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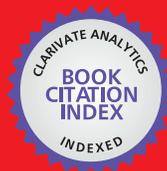
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Transport Planning and Global Warming

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1. Introduction

Transport energy consumption in industrialised countries is based primarily on fossil fuels, and is associated with the main negative impacts of transport: climate change, air pollution, congestion and accidents (Sperling, 2004). The emissions of many pollutants are being moderated due to improvements in engines and fuels, but the consequences for health are a growing concern, and particularly the risks posed by nitrogen oxides and particles, which are closely associated to transport. CO₂ emissions (the gas considered mainly responsible for the greenhouse effect) are also increasing, and this phenomenon can be seen most intensely in the transport sector.

The European Commission's 2001 White Paper on transport (and the 2006 revised edition) declared that the sustainability of the transport energy model must include the control of transport demand and an improvement in the efficiency of transport modes. It is this area which offers the greatest potential for establishing an effective strategy of action. This requires a greater commitment to the processes of transport deregulation –in order to make consumers aware of price considerations–, the establishment of mechanisms to ensure that these prices reflect actual costs, and the promotion of energy savings. This approach was underlined in the 2005 Green Paper on energy end-use efficiency and energy services, which suggests that overall consumption in the European Union can be reduced by up to 20% without compromising economic profitability. This was subsequently ratified by the European Council's March 2007 Action Plan which established this as an objective for the year 2020. The European Parliament and Council has also approved Directive 2006/32/EC concerning end-use energy efficiency, as well as revising a proposal for a directive for the development of clean and energy-efficient road vehicles.

However, measures require some time after their implementation in order to take effect, and they must be supported by changes in lifestyle which will effectively influence transport use over the forthcoming decades (Rodenburg et al., 2002). A reduction in transport GHG emissions can be achieved by reducing the need for transport, improving the energy efficiency of the different modes of transport and fuels, and balancing modal distribution (Schipper et al., 1997; Steenhof et al., 2006).

The measures that can be applied in the transport sector to promote savings and improvements in energy efficiency are well known in general terms (Rodenburg et al., 2002; Cuddihy et al., 2005). These include everything from correctly setting energy prices, and reflecting these prices in the cost of services, including external costs; economic and tax

incentives which favour a reduction in energy intensity; the optimisation of travel in order to increase occupancy; joint planning of transport infrastructures and land uses so as to reduce average distances; development of new low-carbon fuels and low-consumption engines; and making more use of communications technologies as a resource.

The United Nations' Intergovernmental Panel on Climate Change (IPCC) and other institutions in this area consider that energy savings and efficiency will be a key element in guaranteeing sustainable development in forthcoming decades, until such a time as any current or future technological innovations can be implemented on a massive scale (Kahn Ribeiro et al., 2007). The United Nations Convention on Climate Change outlines the main technologies and commercial practices available to the sector to mitigate GHG emissions: these include energy-efficient vehicles, hybrid vehicles, clean diesel vehicles, biofuels, modal change from roads to railways and public transport, and non-motorised transport (UN-FCCC, 2007). It also details the technologies and practices which are expected to be available on the market by 2030: second-generation biofuels, more energy-efficient aircraft, more advanced hybrid and electric vehicles with more powerful and reliable batteries. All these measures can serve as the basis for a low-emission economy, and this will be possible only if low-emission fuels are used to supply the different forms of motorised energy necessary for transportation, and the complete chain of energy transformations which make that energy available to the end users (Van Wee et al., 2005). Thus the consumption of one unit of energy for railway traction involves the consumption of 2.5 units of primary energy. Energy savings and efficiency are therefore key in securing an energy supply which is low in CO₂.

Another aspect is the reduction in concentrations of air pollutants, for which the European Union is establishing guidelines for all European countries. Many of the directives in this area include measures which coincide with those for improving energy efficiency, and particularly regarding fuels and vehicles.

2. The energy and environmental behaviour of transport

2.1 Transport energy consumption

In the Kyoto protocol, the European Union undertook to reduce GHG emissions in its area by 8% over 1990 levels between 2008 and 2012. The significant increase in GHG emissions for the transport sector cannot be explained simply by demographic growth, nor even by economic growth, both of which have grown at a lower rates. This indicates that productive processes are increasing their consumption of transport, contrary to Community targets which aim to generate economic growth with lower increases in transport flows of passengers and freight (European Environmental Agency, 2008). In Spain, for example, the energy intensity of road transport has gone from 0.46 tonnes of oil equivalent (toe) per inhabitant in 1990 to 0.71 in 2008 (an increase of 54%). Similarly, the energy intensity of road transport (at constant 1995 prices) has gone from 0.045 ton per million euros in 1990 to 0.052 in 2008 (15% growth).

Energy consumption and CO₂ emissions can be estimated based on transport data by using the methodology and the factors developed by the Intergovernmental Panel on Climate Change (1995). These emissions are directly proportional to the carbon content of the fuel used in transport (expressed in kilotonnes of equivalent CO₂ per megajoule, ktCO₂ eq./PJ). Most of the carbon is converted into CO₂ during combustion, although a part is released as CO, CH₄ or hydrocarbons without methane which oxidise into CO₂ over time. The fuel oil used in maritime transport has the highest carbon content, followed by diesel, kerosene (air transport)

and petrol. Also to be taken into account is the carbon consumed in the electrical power used by modes of rail transport, which depends on the mix of fuels used in electricity production (Hernández-Martínez, 2006). Coal has the highest carbon content, followed by petroleum and natural gas. For nuclear power and renewable sources such as biomass, hydraulic, solar, wind and geothermal energy, net carbon emissions equal to 0 are assumed (Schipper et al., 1997).

The energy consumption of different modes of transport is influenced by direct and indirect factors. Direct factors involve the use of the vehicle, and indirect factors concern the construction and maintenance of infrastructures, and the production and maintenance of vehicles (Van Wee et al., 2005). The direct factors can be divided into logistical, technical and operational factors. The most important logistical factors are rate of occupancy and load, and network density. Technical factors include characteristics such as the weight, capacity, engine, fuel and the aerodynamic coefficient of the vehicle. Operational factors refer to the way in which the vehicle is used, and include the speed and the driving dynamic.

The energy consumption required to move the vehicle and for the use of auxiliary features (i.e. lighting and heating systems, air conditioning) and energy loss (in the engine and in the transmission) comprise the direct consumption of primary energy. The production and distribution of fuel and electricity also consume energy ("well-to-tank", WTT). Thus the consumption of 1 PJ of electricity in Spanish trains involves an average consumption of 2.5 PJ of primary energy in the form of fossil fuels in an electrical power plant (40% efficiency), as well as associated emissions of over 185 ktCO₂ eq.

On average, CO₂ emissions occasioned during the production, distribution and consumption of electrical energy are around 80% of the emissions produced during the extraction, distribution and consumption of fossil fuels. This percentage varies according to the energy mix required to produce the energy, and particularly with the technology used during the production and distribution of the electricity associated to the fuels used (renewable energies, nuclear, coal, petroleum, gas, etc.). Thus the technology used by fossil fuels has attained a higher level of development than the technology used in electricity, which is currently still under improvement.

Measures to encourage energy savings and efficiency can therefore significantly reduce the volume of energy required, making it possible to achieve an energy supply which is low in CO₂. Refineries need an average of 1.14 PJ of petroleum to produce 1.0 PJ of a particular fuel, and its distribution requires an additional 0.02 PJ per 1.0 PJ (Pilo et al., 2006). Diesel and petrol are produced from conventional crude oil with an efficiency of 85-90%, depending on the situation of the oil well and the production process (Kaul & Edinger, 2004). The review in this work includes both categories of direct primary energy consumption: well-to-tank and tank-to-wheel (TTW).

For diesel trains, the WTT and TTW losses are between 10-15% and 68-70% respectively (Pilo et al., 2006). For electric trains, WTT and TTW losses are between 57-63% and 13-19%. Electric railways operate using a regenerative dynamic brake which saves 50% of TTW energy during the braking process. In road vehicles, TTW losses vary between 60% and 79% depending on whether the traction is diesel or petrol. In general, electric traction vehicles have lower TTW losses and higher WTT losses than petroleum traction vehicles. The average efficiency of energy production in Spain is 47%, due to the composition of the energy mix, which is based on coal and nuclear technologies.

As well as the direct consumption of energy, the production and maintenance of vehicles and transport infrastructures are important factors in total energy consumption. This is known as indirect energy use. The construction costs represent non-recurrent consumption

and are not usually included in statistics on transport energy consumption. On the other hand, direct energy consumption occurs in a recurrent manner throughout the operative life of the motorways, and is now included in the consumption statistics.

The energy consumption model must include direct primary energy and indirect energy. The contribution of indirect energy to consumption varies according to the different transport modes, types of vehicle and categories of infrastructure (Saari et al., 2007; van Wee et al., 2005). Van Wee et al., (2000) estimates that about four times more energy is used to operate a road vehicle (during the useful life of the vehicle) than in manufacturing it. In Spanish cities, the direct energy consumption of modes of rail transport is 40-50%, and in road transport modes it is 30-45% of the direct consumption of primary energy (Zamorano et al., 2004).

Similarly, Lenzen (1999) estimated indirect energy consumption according to the mode of transport, and this figure varied between 18% (heavy articulated lorries) and 44% (railway) for freight transport. It is therefore important to take indirect energy into account when calculating energy consumption and efficiency. Thus although the energy efficiency of railways is about three times greater than that of road transport with regards fuel consumption, the production energy efficiency is the same as that of heavy articulated lorries, and the total efficiency is only two times greater.

In summary, both energy consumption and CO₂ emissions can be said to depend on the following factors:

1. Global demand for travellers and freight (tkm and vkm).
2. Modal distribution.
3. Energy intensity of each mode, or energy consumption for each unit transported (MJ/tkm-MJ/vkm energy). Another factor to be considered in parallel is the intensity of GHG emissions (gCO₂eq./tkm vs. gCO₂eq./vkm).
4. Energy mix of each mode.

2.2 Energy and environmental efficiency of transport modes

Once a global analysis has been made of the dimension of the problem from the environmental and energy viewpoint, the next step is to analyse the efficiency, as the absolute figures depend to a considerable extent on the increase in the units transported (passengers and freight) in each mode of transport. This is done by merging the data for transport activity with the data for energy consumption and emissions. The result is what is understood by efficiency (energy and/or environmental), and also expresses intensity (understood as consumption of resources).

Energy efficiency is determined by two factors: the energy required to move the vehicle and the use of the vehicle's capacity. The energy required to move the vehicle is determined by the fuel consumption, transport conditions (traffic and geography) and the vehicle's characteristics (model and size). The use of the vehicle's capacity depends on the levels of occupancy and load of each individual vehicle, the relative use of each type of vehicle, and the distribution of the different types of vehicles within the fleet of vehicles as a whole (Leonardi & Baumgartner., 2004).

In addition, the concept of environmental efficiency must be defined for each of the air pollutants, as well as for sound contamination. Environmental efficiency is measured in emissions of each pollutant for the same units of transport.

As an example, the following figure shows the average growth in the period from 1990-2007 of three indicators relating to passenger transport in the following modes: road, railway, air,

boat, and underground railway. The following variables are analysed: growth in demand, GHG emissions, and energy intensity. As can be seen, energy consumption has grown less than demand, which means that in all cases –except in underground railways– the energy intensity (consumption per unit transported) has improved (negative value).

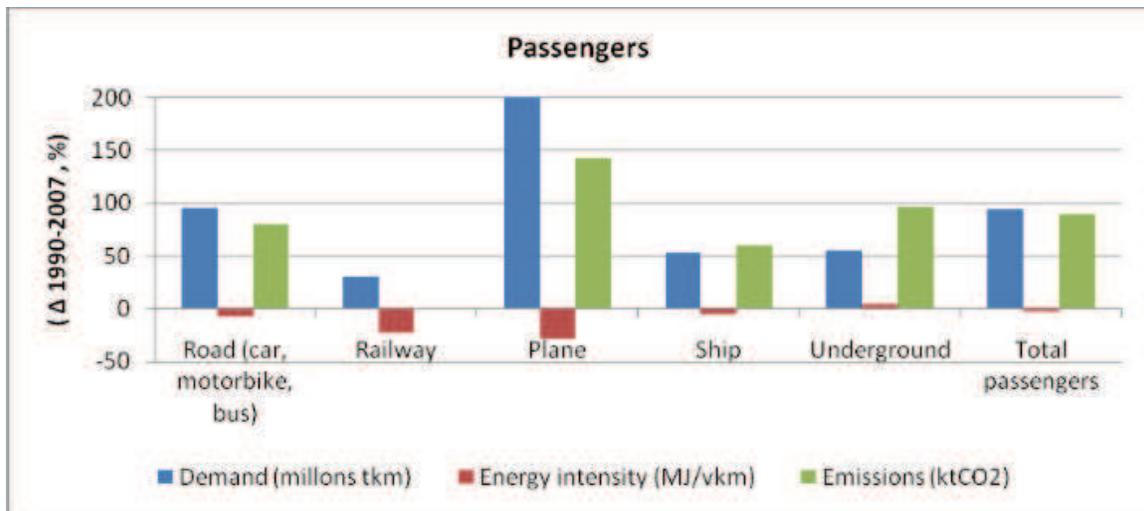


Fig. 1. Change in demand, energy intensity and CO₂ emissions for passengers, 1990-2007. Source: National Inventory of Emissions 2008, Annual Report on Transport and Postal Services 2008 and authors' own compilation.

The figure below shows the average growth in the same period of three indicators relating to freight transport in the following modes: road, railway, air, boat, and pipeline. The variables analysed, as in the case of passengers, are growth in demand, GHG emissions, and energy intensity.

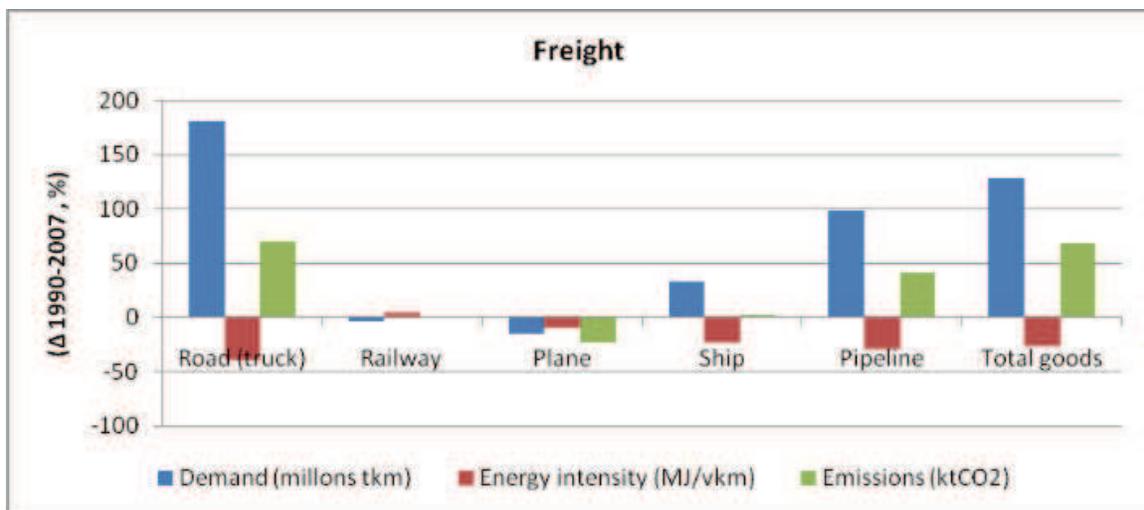


Fig. 2. Change in demand, energy intensity and CO₂ emissions for freight, 1990-2007. Source: National Inventory of Emissions 2008, Annual Report on Transport and Postal Services 2008 and authors' own compilation.

As can be seen from the figures above, the greatest growth in the percentage of demand occurred in road transport (freight) and in air transport (passengers), with a lower increase in GHG and energy consumption. This is most likely due to the considerable technological improvements made in the road transport of freight and air transport of passengers. On the

other hand the cost of fuel is a major item, and a reduction in these costs therefore increases the profitability of road and air services. Passenger trains, which are electrified on the most heavily used routes, have reduced their GHG emissions and upgraded their fleet, leading to significant improvements in energy efficiency. Passenger road transport has also seen a net change for the better, as GHG emissions have grown less than demand, although the reduction in consumption is lower, perhaps due to the fact that the energy efficiency was already fairly high. The increase in traffic congestion may also play a role, as well as the proportion of city travel and the use of ever larger vehicles.

On average, the intensity of CO₂ emissions on the road is 5 times greater than for railways in the case of passenger transport, and 4 times greater in the case of freight. For this reason the decreasing trend in railway transport partly explains the accelerated growth in emissions in our country. In Spain, the energy intensity of transport modes as a whole has decreased, as the energy intensity of the modes has decreased individually.

3. Proposed strategies for action in transport planning to reduce emissions

Transport infrastructures are a vital social and economic resource, as they structure space and determine mobility (Short & Kopp, 2005), providing access to current economic and social opportunities (Richardson, 2005). Investment in the construction and maintenance of transport infrastructures is of considerable importance and has repercussions which affect society as a whole (Hildén et al., 2004; Short & Kopp, 2005). It is therefore essential that the planning of transport systems should be correctly carried out (Hildén et al., 2004).

The increase in the use of transport systems has gone hand in hand with a heightened awareness of the impacts this increase has provoked (RCEP, 1994; Hine, 1998). A new requirement has therefore arisen which demands that this development should also be sustainable and integrated (EC, 1998; US Department of Transportation, 2000).

The decisions concerning major transport plans are taken in a previous strategic phase regarding the development of a particular region.

Strategic Environmental Assessment¹ has been used in recent years as a tool for introducing and integrating environmental, social and economic concerns into the decision-making process for policies, plans and programmes (Dalal-Clayton & Sadler, 1999).

The following are some proposals for possible strategies for mitigating emissions in the transport sector. These strategies should be taken into account in the initial phases of the decision-making process.

The transport sector can apply different measures and instruments to reduce GHG emissions (Accut & Dodgson, 1996). From among these measures, the United Nations Convention on Climate Change (UN-FCCC, 2007) highlights taxing the purchase and use of vehicles, vehicle registration and road use, are based on the vehicle's emissions. Other measures include special taxes on hydrocarbons, tolls for the use of roads and parking, and investment in public transport and other non-motorised forms of transport. The impact of taxation may be minor if incomes increase. It also proposes mixing biofuels and conventional fuels, the admission of CO₂ standards for road transport, and making fuel savings obligatory. These measures may have a limited impact as they are restricted to small

¹Strategic Environmental Assessment (SEA) is "a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest stages of decision making" (Sadler & Verheem, 1996; Arce & Gullón, 2000; Fisher, 2003; Dalal-Clayton & Sadler, 1999).

sector of the total vehicle fleet. New developments include measures to influence mobility through the coordination of land use and the planning of infrastructures.

As the conditions and circumstances of a country change, it should be possible to measure the potential for mitigating GHG emissions for a specific period of time. This measurement should take past trends into account, as well as the current and future state of all the factors and indicators which determine the mitigation potential of a country. According to Pacala & Socolow (2004), we now have sufficient scientific, technical and industrial knowledge available to solve the problem of GHG emissions and climate change in the forthcoming decades, but this will require assuming the structural modifications and economic costs of such a change. This change in trend must be achieved by through a series of actions, aiming to enhance the synergy between them, and which are institutionally coordinated.

The possible mitigation strategies for CO₂ emissions can be grouped into the following categories:

A) Technological improvements in vehicles and fuels (TCC)

The last decade has seen a reduction in vehicle fuel consumption through voluntary agreements subscribed by vehicle manufacturers (ACEA agreements), and an improvement in fuels (AUTOIL programme). These reductions in energy are also thanks to improvements in engine performance, weight reduction, vehicles with a more aerodynamic design, the use of electric and hybrid engines, etc. (Orasch & Wirl, 1997; Advenier et al., 2002). It is also possible to act on the quality of the fuels by improving their strength, or by introducing biofuels and other energy sources, electric or mixed vehicles, hydrogen batteries, etc. (Hill et al., 2006). Governments can encourage these measures through the exemplary use of vehicle fleets which are run on alternative fuels, using reduced power, etc. (Schipper, 2007). Another measure is the application of a system of taxation based on vehicle emissions and not on engine power.

B) Change in the modal distribution of freight (DMM)

This involves reducing dependence on roads, although this may still be the most heavily used mode. However, railways must aim to reverse their current trend in order to attain a similar rate to that of other European countries. Maritime transport also has the potential for growth in the case of large volumes of freight. However the reinforcement of these different modes of transport must include improvements in the multimodal chain, as roads serve as a complementary mode to other forms of transport for the collection of freight and its final distribution. Thus the availability of multimodal logistical facilities will be a key factor in obtaining a significant change in modal distribution (Vasallo & Fagan, 2007; Janic, 2007).

C) Balance in the modal distribution of interurban passenger demand (MTI)

Similarly, quality railway services must be able to capture travel, both from private vehicles and –in the case of high-speed trains– from planes (López-Pita & Robusté, 2003). Bus services by road have also been shown to be a competitive and quality alternative when they are well run, and offer a network with adequate frequencies and destinations.

D) Balanced modal distribution of urban passenger demand, reduction in length and number of motorised journeys (MTU)

This involves the implementation of Urban Mobility Plans in cities in order to change people's mobility habits and reduce dependence on the car. Plans should also be designed for transportation to work centres (industrial estates, business parks etc), and to shopping and leisure centres so that the locations and facilities are accessible by public transport (IDAE, 2006a).

Travel on foot and by bicycle should be encouraged, with the recovery of urban spaces for non-motorised journeys.

Priority should be given to public transport by improving the quality of the following elements: bus lanes, priority in traffic lights, improved appeal through attractive system design and a high quality service. This will in each case involve providing the most suitable resources: buses, underground, trams, etc. Coordination and integration actions will be of key importance in this area: transportation hubs, combination tickets, user information, etc. (Ministry of the Environment, 2008; IDAE, 2006b).

Finally, there is a need for information and awareness campaigns so that citizens can make their decisions fully conscious of the effects of their choice of transport mode on the environment. Many trips can be avoided, others can be clustered or done in a cleaner way. In some cases it would be useful to indicate the economic and environmental costs of lifestyles which are dependent on mobility by cars (Schafer & Victor, 2000).

E) Efficient use of vehicles (UE)

This refers to the proper management of transport systems for both passengers and freight. One aspect of management involves controlling the use of the infrastructure, either by means of restrictions of time, tariffs, or any other aspect for particular vehicles, for example at times of congestion. GHG emissions increase with the speed of the vehicles; speed control is therefore a key factor in reducing emissions. Emissions also increase the longer the engine is running, so traffic jams must also be minimised (Hensher, 2006; Berger, 2007).

The second aspect refers to the fleet, which should be upgraded with suitable regularity and undergo a strict maintenance regime in order to reduce consumption (Van Weet al., 2000). The management of the fleet is also an important factor: variables such as size and power, frequencies, level of occupancy etc. must be optimised in order to improve energy behaviour in both passenger and freight transport. Efficient driving from the energy point of view has also been shown potentially to reduce emissions, as well as reducing the costs of fuel.

F) Impact of fuel prices on consumption

Another possible measure worth highlighting is the increase in the price of fuel. It would be logical to assume that an increase in the price of fuel would provoke a decrease in the use of transport modes, and particularly in road travel. However it can be observed in Spain that alterations in the price of fuel have had barely any effect on changes in transport activity and consumption of energy in the transport of freight and passengers. Figure 3 shows that despite the considerable increases in fuel prices in 1993 and 2000, and decreases in 2000 and 2004, there was no appreciable effect on the consumption curve.

The short-term impact of fuel prices is limited, partly due to the lack of alternatives, and partly to the mobility habits associated with particular modes such as the car. According to AEMA (2008), a 10% increase in fuel prices produces an average reduction of 2.5% in short-term (first year) fuel consumption for passenger road vehicles. The long-term impact is greater, as there are more alternatives available, such as for example changing one's place of work or residence, and using more fuel-efficient vehicles.

4. Scenarios in 2020 for CO₂ emissions from freight transport, and strategies for mitigation

In this chapter, a theoretical study is approached in order to know the CO₂ emissions after implementation of the actions envisaged in the Spanish Strategic Plan of infrastructures and Transport (Plan Estratégico de Infraestructuras y Transportes (PEIT)), which horizon year is 2020.

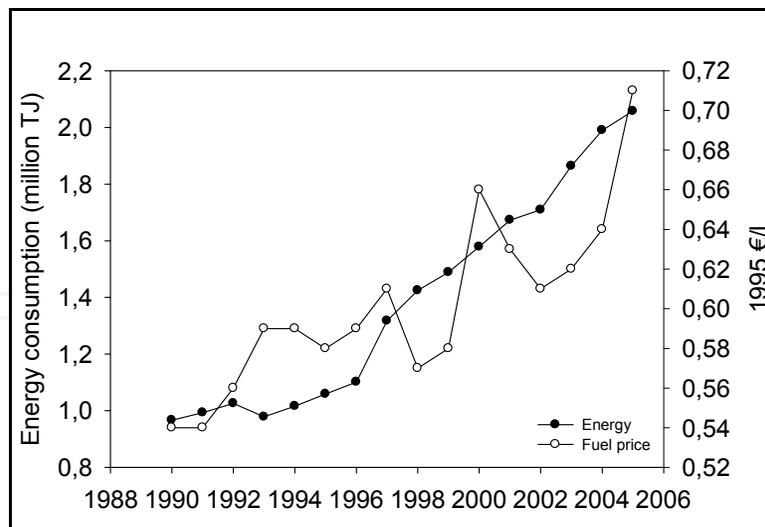


Fig. 3. Evolution of the consumption of energy for transport and fuel prices in Spain (1990-2005). Source: Source: Ministry of Public Works, 2008 Annual Report; Ministry of the Economy, Consumer Price Index, National Institute of Statistics 2008; Ministry of the Economy, Internal Revenue Service 2008.

4.1 Strategic plan for infrastructures and transport

The 2005-2020 Strategic Plan for Infrastructures and Transport (PEIT) aims to establish an efficient framework for transport in Spain by developing a transport system which integrates all the different modes. An additional objective is to use transport as an element which contributes to economic and territorial development, due to its function as a force for linking different areas of the country.

The actions included in the PEIT involve extending the road network to a total of 15,000 km of high-capacity highways, reducing the network's radial configuration and promoting a mesh-type road system, and reaching the target of 9,000 km of high-performance railway lines (Ministerio de Fomento, 2005). The plans for the road network essentially entail a reconversion of national roads into high-performance highways. However, the actions included in the PEIT regarding the railway network consist of creating infrastructures along new routes for the high-performance train system.

The objective established by the PEIT is that the railway system should progressively become the lynchpin in an articulated system of intermodal transport services for both passengers and freight.

4.2 Definition of scenarios

This section analyses the freight transport sector and offers a medium-term prediction under examples of various proposals for action scenarios. Three scenarios are designed to estimate the CO₂ emissions for the Spanish freight transport sector in 2020. The scenarios consist of descriptions of future patterns of behaviour in the sector, and include modal distribution, technologies and mix of different fuels (Pacala & Socolow, 2004). These scenarios are described below in detail, together with a summary of the basic parameters which define them and their estimated variation.

All the scenarios have the same estimates for the levels of future transport demand, based on the projections for Spanish freight transport up to 2007; this trend would represent an

increase of 57% between 2007 and 2020, but with a different distribution of the transport modes and different types of vehicles. With the exception of electric trains, the scenarios include only the vehicles powered by internal combustion engines. The differences in CO₂ emissions between the scenarios stem from the different engine technologies, differences in aerodynamic and rolling resistance, and the variety of modal distributions (Orasch & Wirl, 1997; Advenier et al., 2002, Schipper, 2007). The scenarios represent different fuel conditions. Scenario 1 - "Business As Usual" trend (BAU) assumes that the same trends in activity, energy intensity, fuel and modal distribution observed during the period from 1990-2007 will continue until 2020. There are minor mode transfers from the railways to the road, and the predominance of fossil fuels, –primarily diesel– remains unchanged. The energy intensity of road transport in Spain continues decreasing, due to ever stricter environmental regulations and technological improvements to engines. The use of capacity in the base scenario is 9.4 tons kilometer per vehicle kilometer with load (2007). This value has changed very little from the 9.0 recorded in 1997 (4%). The energy intensity of railways decreases by 2% between 2007 and 2020. Fossil fuels are used in all vehicles with the exception of electric trains.

Scenario 2 - Development of the Railway Sector in Spain (DSF) assumes an increase in the modal share of the railway, and an improvement in energy efficiency through the introduction of new technologies. Freight transport by rail will constitute almost 10% of total freight transport in 2020 (twice the proportion in 1990). This scenario is consistent with the EU's policy measures designed to promote cleaner modes of transport, as in almost all European countries, the railway sector is losing modal share (Vassallo & Fagan, 2007; Janic, 2007). The energy intensity of the railway decreases by up to 20% in this scenario, due to the introduction of new technologies for electric propulsion, which is included in the context of the new railway regulation (Izquierdo & Vassallo, 2004). The decrease in intensity is specific to the fuel used, and is a result of the improved energy use of electrical locomotives as compared to diesel engines. The consumption of fossil fuels decreases in favour of electricity.

Scenario 3 - Road Efficiency and Development of Biodiesel (ECB) assumes that the road maintains its predominance in the freight transport sector, at the same time as there are significant improvements in the efficiency of diesel propulsion engines, and advances in biodiesel engines. Diesel engines show an increase of 55% in efficiency with regards current levels, and significant advances in biodiesel engines makes them more competitive. This increase in efficiency follows the trend of the base scenario (the BAU scenario predicts a 45% increase in efficiency). An additional 10% improvement in efficiency could be obtained by operating high-productivity vehicles. Assuming that the fleet is upgraded every five years, at the start of 2020 all new lorries will need to be 55% more efficient. After exploring the sensitivity of this scenario to changes in the introduction of biodiesel on the market, biodiesel in 2020 will contribute almost 10% of the energy consumed on the roads. The choice of 10% biodiesel is justified by the EU's biofuels directive, which aims to increase the share of biofuels to 5.8% of the energy content of the total consumption of fuel in 2010 (Biofuels barometer, 2008). Biodiesel is studied by analysing the whole of its life cycle (the CO₂ emitted in producing the biofuel), and the real carbon factor for biodiesel (56.1 ktCO₂eq./PJ) is 24% less than for conventional diesel.

4.3 Results

The first point is that actions of this kind are required to achieve the objectives proposed in the E4 for the sector, despite the fact that these measures will not be sufficient to fulfil Kyoto targets, even in 2020.

The second observation is that from the point of view of GHG emissions, the DSF scenario based on enhancing railway travel, would be just as efficient as the ECB scenario with its emphasis on roads, using efficient vehicles and fuels. In the BAU scenario, CO₂ emissions exceed 40 MtCO₂eq. (an increase of 29% since 2007). This is the scenario with the most significant increase in emissions. The scenario with the greatest reductions is ECB, where emissions fall by 2.4% (1.22 million tons per year less than the BAU scenario, and 15 million tons less in the overall period from 2008-2020). In the case of the DSF scenario, the reduction in emissions is somewhat lower (1.20 million tons per year less than BAU, which represents a decrease of 1.9% since 2007).

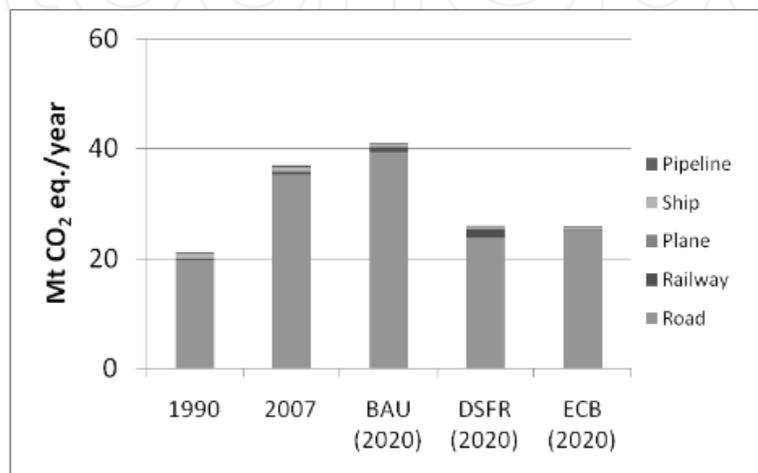


Fig. 4. Scenarios for GHG emissions from freight transport, 1990, 2007 and 2020 (BAU, DSF, ECB). Source: compiled by author.

In the DSF and ECB scenarios, CO₂ emissions are reduced to levels which are lower than the objectives in the E4 strategy; however, none of the scenarios fulfils the target of the Kyoto protocol. In the Kyoto protocol, Spain has undertaken to achieve an average annual increase in GHG –and thus in consumption– of 15% as compared to 1990 levels, between 2008 and 2012 (27.9 Mt CO₂ eq. per year). In the E4 strategy, Spain has committed itself to achieving 38.2 Mt CO₂ eq. a year in 2012, which means 4.5 Mt less than the 42.7 corresponding to the BAU scenario (Ministerio de la Presidencia, 2006).

In the ECB scenario, emissions of freight lorries are 1.5% lower than in 2007, a result of the modification of the different fuel parameters due to technological advances. Similarly, emissions from the railway and maritime sector are 37.3% and 24.3% lower respectively. Aircraft emissions are 38.4% lower, as a result of a decrease in air transport. In this scenario the increase in transport activity cancels out the reductions obtained through technological improvements. The emissions could be lower than the Kyoto target if there were no increase in road transport activity. With the DSF scenario, road emissions are 7% lower and railway emissions are 417.7% higher than in 2007, as a result of the increase in railway activity. With the technological level anticipated in the BAU scenario, emissions from all modes of transport (except air transport) are greater than in 2007.

5. Conclusion

The transport of freight and passengers has grown linked to economic growth, but at a higher rate, especially for passengers. These increases have been well above population

growth, indicating an increase in the number and length of trips per capita. These data indicate an increase in activity, but also a change in the territorial model, with a greater dispersion of activities, whether industrial, and commercial and residential.

In spite of the decrease in energy intensity and emissions of pollutants, the growth in the mobility of persons and freight suggests the possibility of an undesirable growth in emissions, which may also be unsustainable in the long term.

There are some possible mitigation strategies for CO₂ emissions. They can be grouped into six categories. Efficient use of vehicles is the option which offers the greatest potential, and is also vital in drastically reducing emissions of carbon and other pollutants. In second place are the technological improvements in vehicles and fuels. The recourse to multimodality is perhaps an option which requires a greater co-operation between operators, as well as technical and administrative coordination. Achieving a greater balance between modes and dedicating each mode to the segments of the market where they are most competitive would lead to a greater efficiency in emission factors and a reduction in costs, through the improved exploitation of the capacities of the existing networks.

From the point of view of GHG emissions, the enhancing railway travel would be just as efficient as the using efficient vehicles and fuels.

It is necessary that all these strategies be coordinate and integrated into the planning process.

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