regulated by the new Clean Air Act No. 86 / 2002 Coll., which came into force 1 June 2002. Regulation No. 350 / 2002 Coll. sets air pollution limit values. According to assessment carried out by Czech Hydrometorlogical Institute (CHI 2003, 70-71) more then 64 % of the Czech population is exposed to ground-level ozone concentrations exceeding limit values for protection of health. Carried out assessment shows also that pollution caused by suspended particles exceeds the limit values. At 2002, areas where concentrations of suspended particles exceeded the limit values were inhabited by more then 23 % of the population. Also the situation concerning benzene concentrations is unfavorable; the limit values were exceeded in Ostrava (east-north Bohemia). In addition, further cases of surpassing the concentration limits can be expected due to newly established monitoring stations meeting requirements of the new directive on monitoring transport impacts on quality of urban air.

7. Measures for sustainable transport

7.1. Transport policy and targets

In chapter 5 of this paper it has been shown that the Czech Republic as well as the whole European Union is facing a problem of increasing freight transport and of growing imbalance between modes of transport. The road transport, which is a large contributor to air pollution and congestion, is taking a share from more environmentally friendly modes as railways and inland waterways. Consequently, reducing the negative effects of freight transport on environment and human health and creating a sustainable transport sector is one of the main priorities for European transport policy as well as for the Czech transport policy.

A healthy environment is a condition for long term prosperity and quality of life of European citizens, consequently air pollution is considered as one of Europe's main political concerns. Among the main objectives for the European Commission is to achieve levels of air quality that do not give rise to significant impacts on human health and the environment (European Commission 2004 (a)). In order to achieve this, changes in many areas are required and environmental concerns should be fully implemented in the early phases of the different sector policy processes. Therefore, the European Union policy on air quality aims to develop and implement efficient instruments for controlling of emissions from transport as well as energy sector (Commission of the European Communities 2001).

Also reduction of CO_2 emissions in order to protect the environment and fulfil the Kyoto agreement is one of the priorities of the European Unions environmental policy. The target for reduction of CO_2 emissions stemming from Kyoto Protocol is 8 % reduction of emissions in 2008 – 2012 compared to 1990 levels. Because transport sector is a significant contributor to CO_2 emissions, the European Commission emphasises the need of transport measures that will contribute to the reduction of those emissions (European Commission 2004 (b)).

Among the main objectives for freight transport sector at the EU level expressed by the European Commission is to revitalise the railways and thus get freight traffic to switch from road to alternative transport modes, especially rail. Also promoting alternatives that combine transport modes for freight transport are seen as a priority (European Commission 2003, 15). The White Paper, the European Transport Policy for 2010 emphasises that railways still are a means of transport with major potential and sees its revitalisation as the key to achieving modal rebalance. Thus, the commission suggests a number of measures to be implemented in order to attain those objectives. The most important objectives to achieve until 2010 are:

- Creating internal market in rail transport is one of the core stones of this document. By 2008 the entire trans-European freight network opened for free competition should be completely finalized and opened. Opening up the competition will bring companies form other backgrounds with fresh experience

of logistics to this sector. Entrance of new companies on the freight railway market is expected to increase the competition between operators, and thus make the rail industry more competitive against other modes of transport (European Commission 2001).

- Setting high safety standards for the rail network. This means setting clear definition of responsibilities of each actor involved in order to ensure safe operations on the market with several operators sharing the some part of network (ibid).
- Improved interoperability, thus removing of technical barriers hindering the trains to run on some stretches of the network. There are still significant differences between networks, such as different electrification and signalling systems in Europe (ibid).
- Encouraging the development of trans-European corridors for priority, or even exclusive use by freight trains. Also establishing well equipped freight terminals with access to all operators is considered as important factor for promoting rail freight transport (ibid.).

The large scale external costs caused by freight transport and their consequences were discussed earlier in chapter 3. European Commission (2001) sees the fact that transport users have not been fully confronted with the real cost of their activities an important reason for imbalance and ineffectiveness in transport sector. It is emphasised that "*The thrust of Community action should therefore be gradually to replace existing transport system taxes with more effective instruments for integrating infrastructure costs and external costs"* (European Commission 2001, 71). Charges for infrastructure should therefore cover both infrastructure and external costs and thus include costs of congestion, accidents and environmental impact (ibid).

The Transport policy of the Czech Republic for years 2005 – 2013 is currently under preparation. It will derive from a consensual frame of international agreements steaming from the countries membership in UN, OECD and EU. Thus, the Czech transport policy will be compatible with EUs White Paper. However, specific conditions in the country will be taken into consideration. As in White Paper, the European transport policy, one of the basic attributes of the Transport Policy of the CR for years 2005-2013 will be to gradually transfer part of road freight transport to environmentally sounder kinds of transport, such as rail or combined transport. The main priority for railway sector is going to be to finish modernization and gradual electrification of the main corridors connecting to Trans-European Railway Network. For road infrastructure, maintenance and construction of highways at routs with high traffic is priority (MDCR 2004 (b)).

7.2 Measures for road freight transport

For achieving its environmental objectives, the governments can use a variety of policy instruments. It is possible to distinguish four broad types of policy instruments: regulations, voluntary actions, government expenditures and market-based instruments.

Transport policies usually consist of a mixture of those instruments, because sustainable transport policy must address both the supply side, to make vehicles more fuel-efficient and the demand side, to reduce demand for road transport. The instruments used depend on conditions and preferences in a specific country, there are different ways for achieving sustainability. However, there is growing interest in using market-based instruments to correct market failures and internalize environmental and social costs of transport (Carter 2001).

7.2.1 Technical opportunities

The environmental impacts of transport are highly dependent on the technologies used and there is available a large of number technologies that can decrease fuel consumption of vehicles and air and noise pollution. Modification of engines, electronic control system, and improved exhaust systems are examples of these technologies (European Commission 2000). New developed technologies such as catalytic converter or computer control of combustion have reduced motor vehicle emissions significantly. For example, in comparison to cars built before 1968, new vehicles emit 4 % as much VOCs and CO. Technologies that are now visible on the horizon, such as the hydrogen-powered fuel cell vehicle, give promises for future reduction of emissions from motor vehicles (Greene and Wegener 1997). Also, drivers' behavior has an impact on fuel consumption, thus training the drivers and encouraging them to keep the speed limits, switch off the engines when standing still or avoid heavy accelerations can bring fuel consumption reduction 5-10 % (European Commission 2000).

Environmental pollution from motor vehicles is highly dependant on fuel used. So promoting cleaner fuels such as low sulphur diesel can bring substantial environmental benefits in form of reducing of SO_2 emissions and particulate matter (Koopman 1995). Also the possibility of substituting cleaner alternative fuel for diesel has drawn increasing attention during the past decade. Currently less then two percent of the global motor vehicle fleet are powered by alternative fuels including electricity power. However, alternative fuels have a large potential to reduce air pollution when used in vehicles with dedicated engines and optimized emission control system. The greatest emission reductions can be obtained with hydrogen. Because of absence of carbon atoms in hydrogen's molecular structure, its combustion produces no direct emissions of carbon dioxide, thus the use of hydrogen fuel produced from renewable energy sources would be a possible solution for measures to reduce carbon dioxide emissions. The only pollutants produced by hydrogen combustion are nitrogen oxides. Also use of electricity, natural gas and liquefied petroleum gas (LPG) for powering motor vehicles can bring significant reduction of air pollution (Faiz et al. 1996)

Also, drivers' behavior has an impact on fuel consumption, thus training the drivers and encouraging them to keep the speed limits, switch off the engines when standing still or avoid heavy accelerations can bring fuel consumption reduction 5-10 % (European Commission 2000).

As mentioned earlier, EU regulates emission standards for heavy duty vehicles, thus this regulation is valid also in the CR. Regulatory standards are a helpful tool for achieving sustainable transport, and they made vehicles more fuel efficient and cleaner by forcing manufacturers to develop cleaner technology. However, the emission standards are valid for new vehicles only and as was shown in a previous chapter a large part of the vehicle fleet in the CR consists of old vehicles, thus not fulfilling those standards. Therefore, it takes time before the Czech fleet is renewed and at the some time, the rapid increasing number of vehicles can take out the benefits from technological solutions. The problem of implementation of other, not regulated technical measures is that they are costly and it is not probable that many companies in the CR will adopt new techniques, unless authorities either require or by other measures promote this.

7.2.2 Reducing the demand for transport by preventive measures

There are many preventive solutions that can reduce the number of vehicle kilometers traveled and thus reduce the negative environmental, social and economical effects caused by road freight transport. Reducing vehicle numbers through consolidating loads can bring large efficiency gains. For example, Swedish retailers have opened a mixed consignment centre in the city of Malmö. Here, goods are assembled from 25 suppliers and are to be transported to 11 regional warehouses. This solution has a huge potential to cut daily deliveries to supermarkets (European Commission 2000).

Creation of new packaging design, from a transportation efficiency point of view offers considerable potential for increasing the utilization of vehicles and thus reduction of the number of vehicle movements and kilometers traveled. A French mashed potato producer changed the size of the packages and succeeded to increase the loading rate by 60 %. This reduced considerably the distances traveled and thus the consumption of fuels (European Commission 2000). Also reducing the volume or tonnage of the product can have a significant impact on transportation needed. This can be done by redesigning the product and by cutting down the amount of air and water transported. Examples for this can be juices that are diluted at home by customers in stead of juices that are sold ready for drinking (Houtsma 2001).

Today, many products go long distances to be modified and then back to the country of origin, or are imported from countries which can produce them cheaper. Solutions in form of finding local suppliers or carrying out manufacturing processes close to the production site would certainly decrease the distances traveled (Houtsma 2001). According to Strutynski (1995) formation of stronger regional networks of activities would facilitate for suppliers themselves to coordinate production with the customers and other enterprises operating in the region. Those would be able to establish co-operatively supply network within the region. However, here it is also necessary to point out that having local supplier does not necessarily lead to reduction in environmental damage. For example, tomatoes grown in warm countries need to be transported to northern part of Europe, but it is doubtful if this transport causes more environmental damage in terms of energy consumption then tomatoes grown in greenhouses (Houtsma 2001).

There are various estimations on how much it is possible to reduce transport levels by those preventive measures. According to Houtsma (2001) this could be as much as 7-20 % in Holland. Many of those approaches are so called "win win" situations, where the environmental benefits are either equal or exceeded by the economical benefits to the company (European Commission 2000). Thus, many companies enterprising in the CR might be interested in adopting those solutions in cases they are easy to implement and would bring economical benefits to the company. However, many of those approaches are non-win-win, thus situations when reductions in transport volumes require large investments. Those costs are likely to create a barrier for adapting the measure (Houtsma 2001) and are unlikely to be realized until transport reduction becomes economically feasible for the companies.

Information and implementing solutions for reduction of road transport is important in work towards sustainable transport. Nevertheless, all those measures together are unlikely to divert the negative trend of increasing road freight transport and its increasing social, economical and environmental impacts.

7.3 Increasing share of railways

It has been shown earlier in this paper, that the demand for transport in the Czech Republic is going to grow in the nearest future, because of economic growth and also country's geographical position. It has also been discussed, that railway freight transport is more environmentally and socially sound transport mode then road transport. Thus, in order to achieve sustainable transport system it will be necessary to shift part of freight transport to railways.

It was also stated that Czech Railways a. s., the largest operator on Czech rail freight market, is lacking of business policy. This is naturally making the company less efficient and gives it fewer opportunities to increase its shares on freight transport market, because the road sector is a strong competitor. In policy recommendations to Czech government, made by OECD (2001 (b)) it is emphasized that increases in efficiency will be required, so it is of high importance that the authorities continue to pursue internal efficiency reforms within Czech Railways a. s. Among those measures, reducing of staff and housekeeping on a private enterprise base are most important. For example, Czech Railways a. s. owns large areas of land and many facilities nearby the railway stations that are not utilized. Those could be used for purposes such as warehouses or hotels and increase incomes for the company (Kloutvor et al. 2001). Thus, implementation of new governance arrangements promoting commercial orientation can be recommended (OECD 2001(b)).

Also, for increasing of railways ability to compete with road sector, it is vital that competition within the rail freight sector itself is ensured. Increased competition will force Czech Railways a. s. and other companies operating on rail freight market to ensure quality of their services and reduce the costs. Such environment can create conditions for investments and attract private funding (Kloutvor et al. 2001). Thus, the adoption of the Railway Transformation Act, which has enforced separation of railway operator from

railway infrastructure, was an important step in this direction. However, further changes in legislation which would facilitate for non discriminatory access to rail market in the CR will have to be done.

An important factor for increasing of share of railway is promoting intermodal transport. Intermodal transport is goods transport using various modes of transport without any handling of goods themselves during transfers between modes (Macharis and Bontekoning 2004). A factor hindering multimodal transport is that transport networks of different modes are not interconnected. To increase intermodal transport where rail is involved, it will be necessary to build intermodal terminals (centers where the transshipment of goods from one mode to the other takes place) at places that are connected to railway. The current situation in the Czech Republic is going in a completely opposite direction, where large companies are building their own logistical terminals near the highways. This further decreases the importance of railway. Thus, it will be necessary to build regional intermodal terminals with access for all companies (Sedimbursky and Vichta 2003(b)).

7.4 Market based policy instruments for sustainable transport

There is a wide range of different market based instruments used in transport policy. It is possible to distinguish three groups of charges according to leverage points. The first group includes vehicle – based charges, such as vehicle tax or purchase tax. The second group is fuel-based charges, e.g. fuel tax and, finally the third group consists of road-use-based charges. However, the concrete design of those charges can differ, for example road charges can differ according to vehicle characteristics, time of the day or location (ECMT 2000). A significant increase of the charges for road freight transport would motivate enterprises to take measures in order to decrease transport costs.

7.4.1 Fuel taxes

Many environmental externalities are related to fuel use so fuel taxes are considered as an attractive economic instrument for internalizing of externalities. Fuel tax is easy and non costly to implement and it has continuous short-term as well as long-term effects (ibid.) When fuel becomes more expensive road haulers will make effort to reduce energy consumption per tonne-km transported. This can be achieved by different measures such as larger trucks, fuller trucks or driving behavior. However, fuel costs comprise only roughly 10-15 % of total road haulage costs, so the total transport price will be affected only moderately by increased fuel costs (Koopman 1995). A Danish study over price elasticity (not fuel cost elasticity, which is only around 10-15 % of total transport costs) indicates that a 10 % increase in the cost of freight transport would reduce the truck transport by 5 %. This reduction in road truck transport can be divided into 3 % decrease in transport volumes and 2 % is substituted to other modes (Bjørner 1998). Thus, in a long-term fuel taxes stimulate the modal change to less energy intensive transport modes as train.

Increased fuel taxes will have positive impact on air emissions, particularly on emissions of CO_2. However, the disadvantages experienced by use of fuel taxes is that they reduce the overall mobility, while what is often needed is to reduce traffic at certain places and points in time (Koopman 1995). Furthermore, fuel taxes do not allow differentiation according to vehicle characteristics, such as different emission standards. Also, if taxes are different in neighboring countries, there is a risk of rising of fuel tourism (ECMT 2000).

Within the EU, motor fuel taxes are regulated by Directive 2003 / 96 / EC, which makes communities framework for taxation of the energy products. The directive lays down a minimum tax rate on each type of mineral oil. The purpose of this directive is to reduce distortions that exist between member states as a result of divergent rates of tax (European Commission 2004). In the Czech Republic, tax from fuels containing hydro carbons is applied at slightly higher rates then a minimum tax rate according to Directive 2003 / 96 / EC. (EU minimum 302 €, CR 312 € per 1000 l diesel) (Kutacek 2003). Apparently, this tax is not giving the haulage companies in the Czech Republic the right incentives to change the behavior towards more efficient transportation and efforts to switch towards railway. Consequently, only a drastic increase in fuel taxes would bring reduction of road freight transportation and promote the shift from road to rail.

7.4.2 Road and Highway tolls

Directly charging for road tolls gives a user signals about the economic costs of providing infrastructure. This can influence the overall use of the facility, and even though road tolls are not a direct instrument of environmental policy, it removes governmental failure that contributes to environmental degradation. The use of direct road charging both on highways and in the cities has received increasing popularity in Europe (Button 1999). There are different designs of road pricing, and it is possible to distinguish between four different charging types. Flat charge for road users is an annual charge levied at car users. Road tolls correspond to charging for specific passages of the infrastructure. Km-charge is a continuous charge for specific networks, levied at entry and exit points. Finally, electronic road pricing is also continuous charge for specific networks, levied at car holders (ECMT 2000).

The advantage of road use charging is that, apart from flat charge, those instruments allow for wide differentiation according to vehicle type, time of day or other parameters. One of the disadvantages with this system is that the implementation and maintenance costs can be rather high (ECMT 2000). Also, imposing tolls on parts of networks can cause a shift of part of traffic to alternative roads, where no toll is imposed (Ferrari P 2002).

Many of European countries are combating the problems caused by road freight transport by raising the charges for roads. In January 2004, Austria has introduced electronic, distance-dependent road pricing on motorways and expressways for all vehicles with a

total admissible weight of more then 3.5 tonne (SDFI 2004). In Switzerland a km-charge to heavy vehicles with a total admissible weight of more than 3,5 tons has been introduced in 2001. The level of the charge depends on three factors:

1. The distance driven on Swiss roads
2. The admissible weight of the truck (the maximum permitted total weight according to the vehicle registration documents)
3. The emission category of the vehicle (there are three different categories, where vehicles meeting only EURO 0 standard pay the highest fee, next level are vehicles meeting EURO I standard and the last category, thus vehicles paying the lowest fee are vehicles meeting EURO II/III standard (Suter and Walter 2001).

The charge is collected electronically and its implementation has been successful, the kilometers traveled by heavy goods traffic on the roads has decreased by 3 %. This can be compared to preceding years, when heavy goods traffic was increasing by 6 % annually (OECD 2003). Also the renewal rate of vehicle fleet has increased; a higher share of new, cleaner vehicles was put into the traffic a year after the implementation of the fee then during the years before its implementation. One of the negative effects is the case mentioned above, that some truck drivers chose smaller roads leading through villages instead driving on motorway (Suter and Walter 2001).

However, the benefits of this measure show very good results in combating road freight transport and there is a lot of knowledge that can be learned. The success in implementation of road toll in Switzerland was a breakthrough for the principle of internalization of transportation external costs. The fee is based on uncovered infrastructure costs and the difference between external costs of heavy vehicle traffic over its external benefits. According to the Swiss constitution, the revenue from high highway tolls should be used to cover the external costs. Now, two thirds of the revenue is invested in New Alpine rail tunnels, an important project for shifting freight transport from road to rail (Suter and Walter 2001).

A current system of road tolls on the territory of the CR is applied on specific sections of infrastructure. This system allows the differentiation of prices according to the weight of vehicle to three different categories: up to 3.5 tonnes, 3.5-12 tonnes and more then 12 tonnes. The fee can be paid for a period of one day, ten days, one month and one year (Codlova 2004-10-25). As shown in table 8, at present, the average charges for heavy duty vehicles on motorways are considerably lower in the Czech Republic then in other European countries. Implementation of electronic road pricing for duty vehicles from year 2006 is discussed in the CR. It can be assumed that unless road charges will be raised considerably, both domestic and transit road freight transport will continue to grow.

Table8: Prices in Kč for 1 km on the highways in European countries

Price in Kč for 1 km for heavy duty vehicle				
Italy	Czech Rep.	Switzerland	Germany	Austria
3,93	1,40	9,47	3,26-4,89	6,85-8,82

Source: SDFI (2004)

7.4.3 Vehicle tax

Besides fuel taxes and road charging, vehicle tax is also an instrument used for internalizing external costs. The design of vehicles taxes vary, it can be charged in form of registration tax, which is annual tax usually based on vehicle characteristics. Also purchase tax or import tax can be applied. Vehicle taxes generally change behavior only in the long run, according to the car's lifecycle. The size of the tax must be chosen carefully according to situation in the country. On one hand, an environmentally oriented annual vehicle tax differentiation can be effective and help to accelerate a path to clean technology. But on the other hand, too high purchase tax, particularly if there is no tax decrease for technologically improved vehicles, might even slow down the renewal of vehicle fleet (ECMT 2000).

In the CR registration vehicle tax is charged annually. The amount of the tax varies according to weight of the vehicle and number of semi-trailers. Heavy duty vehicles meeting EURO emissions standards pay significantly lower amounts (Kutacek 2003). Lower fees for cleaner vehicles are considered as feasible for the renewal of vehicle fleet and for overall environmental impacts of road transport. However, this measure does not stimulate the reduction of transport demand or change of transport mode, and thus must be considered as additional measure only (ECMT 2000).

8. Conclusions

As shown in this paper, the current freight transport system in the Czech Republic is not sustainable for many reasons. During the studied period, its energy consumption has increased considerably in both absolute and relative terms. Air pollution from road freight transport has also increased considerably and carbon dioxide emissions are still on the increase. Also the quality of air in many urban areas is exceeding the limits for pollutants concentrations, thus affecting human health and this contradicts the main objectives of sustainable development. Consequently, the measures aiming to reduce environmental impacts of freight transport currently used in the CR are not sufficient and there is a need for increased efficiency of those measures.

Governmental regulations and measures promoting development and implementation of new technologies are promising for future reduction of air pollution. Modifications of engines as well as increased use of alternative fuels can bring forth significant reductions in air pollution. The analysis of air pollutants from the road freight sector showed that the emission regulations for new vehicles proved to be efficient and started to show results. Despite increasing road transport performance, nitrogen oxides slowed down the increasing rate and volatile organic compounds have started decreasing. Thus, technological fixes and their implementation is an important solution for reduction of many of the negative environmental effects caused by road freight transport. However, those do not address all environmental or social problems caused by freight transport such as congestion, road accidents or land fragmentation. Consequently, technological measures have limited potential and need to be combined with other measures for reducing the demand for road freight transport.

Among the most important driving forces for increasing demand for freight transport identified in this thesis was economic growth. As shown, transport demand closely followed economic growth during the studied period and this trend is estimated to continue in the future. Prosperous economic growth is important for countries development and employment opportunities, and tackling the problem of increasing demand for transport via reduction in economic growth can not be considered as feasible. In contrast to the energy sector, it is difficult to decouple economic growth and transport demand. Yet, there is no measure for that and more experience and research is needed in this area. Thus, this remains a challenge for research and politics to achieve it.

Enhancing goods transport by railways is an important solution that will reduce environmental pollution caused by the freight transport sector. The important measures for enhancing railways discussed in this paper are solutions promoting intermodal transport as well as ensuring free competition of the railway market. However, the driving forces which tilt the modal towards road transport are powerful and it is not probable that implementation of those solutions alone would divert the trend of increasing road freight transport and its negative environmental effects. The conclusion from this is that for increasing the role of railways in the freight transport market and achieving more environmentally sustainable freight transport system, it will be necessary

to combine those strategies with more efficient economic instruments for internalization of external costs in transportation.

Low transport prices have been established as a strong driving force for increasing transport demand. This factor, in contrast to many other driving forces identified in this thesis, e.g. economic growth, increasing globalization or production specialization, is possible to change by various policy measures. It is possible to assume that increased transport prices would reduce the demand for transport as well as promote the modal shift from road to rail, however the prices would have to increase significantly. This change can be seen as unpopular from the road sector representatives. Road sector has a strong lobby in the CR and the protests against implementation of more radical measures can be expected. It is well known that governments do not like to implement unpopular measures; however external costs caused by road freight transport should receive more attention and considered as arguments justifying a significant increase in freight transport prices.

Low prices for motorway charging in the Czech Republic are not only driving forces for domestic transport but also significantly encourage increasing transit transport as transport companies want to avoid driving through Austria and Germany, where highway tolls are much higher. This is causing considerable environmental, social and economical problems and if the road charges in the Czech Republic will not be increased soon, this will lead to inadequate environmental degradation as well as congestion threatening the functionality of whole transport system in the country. Thus, there is a urgent need for increasing the charge for motorway for heavy duty vehicles in the Czech Republic.

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