

Decoupling freight transport growth from climatic effects

German Case Study in context of the OECD project “Decoupling transport impacts and economic growth”

Umweltbundesamt

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Preface

The Environment Directorate of the OECD and a group of countries have been working since the mid 1990s on a project of significant scope on the subject of Environmentally Sustainable Transport (EST), in order to find ways and means to significantly reduce the harmful impacts of transport on the environment. The project, which included case studies in several countries, came to the conclusion that long-term, environmentally sustainable transport development cannot be achieved alone by technical measures to reduce environmental damage. What is necessary is a broad spectrum of measures relating not only to technical improvements but also to transport demand management. As transport and economic growth are intimately connected, the insights gained from EST 2002 led to the birth of the project “Decoupling Transport Impacts and Economic Growth”. This project is intended to find ways to slow down transport growth without harming the economy. Various aspects of the whole question are considered in case studies from Sweden, Austria, the Netherlands, Italy, Spain, and Germany.

The German case study revolves around the possibilities offered for freight transportation and logistics with respect to reductions in transport levels and to CO₂ efficiency. The study brings together the results of six small surveys carried out in Germany on the decoupling of road haulage from its climatic effects. The chapter 1 presents the problem and chapter 2 reflects the state of the art in the freight transport and energy trends, and the potential efficiency measures in Germany in 2005. Chapter 2 and 3 presents the outcomes from surveys and analyses carried out between 2003 and 2005. Policy recommendations, derived out of the main results, can be found in the conclusion, in chapter 4.

The surveys presented were performed in teamwork in the frame of the project NESTOR (sustainability effects of efficiency measures in the transportation and logistics sector), between July 2002 and September 2003, and NESTOR2 (sustainability effects of efficiency measures in road haulage, with particular reference to Courier Express and Parcel Services and to co-operations) from July 2004 to December 2005. Thanks go to the colleagues Karin Hoffmann, Ingo Möller, Karin Hartmann, Sabine Hutfilter, Ralf Müller, Annika Schäfer and Jan Sellmann. In both project phases, the funding was provided by the Federal Ministry of Education and Research. Between the two periods, the Max Planck Institute for Meteorology in Hamburg provided financial support.

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Summary

The aim of the German case study is to survey and analyse the potential for decoupling road transport from its climatic effects. To this end, CO₂ reduction measures were recorded and analysed in a large number of businesses in Germany, problems and barriers were identified, and the potential for efficiency improvement was described both quantitatively and qualitatively. In six small surveys, complementary datasets were collected (table 1), allowing new insights. There is a need for further research across every one of the relevant fields of the surveys and analyses. One limitation of this study is that the impacts of policy instruments in term of quantified cause-effects relations could not be measured at the company level.

Table 1: Overview of the surveys samples and main quantitative results

	Company C	Base survey	IT scheduling impacts	Technology	CEP sector	Company GO!
	Chapter 2	Chapter 3.2	Chapter 3.3	Chapter 3.3	Chapter 3.4	Chapter 3.4
Nb of companies	1	52	22 (7)	20	24	1
Nb of datasets	1931	153	14	20	24	139
Surveyed period	2001-2004	Spring 2003	Spring 2003	Spring 2005	Spring 2005	Spring 2005
Mean fuel use	33.3 l/100 km	31.6 l/100 km	33.7 l/100 km	-	-	8 l/100 km
CO ₂ efficiency	11.6 tkm/kg CO ₂	10.5 tkm/kg CO ₂	-	-	-	2 kg CO ₂ /parcel

The trends in decoupling fuel use and freight transport performance are observable in Germany and for company C: a slight decoupling of GDP growth and growth in transport performance and tonnage on the one hand, and fuel use and emissions per truck on the other, is taking place. Using one business as a case study, a CO₂ reduction per goods vehicle is recorded for the years 2001 – 2004. The distance per vehicle is continuing to increase, but at slower rates than GDP.

The base survey shows large variations for CO₂ efficiency and identifies a potential for improvement: the aim of the empirical base survey (January to May 2003) was to calculate the state of the art in CO₂ efficiency and estimate the available potential for optimisation in the German road haulage sector. 153 datasets with a total transport performance of more than 1.6 million tkm show that the CO₂ efficiency of the transports carried out fluctuates from 0.8 to 26 tkm per kg CO₂ in the average values from 2 to 4 day runs. It can be shown that a close correlation exists between efficiency of vehicle use and CO₂ efficiency. Other factors like load factors, vehicle size, and payload/empty weight ratio are important, as is the size of the business, for improving the efficiency. The market share of CO₂ efficiency measures was determined for 52 German companies. According to these figures, across Germany only a few successful technological and other measures have been introduced in logistics and transport companies. The potential for improvements in efficiency is therefore high.

Companies are not systematically scheduling their transport with IT support and telematics and the technology could be improved: In a before-after study, it was demonstrated that, while the load volume and the load factor increase in the surveyed companies, the CO₂ efficiency improves by about 10% after introduction of an IT-supported scheduling system. Less than 10% of the base analysis companies used IT scheduling and telematics in parts of their fleet. Due to the lack of diffusion of these technologies, the efficiency potential remains high. Technologies and markets are not transparent for the end-user, so a statement often repeated by interview partners, and this is a barrier to the larger diffusion. To what extent could IT scheduling and telematic systems be improved? Users mentioned a greater degree of integration between the various IT supported scheduling and telematics systems, as well as improvements in the stability of the on-board systems. Further improvements identified are creating interfaces between IT scheduling and on-board monitoring systems, the automatic measurement of volume load factor, and an improved or more widely used semi-automated route and trip optimisation system. The need for simplified technology and transparent market information is high.

Efficiency potentials are identified in the CEP sector analysis. To understand the conditions and constraints for the implementation of efficiency measures, records surveyed in company GO! confirm that a potential exists. Due to lower shipment weights and sizes, the market for CEP services is growing in Germany, and the potential for efficiency improvements lies with the vehicles themselves and transport organisation. The use of gas-powered vehicles, IT-supported trip optimisation, driver training, and many other measures all have potential. Barriers have been identified in the form of functional disintegration, the limited availability of free decision space for self-employed drivers and in the low level of interest shown by company central offices in making sure through organisational means that the fleet operating is carried out/organized in the most energy efficient way. The reason for this is that time efficiency is focussed, the distance travelled or a high load factor through more parcels per vehicle per day are comparably less important for central offices. In the case of the company GO!, the lowest average efficiency value is around 0.57l per parcel. This is a value showing that a high level of efficiency can be achieved even by CEP firms under high time pressure. The potential for improvements in efficiency was identified for the parts of the CEP business activities related to direct couriers and to parcel collection. Vehicle and driver oriented solutions like maintenance, driver training, new technologies etc. would be adequate.

For the **policy implications** of these results, corresponding interests for the public sector and for private companies are the starting point. In conclusion, identified policy options could facilitate the application of efficiency measures (chapter 4).

1. Introduction: Decoupling in freight transport as a challenge for research, the economy, and policy making

1.1 Problem, research needs, objectives of the study and framework conditions

The problem is as urgent as ever: European road transport generates high demands on energy in form of petrol and diesel fuels; demands that are growing at the level of the whole Europe. At the start of the new century, private car and freight transport was responsible for the emission of numerous environmentally damaging exhaust gases, including the greenhouse gas carbon dioxide (CO₂). Europe as a whole has managed to stabilise or even reduce the transport related emissions of certain harmful substances, but CO₂ is not among them. In the last two decades, CO₂ emissions are particularly increasing in road freight transportation. This raise in emissions compensates for the significant advances made elsewhere e.g. in the industrial and energy sectors, and consequently the climate mitigation problem remains ongoing for Europe in parts because of the transportation sector. In terms of environmental politics, this could lead to significant failures. If the actual growth trend continues, the EU-wide Kyoto objective of a reduction in greenhouse gas emissions of 8% by 2012 compared to 1990 will not be met. In addition to climate problems, further increases in road transport will continue to generate a range of socio-economic and environmental problems, like accidents, transport congestion, air pollution, land use, noise, and the degradation of ecosystems. These factors, as a whole, are leading in Germany to an unsustainable mobility situation. This diagnosis was made as early as 1994 by the Enquête Commission of the Federal Parliament on the Protection of the Earth Atmosphere (Enquête Commission 1994), underscored by the Federal Environmental Agency (UBA 2002), and confirmed again by the German Advisory Council on the Environment in 2005 (SRU 2005).

Pressure on economic and political decision maker: the broad consensus achieved between the principal players from politics, administration, economics, and science has not lead to a solving of the problem. In the meantime, the Association of the German Automotive Industry has also made the political commitment to reduce environmental impacts from road transport. Despite this willingness of the most important actors, the problem does not disappear and most of the experts mention structural boundary conditions like market concurrency and others tendencies that are leading to narrow the space for decision. Many strategies to counter the negative consequences of road transport are either on trial or running, especially in the leading logistics companies and the goods vehicles sector. A generally agreed approach consists in increasing energy efficiency in different fields of activity. It consists in achieving a higher transport performance for the same amount of energy consumed. However, the improvement in efficiency, as far as it can be observed in some countries, has not yet resulted in a noticeable reduction in greenhouse gas emissions in the EU transport sector (EU 2004, EEA 2006). The high growth rates in road transport in Europe are leading to an over-compensation for the efficiency increases in new vehicles, which have been achieved. Thus, the pressure on the economy and the political process remains constant.

Main aim of the case study: it is the aim of the German case study, on the background of the above-mentioned processes, to survey and analyse the necessary conditions for, and chances of realisation of a decoupling between CO₂ emissions and freight transport. This study is positioned in the frame of the ongoing OECD debate of the wide societal objective of decoupling the growth from a sector from its deleterious consequences for the environment, thus contributing to sustainable development without compromising economic growth (OECD 2004).

Definition of decoupling: developments in the freight sector are above all characterised by the growth of transport performance (in tonne-kilometres), which needs to be decoupled from the parallel increase in CO₂ emissions. Decoupling total emissions from business volume and turnover growth (in €) is also both intended and necessary. Decoupling business volume growth (or of GDP in €) from distance is equally desirable both from a traffic point of view and from that of environmental policy. Decoupling does not mean that a the reduction of CO₂ should be reduced to zero, only that it should decline while the transport performance and the turnover of the sector is increasing.

This definition of decoupling is distinct from the more classical transport policy discussion on decoupling freight transport from economic growth, because the formal, older decoupling definition has no explicitly environmental or CO₂ related dimension (SPRITE 2000). Freight transportation was meant originally to become decoupled from economic growth in term of total transport demand (expressed in tonne or in tonne-km). To this aim, successful solutions have already been suggested (REDEFINE 1999). For some experts, recently, the definition of decoupling has been slightly modified. Now the two main trends to be analysed are the “quantitatively measurable reduction of the environmental deleterious effects of freight transport”, and the “simultaneous business volume growth of the sector as a whole” (SPRITE 2002).

Secondary aims: optimising logistical systems may catalyse transport, environmental, and regional development and socio-economic effects. However, these “external” effects can be measured and evaluated by a sound scientific survey and verification procedure. This study can help the decision makers by providing some new key facts.

This case study is surveying some expected and realised efficiency effects of optimisation measures in freight transport. This is done from an environmental and a transportation perspective and will take particularly the reduction of CO₂ emissions and empty runs into account. Expected, potential future reduction effects will also be estimated.

Regarding the perspective of companies and private decision-makers, the analysis, evaluation, and identification of the best possible future IT and process optimisation measures will be presented. The potential for extending these measures to all businesses in the transport sector will be checked.

Central questions: At the core of the research are the questions: what is the status quo? Where is the potential for further emissions reduction? Where are the current information deficits and research gaps?

Further increases in goods vehicle transport are probable: a study carried out by the Prognos institute predicted a further increase in road haulage in the next ten years. According to it, it will not be possible to decouple transport volume (in tonnes) from economic growth (Prognos 2000). This prognosis is underscored in the OECD transport report (OECD 2000). EU statistics on transport development at the start of the 21st century confirm this tendency (EU 2004, EEA 2006).

Unsustainable transport: the German Federal Ministry of Transport, Building, and Housing, explicitly assumed in its Transportation Report 2000 that, despite climate protection programme, the reduction in specific fuel consumption of road haulage would not be enough to compensate for the growth in distance (BMVBW 2000).

Central data are not available: the optimisation of goods streams by means of logistics and internal business organisation cannot currently be achieved extensively due to structural characteristics of the sector, and because of missing data. In particular, no systematic enquiry has been conducted yet into the changes in fleet management and energy use, either in Germany or internationally, according to the result of an OECD workshop on the subject of “baseline” methodology (OECD 2001). One reason amongst others has been the unreasonably high costs of such an undertaking. In the course of the case studies presented here, new primary data could be collected and an improved knowledge base created.

Reduction potential exists: calculation of the potential for greenhouse gas reductions in road haulage faces large uncertainties. Some of these are, e.g.: no statistical record on freight energy is maintained, hinterland transports from Hamburg and Bremen are not monitored, CO₂ emissions from road haulage are only known for the very global figure, and the number of businesses operating in the sector is uncertain. The climate protection programme made provision for a reduction of 3 million tonnes of CO₂, to be achieved by investment promoting the use of telematics in road transport, mainly related to freight (BMU 2002). A study carried out by Prognos for the Fed. Environmental Agency has reached the conclusion that using telematics could reduce inter-regional goods vehicle transport by 2.6 % until 2010 (UBA 2003; Prognos 1999). The IPCC assessment report 2001 talks in terms of a total potential reduction in freight related greenhouse gas emissions of over 60% (IPCC 2001). According to the statements of experts from OECD workshops and the European Commission, only very few field trials have yet taken place (Fulton 2004). Quantitative data on potential CO₂ reductions are therefore very difficult to obtain. The purpose of the NESTOR surveys was to provide new records, and fill some gaps in the current knowledge on reduction potential and related practices.

1.2 Origin of the case study, definitions, and work plan

First pilot survey on hinterland container transport: A first pilot survey, carried out in August 2001 by the MPIMET, demonstrated in an exemplary company a purely theoretical potential reduction in empty runs (trips with empty containers or chassis only) of about 50%. It also calculated a container load factor by weight of 52%, a high efficiency potential in terms of trip distance, and a high efficiency potential in terms of journey time. These first surveys allow the development of methodological steps and a test of the survey methodology.

It was already visible in these first numbers that the difference between the calculated theoretical potential and the “realistic” potential is very important. It was also clear that the influence of environmental policy instruments, like higher taxes, on the company situation was not discovered, nor clearly attributable to a cause-effect relation, in the data collected. The data only gives insights on the static or dynamic situation of a company. How the company performance and efficiency indicators get influenced by political changes, could therefore not be directly demonstrated by quantitative survey results. This question remains challenging.

First project phase: the promising results of the first pilot study led to the conception of the NESTOR project, initiated in 2002 and carried out until summer 2003. In NESTOR, the survey type carried out in the pilot study on reduction potential was extended to the German freight transport, by including as much companies of different road haulage sectors as possible, and some assumptions on efficiency were verified quantitatively. The container sector was surveyed in qualitative interviews and quantitative questionnaires. Here, specific potentials for, and obstacles to, the implementation of efficiency

measures were analysed. Furthermore, other businesses in various transport sectors were considered, and the question of the potential exploitation of rail and ship – co-operation between road haulage and other carriers – was also raised.

Definitions of optimisation and CO₂ efficiency. The central concepts optimisation and efficiency can be broken down into several components, and each of them can be considered individually. In the first case study on CO₂ efficiency in goods transport, distinctions have been made between energy efficiency, empty run efficiency, loading efficiency, and spatial efficiency (short or long haul). Surveys produced the data compiled from 600 haulage contracts (with a return of questionnaires of 52.5%) leading to important first indications on how the structuring of potential analysis could lead to improvements in the various categories of efficiency. A combination of the factors energy consumption, time, proportion of empty runs, load capacity utilisation, company turnover, and distance determines the total CO₂ efficiency of a business. One of the aims of the project was to calculate quantitatively the CO₂ efficiency of both technical and non-technical measures by looking at these identified sub-criteria. Regarding the technological side, variations in CO₂ efficiency were measured by considering various classes of vehicle in operational use with varying loads and routes, which were then compared and analysed statistically. Precise data on the carbon intensity of various classes of vehicle, based on observation under real German business conditions, were not available. Data to this end were compiled in NESTOR.

Mix of methods of the approach: the economic, social, ecological, and transport-related effects of diverse methods and efficiency technologies were measured and evaluated. The technologies were considered on the basis of existing, current products. The non-technological measures were mainly measured and evaluated by means of questionnaires and interviews. Data were collected with regard to businesses, vehicles, transport performances, diesel consumption figures, weights, and times. Statistical calculations were subsequently made. Time sequences were constructed successively during the evaluation, and the applied methods and techniques of recording and analysis were refined.

No information is available about the optimisation potential of different IT options in businesses. Science has today no answers to the following question: which business options and IT solutions appear to be the most promising from the perspective of freight transport sustainability and carbon efficiency? Only few scientifically verifiable statements about the best possible efficiency increasing practices in logistics and haulage companies have yet been made. UK provides some figures derived from experience with respect to efficient operational diesel management. In the Fuel Management Guide (Fuelwise 2004), which presents the outcomes of the British energy efficiency programme that is leading in Europe, complaints about the lack of data can be found. NESTOR generated data, indicating quantitatively that assumptions made in UK might also apply for the situation in Germany. The need for research at OECD or European level remains high.

Next step in surveys: expands the field of research. The next project phase NESTOR2 was initiated and performed in Germany. Targeted research fields were Courier, Express and Parcel services businesses and the observed use of small vehicles for goods transportation (chapter 3.4). Another survey point was the potential for intensified co-operation between haulage companies and the potential of new scheduling concepts and technologies (chapter 3.5).

The sub-aims of these surveys consist of estimating more accurately the potential for road haulage CO₂ reduction, in the areas where high benefits are expected. The hypothesis is that the optimisation of scheduling system procedures, the use of telematics systems, and a more efficient organisation of goods transportation, by means of closer co-operation, bundling measures, and changes in customer/supplier relations, will have significant climate mitigation effects. These hypotheses were investigated more in-depth by using the results and approaches achieved in NESTOR so far.

In order to achieve the aims, it is necessary to measure again quantitatively and more precisely the observed efficiency effects and to analyse them qualitatively. As secondary aims, the following questions should be answered:

- What has been achieved in the companies, and what were the factors inducing the increase in efficiency (if any)?
- Which external and internal conditions need to be fulfilled in order to achieve better results in the introduction of individual emissions reduction measures and to lead to the increased adoption of such measures?
- Which technologies should be developed as a priority?

The need for research and the institutions involved: today, no German institution is committed to the monitoring of freight transport emissions and the development of solutions to comply with the Kyoto targets. Based on the domestic reduction obligations that could come into force for parts of the road haulage industry, it is reasonable to expect that scientifically validated emissions controls will become necessary. The methodology standards used for project monitoring and proposals in the frame of the Kyoto mechanisms are today very advanced, since a scientific panel composed by numerous experts validate the methods of work for all projects related to climate mitigation. The quality of the validated methods can be seen as a reference for the quality of the surveys. However, the absence of a validated method for transport projects for the UNFCCC institutions, in spring 2006, have a consequence on the overall survey quality. Due to the lack of similar methodological debates and framework conditions in the domestic climate mitigation policies, relevant for the road freight transport sector, the approach and methods selected for this research can be considered as an exercise with limited legitimacy, reflecting the opinion of a small group of international experts. Here again, further research and the collaborative organization of a world wide network, are needed.

2. Trends towards the decoupling of freight transport from environmental effects

2.1 Decoupling: theories and trends

Transport and the economy

Decisions made in the transport sector influence the mobility of people and the movement of goods and can therefore in principle trigger positive effects on productivity, GNP growth, and job markets. Economic growth, however, generates higher transportation demands. Greater amounts of manufactured goods are moved over long distances. Increased division of labour in the global economy - which has repeatedly been shown to be characteristic for globalisation - new production technologies, and new supply conditions such as just in time and concentration on core business give rise to increased levels of transportation demand and more significantly deleterious environmental effects. In the first instance, one has to assume as fact the coupling of transport and economic growth with negative environmental effects such as poorer air quality and greenhouse gas emissions. This non-decoupling is the subject of an established debate, but in recent analyses, this argument appears to be too simplistic (Tapio 2005). The principle difficulty in the discussion about interconnections between transport, economy and environment is to be found in the fact that numerous other factors also exert an influence on these complex interrelations. The first difficulty therefore is to characterise the key elements while ignoring the multiplicity of further interactions, in order to reduce the complexity.

The effects of transport growth on the economy: an efficient transport system and a well-developed transport infrastructure are vital for a strong economy. This is equally true on local, regional, and national levels, as it ensures a high level of accessibility to economic locations, thereby facilitating access to jobs, industrial companies, suppliers, and customers. This is why continuous investment has been made in the expansion and improvement of transport infrastructure, especially in the networks developed in the post war period. The road network received the most privileged treatment, but heavy rail transport, urban public transport, ports and airports were also beneficiaries.

Effects of economic growth on transport: it is additionally true that economic growth and development influence demand for, and patterns of, transport services. Increased income stimulates private car ownership, company sales growth increases the amount of goods transported, technological advances create new methods of communication, and the adaptation of elements of economic activity in particular brings about a de-industrialisation, which in its turn generates new transport routes and flows. Numerous further processes at the interface between transport growth and economic growth have been identified in the fields of industry, trade, and logistics (McKinnon et al. 2003).

Interdependencies: that economic growth influences transport demand is relatively clearly demonstrable. However, it is relatively difficult to carry out studies on the macro-economic effects of transport infrastructure on productivity and economic growth. Such studies are therefore relatively rare in industrialised countries. One of the reasons for this is that most studies in the field of economic development work principally with examples from developing countries. It is thus necessary first to establish the level of development reached in order to carry out a consequent analysis of the interrelations between transport, economic growth, and environmental effects. The question of transportation demand growth effects on the jobs market is a relatively recent question, particularly relevant for transport policy and strategies, and the question of the economic effects due to changes in transport costs have recently becoming actual.

The topic of the influence of transport on economic growth is not restricted to the aspect of whether positive or negative economic effects arise as a result of investment or improvement in transport infrastructure. It is also a question of quantifying the strength of these effects. For example, it is unclear whether improvements in a section of road lead to more than marginal economic benefits, or whether an improvement in the transport situation does not enable many companies to reorganise their operative business, resulting in effective gains. Such gains would then lie outside the sphere of the typical investment effects already identified.

The debate about transport and the economy is also generally complicated by the unclarity of the terminology used. The words "transport" or "transport" can be taken to mean transport investment, transport infrastructure, transport improvements, transport volume or transport performance. Most empirical studies investigate transport or one of its aspects, and leave out the difficult interrelationships with these diverse transportation dimension and the related economic effects, because of lack of data, implying immanent difficulties of analysis.

Broader definitions of transport

It is clear that the possibility exists of more broadly defining transport, statistically covered by the categories land transport, pipelines, sea transport, air transport, and the supporting activities such as logistic centres or travel agencies. The economically relevant transport sector, defined in its broadest terms, therefore includes the following:

- In the processing industry, activities such as vehicle and equipment manufacture, including the component suppliers
- In civil engineering, the provision of transport infrastructure e.g. roads, railway lines, stations, ports, and airports
- In retail, vehicle workshops and fuel filling stations
- Car rental
- The demand for individual or collective transport (of goods) on the part of private individuals.

Attempts to cover the entire vehicle supply chain back to the mineral resources and fuel refineries are going, in our view, too far for the purpose of this energy efficiency study. These dimensions could be relevant for a study on fuel switch.

Further narrowing the range of questions structuring the survey

It has become possible to collect data from all sectors of both core and extended fields and to draw up a balance sheet of all activities, especially those concerned with energy use and material flow. Such a balance sheet would go way beyond those values normally credited statistically to transport, including “industry”, “construction”, “retail”, “service”, and even “household”. In the present context, however, the parameters are set much more narrowly, for one simple reason. The focus is placed on the economic sector, which can be directly influenced by the operational decisions made by logistics and transport companies. The scope of these decisions is a narrow one, such that surveys become more manageable. In any case, the results are too limited in scope to do full justice to the problem when viewed from a climate-oriented perspective.

Business decisions can only have an influence on a small part of the emissions of the whole (extended) transport economy: *the emissions from commercial vehicles when driving*. As can be seen below, this sector corresponds to about 6% of all CO₂ emissions in the Federal Republic.

It can be assumed that taking an extended definition of transport into account would mean far higher total emissions figures. The need for research in the form of a much broader based investigation therefore remains very urgent.

Political measures to improve efficiency in freight transport

Political measures are not the main focus of the surveys. Not because they are not of interest. Road transport policy and the options for decoupling have been taken up with great thoroughness by the German Advisory Council on the Environment (SRU 2005). An investigation on 62 measures was recently presented, in the frame of an Austrian “environmentally sustainable transport” scheme and their effects on the decoupling of transport demand from the economy (OECD 2005). Both studies have created a new framework and a new reference for policy makers in these countries. But they derive their recommendations from scientific reports and studies. Because most political recommendations made by the German Advisory Council on the Environment and many other advisory committees are obtained by compiling conclusions from scientific studies, politics assumes a leading role in the establishment of normative settings for science. This role must be maintained for each discipline, and also for this study. For this reason, the need for political conclusions is seen as a motivating force for a deeper examination of these promising fields of research.

The approach selected reveals at this point two disadvantages: it makes the study less directly relevant to those “classical” decoupling research issues derived directly from scientific enquiries. In addition, other businesses could also have been placed in the focus.

For example, vehicle manufacturers can influence emission values through vehicle design. These companies, along with vehicle-related technical measures, have thus been at the centre of European policy on energy saving in the transport sector. But the improvements are rather slow. The relatively large scope for influence of shippers, logistics companies, and forwarding companies has, in contrast, been almost completely ignored. This group of players, according for example to the German climate protection programme 2005, as presented in the sixth report of the inter-ministerial working group on CO₂ reduction, has only received few consideration so far (IMA 2005).

Lately, with the introduction of goods vehicle tolls on German motorways, and the recent high fuel prices, the companies working in road haulage have moved somewhat more into the centre of the discussion. This is because they have been directly concerned by a specific political measure: the so called “toll collect” system. It is true that the toll is meant in the first instance to compensate for the costs of road building, and less to reduce the external costs of emissions. However, the toll could generate ecological effect, due to changes in the behaviour of the transport sector. It will only become possible to test this hypothesis empirically once the toll has been in operation for a longer time.

Transport companies as customers themselves can also choose to buy those kind of vehicles, which offer the greatest efficiency. The markets for commercial vehicles are, in relation to energy performance and fuel consumption, significantly more open and more diverse than, for example, the aircraft market. In civil aviation, only two manufacturers set as definitive the conditions and the energy consumption per passenger kilometre. The situation in freight transport is noticeably more open. If one adds the logistics and IT sectors, then one can speak of markets, which, with regard to

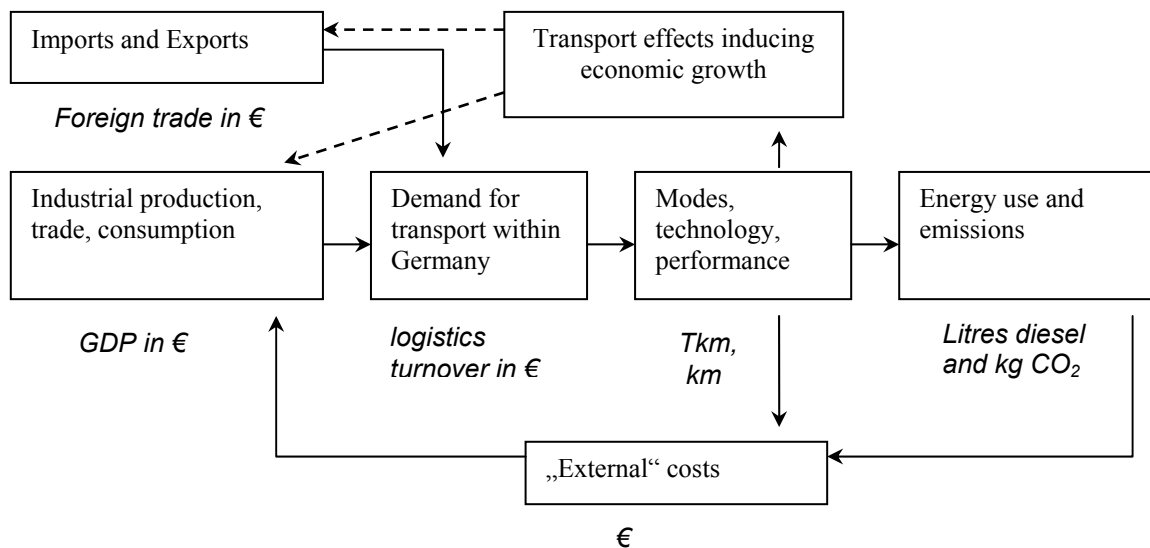
optimisation and energy efficiency, are yet more diverse than commercial vehicle manufacturing. If one goes further by taking the supply chain as a basis, then decisions about business location for whole chains of products move into the circle of business tasks with a high degree of energy relevance. In this way, whole sectors of industry and their supply chain strategy will also need to be taken into account. Decisions from those responsible for transportation operation set-up influence, directly or indirectly, freight transport performance. The need for (exploratory) research is accordingly high.

Models

Theoretical models have the advantage of quantifying individual trends, having already quantitatively determined the influence of various interactions between relevant variables (demand, infrastructure, regions, input-output, transport flows, capital, transport modes, economic development etc.) Understanding of the interrelations between transport and economic development has been deepened in various kinds of (neo-classical) models, and, in an advanced and manageable model, van de Vooren arrives at a figure of 37 endogenous and exogenous variables of influence on the interaction between transport and the economy (Vooren 2004). In addition to the land use-transport interaction model type, further types of models were developed to analyse transport and the economy: input-output analysis, general balance models, location models, production function models, transport models, and activity based models. Numerous models for supporting decision-making have also emerged to take into account the political dimension of the transport/economy interface (Tavaszy et al. 1998).

A model outline for the analysis of decoupling in road haulage, presented in a simplified form, could be used (Fig. 1).

Fig. 1: Model outline of the analysis on decoupling of GDP, road freight transport and energy use



Source: own draft

According to this model, a short **strategic interim evaluation** could be outlined: the aim of future actions from decision makers in transport and environment would be to reduce external costs and emissions whilst maintaining the positive effects of freight transport that are inducing economic growth. Whether the demand for freight transport in terms of turnover would also need to be reduced is unclear and not definitively necessary. It is conceivable that the turnover increases further, the tonnage too, but not the distance travelled. The km and the external costs could thereby be reduced in spite of growing branch revenues. This task is by no means easy. One of the hypotheses of this work is that it could succeed.

Numerous studies investigate the economic effects of changes in the transport system, in order to analyse costs and benefits. The most significant effects on the economy of a change in transport costs are influences on regional trade structures, on investment incentives, on the willingness to innovate, on business location decisions, on commuting habits, and on choices of residential location.

A question that has rarely been considered is the effect on growth of investments made by transport companies in vehicles. As fleet investments are to both a part of the transport economy and a direct constituent of the demand for industrial products, a quantitative analysis of the feedback effects of a change in the transport system on economic development would be necessary. In the published literature, such a study does not exist in Germany. It can be assumed that fleet investments constantly induce positive effects on the economy and, indirectly, on the employment situation.

External costs are not internalised

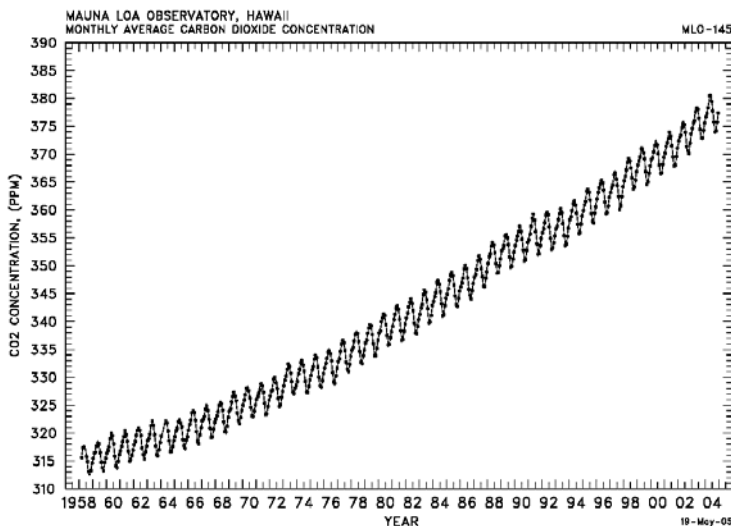
These basically positive effects are accompanied by numerous externalised costs, such as climatic effects, air pollution, noise, accidents, and transport congestion. These negative phenomena are categorised as external costs, because they are not included in the prices that transport users and service providers have to pay. Quantitative estimates assume very high external costs in German and EU-wide road transport. Costs generated as a consequence of bad air quality, risks to health, climate change, and noise in Austria alone are estimated at more than 4 billion € (OECD et al. 2005). Accidents must also be added to this sum. According to the premises and assumptions made, studies reach widely differing conclusions in the calculation of the external costs of road transport. Comparisons with external costs of rail freight have established consistently lower costs than for road freight (Forkenbrock 2001).

Elaborations of the external climate change effect relevant to this question and its solutions are already widely circulated, so a short summary will be adequate here.

What are the central characteristics of the climate problem?

- Increases in CO₂ concentration in the atmosphere, continuously measured at Mauna Loa, Hawaii, from 317 ppm in April and May 1958, to 380 ppm in April and May 2004 (Fig 2). This corresponds to a rise of 1.3 ppm per year between 1958 and 2004 and 1.8 ppm per year for the period 1993 – 2004 (Keeling et al. 2005)

Fig. 2: Increase in atmospheric CO₂ concentrations



Source: Keeling et al. 2005

- Warming of the earth's atmosphere by an average of 0.6 degrees since the start of the industrial age (IPCC 2001)
- Regional disparities in the level and rate of warming
- Retreat and reduction in thickness of sea ice
- Retreat of most alpine glaciers

In what ways could the climate problem get worse?

- Expected increase in extreme weather effects and the El Nino phenomenon
- Greater vulnerability of people and ecosystems
- Abrupt climate changes

What do people need to do about it?

- Significantly reduce the emissions of greenhouse gases
- Develop greenhouse gas free energy (and transport) technologies and establish them on the market
- Meet the energy needs caused by world economic growth, especially in poor countries, with the targeted application of greenhouse gas free energy sources

Are petroleum and eco-taxes motors for decoupling?

The total mineral oil tax income of more than 50 billion € annually collected by the German Federal Government since 2002, including the so-called "eco tax", could be seen as a part of an internalisation of the external costs of transport.

The revenues are going to the general Federal budget and are spent mostly in other areas than transport or environment. It would be possible to reinvest parts of these tax revenues into rail and local public transport services, inter modal infrastructures, noise protection, accident prevention, technologies to combat congestion, clean air technology or clean automotive technology. It would also be conceivable to reinvest in environmental technology, in order to reduce emissions as well as to promote research and innovation. However, even those people who suffer long term health problems as a consequence of road transport related accidents are supported by public health insurance schemes, in other words, by the tax payer, rather than from a special reserve in the Federal budget drawn directly from those whose actions are at the source of the problem. This means that one can hardly talk in terms of internalisation, even if the taxes (petroleum and eco-taxes) were meant to serve this purpose in the original strategy.

However, tax could continue to be used as a major economic instrument of achieving the intended aim, but the use of money alone, without other supporting action from the state, will not help to solve all the dimensions of the problem.

Efficiency is not an abstract theoretical concept: the definition of ecological efficiency is directly connected with the concept of external effects. A general increase in efficiency should result in the reduction of negative environmental effects per service unit or per product. This concept of energy efficiency is applied by industry, power plants, households, and the transport sector. The efficiency strategy was recently at the core of a new policy direction in the European Commission (CEC 2005). For this case study, the following definition of efficiency applies:

Efficiency in the current context is understood as the achievement of the aim of “transport performance” (meeting the same demand) whilst reducing the environmentally damaging effects. More precisely, energy efficiency and CO₂ efficiency relate to the reduction of energy consumption and emissions per unit of freight transport performance, measured in tkm or shipment (pallet, parcel) delivered.

Energy efficiency cannot be separated from the classical definition of economic efficiency. Achieving the same performance (whether of product or service) with fewer means (money, time, or operating expense) is the classic objective of business optimisation strategies. This aim can, in the logistics sector, be similar with energy efficiency to the extent that more efficient logistics generally lead to a better use of vehicle load capacity. This means that more tkm per unit of energy are performed, which is exactly corresponding to our definition of energy efficiency.

There are, however, many cases in which logistical energy efficiency increases only in the form of higher yield, and do not have any effect on physical transportation processes. Therefore, one cannot automatically conclude that logistical efficiency and energy efficiency are coupled (Rodrigue et al 2001).

It can be assumed that a political consensus has been reached in the EU, perhaps worldwide, that transport developments should proceed sustainably (Anderson et al 2005). This means that future external costs should be more strongly internalised in mobility services. Such internalisation is not only to be achieved in the freight sector with increases in efficiency but also by means of innovation, relocation, and avoidance strategies.

On the way to such an internalisation, it is necessary to clarify several questions, amongst them:

- Which effects can be expected from the various measures in the fields of economic growth, transport situation, freight transport volume, and personal mobility?
- If additional transport demand is to be generated, how can sustainability and environmental protection be assured?

Set of indicators: The set of indicators used in the case study is detailed in the following table. Most of the statistics used are from the Federal government, the EU, and the OECD. The indicators are explained in the text when they first appear (see also glossary and index of abbreviations).

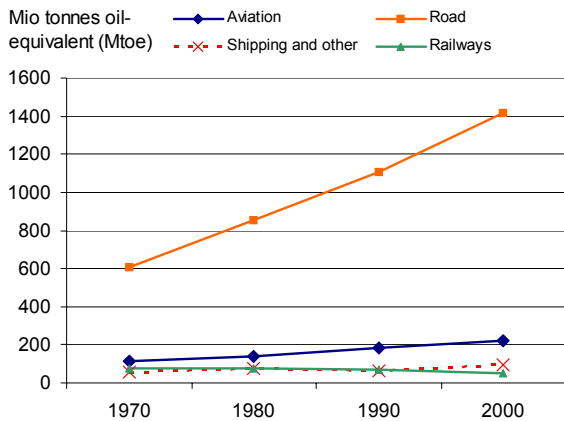
Table 2: Set of indicators used in the survey

Indicator	Parameters, measurement
Energy use	Tonnes (kg) of oil equivalents
Fuel consumption	Litres (l) or tonnes (t) of diesel or petrol
Carbon dioxide emissions	Tonnes or kilogrammes (kg) CO ₂
Transport performance	Tonne-kilometres (tkm)
Distance	Kilometres (km)
Payload	Tonnes (t)
Load factor	Payload proportion in % of the permitted maximum carrying capacity
CO ₂ efficiency	Tkm or parcel per kg CO ₂ / kg CO ₂ per tkm or parcel
Gross domestic product	Billion €

Transport and Energy demand: trends

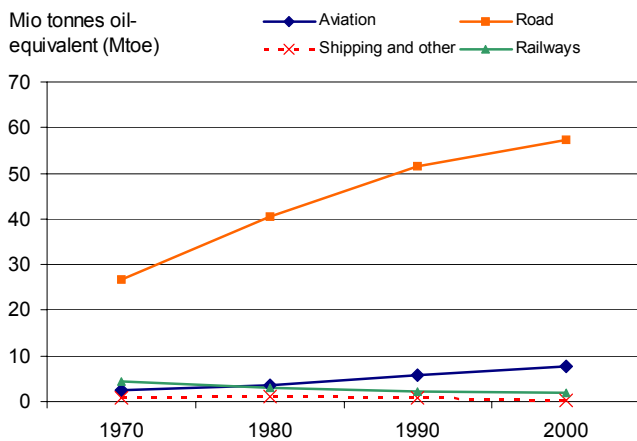
The demand for energy in the transport sector is increasing globally, and 98% of the primary energy demand is covered by oil. The combustion of oil-based derivatives (heavy fuel oil, diesel, petrol, kerosene) leads directly to CO₂ emissions. Looking at the different transport modes, only rail freight show a decreasing fossil fuel consumption. All other means of transport show increases. Road transport energy demand, with a world wide increase from 1,105 to 1,414.8 million tonnes of oil equivalents between 1990 and 2000, represents by far the largest demand sector (Fig. 3). Air transport is in second place, but road transport consumes world wide some 7 times the amount of energy used by aircraft. The increase in the road sector is particularly pronounced in the developing and newly industrialising countries.

Fig. 3: Global energy demand in the transport sector, by mode 1970 – 2000 (Source: OECD 2002)



According to the prognoses of the IEA, this global trend is set to continue for many years: “Global primary oil demand is projected to grow by 1.6% per year, reaching 121 mb/d¹ in 2030. Demand will continue to grow most quickly in developing countries. Most of the increase in world oil demand will come from the transport sector. Oil will face little competition from other fuels in road, sea and air transportation during the projection period” (IEA 2005). Similar trends are demonstrable in Germany up to 2000 (Fig 4). However, the saturation of the road network in Federal territory means that the increase in road transport has slow down since 1990.

Fig. 4: Energy demand in all transport sectors in Germany, by mode, 1970 – 2000 (Source: OECD 2002)



Considering CO₂ emissions, then nearly 100% of the energy required by road transport is connected with immediate emissions of carbon dioxide. The calculated emission factors for Germany (INFRAS et al. 1999), indicating this direct coupling of energy consumption, CO₂ emissions, and costs in road transport, are as follows:

- 1 litre of gasoline = 2.35 kg CO₂ = about 1.2€ (in the period 2004-2006)
- 1 litre of diesel = 2.64 kg CO₂ = about 1€

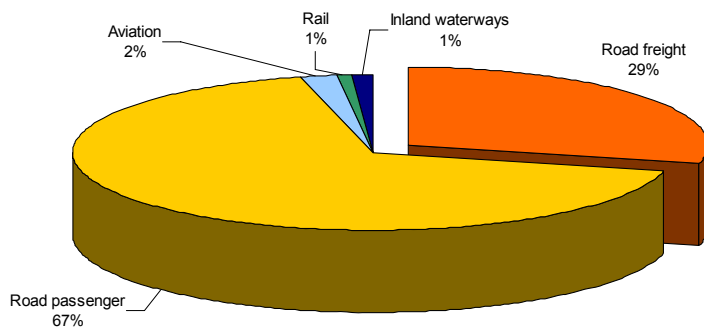
This conversion relates only to those emissions generated directly by fuel combustion. Some studies are also including further processes connected to the greenhouse effect or the production cycle of vehicles. In such cases the emissions factor would need to be increased. But here, the focus is on decisions made by transport companies. Therefore, other less directly influenced system boundaries, such as for example a life cycle analysis, remain excluded from the calculations.

¹ Mb/d = million barrels per day

What is noticeable in the statistics on transport energy consumption (like those of the OECD) is the focus on the Federal German territory (OECD 2002). But out of this, the international air transport generated by the German national economy may consume more than 10 Mtoe per year. Lufthansa alone, one of the world's largest carriers with a fleet of around 400 aircraft, returned consumption figures in 2004 of just under this figure, at 6.5 million tonnes of kerosene. 20% of this volume was accounted for by cargo transport (Lufthansa 2005).

CO₂ emissions in freight transport: When one considers the emissions of the year 2000 for the federal German transport, it is obvious that road with 69% of the total, and road haulage with 29% are the most relevant sectors (Fig. 5). The amounts emitted by road haulage account for around 6% of total German CO₂ emissions.

Fig. 5: CO₂ emissions by transport mode, Germany 2000 (Source: UBA and Stat. Bundesamt 2002)



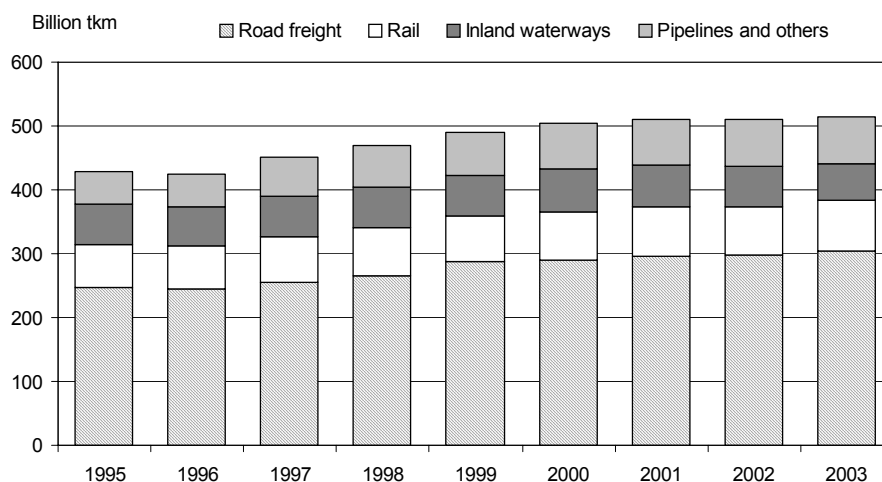
Changes in transport performance

Private transport, as a proportion of the total driving performance, declines continuously in Germany. Driving performance fell from 911 billion person kilometres (pkm) in 1999 to 851 billion pkm in 2003 (Stat. Bundesamt 2005a).

Land freight transport performance in Germany shows a similar pattern over the last ten years. Until 2000, the increase in road haulage was exaggerated in comparison to other carriers. Since 1999, however, the increase in transport performance in total, and also for road transport, has been very slow (Fig. 6). The current total domestic transport performance only reaches a figure of 514 billion tonne kilometres (tkm) (not counting foreign goods vehicles).

In contrast, the air cargo sector has shown dynamic growth, but remains according to federal statistics at the very low level of 0.7 billion tkm (for flights within the federal republic). The "real" figures may well be higher. Lufthansa alone sold a transport performance of 7.4 billion tkm in 2004, with 15 aircraft from its own fleet and others (Lufthansa 2005). This means that the total air cargo transport performance resulting from German economic activity must be calculated at a significantly higher level. The company DHL in particular, a global player with headquarter in Germany, with 420 aircraft of its own and from other carriers, must surely generate significantly higher freight transport performances (DHL 2005).

Fig. 6: Domestic freight transport performance in Germany 1995 – 2003, by carrier



Source: Stat. Bundesamt 2005a

GDP and transport performance growths are equal: It is striking that GDP growth in Germany in the years 1996-2002 (3.23%) shows about the same average development rate as domestic road haulage performance (3.20%). Tapio confirms this coupling of GDP and transport performance in Germany (Tapio 2005).

Is globalisation acting as a motor for growth in road haulage? It is very revealing to look at all national and international transport, generated by the German national economy, which contributes to the developments in GDP and thereby in real terms to total emissions. It therefore becomes possible to check the hypothesis that globalisation and increases in international transport have a structural effect on total demand. Commercial shipping is by some distance the most important carrier for external trade, due to the vast distance by ships, with a performance of around 1,400 billion tkm in 2003 (Stat. Bundesamt 2005a).

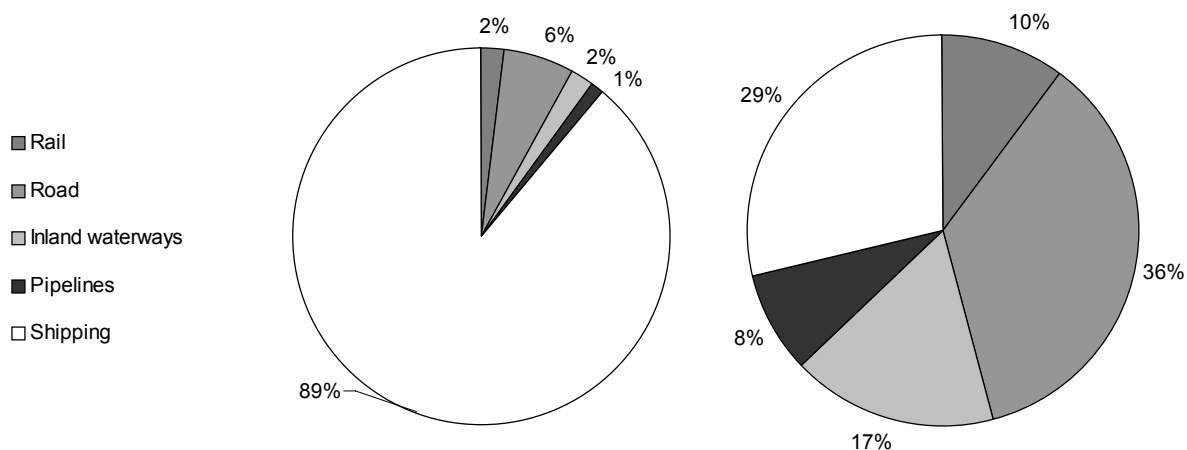
Nearly 90% of all import-export performance, measured in tkm, rely on maritime transport, but only 6% on road transport (Fig. 7, left). For these figures, it must be remembered, that road distances are measured within the Federal Republic only, whereas for shipping transport, worldwide movements to and from Germany are included.

If one takes into consideration only the indicator for domestic and external transport performance (tkm), generated by the German national economy, then the hypothesis of the dominance of globalisation would appear to be confirmed.

If, however, tonnage alone is taken into consideration, then it is certainly true that road (at 36%) and cargo shipping (at 29%) were factors in import and export transport volume in 2003 (Fig 7, right). According to this analysis, the weight of global transport is not as high relative to European transport.

In addition, it can be seen from the tkm time sequences for road freight accounted for by German goods vehicles that import and export transport was subject to a growth trend, but that domestic transport also grew commensurably (Fig 7).

Fig. 7: Modal split in import and export: freight transport performance (tkm in %) (left) and transport volume (t in %)(right) in the year 2003

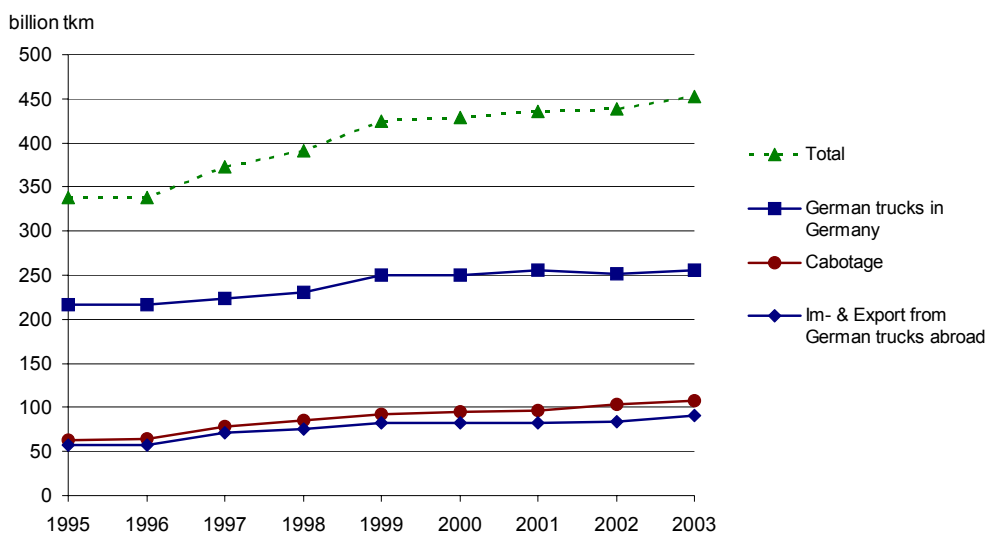


Source: Stat. Bundesamt 2005a

The hypothesis suggesting that globalisation has a structural role to play in the trend of transport growth is correct, but domestic demand still have a clear structural dominance. This does not apply for freight transport as a whole, but only for transport performances per goods vehicle on the road. What is identifiable, however, is the decline in total market share of German goods vehicles on Federal territory since 1999. The lack of domestic growth can partially be compensated for by a sharp increase in German business presence abroad (Fig. 8).

Import-export statistics do not explicitly contain those goods vehicle transport performances generated by foreign companies. Their transport performance in the Federal Republic (also known as cabotage) is currently 107 billion tkm per year, and the tendency is to increase. A classification according to this category is problematic for the statistics results, because such cabotage transport is related to domestic and foreign transport. The estimate for 2003 of through transport levels (from one foreign country to another) of 46.5 billion tkm (BMVBW 2004) is relatively uncertain. It can however be assumed that the globalisation trend and the significance of domestic demand generated by this effect cannot be otherwise interpreted.

Fig. 8: Road transport performance of German goods vehicles in federal territory and abroad (import and export), and performance of foreign trucks in the federal territory (cabotage) 1995-2003.



Source: Stat. Bundesamt 2005a

It appears that globalisation is not the primary cause of growth in foreign transport performances on the federal territory. This might rather be European expansion or questions of new competition. A quantitative analysis of the cost advantages for foreign companies operating on the German transport market indicates that foreign haulage companies enjoy significant advantages in the areas of personnel costs and fuelling abroad (Cloes 2004). This argument was used as the justification for introducing the goods vehicle toll and the system of compensation for German hauliers and forwarding companies.

This analysis establishes that German trends in road haulage have only been little affected by “globalisation”. An analysis of internal transport at the port of Hamburg (presented below) has confirmed the dominance of domestic demand and European expansion, as container transport only accounts for about 3 to 4% of the total demand in road haulage.

In spite of uncertainties, prognoses assume further growth

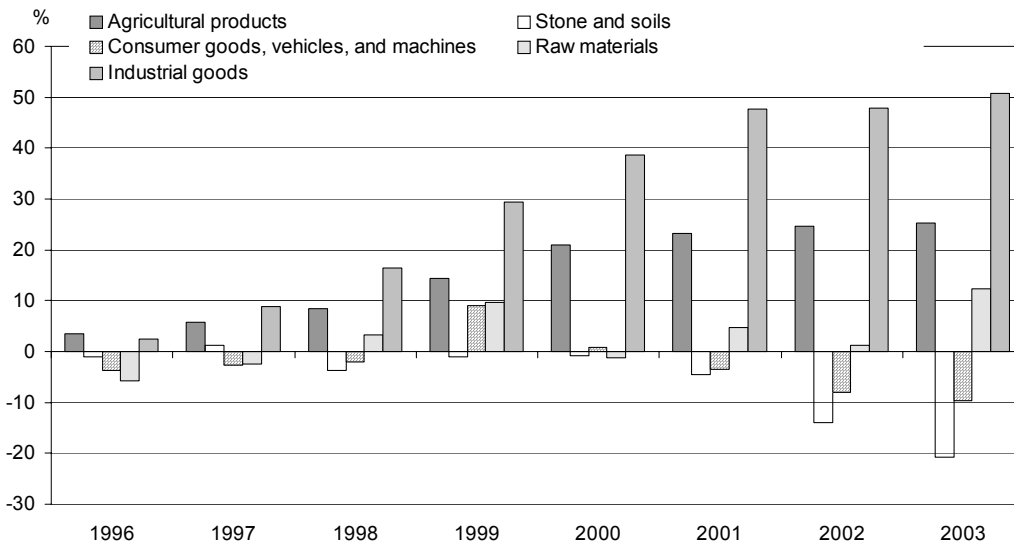
The EU extension of 10 new member states will probably reinforce the trend of increased German transport performance. Prognoses made by the IEA and the “Sustainable mobility Project” of the WBCSD predict a sharp global increase in transport performance; an average annual freight transport growth rate of 1.9% until 2050 is predicted for the European industrial nations (WBCSD 2004). In the face of an annual container transport growth rate in Hamburg of 10-14% - doubling the level of 1998 in 2004 - and annual increases in Shanghai of more than 40% in the last two years, the development could take off in a fully different direction (HHM 2005).

Sea container transport accounts for only a small proportion of German road haulage, but the growth in this sector has been very regular and steep over the last ten-twenty years. Interrelations between the German national economy and other OECD countries are so diverse that long term growth in global demand will certainly have an effect on transport performance, at least for import and export. For this reason, the prognoses (and the growth rate of transport performance of 1.9%) for Germany made in the study *Mobility 2030*, which was carried out with the participation of numerous global players from the oil industry and other industrial sectors, as well as numerous consulting institutions, is probably not very realistic. In any case, numerous past prognoses and scenarios were unlikely to occur, or at least underestimated freight transport development.

Changes in the goods structure

Are changes in the structures of produced goods behind this growth? Vanek and Morlok made such an explanation for the USA (Vanek and Morlok 2000). The starting point chosen by the authors was the individual analysis of the respective share of different goods in transport performance, in order to define more exactly the interrelation between production and transport. The idea is attractive, because there are many possibilities for decision-makers to organise efficiency measures along one production chain. Great potential for efficiency is identified, particularly for products with a high level of energy consumption per tonne kilometre. The opportunity for using this potential can be taken by means of reorganisation.

Fig. 9: Transport performance (tkm) of goods categories in road freight 1996 – 2003 (1995 = index 100)



Source: Stat. Bundesamt 2005a

An important structural change has taken place in recent years in the structure of transported goods in Germany. Transport performance has grown by about 50% in the areas of semi-finished and finished goods, vehicles and machinery (Fig 9). At the same time, the figures for raw materials, stone, and soils have declined slightly, because there has been a reduction in turnover, and also because they are now more transported by other means. Transport performance for industrial goods increased only slightly in the years 1995 – 2003, by 12%. An adjustment in share between the sectors in these years is significant. It can be assumed that the growth in freight transport can at least partly be attributed to changes in goods structure. The literature shows that long-term transport growth is conditioned by trends in goods structure (Deiters 2002). It appears to have the same significance in the period 1995 – 2003 as in the past. This tendency is confirmed by statistics on the development of GDP in individual sectors. The figures also indicate a change in German economic structure. The growth is thus mainly due one larger production sector: consumer goods, vehicles, and machinery. Strong growth is also observable for agricultural products and foodstuffs.

The problem with the analysis of goods structure is that the related detailed energy data are missing. This is because transport companies mostly do not know what kind of goods they are carrying, and the statistics do not allow for such an approach. The actual goods do not feature in the energy statistics on road haulage (Stat. Bundesamt 2005a). It remains actual, therefore, to identify the efficiency potential in the field of consumer goods, vehicles, and machines. It would be worthwhile to carry out a case study into the improvement of energy efficiency in the consumer goods sector. This could be achieved through reorganisation of the production-distribution networks or through modelling different options on spatial structures. Should a pilot activity on this subject be undertaken, transport companies and logistics firm should be involved, together with shippers (transport clients at production and trade locations) and supply chain managers. Such an undertaking would be very complex. Software to simulate such decisions and their consequences for transport volume is available. But consequences for energy use have been neither modelled nor empirically validated.

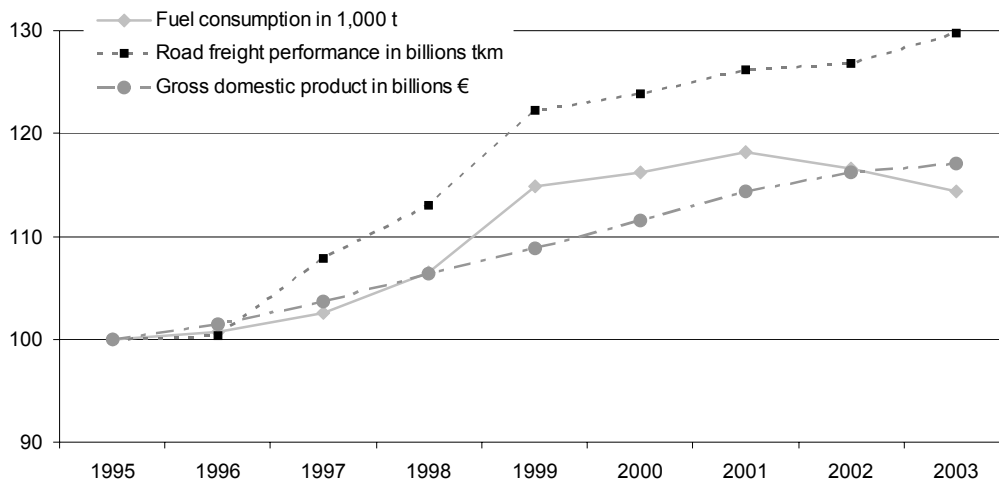
The goods structure approach is therefore valuable for this part of the analysis. It has however highlighted significant limitations due to the non-availability of data. Personal communication from the Stat. Bundesamt 2005, however, states that the data problem will be solved within the next few years.

A goods structure approach would be particular in another way: the principal implementing actors in a transport climate strategy until now were always government and vehicle design engineers. In our approach, both would retreat into the background. A close co-operation between industry, trade, logistics and carriers would be necessary.

Coupling or decoupling of GDP growth (€), transport performance (tkm), and energy consumption (litres) in Germany?

Looking at the total road freight transport of German companies 354 Mrd. tkm was the performance in 2002. For diesel fuel, the total amount of 21.9 billion litres used in 2002 is corresponding to 57.8 billion kg CO₂ emissions. These statistical numbers could be used, only for illustration purposes, to calculate the mean German road freight CO₂ efficiency. This is 6.12 tkm per kg CO₂.

Fig. 10: Decoupling of GDP and transport performance from fuel consumption of road haulage in the German territory 1995 - 2003



Source: BMVBW, 2004

Recently, these three indicators have not been as clearly coupled as in previous decades. Energy consumption has not increased since 2001. In contrast, GDP and transport performance growth remains very clearly coupled in the years 1995 to 2003. On the basis of these territorial German statistics, the hypothesis is confirmed that a decoupling is taking place between, on the one hand, GDP and road freight transport performance growth, and, on the other, road freight energy consumption and CO₂ emissions (Fig. 10).

Until the year 2001, a clear **coupling** between road haulage performance and road transport fuel consumption is confirmed. The correlation of both indicators (tonne kilometres and litres) amounted to $r^2 = 0.98$ for the years 1995-2001 (BMVBW 2004). After 2001, the **decoupling** has become clear, and the correlation amounts to $r^2 = -0.96$ for the years 2001 – 2003. The significance of a reduction of fuel consumption in this short period does not allow the prognosis that the trend in fuel consumption growth has changed in a long-lasting way, because estimates for the year 2004 assumed a rise in total turnover for diesel. In 2005, however, a renewed decline was observable.

There are interpretations explaining this decline in consumption. The SRU, in its recent special report, comes to the conclusion that the German eco-tax has contributed significantly to the reduction, and that “the decline in turnover shown makes a convincing case for the effect of pricing mechanisms” (SRU 2005). It is however open to doubt if the eco-tax is the only cause of decoupling and whether the decline in fuel turnover has also effectively contributed to a corresponding level of reduction in CO₂ emissions from road vehicles on the federal territory. Kloas et al. (2004) show that attempts to side-step the relatively steep price increases in diesel at German filling stations by going to other countries started to happen after the introduction of the eco-tax. In the case of road freight, it is impossible to show whether the amount of refuelling done abroad overcompensates for the domestic decline or not. In addition, the same year saw a massive increase in diesel prices on world markets and in Germany, which means that a cause and effect mechanism also becomes apparent.

The lack of reliable data means that it will be necessary to conduct an empirical test for this decoupling hypothesis. As the federal statistics allows only limited conclusions, it would make sense to conduct a case study and to collect new data in one company. The method of collecting coupled data on tonne kilometres, driving performance, and fuel consumption has already been developed and applied successfully (Leonardi 2005). The socio-economic methods refined specially for this specific targeted survey are presented here in a general context. Details, principles and elaborations on this method can be found in Chapter 3. The same basic approach is used in chapter 4.

2.2 Decoupling GDP, freight transport, and CO₂ emissions: case study from a German company in the years 2001 – 2004

2.2.1 Design of the company case study

From a total fleet of 90 goods vehicles run by the south German company C, 63 vehicles were equipped with telematics devices from 2001 to 2004, and their trip recordings were collected digitally. The telematics data provide for the first time

an exact insight into company C's transport activity during this period. There are some evidence that the data and the insights derived are representative for the German trucking services as a whole, as demonstrated in several following steps.

Company C: the business activity of the south German company C is general freight forwarding, without a particular specialisation. Like each company in this business sector, C is facing stressful competition conditions in the daily business. Planning in advance is not the normal case. Paper and steel are occasionally carried but are not the main part of the business. The density of goods transported is variable. The mean load capacity utilisation by weight varies between 20% and 80%. The years 2001 to 2004 saw no business decisions that would have led to significant changes in the fleet, goods structure, or distance. Company C is owning a very standard vehicle fleet, and was chosen precisely because of this "normality". With the exception of four, the fleet consists in goods vehicles with a GVWR of 40 tonnes. They were in operation to about 90% of the total kilometres driven in Germany, less than 10% in European neighbour countries. Only a small proportion of the distance travelled was in import-export.

Data collection: the data on kilometres driven (km), tonnage (t) or transport performance (tkm) and fuel consumption were collected by using telematics technology (hardware and software). They were digitally recorded in the vehicles and then centrally stored. The data was made available through reports that originally appeared in Excel format. The basis for the data is the respective average performance per goods vehicle in one month. 1,931 individual monthly average sets of data were evaluated. Among other, key indicators for performance and energy use were average tonnage, distance, fuel consumption in litres, unladen vehicle weight, average speeds, and time (month). This set is comparable with the set of key performance indicators used in UK logistics research since many years (McKinnon 2004).

Plausibility testing: in this linked form, the data are only otherwise available in one previous German study (NESTOR base survey Chapter 4). In this other study, the data were not compiled monthly but for a period of 2 or 3 days (Leonardi 2005). A comparison of both sets of data was undertaken for the purpose of establishing plausibility. It was found that the monthly means for the main indicators (tkm per truck, fuel use per 100 km, kg CO₂ emissions per tkm, etc.) lie within the mean value range of the data sets used in the other (base) survey. In the base sample, this company was absent. Therefore, this first step of plausibility testing confirms the assumption that the company could be rather representative for road freight logistics as a whole. Further tests are integrated into the next analytical steps.

Data measurement quality: The telemetric data, when compared to standard socio-economic survey instruments, are of high quality for a scientific investigation (Leonardi and Baumgartner 2004). The method of measuring fuel consumption on board is very precise, with a margin of error of below 1%. Weight measurements deviate by about 3%, but only after 20 km trip length. Therefore all data for trip length below 20 km were excluded from the company C database. The data on distance and speed demonstrate similarly low error values. For the comparison purposes, the data on German gross domestic product (GDP) are given (Stat. Bundesamt 2005a). They relate to the economic activities in the territory of Germany.

Method of calculation: tkm and CO₂ values were calculated from the primary data. Standard deviations from quarterly mean averages were calculated in order to enable a comparison with Federal statistics. For one quarter, first the three monthly means registered by telematics were obtained as direct output from the on board software. Then the mean quarter values were calculated by using the function of the Excel software. The quarterly means figures for the 16 quarters 1-2001 to 4-2004 were then calculated using standard deviation and standardising functions (Figs. 11 – 14).

2.2.2 Results

The transport performances per goods vehicles were around 115,000 tkm per month. The vehicles travelled an average distance of around 11,460 km per month, use 31.8 l/100km and emitted per month around 9.9 t CO₂ on average. In terms of weight, the load factor was up to around 44.8% in 2004. The trends and patterns will be described first. Explanations will then be presented with a causes-effects analysis, and study and interview evaluations (chapter 2.2.3).

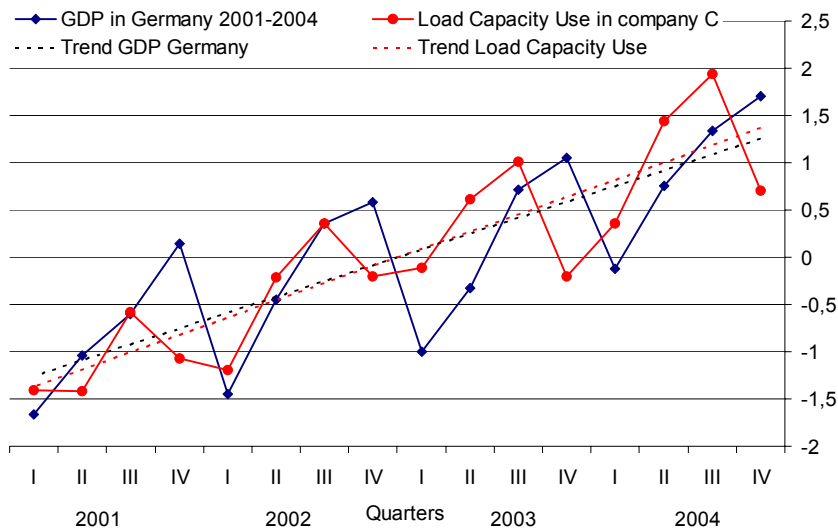
Gross domestic product (GDP) and load capacity by weight

As usual, the load factor varies for each trip, and the telematics software gives an average total vehicle weight per trip. The vehicle's total weight (in tonnes) is recorded by the telematics instruments on the basis of braking momentum. The effective load was then calculated by subtracting the empty weight from the total weight. If the load for every trip is known, then its value as a proportion of the maximum load (total permissible weight minus empty weight) is calculated in %. The average monthly values of capacity utilisation (in %) are calculated and finally standardised per quarter.

What can be observed are a cyclical interlinking and an almost perfect correspondence between the four-year trend in German GDP development and the capacity utilisation of Company C's vehicles. It is difficult to compare Company C with average federal figures because the annual figures on capacity utilisation by weight are not available for all German freight

vehicles. Therefore, an estimate of the situation on Federal territory cannot be made alone on the basis of more details, nor can it be derived from other sources. The content of the information gained by these means is thus innovative.

Fig. 11: Strong link between GDP and capacity utilisation by weight in companies



Source: Stat Bundesamt 2005b, Survey 2005

What was not possible to clarify with the company representative, is why a decline in capacity utilisation begins one quarter before the corresponding decline in GDP.

Transport performance of company C vehicles and German road freight transport performance

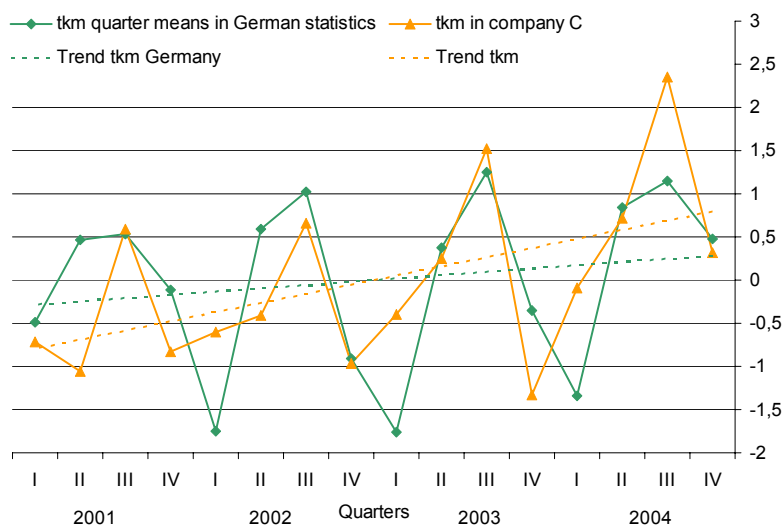
The “real world” total transport performance (P_{tkm}) per quarter was measured in tonne kilometres for each vehicle. It was calculated using the formula

$$P_{tkm} = (t_1 * km_1) + (t_2 * km_2) + (t_3 * km_3)$$

Where t_1 = mean load weight in tonnes for the first month (t_2 for the second month etc.) and km_1 = distance for the first month (km_2 for the second month etc.)

This calculation is differing from the Swiss model for tonne kilometre calculation for HDV taxation. In Switzerland, the duties are calculated as if the vehicle were always operating with a full load; that is, at 100% of its carrying capacity (ARE 2002). In this way, the tkm values are fixed theoretically but not as they are in reality. By contrast, what we get for company C in this survey are the tkm values per vehicle with a low margin of error.

Fig. 12: Trends in road freight transport performance in Germany and in the case of Company C.



Source: Survey 2005, ECMT 2005

A comprehensive measurement was required to determine the monthly values t_1 to t_3 for each quarter. Only when all the individual transport performance of each trip within one month are added together, then the real tonne kilometre performance of a vehicle can be obtained. Each loading and unloading procedure within a given run needs to be included and the distance between them measured and recorded, if this condition is to be fulfilled. This value is so difficult to monitor that most of the companies do not know them exactly. In the case of company C, this gap can be closed technologically by the use of telematics. However, only few companies own such technology. As the definition of tonne kilometres varies widely in the literature on the subject, close attention must be paid to the particular characteristic of telematics data. This technology makes it possible to calculate the real transported load weights in combination with the distance. It thus becomes possible to work out the values precisely and thereby to obtain the “real” tonne kilometre performance.

The tkm value statistics for Germany are not nearly as reliable, because the primary data are based on compulsory figures submitted by companies, which were manually entered into questionnaires. An informative comparison is that between the statistical quarterly values (ECMT 2005) for the freight transport performance of goods vehicles within Germany and the same tkm values for Company C on the basis of performance per goods vehicle (Fig. 12). This comparison allows a further plausibility test and an interpretation of the differences between federal statistics and those in companies to be made.

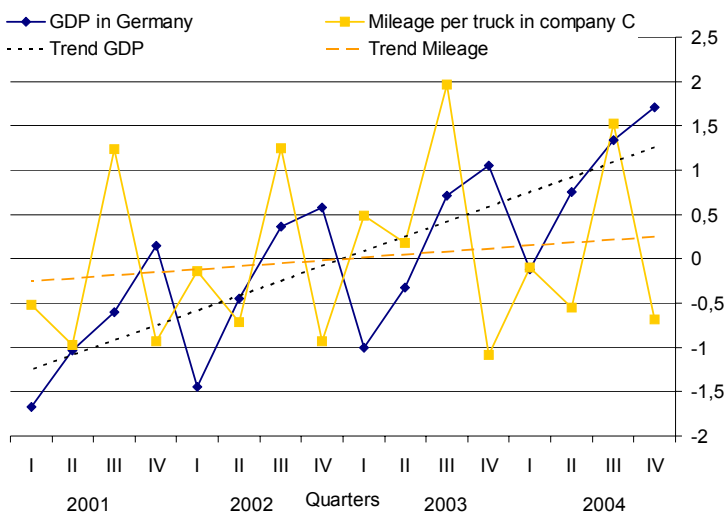
- Total German tkm and transport performance of company C increase at about the same rate over 4 years
- Both quarter means curves demonstrate a well-developed, rather similar annual cycle of the business
- This rate is only very slightly below the GDP growth rate
- Thus, tkm curves and trends compared to GDP are leading to a somewhat “no-decoupling” observation
- The increase in Company C transport performance (as in capacity utilisation by weight) takes place a quarter before the corresponding increase in total German tkm
- The amplitude of the annual cycles in the company C is slightly more increasing compared to national figures, this increasing amplitude is more visible for transport performance than for capacity utilisation
- These small differences between the German mean performance and the performance of company C lead to the confirmation of its potentially good representativity for road freight transport. Other criteria will be checked.

GDP and distance

Distance per goods vehicle per quarter is recorded by telematics data. Its relation to GDP growth is in fig. 13.

- Distance per goods vehicle increases significantly less than GDP. A partial decoupling between distance and GDP can be observed, as well as between distance and capacity utilisation by weight. As the distance travelled goes hand in hand with negative affects brought about by transport growth, this slight decoupling from GDP means a relative reduction in negative transport-related effects. One cannot however talk in terms of a net reduction in negative transport-related effects, because, amongst other reasons, the four-year trend in quarterly distance per vehicle is still an increasing one. We can assume a stagnation of the total distance per vehicle, but due to fleet number increases, the total fleet distance in Germany might be continuing to grow. The statistical German data to verify this hypothesis is not very reliable.
- Each year, the distance travelled in the second quarter is less than that in the first. This results in an atypical seasonal pattern when compared with GDP.

Fig. 13: Slight decoupling of GDP and distance (distance) per truck in company C



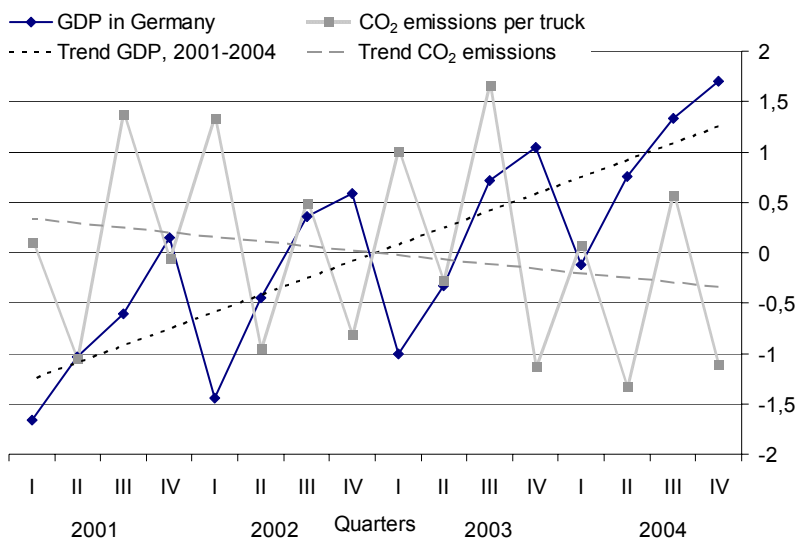
Source: Stat. Bundesamt 2005b, Survey 2005

GDP and CO₂ emissions

The total amount of CO₂ emissions per goods vehicle per quarter was calculated on the basis of the recorded fuel consumption data of each trip, with the same method.

- A net reduction in CO₂ emissions per goods vehicle can be observed, in opposition to the slight rise in GDP. The decoupling effect is pronounced in these four years. This confirms the decoupling trend observed with national statistics data, presented in figure 10.
- The mean CO₂ efficiency recorded in the period 2001-2004 for all 60 vehicles is 11.6 tkm/kg CO₂. This value is less reliable than the findings from the general survey, as the tkm has not been measured by including all load and unload movements, but only calculated by multiplying the mean tonnage of each day by the distance.
- A substantial reduction in CO₂ emissions can be observed in the second quarter of each year. This reduction is so large that it presents a significantly different seasonal pattern in comparison with the other indicators. The fluctuation occurs on a six-monthly basis.
- The decoupling is not only observable for the four-yearly trend, but for the pattern of the annual variations as well.

Fig. 14: Decoupling of German GDP from CO₂ emissions per vehicle in company C

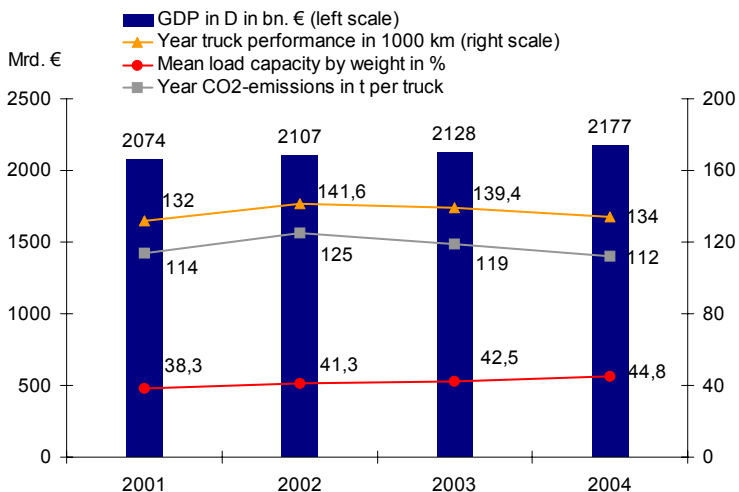


Source: Stat. Bundesamt 2005b, Survey 2005

Analysis of key annual data for Company C and the development in German GDP

Collecting annual data was leading to new conclusions, because these data reveal another trend in the same set of indicators (Fig. 15). First the annual data contain the GDP figure for Germany. Secondly, distance and CO₂ are given as a mean annual total amounts per vehicle in company C's fleet. The capacity utilisation data are calculated as a percentage of the total permissible laden weight averaged out over all goods vehicles.

Fig. 15: Annual figures comparing key indicators for Company C with German GDP



Source: Stat. Bundesamt 2005b, survey 2005

- Yearly distance per truck is reduced to 134.000 km and CO₂ emissions per truck to 112 t per year in 2004.
- CO₂ emissions values are 0.882 kg/km in 2002 and 0.835 kg/km in 2004, confirming a slight fuel efficiency improvement per km.
- According to the Stat. Bundesamt 2005b, GDP grew in this period by about 1 to 2% per year
- Distance only decreases after 2002 but does not fall below the level recorded in 2001
- CO₂ emissions decrease after 2002 and fall below 2001 levels
- company C's average capacity utilisation by weight increases in from 38.4% to 44.8%. This could have had a negative influence on fuel consumption per km, since a heavier truck needs more fuel per km. As it is not the case in total, this leads to the conclusion that fuel efficiency increases from 2002 to 2004.

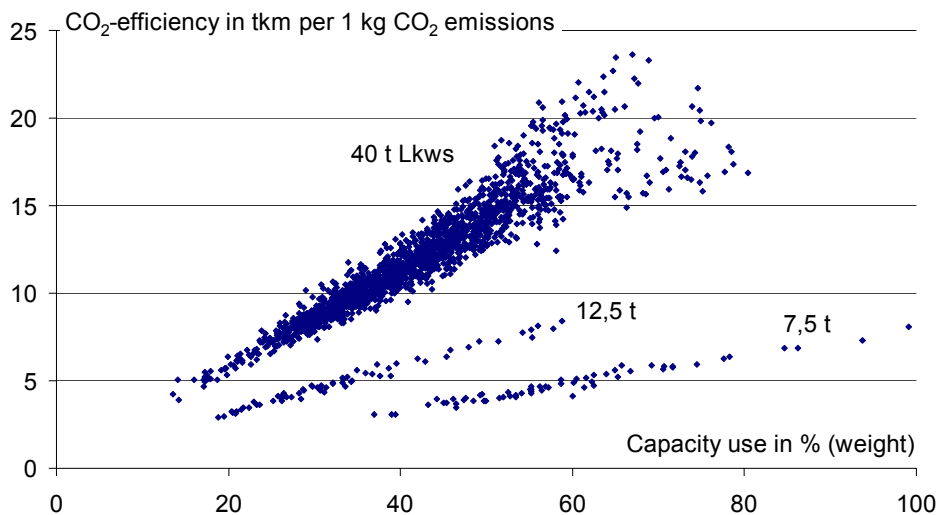
Another cause influences this result: The increase in capacity utilisation is, for other reasons, the cause of the reduction in CO₂ emissions and the lower distances travelled per goods vehicle. How this conclusion is reached, is shown below.

CO₂ efficiency and capacity utilisation by weight

The interrelation between these indicators is more complex than in previous analytical steps, because three dimensions are presented in a unity: CO₂ emissions, transport performance, capacity utilisation by weight. These indicators are always considered separately in standard analyses and statistics. The following analysis attempts to integrate them. In line with the definition of efficiency presented above, the **CO₂ efficiency indicator** is calculated by using the consumption in litres multiplied by the emissions factor 2.64, and the transport performance. The CO₂ efficiency is measured in tonne kilometres per kg CO₂ emissions. Also calculated is the level of transport performance generated during the emission of 1kg of carbon dioxide. The higher the value in tkm/kg CO₂, the higher the efficiency. In publications, the opposite method of indicator calculation is used, in other words, how many kg of carbon dioxide are emitted per tkm. The principle is the same, but the disadvantage is that efficiency increases when the values decrease. For this reason, the reverse formula is used here.

The monthly CO₂ efficiency averages were calculated for all of the 1,931 datasets obtained for HDV in company C. The efficiency values vary between 3.9 and 23.6 tkm per kg CO₂ (Fig. 16). Most of the values lie in a range between 5 and 20 tkm per kg CO₂, which means a **factor 4** between the most and least efficient monthly mean.

Fig. 16: Interrelation between CO₂ efficiency and capacity utilisation by weight



Source: Survey 2005

The raw data show significantly worse efficiency values for good vehicles with a total weight of 12.5 t and again for those with a weight of 7.5 t. In the case of small trucks, improvements in capacity utilisation do not lead to a sharp improvement in CO₂ efficiency. The reason for this is the configuration of vehicles on the basis of legal requirements for delivery vehicles in city centres, particularly their unfavourable relation carrying capacity – empty weight. A 7.5 tonner, for example, has a tare of 5 tonnes and a maximum carrying capacity of only 2.5 tonnes. This low efficiency confirms the results of the empirical investigation carried out in 2003 (Chapter 4).

The illustration also shows that a higher CO₂ efficiency rate can only be achieved in the case of Company C when very good figures in capacity utilisation by weight (of around 60%) are reached. This monthly mean load factor of 60% does not necessary mean, however, that the CO₂ efficiency value is much higher than it is the case when the monthly mean load

factor is only 50%. With increases in capacity utilisation, further influencing factors are also affecting the efficiency. The most important one are driving behaviour, whether the vehicle is in use in local or long -distance haulage (city, trunk road, motorway), driving conditions (congestion), and particularities of the road network. See chapter 4 for further efficiency influencing factors.

Increasing capacity utilisation is therefore a necessary precondition for improvements in efficiency. It will be difficult to increase the mean capacity utilisation. How this can succeed is to be found out by further surveying the influencing factors and framework conditions like time, general market rules and specific business settings. A more precise qualitative part of this study is necessary for these reasons.

As direct consequence, **increases in efficiency** and the further decoupling of transport performance from emissions will only be possible, if capacity utilisation increases at the same time through targeted optimisation measures.

2.2.3 Analysis of causes, evaluations and interpretations

What are the reasons behind

- The coupling of GDP and capacity utilisation trends observed?
- The decoupling of GDP from energy consumption at the vehicle level?

In order to establish and to understand these causes, study results were evaluated, data compared, and interviews carried out with those in positions of responsibility in the company and with German experts. This analysis is to be continued but has already provide following explanations.

Changing **energy efficiency** is an important process in the company. Company C does not have any explicitly pro-active logistical or technical measures in place to increase efficiency, but organisational decisions on scheduling influenced it. Furthermore, the company made investments in telematics systems, and purchase new vehicles. A previous before/after study (Leonardi et al. 2004) established for businesses across Germany that an increase in CO₂ efficiency of around 10% was achieved in the year after the installation of telematics and scheduling systems. The same amount of energy was consumed with a higher capacity utilisation by weight but in the same distance travelled. A net reduction in energy costs per unit of transport performance (tkm) was established for the time when the “after” study was carried out, which of course meant an advantage in terms of costs. Whether this is also true for the company surveyed is not clear, because the tkm data for the period prior to the installation of the telematic system are missing. Taken across the company C as a whole in the years 1999 (before) to 2001 (after), key indicators for the energy efficiency question show following values:

- Load volume in t: +18%
- Distance in km: +1.2%
- Fuel consumption in l: +5.3%
- Fleet (number of goods vehicles): 0% (unchanged)

The energy efficiency improved because the tonnage increased much more than the fuel consumption. The modest increase in distance is an equally good sign of efficiency.

The **increases in Company C’s fleet size and turnover** corresponded closely to the rate of economic growth for the years 2001 to 2004. When a new vehicle is purchased, energy saving motors and the overall design of the truck control energy consumption. Furthermore, the various regulatory instruments such as EURO IV and the voluntary commitment of the manufacturers to emissions reductions influence improvements in technology. But the strength of the post purchase effect for a company as a whole cannot be definitively demonstrated. It is important that Company C bought new goods vehicles at irregular intervals. One can plausibly assume from this that improvements in vehicle technology only leave visible traces in long term trends, and are therefore invisible in quarterly averages of efficiency values. Because of the pattern of CO₂ emissions, and tkm and km performances, which fluctuate regularly during each year, there must be another substantive cause than new truck and new technology behind the decoupling. New vehicle purchases can accordingly only have had a secondary influence.

The **goods structure** and the composition of the goods transported remained heterogeneous during this period. Assumed is a Germany wide long-term trend towards less dense goods. As this company does not regularly carry heavy mass goods like steel, building materials or agricultural products, no unusually heavy loads were transported. This means that the efficiency changes due to weight or load density changes are not expected. However, there is an important uncertainty here.

The **average load factor by weight** fluctuates for each vehicle and each month. The total average value of all 1,931 monthly average values in the 4 years 2001 to 2004 was 44%. This includes empty runs and the value is significantly below

the Federal average of load factor by weight, which was given for all freight transport vehicle types above 3,5 t, as 66% for 2003 (DSLIV 2005). There is some evidence that the company and its load factor figures are representative, and that its way of improving efficiency can in principle be adopted by every other company.

The problem with measuring **distance by truck** lies in the absence of accurate information about the business' total distance (km). As long as not all company's vehicles are connected to a telematic system, and the data collection system is not "standardised" over a number of years, this information gap will remain. For this reason, only relative statements can be made about increases or decreases in the road network use intensity. Due to the low growth in the German freight vehicle fleet, it can be assumed that the burden caused by road haulage has increased in a similar way. This is a well-known effect in the field of research on the subject of transport and energy (Kloas et al. 2004). Increases in vehicle numbers overcompensate for efficiency gains at the vehicle level.

The cause, as has been demonstrated above, is the **increased demand for freight transport performance** (in t and in tkm) on the national level and in GDP. Further causal processes in demand development are, for instance, the expansion of the EU and increasing material throughput in the economy (Tapio 2005). There have only been a few quantitative studies on the regional level. The decoupling study undertaken by the OECD five countries including Germany established that the growth in transport performance (tkm) in each country between 1985 and 1995 was between 30% and 60%. There were however different reasons for this growth (OECD 2004). In Germany, the principal causes were the increase in road transport in comparison to rail and the increased distances travelled per shipment. In general, the EU statistics on energy and transport establish a somewhat decelerated, but still robust, growth in road haulage performance in comparison to GDP (EU 2005). In recent years, according to the EU, there has been a clear coupling between both indicators at a growth level of around 2 to 3% annually. According to the OECD report, German freight transport growth is subject to the influence of the following factors: increases in production, longer distances travelled, globalisation, market integration, investments in infrastructure, and, above all, changes in logistic practices. This interrelation has been statistically underpinned (OECD 2004).

2.2.4 Intermediate conclusions: decoupling is recorded at the vehicle level, but not clearly established for the level of entire businesses and sectors

Total diesel consumption in freight transport in Germany is probably not declining, due to the phenomenon of "diesel tourism" (buying diesel in neighbour countries to avoid high taxes) (Kloas et al. 2004). It can be assumed that the observed trend in decoupling on the basis of individual goods vehicles and the specific data provided by the company do not represent a 100% accurate overview of the whole situation. Which strategic considerations does this imply? Answers to this question may vary depending on how wide the approach is, from the global-scale level to that of the individual driver.

On the company level, numerous efficiency measures can be introduced to influence the demand for transport performance, measured in tonne kilometres, without a negative impact on the order situation or company turnover. Foremost is the logistical configuration of business transport organisation or of whole chains of production and supply, with the corresponding network patterns and the decision-making system concerning locations, times, and products. At the level of individual storage area, locally, a high influence on transport performance can be reached, for instance, by the definition of processes and of the scheduling system for individual runs, the purchase of new vehicles, and the coordinated choice of routes. Even the driver can directly influence the tonne kilometre performance by his individual route choice.

Company C only marginally increased the size of its fleet, and it remains unknown if this increase have compensate for the improvements in efficiency per vehicle. There is probably no total net reduction in emissions and negative environmental impacts. If we wish to draw conclusions from these results for the whole road haulage sector in Germany, we would have to make projections. In any case, uncertainties in the statistical data on turnover, tonne kilometres and distance would not permit sufficiently reliable insights. The difficulties in accounting for "diesel tourism" and the other established statistical uncertainties do not, however, give any fundamental grounds for doubting the results of the investigation at the level of individual vehicles. The cross-check with other small survey samples, collected independently from company C, and presented below, will show how to overcome some of these data uncertainties.

For the question if a decoupling trend in German freight transport is observable or not, the data provide some evidence that individual goods vehicles consume on average less fuel for the same performance. However, a net reduction at the Federal level is not to be expected. Further political steps are needed for attaining a net tkm demand and CO₂ emission reduction.

3. CO₂ reduction and efficiency in road haulage: results of surveys

3.1 Typology of efficiency measures and technologies

Measures that can be implemented to reduce the CO₂ intensity of freight transport are divided in two large groups: measures introduced by public authorities e.g. road tolls, taxes or speed limits, and those introduced by businesses themselves. From the perspective of companies, improvements in efficiency and reductions in fuel costs are of high priority, for short-term cost-benefits reasons. It is daily practice to apply packages of measures including several individual measures. This is one of the reasons, why it remains difficult to quantify the individual contribution of each measures. The study focus on the analysis and measurements of efficiency measures from companies. An overview can be presented over the multiplicity and diversity of individual measures. They can be categorised according to the CO₂ emission factors. In this overview, individual concrete measures and technologies can be fitted into categories. The list presents seventy-six categories of efficiency measures identified in the course of the surveys (tables 3 to 5).

To the measures influencing CO₂ emissions per kilometre belong technologies, plans, and systems that have an effect on fuel consumption or on the sort of fuel used. Examples would include driver training (ecodriving), using biodiesel, or switching freight transport to the railways (tab. 3). Because these measures influence the total distance, they can be seen as measures influencing the transport demand. But they are not related to the payload demand.

Table 3: Technologies, measures, and systems aiming at CO₂ reduction per km per vehicle

Changes in driver behaviour

1. Driver training (ecodriving)
2. Introduction of a bonus system to promote low consumption driving
3. Use of an autopilot (cruise control)
4. Introduction (and respect) of a speed limit
5. Use of on-board systems to monitor fuel consumption

Optimisation of vehicle running condition

6. Use of on-board systems to monitor tyre pressure
7. Use of on-board systems to monitor engine performance
8. Reduction of maintenance intervals
9. Introduction of pro-active maintenance, supported by software systems
10. Reduction in maintenance needs in the course of production

Changes in fuel without changes in vehicle technology

11. Use of biodiesel instead of normal diesel
12. Use of super diesel instead of normal diesel

Technical changes to existing vehicles to achieve reductions in fuel consumption

13. Fitting a roof spoiler
14. Using low resistance tyres
15. Use of high performance lubricants

Purchase of new vehicles

16. New vehicles (combinations) with low empty weight and better carrying capacity/ empty weight ratio
17. Vehicles with lower fuel consumption and standard diesel engines
18. use of vehicles with multi-point injection
19. use of electric hybrid systems with storage capacity
20. use of electric vehicles
21. use of natural gas powered vehicles

Shifting freight transport from road to other modes

22. shifting direct transports (lines) onto rail
23. using rail in “accompanied” combined transport (CT) (with truck drivers in the trains)
24. using rail in not accompanied CT with containers or semi-trailers
25. shifting direct transports to inland waterways
26. using inland waterways for CT with /without containers
27. shifting direct transports to “short sea shipping”
28. using short sea shipping for CT with containers
29. using short sea shipping for transport of bulk goods with pre-run or post-delivery by road
30. using complex transport chains with the use of more than two or one changing combination of carriers
31. using underground distribution systems
32. using automated guided vehicles (AGV) on or between company sites

Shifting from rail to other carriers

33. using inland waterways rather than rail transport
34. using short sea shipping instead of rail transport

Other measures relate to technological systems to increase the capacity utilisation by weight (tab. 4). This achieve the goal of reducing the number of kilometres driven per unit of transport performance. The load capacity increases, if empty or partially empty runs are avoided. In this way, distance is reduced whilst maintaining the same payload (level of orders). Starting points here are organisational bundling of load streams along networks and transport chains, and, above all, increases in the quantity of transport orders that can be scheduled. This can be achieved by e.g. company growth, co-operation, or by outsourcing the logistical management to a fourth party logistics provider.

A large number of efficiency measures can only be put into effect in combination with the control of processes by means of IT systems including hardware, on board systems (telematics) and adapted software. Measures for improving the density of the payload represent another approach for increasing the level of capacity utilisation.

Table 4: Measures and systems to improve the load capacity of vehicles, aiming at CO₂ reduction per tonne-km

Optimising scheduling system

- 35. Use of software to support manual scheduling systems
- 36. Use of semi-automated scheduling software (route or/and tour optimisation system)
- 37. En route scheduling with the help of on board systems or telematics
- 38. En route scheduling with the help of mobile phones
- 39. Including driver availability into resource planning
- 40. Implementation of integrated process and data management systems
- 41. Use of track and trace systems

Improving the payload density (to reduce the volume capacity needed for one tonne of freight)

- 42. Use of a density optimisation software
- 43. Implementation of packaging and density optimisation by means of packaging technology or product design
- 44. Relocation of a plant to the proximity of the customer (transport in kit form)
- 45. Adapting unit loads to the dimensions of the transport mode employed
- 46. Adapting the dimensions of the transport mode to the unit loads

Bundling goods streams

- 47. Use of a hub and spoke network with or without permitted direct transport
- 48. Adding a hub or a sequence to a network
- 49. Reducing the number of sequences in a network
- 50. Shifting locations within a network
- 51. Use of a cross-docking concept with collection from the supplier and trans-shipment
- 52. Use of a cross-docking concept in which the supplier delivers to the cross-dock
- 53. Breaking up transport streams before the “last mile”

Increasing the volume and quantity of available resources

- 54. Using a closed logistics and transport co-operation
- 55. Using an open co-operation network
- 56. Participating in an alliance with or without resource pooling
- 57. Participating in a city logistics co-operation
- 58. Informal co-operations in individual cases
- 59. Using open electronic freight exchanges
- 60. Participating in a closed freight exchange with GPS based order allocation
- 61. Building purchasing co-operations
- 62. Building supply co-operations
- 63. Co-operating in horizontal global networks

Logistics management spanning more than one company (process or supply chain orientation) (Rizet and Keita 2005)

- 64. Customer takes responsibility for managing the supply chain logistics processes
- 65. 4PL undertakes the management of procurement, distribution and logistics processes
- 66. Outsourcing of warehouse or transfer of operations to a logistics provider
- 67. Outsourcing of transport services to a freight carrier
- 68. Process chain driven by the customer (implementation of the pull principle)

Differentiation strategies

- 69. Multi channel distribution
- 70. Product customising

Some measures are related to the organisation and influence directly the transport demand in tonnage or kilometres (tab. 5). As part of a package of measures, they influence the general framework for physical movements and thus the CO₂ reduction potential that could be achieved. In the course of company interviews, it was confirmed that the firstly developed typology of the individual reduction measures were corresponding to most of the real changes in the last years. However, the list is showing only potentialities, not a certainty for CO₂ efficiency improvements.

Table 5: Further technologies, measures, and systems to improve the CO₂ efficiency of transport

Measures and systems for reducing the demand by tonnage or kilometre

71. Cluster formation
72. Selection of those customer or supplier relations that lead to “efficient” transportation
73. Reducing vertical integration at any given business location
74. Supply chain management
75. Global procurement and distribution

Technologies for reducing CO₂ emissions per tonne transported goods

76. Increasing the load volume of the truck used (“megatrailers”)

3.2 CO₂ efficiency in road haulage: general survey, results, analysis

3.2.1 Introduction, methodology and sample description

The aims of the general survey carried out in spring 2003 were the quantification of the CO₂ efficiency of German haulage companies and the verification of the main hypotheses. This general survey is referred to as the “base analysis”. In the survey, empirical data on fuel consumption were collected in journey-specific dependence with the main transport and performance parameters. This enable the measurement of the influence of parameters like load capacity on CO₂ efficiency. The results are intended to provide a comparative basis for calculations of the efficiency potential of the “IT scheduling” and “co-operation” efficiency measures (next chapters).

It was necessary to obtain new primary data because no measurement data on fuel consumption were available under “real life” business conditions from any other source in Germany.

Methodology: statistical population

The statistical population of the base analysis is made up of hauliers located in Germany, with own fleet consisting in freight transport vehicles between 3.5 and 40 or 44 tonnes GVWR. Special vehicles (dangerous goods, etc) were left out. Up to 30.000 road freight transport companies were estimated to be active on the market by diverse sources in 2002, but no indication was available on the number of companies with own fleet.

Data survey

The survey consists in the collection of primary data on fuel consumption, transport performance, the logistics context, the company. Questionnaires were distributed to hauliers and the drivers completed them. On the questionnaire, the driver note at each stop the distance, the tonnage of each loading or unloading operation and the estimated load capacity by volume of the vehicle. One questionnaire was filled between two refuelling points. Record duration was between two and four days.

A precise dataset was compiled. The indicators of relevance to CO₂ were payload (in tonnes), distance (in kilometres), consumption in litres, volume utilisation ratio estimate, vehicle type and tare, and type of business.

In addition, a phone interview was carried out on the measures implemented by the companies to reduce fuel consumption. During the survey, 52 businesses with usable data were interviewed.

Acquisition of participants, sample description, and representativeness

Potential participants in the enquiry were randomly selected within Germany, using the following sources:

1. Internet databases: www.transportunternehmen.de, www.transport2010.de, www.luebeck-logistik.de, www.transportadressen.de, www.vshhamburg.de (Verband Straßengüterverkehr und Logistik eV), www.gelbe-seiten.de
2. Business listing: Seehafen Verlag/Verein Hamburger Spediteure eV/Verband Straßengüterverkehr Hamburg eV (2001): quer durch Hamburg Spedition und Transport. 29. Auflage, Hamburg

The contact of 230 selected businesses was carried out by phone. By interest, the potential participating company receive a sample copy of the questionnaires. Then, the encoded questionnaires were sent. The performing of the measurements and open questions were clarified by phone. After a period of four weeks and if the documents were not returned, then a reminding call was made to the business concerned.

The 65 businesses, which received questionnaires, are located all over Germany. No weighting was given to any particular region or size of company, nor was any company excluded from participation on that basis. It was far from easy to get

companies to participate at all, due to the existence of significant negative opinion concerning environment and research matters. It was therefore crucial to clarify the cost benefit ratio of such participation. Main argument here is the explanation that the company will receive the results on how much savings the concurrence was able to reach, and where they are now compared to them. Out of all companies randomly selected and contacted by phone, 16.5% sent back usable documents (tab. 6). The sample consists in 153 completed questionnaires from 38 companies, and one dataset on the measures implemented for 52 companies, collected between March and May 2003.

Table 6: Sample size and return rates of the base analysis

	Total	in %
Businesses contacted, in total	230	100
• Businesses agreeing to participate	65	28.3
• Businesses with responses to the questions about measures taken	52	23
• Businesses, which sent back usable questionnaires	38	16.5
Data questionnaires sent out	336	100
• Of which: returned and usable	153	45.5

Source: Survey 2003

Data correction and exclusion criteria

During the measurement period, the vehicles were driven on average 2 to 4 days (per set of data), covered an average distance of 1121 kilometres each and used on average 354 litres of diesel between the two refuelling points.

Some data (<2%) were left out of the evaluation of the base analysis, due to unusually high or low fuel consumption. It cannot however be ruled out that there may be large numbers of specialised road freight transport vehicles in an industrialised country like Germany, which, due to particular installations (cranes, compressors etc.), demonstrate unusually high consumption levels. Five datasets were excluded from evaluation due to the use of biodiesel (see section on biodiesel). The following results from the base analysis are derived from the figures submitted in 153 completed sets of data.

Characteristics of the businesses

The businesses that participated in the base analysis can be categorised according to size (tab. 7). The key factor in this categorisation is the fleet size of the business or branch. The categorisation is derived from the statistics provided by BGL (BGL 2002): a small business possesses a fleet of up to ten vehicles, medium sized businesses have between eleven and 50 vehicles. Large businesses operate more than 50 vehicles. These categories are represented in the sample as follows:

Table 7: Road haulage companies size distribution in the control sample and in Germany

	Distribution in the sample in %	Distribution in all German road haulage companies in %
Small (<10 vehicles)	43,3	87,1
Medium (10 to 50)	43,3	11,9
Large (>50)	13,3	1,0

Source: Survey 2003; BGL 2002

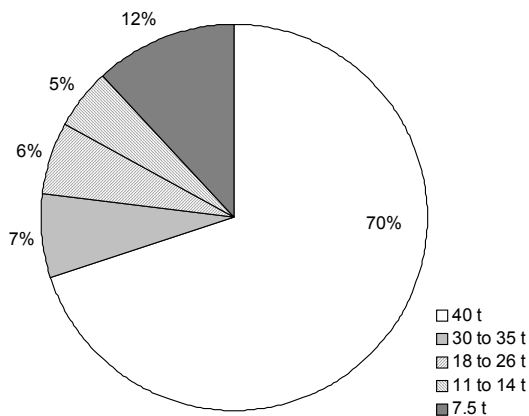
The comparison between the sample and the statistical population clearly shows that small companies are under-represented in this survey, compared to their presence in Germany as a whole (tab. 7). However, as large companies account for a much greater distance than small ones, the representativeness of the survey is only slightly affected. However, a larger sample would be necessary for providing a representative assessment of the German freight transport companies.

Not all economic sectors are represented in the sample. Even if a sector is represented, this is never matching exactly its share on the road freight market. Sectors represented are logistics, freight forwarders, container transport, construction, trade, and few other sectors (food, chemicals etc.). The distribution of the sectors in the control sample shows that every second measurement was carried out in the logistics/freight-forwarding sector (47.5%). This sector is also referred to as general cargo. Many companies surveyed include both full truckload and less-than-truckload activities. Trade (14.5%), container transport (16.5%), and other sectors (e.g. construction 14.5%) are roughly equally represented. Amongst the missing types of company are CEP services, and companies with small vehicles, which account for a large proportion of German vehicle fleets, but for a relatively small proportion of total tonnage.

Fleet, distance, and performance in the control sample

The total distance of the vehicles of all the companies included was 177,124 kilometres and the fuel consumption 55,989 litres of diesel. They emitted a total of 147,811 kilogrammes of CO₂. They accounted for a total of 1,668,193 tonne kilometres. This figure represented a proportion of 1:270,000 of the total German figure of about 450 billion tkm for 2003. The vehicles in the control sample were on average 3 years old, with an average tare of 13.8 tonnes and an average GVWR of 34.2 tonnes. Not all GVWR classes were represented (fig. 17). Over two thirds of the measurements were carried out on vehicles with a maximum permitted weight of between 40 and 44 tonnes. 44 tonnes is the maximum value, permitted in particular cases for container transport. Usually, 40 tonnes is the upper limit. The transport performances (in tkm) of the 40 tonne vehicles are, according to the available statistics, much higher than all other classes of vehicle. This is also true for the control sample, so that the representativeness related to transport performance is stronger. As this criterion is decisive for efficiency analysis, the survey can be considered as representative.

Fig. 17: Vehicles classes in the sample, by GVWR



Source: survey 2003

3.2.2 Market overview: efficiency measures introduced

Road haulage companies can achieve reductions in fuel consumption, and thereby in CO₂ emissions, by implementing numerous efficiency measures (tab. 3 to 5). They were asked how far they applied some of the efficiency measures, at least in part of their fleet or with regard to their drivers, during the last two years (tab. 8).

Table 8: Market overview: the implementation of efficiency measures in German companies

	% of firms		% of firms
Technical improvements (oils, tyres, spoiler)	54	Others	15
Driver training	52	Modal transfer (road + rail / shipping)	15
Informal co-operation	40	Semi-automated scheduling with telematics	10
Bundling goods streams	27	More frequent maintenance	10
Manual scheduling with IT support	23	Stacking area (density) optimisation software	6
On-board-systems	17	Formal co-operation	4

Source: Survey 2003; more than one answer is possible

Every second company improve the techniques (e.g. buying high performance oils or low resistance tyres) and trained their drivers on ecodriving in the last two years. In contrast, many of the companies had not introduced the more cost intensive IT supported efficiency measures. Modal shift to rail or shipping applied only for small parts of the business of the companies surveyed. Even in the cases where the idea of implementing IT scheduling and on board telematics systems was positively received, investments in new devices were mostly made for new vehicles, not for the entire fleet. Due to the very low numbers for the measures in the areas of IT scheduling, on board systems, and co-operative agreements, the conclusion can be drawn that a high growth could potentially exist here. The survey of these measures seems to be promising.

Smaller companies implemented fewer measures, and IT supported measures had hardly been introduced at all. The most frequent measures were in the technical field (e.g. technical improvements 30.8%) and in driver training (changes in driving behaviour 23.1%). In contrast to the small companies, IT measures scored significantly higher in the medium sized

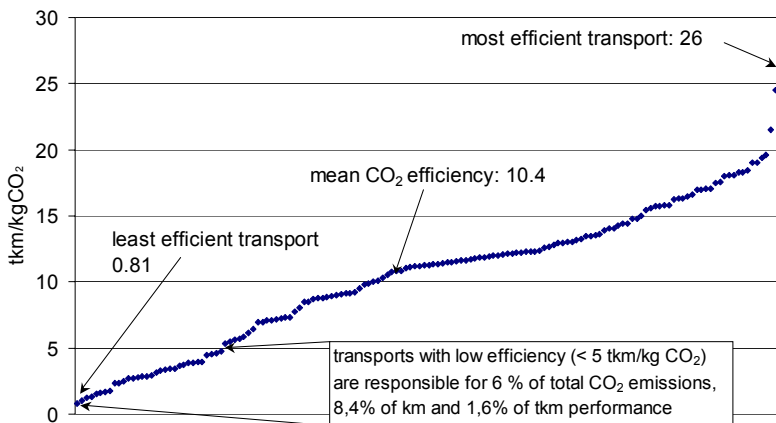
companies. What is special for medium size companies is the broad range of efficiency measures: only two of the measures listed (density optimisation and formal co-operation) were ignored in this group. In large companies, a higher rate of implementation can be observed.

26.6% of all companies have failed to introduce any efficiency measures. They are small (75%) or medium-sized (25%). Whether the large companies have managed to improve their efficiency to a higher level than the others, has not been confirmed by other quantitative findings in the survey.

3.2.3 Fuel consumption, CO₂ analysis and results

For the analysis of the data on fuel consumption, the first step is to look at the most important criterion – that of CO₂ efficiency. It is useful to present and analyse first the raw data (fig. 18). The mean CO₂ efficiency was 10.4 tkm per kg CO₂; the values fluctuated between a minimum efficiency of 0.8 tkm/kg CO₂ and a maximum efficiency of 26 tkm per kg CO₂.

Fig. 18: CO₂ efficiency in road haulage: raw data, 2-4 days run means



Source: Survey 2003

This is a 32 times difference in the CO₂ efficiency of vehicles in road haulage, probably due to the very large differences in the daily business activities in German road freight. Most of the values are above the 5 tkm/kg CO₂ threshold. Transports with very low efficiency (below 5 tkm/kg CO₂) were responsible for 6% of all CO₂ emissions, 8.4% of all distances driven, but only 1.6% of total transport performance.

It is very likely that further potential for efficiency improvement exists, even in the highest efficiency cases. When the unit of measurement for efficiency is inversed (litre per tkm instead of tkm per litre), the best efficiency value of 38 g CO₂ per tonne kilometre shows a high level of efficiency. In this “best case of the sample”, the vehicle, a well loaded 40 tonnes truck, has only used about 14 ml of diesel on average for the transport of one tonne over one kilometre during a 3 days run.

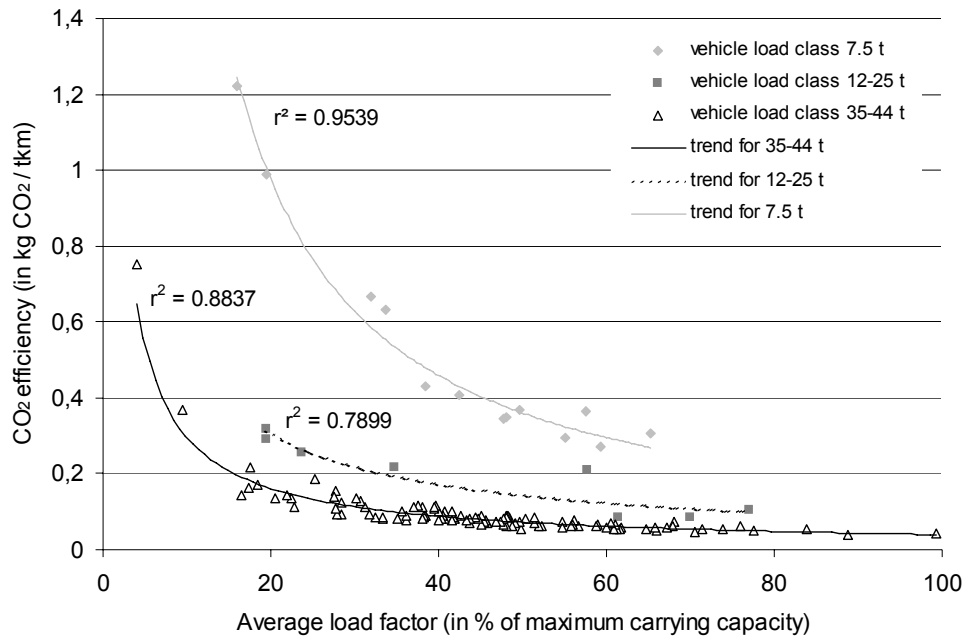
Factors influencing CO₂ efficiency

The next data are presented in their relation to efficiency. This observational-analytical steps answer the following question:

- Which factor most significantly influences CO₂ efficiency?

The survey clearly confirm the well-known correlation between size of vehicle, load factor, and CO₂ efficiency.

Fig. 19: CO₂ efficiency in relation to class of vehicle size by GVWR and load factor for weight



Source: Survey 2003

The vehicles with a total gross vehicle weight rating of 7.5 tonnes are the least efficient. CO₂ efficiency does not only improve with increased vehicle size, but also with increasing weight capacity utilisation. It therefore follows that vehicles with a high gross vehicle weight rating (GVWR) and maximum weight capacity utilisation return the best figures.

Vehicles with a GVWR of 7.5 tonnes emit an average of 0.511kg CO₂/tkm. This value falls as the GVWR increases and reaches an amount of only around 0.097kg CO₂/tkm at weights of 40 – 44 t.

Average load factor by weight is around 49%, which is an astonishingly low figure in comparison with the average of 70% in the German statistical databases. This factor was calculated including empty runs. In the light of the interest shown by those companies agreeing to participate in our study for the whole subject of optimisation and efficiency, it should not be assumed that they work particularly inefficiently, compared to the market competitors. It follows that the capacity utilisation of their vehicles should be rather good compared to the Federal German average. In the statistics, good figures are shown by heavy trucks (which dominate in the survey sample) and poor figures in the case of light goods vehicles (which dominate in the statistics). This tendency is however quite obviously contradicted in the control sample: vehicles of 7.5 t demonstrate a better load factor by weight (43.4%) than the 40 – 44 t trucks (40.1%) but a lower one than 25 t vehicles (52.5%). The conclusion therefore arises that the statistics on capacity utilisation rate might be too optimistic; implying that the potential for load factor optimisation is greater than expected.

What remains decisive is the fact that the CO₂ curves for each vehicle class along the weight capacity utilisation axis show a high degree of consistency and a high correlation coefficient ($r^2 > 0.78$). These astonishingly regular raw data curves lead to the assumption that further sets of data would not lead to a significant change in the shape of the graph, which means that the curves demonstrates in a fairly representative way the emissions arising from road haulage in general. All datasets obtained later from companies and telematics records were confirming these initial values from the survey 2003.

The variations have not, however, been sufficiently well explained yet. Further factors are relevant.

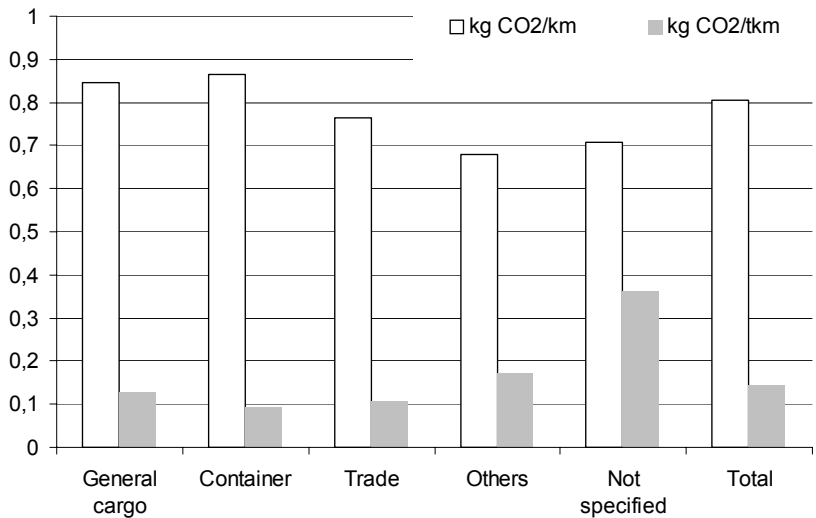
In contrast to the variables vehicle class and load factor, the influence of the activity sectors on CO₂ efficiency is not clearly demonstrable (fig. 20).

For transports in the areas of general cargo, containers and trade, the efficiency in tonne kilometres is comparable, whereby containers shows slightly better results. The CO₂ emissions by vehicle kilometre are higher for container and general cargo than in the other sectors. This is due to the vehicle size and the intensive use of HDVs.

Looking at the average load factor, it is lowest in vehicles without specified sector (33.9%) or in container transport (35.4%). A better average load factor is demonstrated for vehicles from general cargo companies (44.9%), those used for

retail and trade (52.7%) or those from other sectors (55,8 %). For general cargo, an average of 10.9% of all vehicle kilometres is driven empty, this proportion is significantly higher in the case of container transport (36%).

Fig. 20: Mean CO₂ efficiency by sector

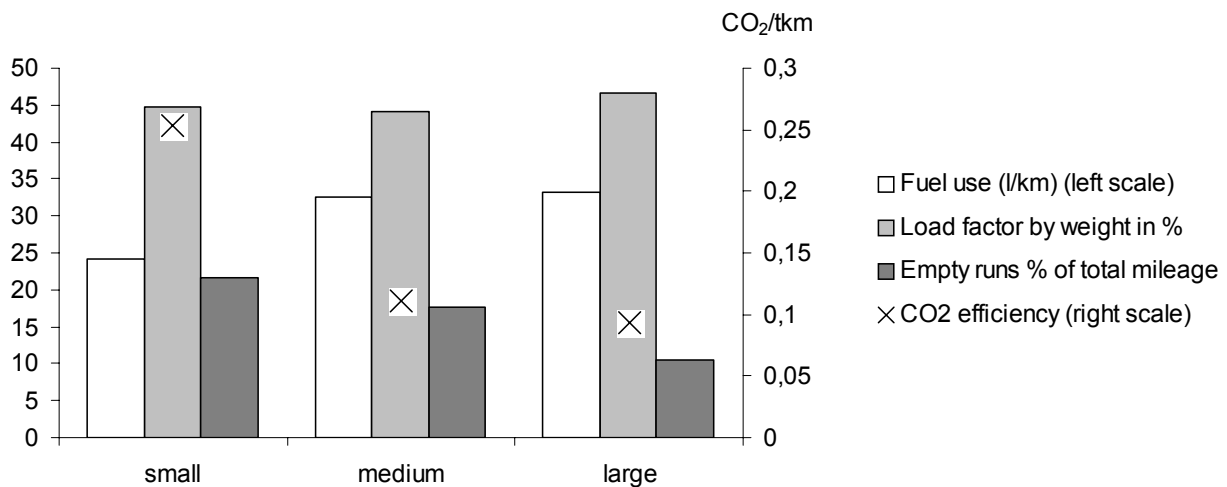


Source: Survey 2003

It follows that, in this step of analysis of the base survey, it is again vehicle size and load factor which are the most influencing variables for CO₂ efficiency, and not the sector of activity. The differences between branches are too small. What is confirmed here is the intuitive fact that the weight of the goods, the distances travelled and other organisatory factors influence the CO₂ efficiency more than the type of goods transported.

The next step is to analyse the correlation with the size of company, because it is assumed that large companies will organise transport processes more efficiently due to the broader range of available vehicles. The sample contains 44 datasets from small companies (<11 vehicles) 59 from medium (<51 vehicles) and 52 from large businesses (more than 51 vehicles). CO₂ efficiency is similar for medium-sized (average value 0.111 kg CO₂/tkm) and large (0.093 kg CO₂/tkm) companies (Fig. 21). This is better than the efficiency of small companies (mean value: 0.253 kg CO₂/tkm). It is questionable whether these numbers are the result of a company structure, because small businesses show a comparatively high number of lighter vehicles in their fleet, and they show an equally good load factor (44.8%).

Fig. 21: Company size analysis: Fuel use, load factors, empty runs and CO₂ efficiency



Source: Survey 2003

The average fuel consumption of small company vehicles is only 24.3 litres, whereas for medium-sized and large companies it is as much as 31.5 and 33.3 litres. This is explained by the large number of lighter vehicles in small businesses.

In any case, the significance of business size as a factor of influence cannot be excluded; the participating small businesses demonstrate for example a lower level of implementation of IT efficiency measures.

In the sample, the proportion of kilometres driven empty falls significantly as the company size increases: 21.7% of the distance of the vehicles of small businesses was empty runs, as opposed to 17.7% for medium-sized companies and 10.5% for large firms. But for the load factor, the differences are not significant.

There is no evidence, at this stage that the organisational differences are leading to significant efficiency differences besides the number of empty runs. This might be one of the explanations why the large companies present a slightly higher CO₂ efficiency than the others. A larger control sample would be necessary to determine this point. Thus an important initial hypothesis is confirmed, according to which large companies return better CO₂ reduction results than medium-sized and small ones. Main reason is probably a better fleet organisation. The efficiency of large companies therefore remains an important topic of research.

Businesses that had implemented various efficiency measures participated in the base analysis. It is apparent that those businesses with a scheduling system achieve the best CO₂ efficiency. If this system is operated in conjunction with telematics, then all measurements show the comparatively good efficiency (although the control sample, with just four sets of data, is very small). If a scheduling system is operated without telematics the figures show a broader spread, in which many vehicles return similar CO₂ efficiency values to those of the same size without this system.

The measurement results for vehicles with on-board systems show a substantially higher efficiency rating than the average of vehicles operated without on-board or scheduling systems. At the same time, the vehicles with on-board equipment demonstrate a small spread of CO₂ values, that is, they do not give any values in the higher or lower ranges of CO₂ efficiency.

At the end of the first screening through the efficiency indicators and technologies applied, it appears that the degree of explanation remains unsatisfactory. Many indicators are relevant for CO₂ efficiency but none of them is really dominating the others. In order to define more precisely what is the main factor influencing CO₂ efficiency, however, a further measurement criterion is necessary, in complement to the observed criteria.

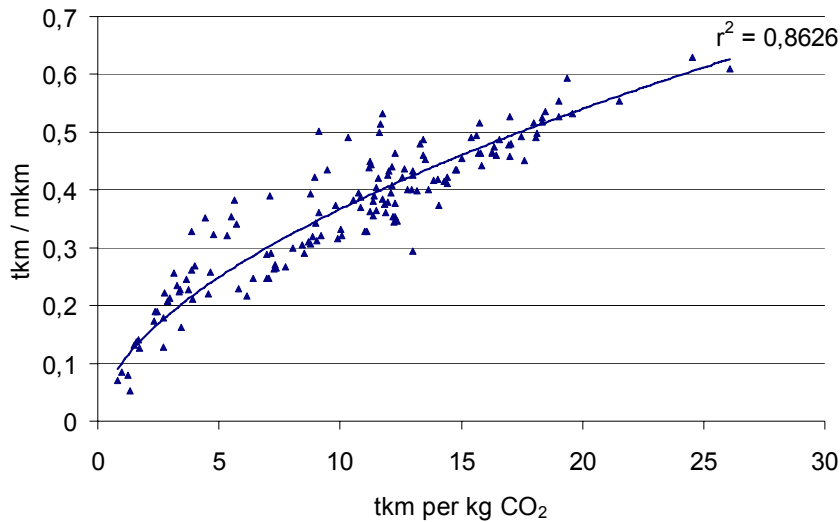
Fuel efficiency can also be defined according to the following observation done for the high efficiency values: that the empty weight of the vehicle was not too high, compared to the weight of the goods transported and that a low number of empty kilometres are driven, meaning that a high efficiency of vehicle use is achieved. To quantify this observation, the quotient tkm/mkm was calculated. The measurement indicator tkm includes neither empty kilometres nor empty weight of the vehicle (for empty runs, tkm=0). But energy is needed anyway for moving an empty vehicle. So the calculation of total weight kilometres or mass kilometres (mkm) is necessary. This is done by multiplying the total vehicle weight (mass) by the total number of kilometres. The result for the efficiency of vehicle use E_v is given by the equation:

$$E_v = \text{tkm} / \text{mkm}$$

The maximal possible value for E_v is 0.725 in Germany, corresponding to the truck combination with the best empty weight (11t)/ maximum carrying capacity (29 t) ratio on the market, and the idealistic hypothesis that this truck is running permanently under full load. In our sample, the best dataset has a high E_v value of 0.63 tkm/mkm.

The relation tkm/mkm shows how efficiently used the vehicle really is between two refuelling stops. In figure 22, it is visible that vehicle use efficiency has a very corresponding pattern with that of the CO₂ efficiency.

Fig. 22: Efficiency of vehicle use: quotient tkm/mkm for each data set, related to the CO₂ efficiency



Source: Survey 2003

This result shows that CO₂ efficiency is conditioned strongly by the efficiency of vehicle use ($r^2=0.86$). A higher (good) tkm/mkm factor means a higher capacity utilisation by tonnage, few empty kilometres and a good payload/empty weight design of the truck or combination.

The analysis of the data shows a 12-fold difference of efficiency between the lowest and highest efficiency values in Germany. Most of the data are to be found in a range of less than 50% below the best value. The mean vehicle usage efficiency rating is around 0.36 tkm/mkm. The most efficient company returns an average of 0.56 tkm/mkm at a load factor of 70% across the whole fleet.

3.2.4 Analysis of the existing potentials

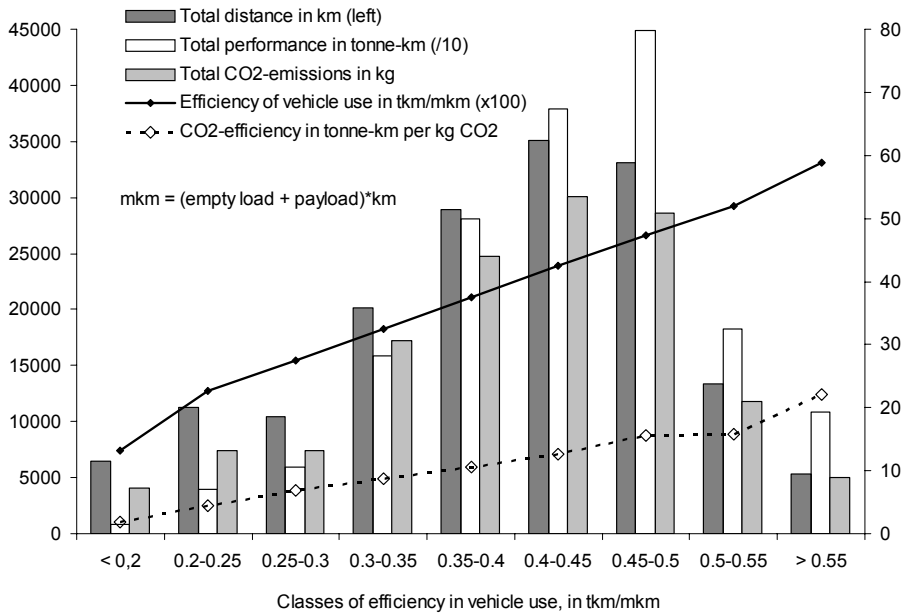
The potential for further improvements in CO₂ efficiency can be estimated by analysing the survey data. The sample data are sorted into classes according to the efficiency of vehicle use. For each class of vehicle use efficiency, the total amount of CO₂ emissions, the total transport performance (tkm) and the total distance (km) is calculated. According to this procedure, it can be seen that most of the emissions (light grey columns) occur during less efficiently performed transports, to be found in the range below 0.5 tkm/mkm (Fig. 23).

A mean efficiency value of 0.5 tkm/mkm appears to be a realistic objective for Germany and most of the OECD countries, if the next few years are considered, inasmuch as the best company in the investigation (with a mean of 0.56) do not demonstrate a particularly high degree of implementation of efficiency measures. The best current mean value is shown in a dataset in which 480 km were driven in 2 days, and a capacity utilisation of around 75% and a tkm/mkm figure of 0.63 were achieved. In comparison with the current mean value of 0.36 for all companies, the setting of a target mean E_v value of 0.5 indicates a high potential for future improved vehicle usage efficiency.

Should all the companies, whose figures are currently below 0.5 tkm/mkm, reach this objective in the next few years, then total CO₂ emissions would fall by 20%. The finding indicating a 20% reduction is realistic because existing measures could be implemented with more determination. But if the total transport performance or the vehicle fleet growth too much, or if some branches are not in a position to modify any business conditions towards more efficient vehicle use, this target will not be reachable.

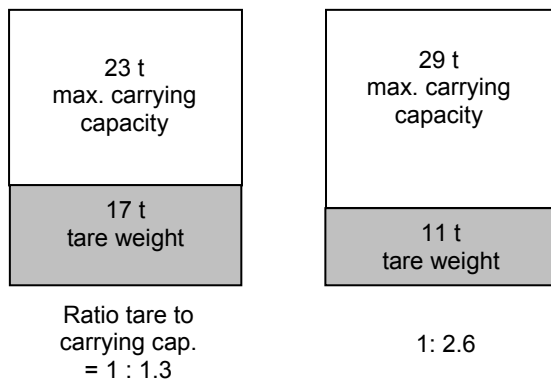
The conclusion is that an improvement in efficiency could be achieved by existing efficiency measures and also by other means, such as, for instance, the purchase of vehicles with a light weight design. The principle, according to which light vehicles bring about an astonishing improvement in efficiency, is illustrated in the following figure (Fig. 24). The best vehicle with a GVWR of 40 tonnes on the market in Germany in 2005 has a tare weight of only 11 tonnes and is therefore potentially very energy efficient. The least efficient 40t truck in the survey 2003 has a tare weight of 17 tonnes. The two ratio tare to carrying capacity of these trucks are very different, this explains again the large differences in efficiency.

Fig. 23: Potential analysis for future increases in CO₂ and vehicle use efficiency



Source: Survey 2003

Fig. 24: Ratio of empty weight to maximum carrying capacity for 40t vehicles



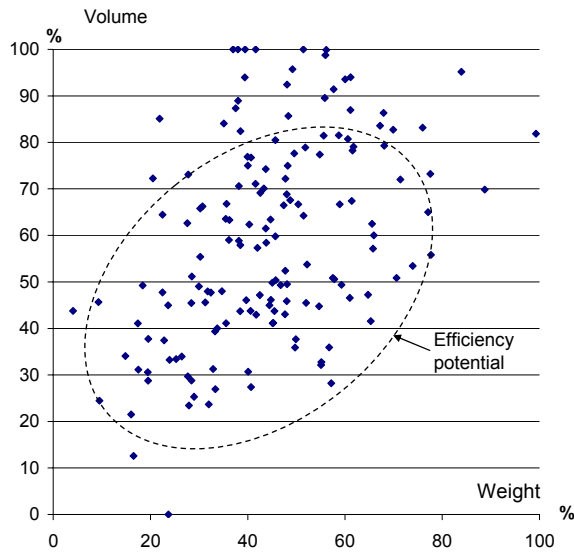
Source: Survey 2003

Load factor by volume

Data collected on load factor by volume confirm that an optimisation potential is theoretically available (Fig. 25). According to these datasets, vehicles in Germany are not fully loaded, even if the mean load factor by volume of around 60% is a fairly high value. The data collected on load factor by volume are less reliable than the other data in the base survey, and a margin of error of 30% is estimated. Due to the lack of electronic devices for on board measurements for volume utilisation ratio, the data quality will remain a problem and there is still a need for research in this field.

As one might expect, the lowest values for load factor by volume are to be found in the smaller vehicles used for final deliveries. In this kind of transport, the vehicle starts fully loaded and is gradually emptied as it delivers the goods. Due to this organisational constrain, the potential for efficiency improvements is very limited. How the efficiency of multiple delivery vehicles could be improved, will to be investigated in other chapters.

Fig. 25: Volume load factors, as estimated by drivers, and weight load factor



Source: Survey 2003

The utilisation of free volume resources is one of the decisive factors for increases in efficiency. While the load capacity is less frequently fully used in terms of weight, the volume capacity is more often reached. However, for most of the surveyed cases, at least 20% of the available volume resource is free in a 2 to 3 day period and, at the same time, 30 – 40% extra weight could have been transported. The theoretical potential for further improvements in efficiency is confirmed.

Special case: the use of biofuels

Five vehicles running exclusively with biodiesel took part in the measurements of the base analysis. Due to the improved CO₂ balance of biofuels (plant growth absorb the amount of CO₂ that is released onto the atmosphere after burning), the 40t vehicles using biodiesel only do not contribute much to the increase in CO₂ concentration in the atmosphere. CO₂ emissions are occurring during the agricultural production, the fuel supply chain logistics processes, and the vehicle life cycle. Positive policy settings are making biodiesel use attractive for some surveyed German companies. A measurement of the fuel consumption remains of interest, in order to analyse the cost-benefit, which might result from the use of biodiesel, and draw some lessons for other companies.

The available test results of the base survey (tab. 9) show a much higher consumption of biodiesel in comparison to diesel for the same vehicle class. The difference in consumption per kilometre gets smaller as the vehicles increase in size. It follows that, for the companies, the use of biodiesel is more efficient with HDV, with a mean fuel consumption of at least 18% higher than the normal diesel. Biodiesel would, in this case, need to be nearly 20% cheaper than mineral diesel to gain any advantage. But the 2003 market prices in the tank filling stations did not show such high differences. The company was asked on prices and the answer was that a special tariff is negotiated with the producer.

Table 9: Consumption of diesel and biofuel in the base analysis

Diesel			Biodiesel			Difference in %		
Veh. class	liter/100 km	l/tkm	class	liter/100km	l/tkm	class	liter/100 km	l/tkm
11-14 t	16.6	0.080	14.5 t	28.6	0.099	11-14 t	72.3	23.8
18 – 25 t	31.5	0.066	23 t	41.8	0.127	18 – 25 t	32.7	92.4
40 t	33.3	0.036	40 t	39.3	0.042	40 t	18.0	16.7

Source: Survey 2003

As the control sample of one or two measurements per vehicle class is very small, the values can make no claim to be representative. It does show, however, that further research in this area would be of interest, in order to help businesses clarify the question of improved return potential for investments in biodiesel. Possible measures involving fuel switch are not further investigated here, because, according to expert opinion, a breakthrough on a broad front for alternative fuels on the commercial vehicles market is years away.

3.2.5 Intermediary conclusion

An overview of the manually recorded efficiency data of the base analysis is given in table 10. There are surprising similarities with the data recorded with telematics from company C. Both datasets, and specially the mean fuel use of the 40t trucks of about 33l/100km and the spread of the CO₂ efficiency values, seem to confirm each other. Since the dataset of the base analysis is recorded in spring 2003, in the middle of the period of 2001 to 2004 of the company C dataset, and the fleet of 40t trucks is dominating, the comparison is relevant. This step is necessary because of the principal weaknesses of small surveys, that can never give results of comparable quality and strength like the statistics sample of 50.000 companies of the Stat. Bundesamt. As conclusion of this comparison, a stronger validity for both survey records is deduced.

Table 10: Overview of the data in the base analysis, compared to the data of company C

Indicators	Base analysis			Company C 40t trucks only n=1008
	Sample n=153	trucks <40t n=44	40t trucks n=109	
Efficiency of vehicle use in tkm/mkm (means)	0.36	0.28	0.40	0.41
• Mean weight capacity utilisation in % (incl. empty runs)	44.2	43.0	44.7	42.1
• Mean volume capacity utilisation in %	59.3	48.2	63.6	-
• Mean empty runs in % of the total distance	17.4	20.3	16.3	-
• Mean vehicle age	3.1	4.4	2.5	-
CO₂ efficiency in tkm/kg CO ₂ (means)	10.4	5.5	12.5	12.5
• Mean consumption in l/100 km	31.6	24.9	33.1	33.3
• Highest CO ₂ efficiency in tkm/kg CO ₂	26.0	18.3	26.0	23.6
• Lowest CO ₂ efficiency in tkm/kg CO ₂	0.8	0.8	1.3	1.2

Source: Survey 2003

The factor tkm/mkm give a good answer to the question about the extent to which companies can have an influence on CO₂ efficiency, but that extent remains rather theoretical. To understand how the solutions can be better applied, it is necessary to further survey the situation in the companies (next chapters). Remaining undefined differences between the patterns of economic and ecological indicators could be more precisely analysed in the course of other surveys and analysis.

Looking at the free volume capacities in the fleet, it can be deduced that the theoretically high potential for improvements in efficiency is realistic. The ambitious objective of a 20% CO₂ reduction could be reached only if existing measures are broadly implemented.

The estimated reduction potential is probably also valid for other countries with similar competitive business conditions and trend developments in fuel consumption. Thus the findings of the base analysis could be transferable.

3.3 Optimised scheduling and telematics

3.3.1 Introduction

There is a necessity to pinpoint the potentially high savings, which can be achieved with the help of a more energy efficient organisation of commercial freight transport systems. To this end, the measures for transport optimisation through introduction of IT scheduling systems and the use of telematics were surveyed in two steps: the impact survey (chapter 3.3.1 to 3.3.5) and the technology survey (chapter 3.3.6).

For the German-wide empirical study “optimised scheduling and telematics”, the CO₂ emissions of 22 German road haulage companies operating under normal daily business conditions were surveyed, and entered into a balance sheet in March-April 2003. The CO₂ reductions actually achieved after the introduction of IT supported scheduling and/or telematic systems for data communication, location and navigation were then quantified. In a second survey phase, the technology was in the focus. The description of the available techniques is in chapter 3.3.6.

The survey was designed after synthesising the most advanced results and survey methods in this special field. Ideas were collected from the various projects carried out by UBA in co-operation with PROGNOSE on the subject of transport

avoidance through transport information and management systems (PROGNOS 1999 and 2000, UBA 1998 and 2003), as well as by the market overview research in the telematic sector carried out by Andres (2002) and the Gesellschaft für Verkehrsbetriebswirtschaft und Logistik e.V. (GVB 2003). In other OECD countries, important basic principles have been gathered from the Energy efficiency Best Practice Programme of the Department of the Environment, Transport, and the Regions (DETR 1996, 1997, 2000, 2001 Fuelwise 2004) and the Best Industry Practices Programme of the International Road Transport Union (IRU 2002). Also important was the approach and the scientific work of McKinnon (1999 and 2003) for improving the energy efficiency at the company level and relate this to the freight transport policy, and the work of Harmsen et al. (2003), related to the environmental policy instruments. Last but not least, the project Environmentally Sustainable Transport (OECD 2001) and the OECD report on the subject of IT use in road haulage (OECD et al. 1999) represent an additional basis of these surveys methodologies, ideas and approaches.

A quantitative evaluation of the effects that could be directly achieved by road haulage companies themselves has not yet been undertaken in any of these studies. Some effects have been quantified and reviewed by Ang-Olson and Schoeer (2002) for the US.

3.3.2 Classification and principal advantages of the scheduling and telematics systems

There is a great variety of IT supported scheduling and transport telematics systems for data communication, location, and navigation on the market. This variety represents in fact a market barrier, and is seen as too confusing for most users and potential customers. All the systems offer multiple functions, often with different specifications, and they are mostly described using different terminologies. In the first analytical step, the available systems were sorted into categories (tab. 11), and the participating road haulage companies allocated to a particular category according to the nature of their equipment. Each system category yields an increase in efficiency, generated by different causes.

Table 11: Classification of scheduling and telematics systems

D0	“Manual” scheduling (including “adapted office applications, order and billing systems, or forwarding software without scheduling module
D1	IT supported scheduling, where software gives advises on the most effective time schedule (= “IT scheduling”)
D1T	IT supported scheduling with telematics application for data communication, location, and navigation (= “IT scheduling with telematics”)

Source: Survey 2003

Main impacts on efficiency after implementation of an IT-supported scheduling system (D1)

- When compared with the D0 category, the use of equipment and software from category D1 results in an increase in the mean load factor (both by weight and by volume). The higher load factor and associated increase in vehicle weight leads, on the one hand, to an increase in CO₂ emissions per kilometre, and, on the other, to a reduction in CO₂ emissions per tonne. Seen overall, the result is a net reduction in total CO₂ emissions, as fewer runs are needed to transport the same quantity of goods. That means, more runs are possible with the same fleet size, which can correspond to an increase in the absolute load volume (in tonnes transported). Greater cargo volumes with the same size of fleet always represent an increase in economic viability for any company. In this specific impact, ecological efficiency, transport efficiency, and economic efficiency are therefore directly related with one another.
- The average transport distance falls (shorter runs) due to better triangulation and the more efficient use of available capacity. It becomes easier to identify, in short-time and in advance, the ideally positioned vehicle for any particular job (shorter initial distances)
- Compared to category D0 (tab. 11), shipments can be combined more easily; it is then less difficult to discover if small orders can be transported as part of another shipment.
- It becomes easy to recognize non-viable or less rentable customers by means of a better information base. The software for IT scheduling usually incorporates a complete management information system. Particular customer data (time, distance, fuel used etc.) can be transparently calculated and eventually identified as loss factors. This enables an appropriate response to the customer, which leads to fewer empty kilometres run, or, as the case may be, a higher load factor. In consequence, the prices can be renegotiated on the basis of the available information.

Main impact on efficiency with the use of an IT-supported scheduling system with telematics (D1T):

- In comparison with the D1 category (tab. 11) a further increase in load factor results from the use of equipment and software of category D1T, as does a further reduction of average transport distances by means of precise location data.

The availability of precise location data at the relevant time makes it again easier to identify the ideal vehicle for each trip, or, depending on the case, to identify orders which may be transported as a part of another shipment.

- “IT scheduling with telematics” minimises detours by means of permanent driver monitoring.
- It avoids detours by the elimination of communication errors such as incorrect names or incorrect figures.
- The minimisation of detours by means of on-board navigation/route planning systems to support directly the driver. In this case the greatest effects are induced when travelling abroad or on unknown routes.
- Transports, which run the risk of being delayed, are more shortly identified. Central scheduling can then very often intervene before it is too late and make another vehicle available for the successor job.
- Drivers who are uninterested in economical driving can be identified using a combination of route-related and refuelling data (derived on the basis of monthly records and evaluations).
- Driver training with the highest impacts went hand in hand with the introduction of telematics systems, which then has a positive effect on the CO₂ emissions per kilometre.

3.3.3 Methodology and analysis of the influencing factors

The most significant methodological difficulty is to **isolate** the surveyed impact. In order to isolate the efficiency effects generated by the measures taken, the central approach is to make a comparison of annual data from a particular business “before and after” the introduction of the IT-supported scheduling and/or telematics system. 79 companies across the whole of Germany with scheduling or telematic systems were randomly chosen. 22 companies provide data on their business and their CO₂ efficiency. On 32 datasets with fuel consumption obtained from these 22 companies, the mean fuel use was 33.7 l/100 km, a value comparable, but slightly higher than the general base survey and the company C telematics results. Out of these 22 companies, only 7 were finally selected for the before-after comparison step. Data of 11 companies were matching all the quality requirements: they include information on the key performance indicators distance (in km), fuel consumption (in litres), and load (in tonnes). They also provided business operative information and important influence factors such as business and fleet structure, business sector and any further efficiency measures taken in the same period. Out of 22 companies, only 11 companies were able to supply data on distance and fuel consumption, as well as business information and important influence factors from the year before and the year after the introduction of the IT measure. Mostly missing were data on the year before the introduction of the IT systems. The specialists in the 11 businesses were questioned in the context of a face to face interview and with use of a standardised questionnaire.

The basic idea behind the **before-after comparison** is only to include firms, which, with the exception of the introduction of the scheduling system, or the use of telematics, have undertaken no further structural changes (e.g. business sector, goods density, fundamental changes to customer or business structure, or other efficiency measures) in the surveyed period. In this way, the changes that occurred can be seen as efficiency impacts and attributed to the individual measures. The long period of observation (one year before and one year after) also minimises the effect of short-term influences. Out of the 11 businesses with valid data, four changed structurally or introduced other efficiency measures, making an isolation of the specific impacts impossible. 7 companies didn’t show any significant other changes and their data are therefore relevant for the before-after comparison.

Astonishingly, none of the companies surveyed could deliver a direct measurement of CO₂ efficiency (kg CO₂/tkm). This was due to the lack of transport performance data in tonne kilometres (tkm). It is clear that only very few companies are in the position to be able to give reliable tkm data. The indicator of CO₂ emissions per tonne kilometre could not be derived out of the indicators of CO₂ emissions per kilometre and per tonne. A new methodological approach to efficiency analysis was therefore developed in order to create a CO₂ balance sheet. In this new approach, the starting point “before” is measured and compared with the changes “after” the introduction of the IT-supported scheduling or telematic system in the areas of annual fuel consumption, annual distance, and annual load per vehicle.

The underlying question in the **efficiency analysis** is this: to which extent would the company indicators have changed in absence of an IT scheduling or telematics system? If this company had not made any other changes in business efficiency or in basic company structure, would the three values (fuel consumption, distance, and load) fluctuate in line with each other as a result of the various economic and order related situations? This fluctuation would affect all three areas to the same degree, in other words, the three figures would rise or fall by the same percentage. For instance, if, in such a case, the total load rose by 5%, then distance and fuel consumption would increase in proportion. If this company introduces an IT-supported scheduling and/or telematics system, then the load will normally rise, but fuel consumption and distance will decrease in relation. Due to improved load factor and shorter transport distances, a vehicle from this company can carry out more transport orders in a year. In our example, therefore, the load volume could increase by 5%, whereas the fuel consumption would stay the same. The difference between the two values represents the improvement in CO₂ efficiency. The same principle applies for the differences in load and distance. The difference represents the change in km efficiency (see fig. 26). This before-after approach allow an estimation of CO₂ efficiency, even if no data on exact tkm performance are available. After discussion with other experts, the conclusion was that this before-after approach might be used for many other case studies, looking at implementation effects of specific policy or company measures.

In the context of the overall economic situation, the results of the before-after comparison confirm the weak tendency of the German freight demand in the survey period (BGL 2002). As far as fleet age is concerned, the environmental reports from DaimlerChrysler (2002) shows that average CO₂ emissions of their new vehicles have only slightly improved since 1995. The factor of mean vehicle age was therefore not taken into consideration.

Sample description

The 11 companies surveyed accounts for 0.26% of the distance, 0.11% of the fuel consumption, and 0.05% of the load volume of all German road haulage in the year 2001 (KBA 2001 and UBA 2006). The participating businesses employed in this year on average 952 workers, 699 among them were drivers, and operated 588 vehicles. The margin of error in the annual raw data supplied by the companies is estimated at ± 5%. Middle-sized hauliers owning all vehicles or parts of their fleet dominate in the sample. As the hauliers record order data, but derive no consumption or distance data from their subcontractors, only the data from the company's own fleet were considered. The dominant vehicle class in the investigation is of 32 t GVWR or higher. The relation of short-haul to long-haul transport is roughly 1:9 in the sample.

3.3.4 Balance of efficiency effects relevant to transport, which have a positive climatic effect

Four companies changed from a D0 to a D1T category system, yielding a reduction in CO₂ emissions per kilometre of 2.2% and in CO₂ emissions per transported tonne of 4 % (tab. 12).

Table 12: Key performance and efficiency indicators for companies changing from “manual” scheduling (D0) to IT-supported scheduling and telematics (D1T); mean annual values

Indicators	D0		D1T		Change (%)
	n	mean	n	mean	
Year (median)	4	2001	4	2002	-
Rating of the economic situation (1-5)*	4	2.75	4	3.50	27.3
Rating of the implemented system (1-5)*	-	-	4	2.13	-
Personal (number per company)	4	84.25	4	83.75	-0.6
Driver (number per company)	4	64.25	4	64.50	0.4
Scheduler (number per company)	4	2.88	4	2.13	-26.1
Fleet (number of trucks per company)	4	50.25	4	50.50	0.5
Vehicle age (number of years)	4	2.95	4	2.65	-10.1
Mean GVWR (t)	4	37.89	4	38.06	0.5
Total distance – short haul (km)	2	2 063 046	2	1 790 659	-13.2
Total distance – long haul (km)	3	5 116 424	3	5 485 157	7.2
Transports (number of trips per company)	3	24 662	3	24 837	0.7
Mean distance per transport (km)	3	336.45	3	350.99	4.3
CO ₂ emissions per km (kg CO ₂ /km)	4	0.91	4	0.89	-2.2
CO ₂ emissions per load (kg CO ₂ /t)	4	33.48	4	32.14	-4.0
Total fuel use (l/vehicle)	4	38 088	4	38 069	0.0
Mean fuel use (l/100 km)	4	34.72	4	33.97	-2.2
Distance (km/vehicle)	4	109 671	4	112 060	2.2
Tonnage/ total load (t/vehicle)	4	3 648.07	4	4 055.21	11.2
Fuel costs (€/vehicle)	3	23 436	3	26 571	13.38
Turnover (€/personal)	2	108 718	2	116 467	7.1
Other efficiency measures					Difference
Partnerships (number)	4	3	4	4	1
Driver training (number)	4	1	4	2	1

* scale from (1) very good to (5) very bad; n = number of businesses with valid data

Source: Survey 2003

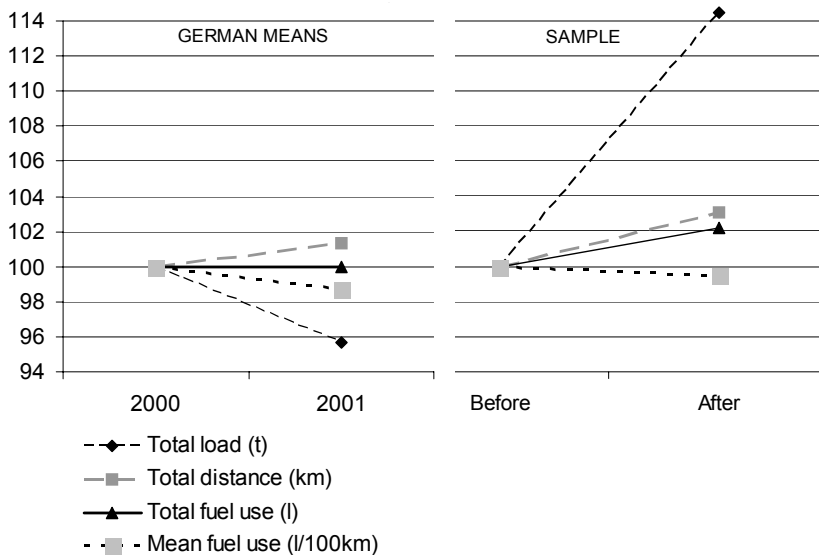
As a result of the efficiency analysis, it can be deduced that CO₂ efficiency per tonne has improved by 10% and km efficiency by 8.1%, while changing from D0 to D1T. A simultaneous increase in long-haul transport of 7.2 % can also be observed after the introduction of the new system. If one take this element into account, then an improvement in CO₂ efficiency per tonne transported of >12% is the result. In each one of the four companies, other influence factors were found: increased informal partnerships and changes in driving behaviour (the level of improvement in efficiency due to

these changes was not calculated). Table 12 shows changes in the four companies in many other important key performance indicators and efficiency values.

The comparison of data from one company, which was changing from D1 to D1T, shows a reduction in CO₂ emissions per kilometre of 10.4% and in CO₂ emissions per transported tonne of 8.2%. As a result of the efficiency analysis, it can be seen that CO₂ efficiency per tonne has increased by 8.2% and the km efficiency has fallen by 2.4%. In this company, a substantial growth and very significant increase in long-haul transport (which corresponds to an increase in the average transport distance per order) can be observed. If this increase in long-haul is factored into the comparison, then the improvement in CO₂ efficiency can be estimated at an even higher rate of >10%.

The comparison of the two companies, changing from a D0 to a D1 category system, shows an increase in CO₂ emissions per kilometre of 6.9% and a decrease in CO₂ emissions per transported tonne of 3.8%. The efficiency analysis shows increases in CO₂ efficiency of 4.2% and in km efficiency of 10.1%. The increase in the CO₂ emissions indicator is attributable to the higher load factor. Vehicles with a higher load factor use more fuel per kilometre. Overall, however, significantly lower distances were needed to transport the same quantity of goods, which reduces the total fuel consumption. This result is in line with theoretical expectations.

Fig. 26: Key efficiency indicators for German road haulage and for the surveyed companies in the years before and after implementation of an IT scheduling and/or telematics system



Source: Survey 2003, DIW 2002

Unfortunately, even if the companies of the sample show an improvement for CO₂ efficiency, the net total CO₂ emissions were increasing by 2%.

3.3.5 Cost efficiency effects and costs benefits analysis overview

The number of vehicles managed by a personal of a haulage company responsible for transport scheduling (controller or scheduler) was increasing by 25% after introduction of a system (change from D0 to D1 or D1T). According to the figures supplied by the companies, a realistic cost per vehicle for an IT-supported scheduling system (D1) was in the order of 1,020 to 1,235€. According to how many vehicles are to be managed and to the functionalities of the system employed (simple to complex), this value fluctuates between 500 and 2,300€ per vehicle. In the survey sample, the costs for one product vary per vehicle by as much as a factor of 4, which can be attributed to the high basic costs of the first workplace license and the significantly lower costs for additional licenses. According to the data submitted, IT-supported scheduling systems have a very short return on investment above all because of personnel cost savings in accounts and billing and, only as a secondary consideration, in savings in controller salaries and reduced fuel costs. IT-supported scheduling systems therefore pay back in 1 to 1.5 years.

The additional investment in telematics, according to an estimate based on the data from the telematics sector, costs on average between 2,050 and 2,350€ per vehicle. The range of fluctuation is about 1,200 to 3,500 € per vehicle. Telematics systems pay back above all through fuel savings, and, secondarily, through savings in controller salaries. In summary, it can be assumed that transport telematics systems for data communication, location, and navigation, pay back within 1.5 to 2.5 years. This calculation is very conservative. After this period, all companies report about substantial gains.

If the incomes from additional payload, which can be transported due to improved scheduling systems, are taken into account, then the return on investment period is reduced to few weeks. In our survey, all companies reported on increasing market share changes, and this trend is contradictory to the German trend of a net reduction in total load of 4% in the same period (fig. 26). Unfortunately, the accounts are maintained separately for fuel use, investments and orders, in company bookkeeping systems. None of the companies surveyed has followed the approach of including in the calculation of the return on investment the price of the increased payload transported by the same trucks.

Intermediate conclusions

Despite the small sample size delivering only first indication that have to be confirmed, these first survey on the impacts of IT scheduling produces new numbers (Baumgartner and Leonardi 2004). They are indicating that the introduction of such technology leads to advantages in terms of economic profitability, transport performance, load factor and CO₂ efficiency. This positive outcomes on the existing situation will have to be checked again in other analytical steps and surveys, presented below, showing that a high potential for further efficiency improvements in road haulage exists in the field of scheduling and telematics measures (chapter 3.3.6).

The IT supported scheduling and telematic systems currently on the market are, as far as CO₂ efficiency and fuel consumption are concerned, not sufficiently mature and, above all, not user friendly enough. In this area, the manufacturers must be required to assist the users in making forecasting calculations of fuel and environmental costs and to allow more room for climate-sensitive decision-making guidelines to be set down. The prospects for higher efficiency can be assumed to be greater, if further developments take place.

3.3.6 Improving the use and the technology of IT scheduling and telematic systems: a qualitative survey

Current state of the art and design of the qualitative technology survey

In a study on IT scheduling systems and telematics, Hubbard (2003) concludes, on the basis of statistical data, that a load factor improvement across the whole US transport industry of as much as 3% between 1992 and 1997 was brought about by the use of on-board computers for location and data communication and of trip recorders (on-board monitoring systems). An intensified introduction and improvement of such systems is thus an important step to be surveyed. The British Government has to this end introduced a programme of intensification of efforts to market telematic equipment in road haulage. However, British company experts surveyed by McClelland and McKinnon did not use the new equipment for calculating energy efficiency in their own firm. Usage is mainly restricted to checking location and running times of the goods vehicles (McClelland and McKinnon 2004). The use of IT scheduling and telematic equipment seems to have run into some difficulties on the market.

This technology oriented survey was designed to obtain interview statements and answers on the following questions:

- To what extent IT scheduling systems and telematics applications can be improved?
- Where are the main weaknesses and disadvantages of these technologies?
- What are the most important suggestions for improvement on the side of the customers?
- Which points are software developers working on, and where do they see the greatest potential for efficiency?

The **initial hypothesis** of the technology oriented survey into IT scheduling and telematic systems is, that the currently available systems could be improved e.g. by combining available optimal part solutions or through targeted new developments, so that further improvements in CO₂ efficiency and load factor can be achieved.

The surveyed targets groups are at the demand side and the supply side of the market: end users and IT developers. The manufacturers were asked where they saw the highest potential for improvements in fuel consumption, CO₂ efficiency and organisational optimisation in the work patterns of their customers, the transport firms. On the other side, hauliers were asked where they saw the highest efficiency potential and what their principal wishes were as far as the software manufacturers were concerned.

Definition and description of the technologies under investigation²

According to Samuelson and Tilanus (1997), the general **efficiency** of freight transport can be understood as follows:

² This chapter is based on the technological state of the art as of 2005. As the development of new products proceeds fast⁴, significant changes have occurred in comparison to the surveys performed in spring and summer 2003, which are laid out in chapter 3.3.1 to 3.3.5. Some necessary explanations are provided in the beginning of the chapter 3.3.6. The fundamental principles of the CO₂ emissions and transport management effects are not repeated here.

*Total freight transport efficiency = time efficiency * distance efficiency * speed efficiency * load factor*

These four dimensions are reflected in the technology by different software and hardware components. In our context, efficiency means the achievement of the aim of “transport performance” (to provide services at the same level of transport demand, measured in tkm, pallet or parcel) with a simultaneous reduction in environmentally negative effects. More exactly, energy efficiency and CO₂ efficiency relate to the reduction of energy consumption and emissions per unit of freight transport performance, measured in kg CO₂ per tkm or per parcel. The levers for improving efficiency are the internal company logistical and organisation decision, and the introduction of technical systems. A number of these technologies were investigated by Ang-Olson and Schroeder (2002) in relation to their fuel efficiency, current and maximum potential market penetration, and potential emission reduction in the US. The options investigated were improved aerodynamics, wide-profile tyres, tyre pressure, light-frame vehicles, low-viscosity oils, reduced idling, speed reductions, as well as driver training and monitoring. For other relevant measures that would need to be surveyed, see tables 2 to 4.

Scheduling

Scheduling is defined here as “the ensemble of co-ordinated practices of time and route planning for orders, vehicles, and personnel”. In the daily run of business, the controller (responsible for scheduling), or scheduler, has the task of sorting the incoming orders and passing them on to the appropriate delivery agents. It also has to manage the material flows and stock inventories in order to achieve the reliable and punctual delivery of all orders at minimal cost. In the process, smaller jobs, which are compatible in terms of time frame and delivery area, are bundled together to form a trip. Return trips need to be taken into account early on. Difficulties of different complexities, depending on the size of the company, the time of business, the restrictions, etc. are arising mainly from the time windows and side constraints for pick-up and deliveries. Each optimisation leads to improvements in load factor and thus to economically and ecologically positive results.

IT-scheduling: Semi-automated route optimisation and trip optimisation systems

IT scheduling systems always form part of the so-called forwarding software, which manage the job process from the point of receipt of the order to billing. Within computerised routing and scheduling systems, two classes need to be distinguished. There are forwarding-orientated systems (partially with semi-automated route optimisation), and more complex systems with trip optimisation for delivery transport, or for the needs of shippers.

The foremost variables in semi-automated route optimisation are kilometres and time. On the basis of these data, the system suggests the optimal routes in terms of distance, load factor and time. Trip optimisation, however, is defined for a large number of delivery points in classic distribution or general cargo transport. An example of this is the delivery of drinks or foodstuffs to various end users or small shops. The separation of the two types of transport (forwarding transport and distribution transport) can also be clearly seen in the range and quality of the software products used. The first type needs and uses route optimisation, the second, trip optimisation. These trip optimisation systems are more complex and more expensive. Vehicles from outside the company’s own fleet are often guided by trip optimisation software. A second, typical characteristic of trip optimisation programs is the diversity of secondary conditions (side constraints), which need to be entered into the system. The transport companies need to enter and take care of the daily changes in these secondary conditions (depots locations, vehicles, trips variables etc.), if the system is to function correctly. Additional conditions, for customers, are limits to vehicle size and prescribed types of vehicle; for depots they can be operating lifetime, changeover times, and opening times. Amongst the conditions for the fleet are operating times and available load capacities.

Transport telematics

The basis of all transport telematics systems is the location function. In tracking and tracing, the position of the vehicle is recorded at set intervals. On the basis of the position history, the route taken by the driver can be recorded exactly. The location is determined either by the use of GPS signals or via the GSM network.

The transport telematics technology can be divided into four functional sub-units. These sub-units currently function separately from each other:

1. traffic information systems
2. on-board navigation systems
3. road pricing systems
4. fleet management systems

The review of Giannopoulos (2004) gives a precise description and analysis of the various available transport telematics technologies. This survey focus on fleet management systems, less on on-board navigation systems, and peripherally with traffic information systems. Road pricing systems have not been included, as they are still in their beginning in 2005. Other technologies like digital tachograph, as well as further systems, might be surveyed in the future.

What all fleet management systems have in common, is that the data that arise are processed, buffered, and transmitted via a mobile computer, or on-board computer. In Germany, communication between the central office and the on-board computer is generally carried out using the data channels of mobile phone networks (GSM or GPRS).

Telematic systems for location and data communication focus on tracking and tracing functions. Additionally, the equipment can vary from mobile communication devices to entire portable computer work stations, complete with printer, installed for the driver. A portable device might be a PC or a bar-code scanner. Many systems also incorporate a printer, a telephone, or a camera, or similar. According to the sophistication of the system, order information, digital delivery notes, status information (e.g. loaded/unloaded), photos, bar-code scans and electronic delivery confirmation may be transmitted along with location data between the central office and the vehicle. Normal phone calls can also be made. The function of these systems is to improve scheduling and order processing. According to Hubbard (2003), telematics systems improve productivity through the improvement in decision quality, with particular reference to the allocation of resources in the framework of scheduling. Many transport companies offer to their customers or to the recipients of their goods access to the location information within the system, defined as external order tracking.

In comparison, on-board monitoring systems do not serve to direct communication between the driver and the central office, although, here too, particular data, which are present in the vehicle electronic systems, are recorded and can be uploaded by means of data communication. On-board monitoring systems serve only to record vehicle and trip-specific data. These data can then be evaluated later by the fleet manager or the controller. Some systems use a display to give support to the driver in the form of direct access to current system figures e.g. fuel-efficient driving practice.

In addition to general data, information concerning driving behaviour, vehicle inspection, and trip evaluation, is also included in the monitored on board data (tab. 13).

Table 13: Efficiency relevant parameters that can currently be measured by on-board monitoring systems

<p>General data</p> <ul style="list-style-type: none"> • Date, time • Position (GPS) • Vehicle, driver, trailer • Status (driving/having a rest) • Change of tachograph • Distance driven • Running and stationary fuel consumption • Speed <p>Driving behaviour</p> <ul style="list-style-type: none"> • Braking behaviour • Gear changing behaviour • Driving pedal movements • Constancy of speed 	<p>Technical vehicle inspection</p> <ul style="list-style-type: none"> • Brake wear • Refrigerant level • Oil level • Disturbances reporting • Maintenance scheduling • Tyre pressure <p>Additional information</p> <ul style="list-style-type: none"> • Load space temperature profile <p>Trip difficulties</p> <ul style="list-style-type: none"> • Gross vehicle weight rating • Number of stops • Average gradient
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Source: Survey 2005

On-board navigation is defined as computer-supported navigation with the aid of satellite positioning information and digital road maps. Such systems are relatively common in passenger cars. With the aid of the GPS location information, the system knows its location and can guide the driver to his destination. The route can be selected for various criteria e.g. shortest or fastest route.

Traffic information systems could in future support on-board navigation, as they provide up-to-date traffic information to the driver or to the central office. Long years of experience on which transport conditions can be expected on which route at a particular time (time of day or of week), the so-called load curves, could be incorporated into the system. Golob and Regan (2005) asked 70 Californian transport companies about the information that was of most interest for their drivers. The most important information was concerned with the location of freeway accidents and lane closures, the weather, the predicted driving time for alternative routes, and waiting times at terminals and port installations.

Methodology and execution of the survey

As the aim of the specific technology survey was more to increase understanding and obtain a limited quality check, rather than to make quantitative statements, the method chosen for collecting information was one of qualitative consultation with experts in the field. 10 transport companies which used IT scheduling software were surveyed (7 of these also use telematics systems), as well as 10 leading software and hardware manufacturers.

The selection of the transport companies was conducted using random Internet searches. On the demand side, a total of more than 40 firms were approached. The firms, which did not participate, either had no IT supported scheduling system or were not prepared to take part in a survey. Discussions with the supply side specialists were mostly held on the phone, one software producer was visited, and others were interviewed directly at fairs. The interviews took place in spring 2005. The representatives from the transport companies were managing directors, either alone, or accompanied by a scheduler and a fleet manager. In software companies, the interview partners came from the development departments and from marketing.

Description of the users and manufacturers surveyed

Each company surveyed was allocated to a group of market player, following the typology of BAG (2005). According to statistics, 57,000 companies were operating in the commercial freight transport sector in 2002 (BAG 2005).

The ten surveyed **end-users of IT scheduling software** are

- eight transport companies
 - a “small transport company with self-employed drivers” (A1, tab. 14)
 - a “niche service provider”(A2)
 - two “traditional forwarding companies(A3)
 - four “medium-sized sector specialists”(A4)
- and two industry companies
 - a “shipper” (without own fleet)
 - and a company, which schedules its internal freight transport with the help of IT support.

Table 14: Sample description of the road haulage companies in the IT scheduling survey

Company category	Number of own vehicles	IT scheduling	Telematics (location and data communication)	On-board monitoring
A4	60	+	-	1 test vehicle
A4	95	+	+	In implementation phase
A3	14	+	+	-
A4	150	+	+	In 60 vehicles
A4	90	+	+	-
A1	10	+	+	-
A2	34	+	+	-
A3	28	+	+	-
Shipper	0	+(run opt.)	-	-
Own transport	22	+(run opt.)	-	-

Abbreviations for the player categories: see above; + equipment available; - equipment not available

Source: Survey 2005

In this sample distribution, a large proportion of the types of players active in the German market is represented. Two companies surveyed were from industry. One of these is a shipper (with external fleet management), the other manages its own internal transport with the help of an IT scheduling system.

Due to the very low number of companies, the representativity of the sample is limited. As the main aim was to gain understanding on the problems arising for the user, longer interviews were needed and this is limiting the sample size. There is no reason to doubt about the quality and truth of the responses obtained, as the results of the interviews are very similar for all ten companies surveyed. However, it was not possible to control the sample by checking other German enquiries. Other market studies and quality checks for fuel use efficiency and transport effects are not available.

The ten **technology provider** were represented by:

- four companies – forwarding orientated IT scheduling systems
- three companies – telematics systems for location and data communication
- two companies – on-board monitoring systems
- one company – telematics systems for navigation, IT scheduling systems with run optimisation (and transport information systems)

The selection of manufacturers was arbitrary. Only well-known companies with established market shares were surveyed. Overall, the selection gives an outline of the current developments on this market.

Results

The answers are presented in three groups, according to the frequency of the responses (frequently, fairly frequently or rarely mentioned) and according to the topics of the solutions discussed.

Frequently mentioned solutions

Higher level of integration of the various systems

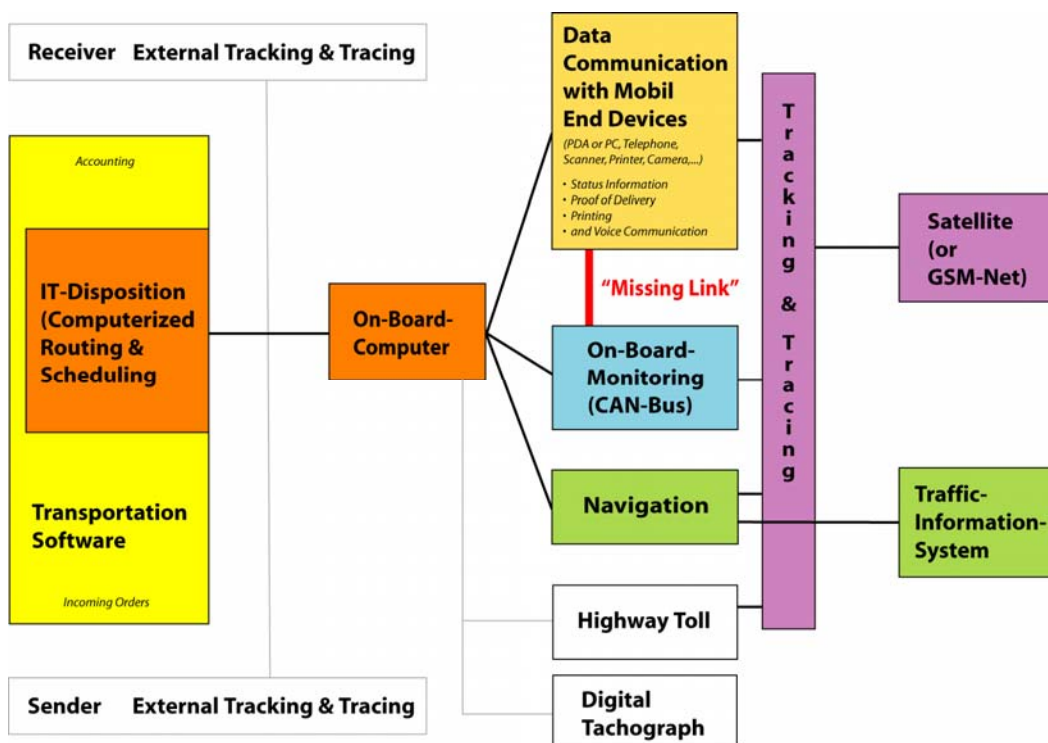
The most frequently stated wish of the users was for obtaining a fully functional, problem-free, integrated system with all necessary components. Individual components should be added in a modular way and all sub-components should function together, independently of their production origins. In concrete terms, it means above all that the users are not obliged to transfer manually data or commands from one sub-system to another (fig. 27). Most manufacturers understand this desire for more integration between the various systems. Positive is that the most important forwarding software packages (with IT scheduling modules) and trip optimisation software are able to function well with the most prominent telematics systems for data communication and location. Nevertheless, this demand for better integration is strong in all companies which use system components from various manufacturers.

The solution to this problem is to be found in the definition of optimisation potential, with following characteristics:

- User friendly
- Network compatible
- Compatibility of individual components

The desire for a “well-integrated and functional system” also include a more or less developed demand for achieving efficiency potential, specially because of the obvious benefits in terms of reduced work and stress. If the various systems are not sufficiently integrated, then transparency and workflow can suffer. Such systems cannot provide optimal results and should not therefore be improved for efficiency reasons. System providers, who are unwilling or unable to offer such an integration, will have difficulties to remain competitive in the long term, as the users have made it very clear that they would prefer to abandon such systems in the medium to long term and to switch to others. Figure 27 presents a possibility on how such an integrated system could ideally be constructed.

Fig. 27: Information architecture with integrated IT scheduling and different telematics applications



Source: Survey 2005

In this context, the users have reported a slight dependency on the manufacturers. After having decided to invest in a particular system, end-users are dependent for a longer period of time on the quality of service of the technology supplier. This can have various effects. It is possible that the manufacturers only support particular telematics systems, which should be made clear in advance. It is problematic, if a software provider gets into payment difficulties, because, in such cases,

product development and service can become seriously affected. At the point of purchase, the transport company becomes dependent on further developments on the part of the software provider, if it wishes to continue to receive a high quality service for its investment. One transport company manager estimated that at least 200 to 300 companies must express a demand for the same new application, irrespective of how useful the suggestion is.

Improvements in stability of the telematics hardware

Frequent were complaints about the instability of the telematics hardware. The managing director of a company with around 100 commercial vehicles reported that “the system normally stops working when between 5 and 10 vehicles are in use”. Professional IT run in a truck is generally one of the most difficult conditions to fulfil for such a system. Nonetheless, the users often felt that the high costs of the equipment or of the service were not justified in terms of their reliability. The fact that, in some areas, it is impossible to use the navigation technology, is of course not the responsibility of the telematics equipment manufacturers. This is a well-known GPS location problem.

Fairly frequently mentioned solutions

Connection of IT scheduling and on-board monitoring systems

From the perspective of CO₂, a central point is the currently existing technological separation of (1) IT scheduling systems with telematics connection for location and data communication from (2) the on-board monitoring systems. This problem is described in fig. 27 as the “missing link”. On-board monitoring systems provide a connection to the CAN-Bus, a device which centralise all sensor data from the vehicle. On-board monitoring systems can collect the wide range of digital information available in modern trucks. The IT scheduling system can use these data in the central office via mobile data communication devices, on request. In practice, the communication devices for the daily business and trip planning are not connected to the on-board monitoring system. If this connexion exists, then by using an on-board computer. This is complicated and very few firms manage to invest in both communication and onboard monitoring systems. There is no technical reason why these systems need to be separated through a computer linking step. Indeed, a high efficiency potential is clearly available, if these two technologies could be integrated.

Reducing the complexity of the on-board monitoring data

The end-user problems with on-board monitoring reveals also that far too many data are generated by on-board monitoring systems. Usually, the onboard computer collect trip data, daily, weekly and monthly means for a high number of parameters (table 11 shows only a small excerpt in the indicator list). “Who is supposed to evaluate all of this?” summed up a typical position. The objective is to supply their customers with simple, easily interpretable data without unnecessary information. The results of the investigation point to the necessity of creating more user-friendly on-board monitoring systems. The aim would be to simplify the results without losing essential information in the process.

Comparison of planned and effectively driven routes

This point was mentioned primarily in the context of road pricing and toll billing, but has more to do with the systematic monitoring of the routes selected by the individual driver. Thus, two companies bought special software that makes it possible to check the bill issued by the Toll Collect system. No differences were observed here. The question is whether, and to what extent, the fuel consumption of a transport firm is increased by driver detours or traffic-related, necessary route changes. Some producers have already made this check a standard function. However, a systematic, statistical monitoring of this parameter does not appear. Simple case analyses in a 3-hour rhythm can be made with a tracking and tracing system for vehicle location. However, no systems offer 2005 a continuous monitoring function with an accuracy down to the last minute. This point, according to the statements made by transport firms, has significant potential.

It is not possible, for cost reasons, to send a current position report every minute. It is possible to save location information every 30 seconds and to send the resulting location track every three hours back to the central office. This makes a precise individual route analysis possible. In order to conduct a systematic statistical analysis, it is necessary to undertake a comparison of the “effective” data with the plan data. This comparison of the planned routes with those actually driven requires advanced IT scheduling systems. If the system could be in the position to record deviations from plan, then the controller or fleet manager can enquire into the reasons behind such a deviation and incorporate the lessons learned into the next planning sequence. This technological improvement would not only influence the efficiency of the organisation, but would also tend to reduce the transport demand in terms of distance.

Measuring volume capacity utilisation

The transport companies were asked for their opinion on an on-board monitoring method for measuring the volume capacity utilisation of a commercial vehicle transport during the actual journey. The advantage of this technology potential: with continuously available information on weight and volume load factor, it become possible to monitor and evaluate the

success of logistical measures introduced by transport companies. Changes over time in the weight and volume load factor can be analysed.

Around half of the companies questioned showed a lot of interest in the possibility of being able to measure the current volume capacity utilisation remotely. Other companies saw no way of implementing such a system in their sector (e.g. car transports), whereas others have no need for it, speed being in their opinion a more important factor than transport or load efficiency. Such volume measurement technology is not yet available. R&D and market diffusion will need time.

Route and trip optimisation using semi-automated IT scheduling systems

Some of the transport companies from the general cargo sector (full truckload and less-than-truckload) have discussed with specialists the semi-automated options for route optimisation of their scheduling software. Some point the fact that such an option was not available to them. On the basis of distance and time data, the system suggests optimal routes, times and load factor. As fuel consumption is very strongly correlated with distance travelled, the software producers and the users did not favour including it in the primary figures. In practice, the procedure looks like this: in the first step, the route optimisation system generates routes suggestions. In the second step, these are either adopted or reworked by the schedulers. As a rule, around 80 to 90% of the suggestions are adopted by the schedulers. The rest needs to be revised. The work pressure is reduced, the scheduler can turn his attention to the problematic transports.

The commonly held opinion amongst companies from the full truckload and less-than-truckload sector is that such semi-automated scheduling systems cannot hope to model with enough accuracy the complex reality of their transport processes. These companies rely on "classic" computer-supported scheduling without semi-automated route optimisation suggestions in their IT systems. This procedure is superior to manual scheduling with scheduling plans, because the computer provides a clear tool and digital work platform.

The question of whether semi-automated route optimisation is superior to classic IT supported scheduling cannot be generally answered. It remains probable however that the introduction of a semi-automated route optimisation system leads to an improvement in efficiency in comparison to manual scheduling. The result depends on the individual company business configuration, or, more specifically, on the individual transport situation within a company.

Introduction of the electronic signature

As far as a transport business and the financial part of the transaction is concerned, the central information required is whether a consignment/payload has been delivered on time. The sooner the company can establish that the consignment has been delivered correctly, completely, and without damages, the sooner the consignment can be billed. In view of the mostly poor financial situation of transport firms and the low level of willingness to pay of their customers, 2 to 3 days can make a difference. If the recipient signs a conventional delivery note, this delivery note needs to find its way back to the central office and to be manually booked into the system before it can be passed on to billing. If a proof-of-delivery with a voucherless electronic signature could be available, this would provide important time efficiency gains.

Rarely mentioned

Statistical analysis of transport processes

The statistical analysis of transport processes is mainly performed in the context of process optimisation from the economic point of view and the generation of economic key data. A "management information system" gives the companies the option of evaluating past consignment data using freely defined filters. The results of these evaluations can be in the form of trip statistics on a customer or partner basis, or of data on order volumes for particular times or regions. One possible option is the targeted search for return trip volumes from particular regions. Such evaluations are not carried out from the point of view of fuel costs or CO₂ emissions. It is unclear whether economic considerations are sufficient to cover the whole area of fuel efficiency (via load factor and distance optimisation). It became obvious in the interviews that such instruments are too infrequently applied or not provided by existing systems. To include the indicators of consumption per unit of performance (l/tkm) and consumption per euro of turnover (1/€) would be starting points.

Better integration of third-party consignment tracking in the telematic systems

Third-party order tracking is an old issue in the area of transport telematics and is the current state of the art for telematics systems for location and data communication. Nearly all the companies view it as a very important instrument for securing customer loyalty. Nevertheless, for two of the seven transport companies with telematic systems, it remains a service that has not yet sufficiently been put into practice. It could not be established whether this is a problem specific to manufacturers or to individual companies. There is potential in this area.

On-board navigation systems tailored for use in commercial vehicles

On-board navigation is the subject of some dispute. Basically speaking, on-board navigation is of interest for short-haul distribution transport and for drivers operating on unknown routes. From this can be concluded that navigation support is only needed at the very end of long-distance runs, in the so-called “last mile”. This is especially true for foreign language areas. Drivers who operate day in day out in the same delivery areas are probably quicker without support, because they can better judge the situation from their daily experience and local knowledge. Many transport companies reject on-board navigation for these reasons. One of the fundamental weaknesses of such systems was always the lack of basic data, or of adequate mapping. Thus, there has been commercial software only since the beginning of June 2005, which takes the requirements of larger trucks into account by providing information on bridge and tunnel clearances, weight limits, or other access limitations. Some firms have reported that these systems can effectively be used only in passenger car transport. At the beginning of June 2005, the market leader introduced a new product, which tackles this weakness with the aid of a new mapping information basis and a new version prepared solely for use in commercial vehicles. No information based on experience of this system is yet available. It can be assumed that this innovation goes some way towards tackling the principal weakness mentioned. This innovation would need to be evaluated in a future investigation. Further efficiency potential is therefore also identified in the field of navigation systems.

Integrating traffic information into planning tools and on-board navigation systems

One area of technology that is currently being researched is the integration of traffic information into the various planning tools and on-board navigation systems. It lasts many years of experience of traffic analysis to be able to make a time variation curve on usual traffic situations for a specific route. These balances can provide information on what kind of traffic and travel time can be expected on a particular route at a particular time (time of day and day of week). On the other hand, instantaneous information on particular events is crucial for driver. The manufacturer research is investigating the potential for a better accuracy and faster reaction time of these tools. Such systems should be able to give suggestions to the drivers on the best possible route at any given point in time, based on historical, statistical, and current information. This information could also be obtained by the scheduler. For navigation, the question arises as to whether such a system would be better accepted than the actual one. Research is needed here and we will have to wait for the manufacturers' R&D results.

Conclusions from the telematics and IT scheduling surveys

The potential for CO₂ efficiency improvements have been demonstrated in the telematics and IT scheduling surveys. Two main fields of activity will have to be targeted by policy measures and company strategic plans:

- increased diffusion of the technologies with the highest efficiency effects in the freight transport companies
- development and application of new technological features according to following main solutions:
 1. Higher level of integration of the various systems
 2. Improvements in stability of the telematics hardware
 3. Connection of IT scheduling and on-board monitoring systems
 4. Reducing the complexity of the on-board monitoring data
 5. Comparison of planned and effectively driven routes
 6. Measuring volume capacity utilisation
 7. Route and trip optimisation using semi-automated IT scheduling systems
 8. Introduction of the electronic signature

3.4 Energy efficiency in the German courier, express and parcel forwarding sector (CEP): survey, analysis, and case study

3.4.1 Introduction and presentation of the targeted CEP surveys

In the period 2004-2005, targeted case studies have been carried out in the German courier, express and parcel transport sector. The purpose has been to arrive at further insights into the energy efficiency issue in those fields of business which have until now remained largely unexplored. On the one hand, the objective is to gain understanding on various processes influencing efficiency, and creating business specific framework conditions that are impeaching or allowing changes. Qualitative surveys were carried out to this end. On the other, it is necessary to quantify the current efficiency performance in order to arrive at estimating more precisely the efficiency potential. The general aim is the same as in the previous sections of the study: to discover whether the decoupling of freight transport from energy consumption is taking place and to investigate the potential for further steps in order to be able to make recommendations on how to achieve this potential.

In order to reduce CO₂ emissions in road haulage, it is necessary to make use of the possibilities and degree of freedom for decisions that already exist in the individual markets. At the same time, it has to be taken into account that not all

companies are in the position to put the possible options into effect immediately. This is because the market situation of each individual company and competitive pressures to which they are subjected may not allow more than a very restricted level of freedom. In order to understand and to estimate what kind of future developments may occur in road haulage in the areas of CO₂ reduction or increased efficiency, it is therefore not adequate to maintain actual quantitative trends at constant rates. A qualitative sector analysis offers a much greater chance of determining the real opportunities, and barriers to their application, than a business-as-usual scenario could do. In turn, this approach could allow for a realistic market development prognosis to be made. The qualitative analysis can however only help one to understand the conditions in relatively small sectors of the market, rather than the whole road freight transport and logistics sector.

The particularities of the CEP sector, such as the widespread use of light commercial vehicles and cars, lightweight parcels, and the organisation of time-critical goods movements, had, before the start of the survey, already led to the estimate that efficiency saving potentials could be identified here. The aim of this sub-study, therefore, was set as the identification of achievable CO₂ efficiency potentials within the German CEP haulage sector. This potential has to be reached while respecting or modifying slightly the individual organisational patterns.

The CEP sector in Germany and in many other European countries demonstrates in recent years a growth in turnover and in transport performance. However, the significance of the sector in terms of its share of road haulage-related CO₂ emissions remains unclear. The CO₂ emissions generated by CEP related air freight and rail transport activities are not very relevant here, because they still only have a limited market share in the Federal territory.

Additionally, available knowledge on the question, whether certain types of orders can be transported more efficiently than others, is currently inconsistent. For this reason, the decision was made to carry out a survey of primary data in one company, offering services in courier and express delivery. The results of this survey are presented in chapter 3.6.3.

Due to the world wide trend to reduce the shipment size and weight, the economic growth of the CEP sector is expected for the near future, making it a relevant field of survey.

3.4.2 Terminology, methodology and results of the general CEP survey

The market designated with the acronym CEP is a subsector of the express delivery market. The types of service offered range from individual parcel delivery to document courier services. The general understanding of “express” is that goods or people are transported at high speeds. With reference to the subdivision of CEP companies into three different structural forms of services within the context of the express market, the Bundesverband Internationaler Express- und Kurierdienste e.V. (BIEK 2004) define the following characteristics:

Courier services: the earlier definition of courier services was that of personally carried transports. The permanent presence of personal with the parcel or letter remains to this day the decisive distinction between this type of service and other express and parcel services. Courier services are associated, amongst other things, with a particular level of security in the transport chain. Personally “escorted” transports take place both nationally and internationally.

Express services: the express deliveries field encompasses all those services, which do not send the consignments directly, exclusively, and with personal escort to their destinations, but via cross-docking centres. The previously agreed door-to-door delivery time is the criterion that distinguishes this service from haulage services. A typical express service is overnight transport, in which next-day delivery is performed.

Parcel services: the delivery times are not guaranteed, but an estimate is given. In Germany, a shipping time of three days can generally be assumed. Package weight is normally restricted to a maximum of around 31kg. In addition, the restriction on size and shape of the packages carried, as determined by automated parcel sorting equipment, is a decisive characteristic.

The integration of previously fragmented transport chain functions is the main success of express service providers, which achieve high-speed movement of goods, and reliability of delivery, without making use of direct and exclusive transports. The organisation of the transport chain in a way that includes more than one interface, and the giving of delivery time guarantees, are two important structural characteristics of this sector. Express services divide their transports up into pre-carriage, main leg, and post-carriage phases, whereby the first and last are carried out in collective and distributive transports, and the main leg is performed between central nodal point and regional distribution centres.

One particularity of CEP services is the regular, nation-wide carriage of largely standardised, low-weight individual parcels, partially in accordance with a timetable. On an individual basis, in the context of the liberalisation of the postal services market, parcel service providers are currently completing their entry into the post (mail) delivery sector. In the survey, only the “classic” CEP services, in absence of a liberalised post market in Germany, are subjected to analysis.

Survey hypothesis and sample size

Main hypothesis of the CEP survey is that the CO₂ efficiency of the CEP sector can be improved through the implementation of available technologies and measures in driving operations and transport organisation.

In the 2005 survey, 16 CEP companies, 2 of them were special service providers, 2 experts of CEP associations and a number of external experts (i.e. technical experts from vehicle manufacturers) were interviewed in Germany during February to May 2005. Responses are presented according to the different topics of the interviews.

Structural market influences on efficiency

BIEK (2004) gives figures for turnover in the CEP sector. According to these, around 1.8 billion deliveries were made in 2003, with a resulting turnover of around 10 billion €.

The average revenue per parcel is estimated at around 5€ per order shipped (Klaus 2003). The different services demonstrate different revenue potentials; about 9€ per parcel can be charged in the courier and express delivery sectors.

A significant success factor behind the volume growth of the CEP sector, the tendency towards reductions in fixed costs in favour of variable costs, influences the whole sector, rather than just CEP customers. Outsourcing of driving operations is a sector trend, which can exert an inhibiting influence on the implementation of efficiency gains. For example a courier service company centre is thus more interested in making a transport service offer to its customers that involves minimal distances. A self-employed courier service driver, whose income depends on the distance driven, will tend to see this process in a critical light.

Customer structure is a relevant influence factor for the efficient performance of services. Especially when private households are customers, the interviewed drivers or employees of courier or express service companies state the problematic profitability of this customer group. One reason for the lack of attractiveness of private persons are the smaller delivery time windows, compared to business customers. Only large companies, the parcel service providers, tolerate the challenges associated with the servicing of a large share of private customers. These companies are responding to the profitability problems by the introduction of innovative concepts for the “last mile” distribution.

Efficiency relevant characteristics of CEP goods transport: time efficiency and load factor

All interview partners mentioned the importance of transport quality for business success. Quality of service is the number one argument in generating customer satisfaction. The most important factor in the achievement of good transport quality is the fulfilment of the customer’s delivery time requirements, or, as the case may be, of production-determined delivery deadlines. The degree of freedom, to choose from different options for efficient vehicle use, is not the same for all business types. Least possibilities are available for the practically immediate and exclusive transport offered by courier service. The number of options is growing because of the longer delivery periods of the express sector. Finally, the options are much increasing for the parcel service sector, where more time is available between pick-up and delivery.

A question checked was, whether an improved vehicle weight/volume **load factor** can be obtained by means of improved vehicle fleet adaptation to the order situation. It appears that there was little room for decision here. Especially those companies depending on fast carriage are choosing more time flexibility instead of higher load factor when it comes to the scheduling of the parcel collection and delivery services. This principle (time versus load factor preference) is true for transport firms who use the same vehicle for different business purposes. Time pressure is one of the main components of the competitiveness of a company. This will remain therefore in the middle term a major difficulty for this type of business.

The parcel service providers have the biggest “time reserves”, compared to courier or express, and they are using them to buffer the fluctuations in order volumes. In the other sectors, the lack of such free time resources is associated with more or less inefficient vehicle use. However, this situation is accepted in the industry, for reasons of product differentiation.

According to this, as far as the use of vehicles is concerned, efficiency becomes more important, when the value of the service provided is decreasing. Therefore, the higher value businesses of courier and express services demonstrate higher optimisation potential than the parcel services. This is also because German parcel services companies are very big and only very few on the market. Due to this, they have already optimised most of the operational processes. A potential that can be activated is derived from the fact that few CEP companies are aware of the need to improve the load factor.

Price structural factors and fuel costs in the CEP sector

An important structural characteristic of the CEP sector, regarding price structuring and fuel costs, is the fact that those players who are the most directly affected by the changes in fuel costs –the self employed drivers – have the least influence on the pricing of the various services provided. This problematic aspect brings about an unequal awareness of the problem

on the part of the various players. It is in most cases impossible to pass the costs on to the customers in short terms, and the costly options for a more efficient fuel use is not a problem of the central offices. The options for higher vehicle efficiency remain on the side of the self employed drivers and are in this case limited by a lack of investment capacity.

A pricing characteristic that is strongly influencing the transport efficiency is the distance-dominated billing principle. Its side effect, due to the control exercised by the customer, is to require from organisers and hauliers to carry out their processes in a distance-optimised and, therefore, CO₂ optimised way. This is an example of the effectiveness of coupling ecological efficiency to the pricing structure, even when this arises as a “by-product”.

CO₂ efficiency potential in driving operations

There are no precise data on the fleets operated by German CEP companies and self employed drivers. One reason for this is the difficulty of isolating individual vehicle usage.

The quantity of vans with a gross vehicle weight rating (GVWR) of between 2.8 and 3.5 tonnes leads to the assessment of a total CEP sector fleet size of 80,000 to 100,000 commercial vehicles. In addition to this must be included an unknown proportion of CEP vehicles, which are registered in the category of business cars, and finally an unknown proportion of private cars, which also have a goods transport function (Pfeiffer 2004).

The CO₂ efficiency potential of consumption-optimised **driving behaviour** is well known to self-employed drivers and CEP central offices. Special training programmes for commercial drivers are estimated to lead to potential fuel savings of a minimum of 10 up to 40%. This figure has been produced through case studies and available scientific surveys (Ministerium für Umwelt und Verkehr Baden-Württemberg 2004; UBA 2006). However, the greater proportion of the interviewed partners does not take part in such training courses. The training of driving staff shows direct efficiency effects and has a high potential in Germany.

As a consequence of the unequal standards that have been established for vehicle **maintenance** and for upgrade of the vehicle equipment with instruments for consumption monitoring and reduction options, it can be deduced that the CEP sector fleet can be optimised.

The use of alternative fuels like natural gas and **biodiesel** is made more difficult by information deficits amongst self-employed drivers, and problems in co-operation with vehicle manufacturers. From the perspective of central offices, a more widespread use of more CO₂ efficient fuels is currently made more difficult by the technical specifications of the vehicle manufacturers, the insufficient level of infrastructure development, and the unclear cost situation. Solving these difficulties at the policy level would allow easier decision-making for companies and drivers. CO₂ efficiency potential can be seen in the case of short-distance transports in urban areas, which have a good alternative tank filling station infrastructure. As far as courier and express services are concerned, the so-called “**modal shift**” offers little room for manoeuvre. The potential for shifting courier transport onto bicycles has already been exhausted. Rail transport is only a serious alternative in specific small market areas.

Because of their own large vehicle fleets, parcel service providers are in the forefront of efficiency improvement measures by their driving operations. Efficiency measures are either already in the implementation stage, or have been subjected to internal test runs. Very precise cost-benefit analyses on efficiency measures are being carried out. The higher implementation rate of the measures in these companies suggests that efforts to achieve ecological and economic efficiency targets are compatible with each other. At the other end of the market, there is, in contrast to it, only very limited potential for efficiency improvements for the operators of small fleets, or for independent driver, even though this potential has been confirmed by the interviews partners.

CO₂ efficiency potential in transport organisation

The following criteria (Gudehus 2000) are relevant to route and trip planning in transport organisation:

- **Transport capacity:** volume capacity and GVWR set limits to the size of payload.
- **Cargo specification:** the sensitivity and characteristics of the parcels limit the logistics options
- **Trip times:** the permitted working hours may not be exceeded on any individual trip
- **Collection and delivery times:** deadlines or delivery windows must be observed
- **Speed:** speed limits must be observed and congestion effects taken into account.

It is unclear to which degree of efficiency the CEP sector is currently working with all these criteria. It was thus important to identify the most important criteria for the interview partners, and understand on which basis organisational optimisation could occur in their businesses.

The existing **co-operative relationships** between CEP hauliers have activated a certain CO₂ efficiency potential, because they contribute to a reduction in the proportion of empty runs and an increase in vehicle capacity utilisation, when, for instance, various different parcels are “consolidated” prior to delivery. A significant obstacle to an intensified activation of

efficiency potential of co-operative agreements in the direct courier sector is represented by the exclusive delivery requirements inherent in certain products. The restrictive time demands, an obligatory condition in this context, counteract the efforts made to improve the load factor. The expansion of co-operative relationships is conceivable, but under current concurrency conditions only practicable to a certain extent. It is, however, stated by company manager that an unexploited potential is available in the area of co-operation, especially in the courier sector.

As stated by the decision makers, **technical systems** for business support, such as vehicle navigation and location, have potential, and should be improved through further efforts to make them more user-friendly. The market transparency of the products could be improved e.g. through the creation of transparent cost-benefit analyses for the successful implementation of IT scheduling and telematic instruments. This in turn could trigger a larger diffusion of the currently available CO₂ efficiency-enhancing instruments in the CEP companies.

The **functional separation** of order data processing from physical driving operations is one of the main characteristics, but also one of the main barriers to efficiency improvement in this sector. This separation is further expressed in the organisation of line operations and cross-docking stations. Specialist service providers exploit the tendency to functional concentration in courier and express service providers and offer cost advantages to their customers, which are then activated by payload bundling and scale advantages. This business model uses the available efficiency potential within the sector as a niche for specialist service providers. The potential seems already to have been activated here.

The main objection to a more intensive use of IT systems in vehicle **scheduling** seems to be the inadequate IT reproduction and presentation of planning parameters. According to the information given by partner companies, the “complexity of reality” simply cannot yet be represented by currently available scheduling systems. From this, it can be deduced that there is a need for innovation and development of the systems, and also a greater need for improved information and consensus on the available solutions. IT-based scheduling systems can best activate efficiency potential if they are running on large order volumes and vehicle fleets. Standardisation in the use of these systems is already ongoing only in the large companies of the parcel services, in which formalised co-operative agreements offer good initial conditions that also have to be taken into account when new technical standards are introduced.

Economic outlook and development tendencies in the sector

Prevailing market conditions dictate a low price level for self-employed drivers. The financial room for manoeuvre for the introduction of efficiency measures is therefore limited. Self-employed drivers will probably remain the weakest group in the CEP hierarchy, both socially and economically. Representatives from the courier and express service centres, in contrary, are expecting very positive market developments. The predicted product shift from courier to express order is to be welcomed with respect to the sectors CO₂ efficiency, because the slower and less exclusive express transport can be organised more efficiently. Such a trend would induce a decrease in turnover for self-employed drivers.

The trend to diversification of the range of service options, offered by courier and express service providers, is ongoing, and is expected to remain in the mid-term future. Ecological benefits can be derived from this business trend above all if synergy effects with other services are put into place. For example, the CEP driver can have a contract beyond transport, like the maintenance of a customer's equipment, instead of a technician who has to make a special trip. Such a diversification process demands new organisation patterns. According to interview partners, a potential for the development of scheduling systems exists in this field.

Representatives of the parcel services assume that the market and turnover volume will increase in future. Recent innovations in the area of shipment distribution (yellow boxes, etc.) have been applied. They have clearly led to the reduction of extra transport and thus to improvements in the CO₂ efficiency balance per shipment, especially in the services provided to private households. It can be assumed that these concepts will be further developed. An evaluation of this development trend, from the point of view of CO₂ efficiency, would have to lead to the conclusion that the highest potential for improvement lies in the last phase of distribution.

There is no reliable way to say whether, for all Germany, it is more efficient for private customers to go in person to city centre or suburban outlets, or for a professional and efficient parcel service to deliver to their door. Nor can it be stated with certainty, whether going to the parcel distribution centre represents the optimal option in terms of efficiency. If a private customer buys many products in one trip, if a commuter journey becomes a shopping trip, or if public transport systems are used, then these household goods transports can demonstrate a high efficiency. An empirical CO₂ balance sheet of the various “last mile” distribution logistical concepts is only available for few solutions (Patier 2005). There is more need for impact evaluation in this field.

3.4.3 Potential for energy efficiency in direct courier and express services: survey of the company GO!

A collection and analysis of primary data on the efficiency of CEP transports becomes relevant, as high emission figures per parcel were expected, but no data were available. As far as the German-based CEP companies were concerned, no scientific investigation had yet been carried out with the aim of measuring the energy efficiency.

The co-operative partner GO!, which was subjected to evaluation, is an important market player with 3000 vehicles connected to the system, with the main activities in the direct courier and express delivery sectors. The business structure of the company is similar to all the other interviewed companies of this sector. The business geographic area covers Germany and the European neighbour countries.

The Hamburg regional centre has 98 self-employed drivers registered in the system in 2005. 10 schedulers and 20 call centre employees are working in the central office. The drivers engage in four different transport activities:

1. **Courier transport:** the courier order (parcel or letter below 30 kg) is carried directly and exclusively from the customer to the recipient, usually within the 750 km² of the Hamburg city area. The order and parcel data are transmitted to the drivers by radio. In the city region, the parcel is delivered within the same day.
- **Express transport:** the express parcels are collected in the afternoon and delivered throughout Germany the following day. These trips are carried out using three separate transport types:
 2. **Collection (export in company jargon):** the parcel is collected from the customer by 19:00 at the latest and brought to the regional centre in Hamburg. The scheduler in the central office organises the trips, by using a fixed regional organisational pattern, each driver being responsible for its own area. The trips are executed by car or van. In the centre, the incoming parcels are entered into the IT system and assigned to their final destination.
 3. **Overnight scheduling:** all overnight parcels with destination outside the Hamburg region are transported in the evening from Hamburg to the hub (central cross-docking station) in Hesse, in central Germany. The last line vehicle (five vans of 3.5 t) leaves the Hamburg depot at about 21:00. The line vehicles come back before 6 am, loaded with parcels for the greater Hamburg area.
 4. **Delivery (import):** the parcels are distributed to the required address. The morning delivery is often subject to restrictions, shipments have to be delivered before 12:00, sometimes before 10:00, or punctually at a prearranged delivery time.

The Hamburg depot handles about 5-600 express import and the same number of express export consignments per day, whereby most of the shipments are single parcels, but some consist of up to 20 packages. In addition, 280 – 350 courier shipments, mainly in the city, are transported throughout the day. Between 4 and 80 parcels are delivered per driver per day, depending on the geographical area and the order situation. These daily variations are complicating the planning and scheduling of persons, vehicles and trips.

Design of the investigation

The company GO! carried out the questionnaire-based fuel consumption measurement procedure in two phases: a preliminary test at the end of 2004 and the main measurement in March and April 2005. Trips data for the four different types of transport were recorded. The questionnaire included data on:

- Number of parcels
- Number of kilometres driven
- Amount of fuel used
- Transport time (maximum one day or one night per sheet) and
- Vehicle specifications (type, empty weight, and GVWR).

Measurement forms were given to the couriers with the request that they should fill up to the same level with diesel or gasoline before and after the measurement. 139 valid datasets were received (sample size), consisting in:

- Delivery (distribution): 48 days
- Collection: 24 days
- Direct courier: 53 days
- Night lines: 14 nights

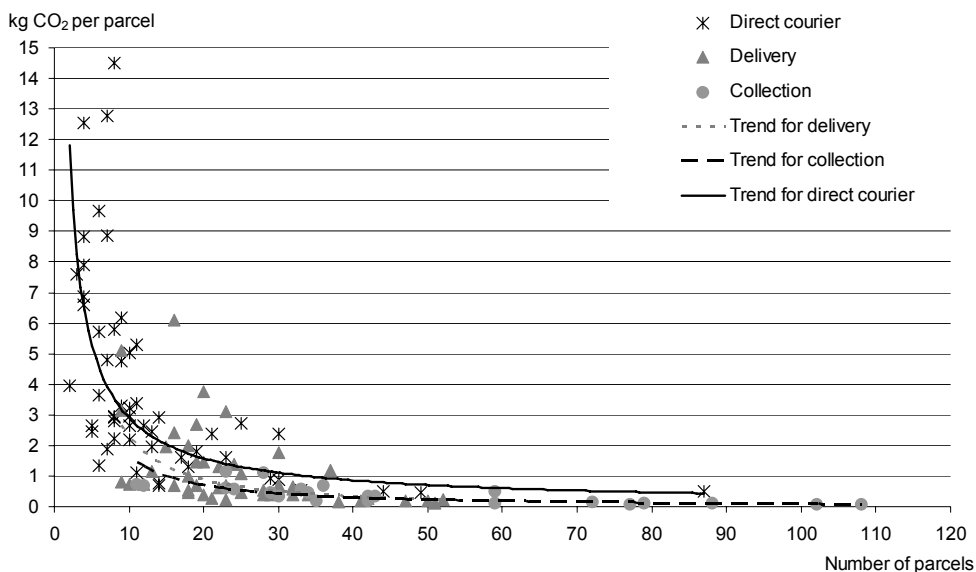
Parcels load and unload activities were recorded. There was little difference observed between the number of shipment orders and the number of packages. The following analysis uses the terms “parcel” and “package” synonymously, whereby it is always packages that are meant, not shipments. The efficiency was calculated in kg CO₂ per parcel.

Results: energy efficiency per parcel

The mean efficiency value, calculated for all transports independently from the distance and the weight, is about 2 kg CO₂ per parcel (2,04 kg). The raw data reveal a high level of variation in quantity of consignments per day or per night for the various transports: between 10 and 53 consignments in import, between 11 and 108 in export, and between 180 and 680 for night lines. These high variations also occur for CO₂ efficiency. The above-mentioned average value for all the activities is therefore not a very useful reference. In figure 29, each point represents the mean CO₂ efficiency and number of parcels for one dataset. The results show very good to good efficiency values for collection, very good to problematic figures for delivery, relatively good figures for nightlines, and good to problematic values for direct couriers. The data show significant improvements in efficiency, when more parcels are transported.

Best mean value in direct courier for CO₂ emission is 0.47 kg per parcel. There are only few examples in road freight transport where the transport cycle of a shipment “from door to door” is associated with such a low level of emissions. After consultation with the company, it was confirmed that the conditions for achieving high levels of efficiency in the express sector are: the mean parcel weight is not heavy (4 kg in average), parcels are carried over short distances, and the vehicle’s capacity is relatively well utilised with a large number of parcels transported per day. For collection, it can be seen that low values of less than 0.1 kg CO₂ emissions per parcel can be returned. The best figure of 66 grams of CO₂ corresponds to a fuel consumption rate of 0.025 litres per parcel. This low value is surprising, because it represents an average for all the collected shipments of a driver in one normal business day. In this case, the consumption per parcel had a market value of about 2 eurocent (basis: fuel prices in spring 2005). The company representatives explain that parcel collection is a part of the business that can be very well organised. Before taking a decision on the trip route and organisation, the schedulers are waiting until most of the daily orders are available, usually in the late afternoon. With a higher amount of order and information, and less time restriction than for the other business parts, the collection trips can be organised efficiently.

Fig. 28: Parcel number and CO₂ efficiency in direct courier and overnight transports



Source: Survey 2005

To arrive at a balance sheet calculation for GO!’s whole overnight service, it requires the addition of the consumption values for collection, nightlines (return journey to and from the hub in Hesse), and delivery, and the consideration of the decision makers that the distance between Hamburg and the hub in Hesse (300 km) is representative for the whole overnight business of this company. According to this, the minima value is around 570 grams per parcel (tab. 15).

Table 15: Minima and maxima in efficiency in kg CO₂ per parcel (Source: Survey 2005)

	Minima	Maxima	Factor
Collection (greater Hamburg area)	0.07	1.15	19
Nightlines (national)	0.4	1.5	3.7
Delivery (greater Hamburg area)	0.11	6.1	55
Total overnight (national)	0.57	8.75	15
Day courier (greater Hamburg area)	0.47	14.52	31

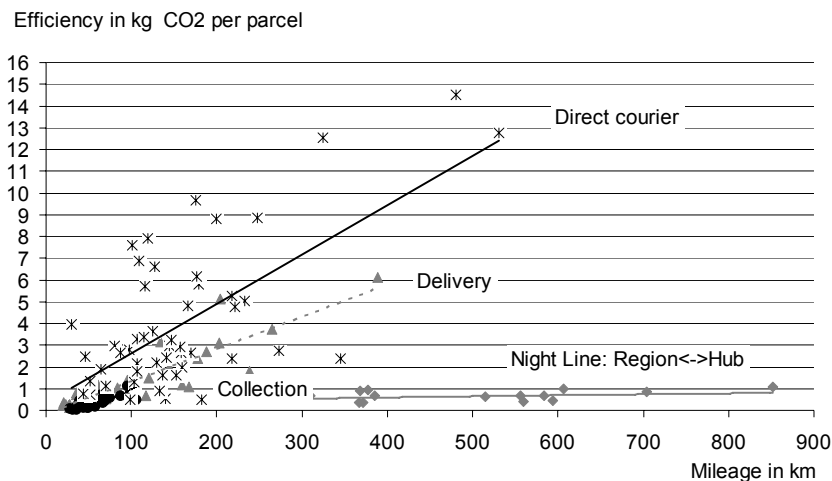
The high variations in trips and order situation in normal business is reflected in the energy measurements, especially as far as deliveries are concerned. Between the most and least efficient delivery, a factor 55 is observed. For direct courier, the factor is 31. This leads to the conclusion that a theoretical potential exists for further increasing the efficiency through organisation in these two fields. Asking the company decision makers on this point was leading to a positive reaction, and the company was deciding to look for solutions and potential efficiency gains. For nightlines, it was clear on visual evaluation and upon survey, that the vehicles' capacity is fully utilised upon departure and upon arrival. The factor of only 3.7 between the two extreme nightline records makes it clear, that there is only very few potential here.

Large fluctuations in distance

The data shows large fluctuations in distance for all transport types (Fig. 29). For nightlines, more distance does not mean a much lower efficiency per parcel. However, for direct courier, it does.

Between the shortest (21 km) and longest (852 km) distance recorded in the frame of one day or one night, there is a 40 times difference. According to the results, nightlines account for the longest distances. For direct couriers, some return unexpected high distance records. Their operative radius should be, by definition, restricted to the city, and most of the drivers covered distances of between 50 and 200 km. Some, however, covered more than 300 km per day, and the peak value is 531 km. In this case, the driver was delivering a single parcel 170 km from the previous delivery point, far beyond the geographic limits of the Hamburg region. This dataset shows therefore a low mean efficiency, with 13 kg CO₂ per parcel. The scheduler, asked on this far distance trip, considers such cases as normal business.

Fig. 29: Distance per day and CO₂ efficiency



Source: Survey 2005

It is also remarkable that a large variation in efficiency exists in the category of trips between 50 and 200km. It is possible to achieve a high level of efficiency of less than 0.48 kg CO₂ per parcel with a small van (VW LT28), operating with a good balance between high number of parcel and average distance (87 parcels on board during the day with a total distance of 182 km on this day). With a similar distance, however, (175km), a car (VW Passat) with only six parcels on board emitted an average of 9.6 kg CO₂ per parcel, which represents a 20 fold increase on the previous case.

Thus, the factors of distance and, more precisely, short distances between two drop-off points are decisive. However, the increased quantity of parcels delivered per day is equally important than the total distance. It will in future be essential to increase the vehicle utilisation in term of total number of parcels per vehicle per day, if further improvements in efficiency are to be achieved.

The efficiency potential for reducing distance, after discussion with the company representatives, seems to be low. It belongs to the daily business to minimise the total distance, as the drivers are paid by parcel and by kilometre. Thus, the expected potential for changes is small. On the other hand, if a new technology would appear, helping to reduce the total distance, this would have a high acceptance and would be applied very shortly in this company.

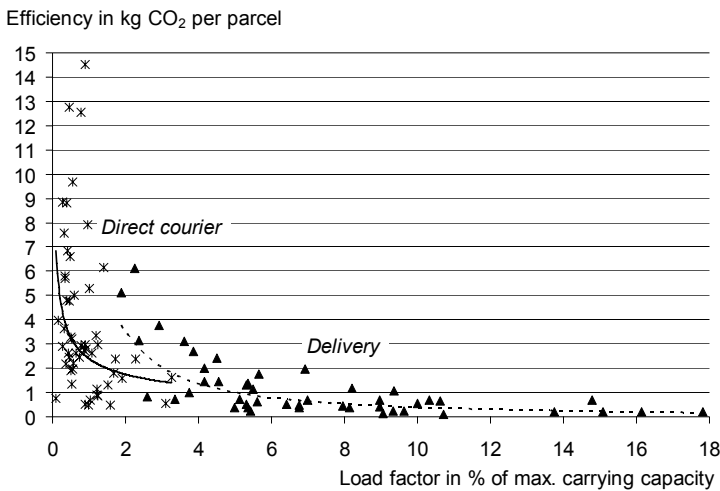
Fluctuations in the load factor

Depending on the type of transport and the order situation, the vehicles are scheduled differently, not only with regard to distances but also in terms of loading. Within one sector, various processes can be identified. Since the load factor is rather good for collection trips and high for nightlines, the comparative analysis focus on delivery and direct courier (Fig. 30).

Below a load factor of 8%, direct couriers and deliveries shows large deviations in CO₂ efficiency. Direct couriers operate mostly at a daily mean load factor of less than 2%.

Load factor calculation for the CEP sector: The load factor was calculated for all vehicles, van and cars, assuming a mean weight of 4 kg per parcel, recorded by the company statistics. For the capacity calculation, the empty weight was deduced from the maximum permissible weight of the vehicle, in order to obtain the maximum load capacity by weight. This max. load is the number of kg set at 100% load factor for each vehicle. The recorded load and unload movements allow the calculation of the load factor for each trip. After weighting the distance, the daily mean load factor was obtained. The load factors were generally low, for small vehicles like for larger vans.

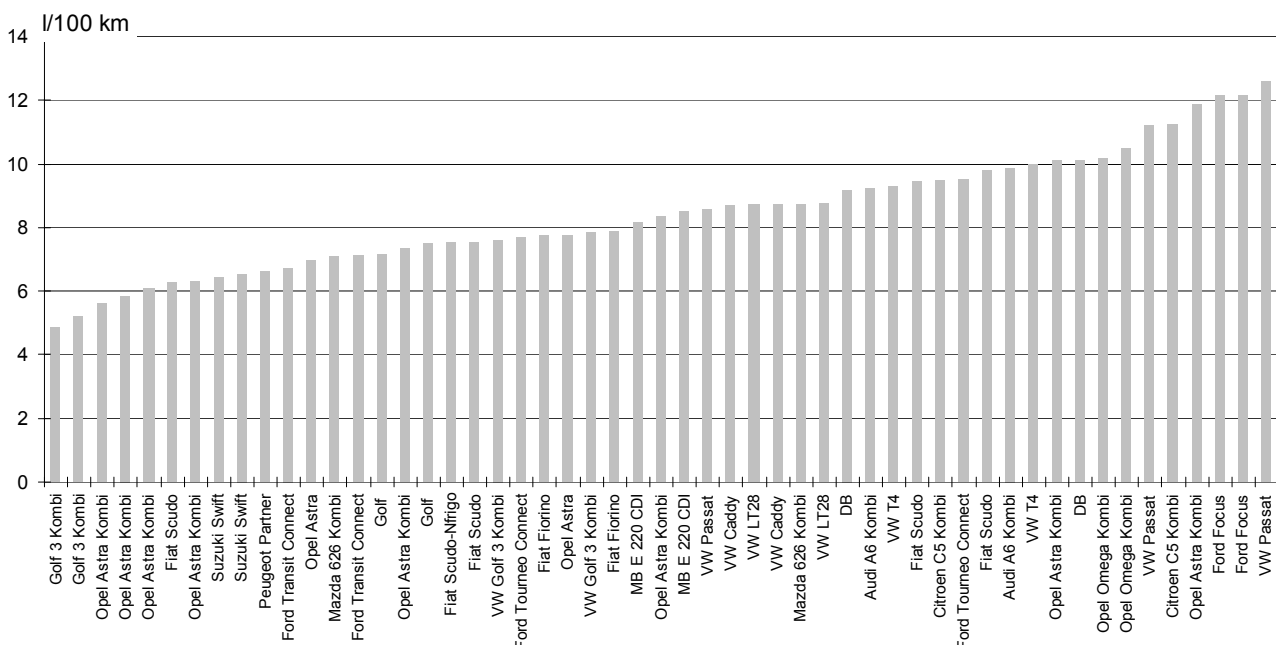
Fig. 30: Load factor and efficiency – comparison of direct courier and delivery transports



Source: Survey 2005

Why do the efficiency values fluctuate so widely in the case of direct couriers, even though they all operate in the same city, were measured on the same day, and operate under comparable business conditions for the same company? In order to understand the reasons for this variations, an approach based on the type of vehicle used was employed (Figs. 31 and 32). All raw consumption data are initially shown in litres per 100 km (Fig. 31). The lowest consumption is a Golf 3 car with a mean fuel use of around 5 l/100 km, which represents a very low rate when one considers the inner city transport environment with congestion and time pressure. The mean fuel use is relatively high, at around 8 l/100km. 6 or 7 litres per 100 km seems to represent a thoroughly achievable target for this kind of vehicle and business.

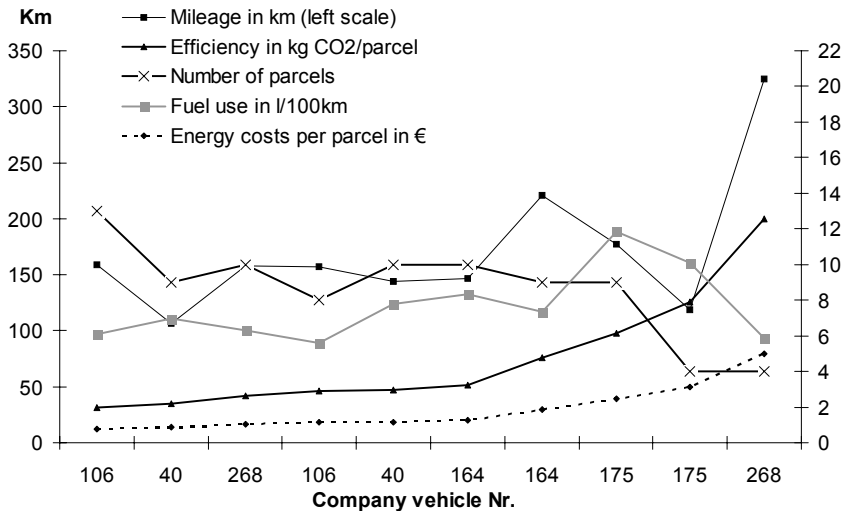
Fig. 31: Vehicles in direct courier service: mean consumption in litres/100km



Source: Survey 2005

Five vehicles of the same type (Opel Astra diesel), used in direct courier services, show different consumption figures (Fig. 32) for the two different days recorded. According to this observation, the reason for the low consumption may be less the type of the vehicle chosen, but the nature of the job, the maintenance of the car, or the behaviour of the driver. Whether this was the case or not was made the subject of a closer analysis carried out into the 10 Opel Astra data. The main outcome was that the conclusions of the preceding survey parts were confirmed: the efficiency values of the same vehicle (Nr. 268) changed from 2.6 to 12.5 kg CO₂ per consignment when the quantity of parcels falls from 12 to 4 per day and the distance rises from 150 to more than 300km. The big difference between the extreme values can thus be attributed to differences in the order situation.

Fig. 32: Direct courier service: efficiency analysis of the Opel Astra



Source: Survey 2005

In the cases of vehicles no. 40 and 164, in the middle range, a lower efficiency (40-50% change in CO₂ per parcel or fuel costs per parcel) have been recorded for the two daily means, in spite of an almost identical quantity of parcels and distance. Here, the variation is not related to the area (Hamburg) nor to the total time (all records are for the whole day). In this case, the time pressure could be responsible for the fluctuations. There are no discernible running times differences between the vehicles, all are above 8 working hours per day. However, the real time situation cannot adequately be represented from the time data supplied by questionnaires, in absence of digital records. Last category of influence factors remaining here are the different vehicle efficiency options (driving behaviour, vehicle maintenance, tyres, oil etc.). These options, as conclusion of this analytical step, are most probably representing the main source of variation for these trips. Options for increasing vehicle efficiency should be considered and the above presented solutions might lead to achieve a potential of halving the fuel consumption per parcel.

3.4.4 Conclusions from the two surveys in the CEP sector

The CO₂ efficiency of the CEP sector can be improved by implementing available technologies and measures in driving operations and transport organisation.

- The different perspectives between the central depot and the driver frequently sets the limits to the implementation of optimisation measures in driving operations. The reason for this is that those who might derive the benefits from efficiency improvements mostly do not carry the costs. The primary cause here is the general trend towards the separation of physical transport from logistical decision-making structures. Through the delegation of the responsibility for the vehicles running activities to the next level down the decision-making hierarchy, the potential scale effect in implementing vehicle efficiency measures is lost. Organisational measures could compensate for this.
- The tendency to bundle (“consolidate”) the orders more intensively for ecological and efficiency reasons, thus extending the delivery times, gives rise to the risk that CEP sector customers will look to other transport service provider. This means that the “consolidation” option can only be put into practice to a limited extent.
- Co-operative options are frequently exhausted. Individual possibilities like vehicle exchanges offer potential in the courier sector.
- The technical standard of vehicles show a clear improvement potential. The main barrier here is the economic situation of the self-employed drivers. Alternative fuels have potential.
- The case study example of GO! demonstrates high efficiency in the greater part of the nightlines and the collection for overnight transports. For direct courier and deliveries, a high potential is recorded and solutions are proposed.

4. Conclusions and recommendations

Main factors determining demand growth in the transport sector, and impacts on fuel use

Road freight transport growth is, in terms of turnover, coupled with GDP growth in Germany. In terms of tonnes (volume) or tonne-kilometres (performance), the growth is less strongly coupled with GDP. Since fuel use is slowly declining in road freight, a weak decoupling of climatic impacts from GDP growth has been observed since 2001. The drivers of road freight growth in recent years in Germany have been demand growth due to globalisation and the opening of Eastern European markets, growth absorption only in the road and not in the rail sector (due to the low competitiveness of German rail freight), reduced parcel size, and an increasing demand for cabotage, etc. Besides of transport demand growth, the potential drivers for fuel use have been tax and higher fuel prices, improved engines and goods vehicle design, improved load factor, and use of telematics. For some of these drivers, the fuel use impacts have been quantified.

Corresponding interests from the public and the private sector

There are, for many points, corresponding interests from the point of view of public environmental and transport policy and the company perspective. An effective increase in fuel use efficiency, measured in litre per transport unit (tkm, pallet or parcel) means less CO₂ emitted and less variable costs. However, the companies interview partners consider fuel use efficiency as a secondary matter, never as priority, and the survey results show weak implementation rates for most of the measures, including those that are the most interesting in terms of cost-benefits ratio.

The policy instruments and measures proposed below are deduced from the study outcomes. Recommended actions can be seen as targeted activities facilitating the application of efficiency measures at the company level.

Policy instruments and measures proposed for decoupling

Instruments with a high potential for lowering total fuel consumption in road freight and improving the market diffusion of efficiency measures in companies or at the level of entire supply chains are:

- Information campaigns and diffusion programmes for all technologies and organisational measures such as telematics systems and technologies, aiming at enhancing the goods vehicle load factor and lowering the emissions per tonne kilometre or per unit (parcel or pallet), (e.g. in the context of an energy efficiency campaign).
- Cost-revenue examples show that, in some cases, a return on investment in efficient technologies and organisational measures is possible within a few weeks. Such cost-revenue examples should be put into practice and, with the aid of independent public agencies, become part of the strategic thinking of company decision makers. Transport agencies, energy agencies, environmental agencies or city authorities could be actively supported here. This would help to overcome one main market barrier: the lack of product and service transparency due to a very large amount of suppliers and concepts.
- Further independent technology tests and evaluations of performance under real road transport conditions are required, aiming at measuring energy efficiency gains for each type of technology. The test results should be available to the companies, with the objective of improving the information base for decision-making, lowering the risk of investments and improving the very low application rate of efficiency technologies.
- Harmonisation of driver regulations and goods vehicle control practices with, for example, the effective introduction of a digital tachograph.
- Driver training programmes and promotion of eco-efficient driving techniques. As driving courses are generally not well attended because of the loss of at least one business day, some incentives are required here. The main barrier to implementation is the high time pressure in the sector. Cost-free training courses offered by goods vehicle manufacturers - for example, at the point of purchase of a new goods vehicle - could include energy efficient driving techniques and become a further generalised practice. The idea to include eco-efficient driving to the driver license knowledge, could be followed.
- Promote the market diffusion of biofuels and fuel switch activities.
- Research and Development on goods vehicle technologies related to fuel switch (biodiesel, CNG etc.), on-board telematics, light vehicle design, improved engine performance (for all vehicle types, not only goods vehicles) etc.
- Market studies on following topics (among other):
 - diffusion of innovative technologies and biofuels
 - restrictions on, and possibilities for, the different logistics concepts aiming at efficiency improvements,
 - solutions for overcoming the market barriers for innovative technologies and biofuels.

- modal change: Improve the competitiveness, reliability and speed of rail freight transport system and rail-road intermodal structures. The objective is a substantial increase in the demand for long-haul rail freight.

Effects of instruments and measures proposed

Positive effects are expected from a further implementation of existing measures, such as road pricing, and also from future efficiency measures (technologies and organisation) such as on-board systems, IT-disposition and telematics, fuel switch, new co-operative agreements etc.

There are no potentially negative effects of the proposed measures on the road haulage and logistics sectors. Most of the proposed measures entail very low cost for the state and the authorities. A significant decrease in total fossil fuel demand will affect the oil industry, but only if its decision makers are not actively developing alternative fuels and not improving the market diffusion of renewable energy sources on their own initiative.

However, the market development could induce some possibly negative effects, and counteract the effects of the measures, for example through an increase in total vehicle fleets and an unexpected growth in international (European) demand for road freight.

Not all proposed instruments are equals in terms of social equity. The social impacts of road freight related legislations and economic instruments on the drivers have to be taken into account. Since the decrease of fuel demand would be mostly positive for the income situation of the self-employed driver, most of the proposed instruments will show positive social impacts. The introduction of mandatory digital tachograph would, however, penalise more strongly the driver under high time pressure, and less the companies. Here, a socially acceptable solution have to be found.

Policy recommendations

- Implement the proposed measures and technologies for decoupling
- Strengthen the decision making process and develop the information base for energy efficiency in road freight transport, with the help of public relation campaigns, thus giving impetus for new company policy directions. It is also necessary to change some regulatory frameworks.
- Internalise at least partially the external costs from the road freight transport sector and improve the ecological effectiveness of fuel tax and other fiscal instruments. Reinvest at least a part of the fuel tax revenues (and the revenues from other fiscal instruments such as road user charges) into measures and technologies proposed above and into accident prevention and safety measures.
- Promote collaborative socio-economic research on energy efficiency in the freight transport sector in OECD countries. Improve research co-operation between European, North American and Far Eastern research institutions in this field. Improve vertical and horizontal integrative research co-operations between applied and theoretical institutions, economics, transport and environmental research organizations.
- Monitor the cause-effects relations of the proposed measures on energy efficiency and fuel use reduction, and analyse their cost-benefits ratios.

Abbreviations, glossary

BGL	Bundesverband Güterkraftverkehr, Logistik und Entsorgung: Federal Association of Haulage, Logistics, and Disposal Companies
BMVBW	Bundesministerium für Verkehr, Bau- und Wohnungswesen: Federal Ministry of Transport, Building and Housing
Cabotage	The transport performed by foreign goods vehicles in a European country
CAN-Bus	Controller Area Network. Element in vehicle electronics used to bundle information streams from sensors. The information from each sensor in the vehicle is made available via the CAN Bus for all control units (that is, for the on-board monitoring systems) in the vehicle
Carrier	A company that executes the transport of goods on a commercial basis. The carrier is liable for the whole stretch covered by its vehicles, irrespective of whether the goods are carried in own vehicles or those of other organisations
CEP services	Courier, express, and parcel services. The service provided by the CEP sector is characterised by the transport of “small”, relatively low-weight and low-volume consignments (such as letters, documents, small packages or small piece goods), short and reliable transport times
CO ₂ efficiency	Carbon dioxide efficiency. A measure for calculating the quantities of CO ₂ per performance and product unit. In freight transport, the CO ₂ emissions are correlated with the transport performance and measured in kg CO ₂ per tkm, per pallet or per parcel. In this study, an inverse unit is also used, tkm per kg CO ₂
CO ₂	Carbon dioxide. The most important greenhouse gas, emitted upon fuel combustion
COST	European Co-operation in the field of Scientific and Technical research
Cross Docking	A method for minimising the expense of goods handling procedures. The goods are precommissioned at the point of sending in a way that is directly suitable to the recipient. At the trans-shipment centre, the goods can be directly forwarded, without any storage time
CT	Combined transport
D	Deutschland: Germany
DB	Deutsche Bahn AG. National German railway carrier
DETR	Department of the Environment, Transport, and the Regions, now DfT, Department for Transport, UK
Distance	Distance travelled over a particular period using one mode of transport (unit in D: km)
ECMT	European Conference of Ministers of Transport
Efficiency	Improvement in (transport) performance at the same or a reduced level of operating expense (use of energy, emissions, work, costs, material, time etc.) (also efficiency potential)
EU	European Union
Fig.	Figure
Fleet management	Fleet management is the planning, managing and monitoring of vehicle fleets, consisting of several vehicles (commercial vehicles, passenger cars, ships, rail)
GDP	Gross domestic product
GPRS	General Packet Radio Services. A way of transmitting data over mobile phone networks. Each user does not have dedicated data connection; rather, the total quantity of data transmission resources available at any given time is allocated to individual users according to need. The data are then transmitted in packets
GPS	Global Positioning System. Operated from US for location finding using satellite technology
GSM	Global System for Mobile communication. Standard for mobile phone networks, which contains all the specifications and interfaces needed for such a network to function
GVWR	Gross Vehicle Weight Rating. The total permissible weight of a commercial vehicle (in combination also referred as Gross Combination Weight Rating). In Germany, 3.5 t GVWR is the upper limit for the car driver license. 7.5 t GCWR is the upper limit for entering several inner cities area. 40 t is the limit for HDV. The 44 t limit is accepted for special intermodal cases like road-sea export containers

HDV	Heavy Duty Vehicle. In Germany, these are vehicles with a GVWR of more than 7.5 tonnes
Hub and spoke network	Goods handling facilities (Hubs) on main transport routes for the delivery of goods to regional distribution centres (spokes)
Hub	The principal base for goods handling. Location for the bundling and handling of goods streams.
ICT or IT	Information and communications technology or information technology. This includes the technical configuration of information and communication systems (ICS), which supply their users with information as inclusive “people-task-technology systems”, and enable the exchange of data or information between subsystems and /or those responsible for contracts.
IEA	International Energy Agency
Intermodal	Including more than one transport mode
IPCC	Intergovernmental Panel on Climate Change
IRU	International Road Transport Union
IT scheduling	Hardware and software support for scheduling, fleet management and the associated decision-making processes. IT scheduling is often connected with telematics devices
Km	Kilometre. Measurement unit for distance
Load factor/capacity	% of utilisation of a vehicle in proportion with its maximum carrying capacity in t or in volume
Logistics	Logistics or logistics management, as defined by the Council of Supply Chain Management Professionals (CSCMP): “Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers’ requirements.“ (Vitasek 2005) At the heart of logistics is the transfer of material goods in space (transport) and time (storage), within a company as well as between companies and customers.
Long-haul transport	Journeys of more than 50 to 150 km (definition depends on author), which may not be travelled as a return journey in one day
Mkm	Mass kilometre, total weight multiplied by distance in km for one trip
Modal split	Distribution of transport, or of transport volumes or performance in various different carriers (road, rail, air, sea, or pipeline transport)
MPIMET	Max Planck Institute for Meteorology, Hamburg
Mtoe	Million tonnes oil equivalent
Nb	Number
NESTOR	Project on sustainability effects of efficiency measures in the transport industry
NESTOR2	The same project with a particular focus on CEP services and co-operative freight forwarding agreements
OECD	Organisation for Economic Co-operation and Development
On-board system	Devices installed in a vehicle including sensors and ICT. Often meant here in the sense of a system for recording fuel consumption
Outsourcing	Complete transfer of business functions to a third party or parties
Own internal transport	Transport between operating sites of the same company
Parcel (courier)	A shipment of one or more packages, ordered by a customer (in this investigation, parcel and individual package are used synonymously)
Payload	Shipment meant as total weight of the load. Calculated in t as gross vehicle weight rating (including trailers weight), minus empty weight, fuel and equipment
Pkm	Passenger kilometre. Measure for transport performance in passenger transport
Potential (efficiency)	Future possible, realistic improvements (in efficiency), not performed yet
ppm	Parts per million
R&D	Research and Development

r^2	Coefficient of determination. Statistical value for giving the strength of a functional correlation between two variables. The nearer r^2 is to 1, the greater the probability of a linear correlation. With the help of this statistical instrument, the supposed strength of an interaction between indicators, parameters or variables can be confirmed. In the base survey, from all the CO ₂ efficiency influencing factors, the variable with the strongest r^2 was tkm/mkm.
Relocation (spatial)	Transport relocation: Changes in route selection. Plant relocation: changes in production place.
Relocation (temporal)	Changes in journey beginning time
Road pricing	Charging for road use
Scenario	A path of development which is in itself consistent, free of contradictions, and theoretically possible to put into practice.
Scheduling	The collective term for co-ordinated practices of time and route planning for contracts, vehicles, and manpower
Shift (modal)	Change from one carrier to another.
Shipper	User of transport and logistic services (as a rule the end customer)
Short-haul transport	Trips of less than 50 to 150 km (definition depends on author)
Stat. Bundesamt	Statistisches Bundesamt: German Federal Administration for Statistics
Supply chain	and supply chain management (SCM): a management concept, which incorporates integrated structure, management, and monitoring of the entire logistics chain from raw materials supplier to end-user. According to this definition, SCM and logistical arrangements spanning different companies amount to the same thing. Some authors extend the concept of integration spanning different companies to include the value creation process
t	Tonnes. Measure of transport volume. Weight of the payload carried
tab.	Table
Telematics	Collective term for the combination of data processing and communications technology
Tkm	Tonne kilometres. Measure of transport performance in road haulage. The payload in t is multiplied by the distance in km per transport procedure (more exactly, per trip between loading and unloading points)
Tkm/mkm	Correlation of tonne kilometres with mass kilometres. Measure of the efficiency of transport performance in road haulage. Of all road haulage variables, it is the one with the closest correspondence to energy efficiency
Tracking and tracing	Consignment tracking with dynamic status information on the transported goods (e.g. via the Internet). Tracking refers to the determining of the status at any one time, tracing to creating a consignment history
Transport performance	Main unit for measuring freight transport activities. Measured by the indicator tkm or pkm. persons or goods carried multiplied by the respective route length or transport distance. Other indicators such as pallet-km or parcel-km are more rarely used
Transport telematics	Use of telematics to collect, transmit, process, and use transport related data with the aim of transport organisation, information, and management
Transport volume	Amount of passengers or goods carried. Unit: persons or t
Trip	Single journey for the delivery of goods. For trips optimisation, a plan could be implemented to reduce the total distance travelled and total time taken by all delivery vehicles used
WBCSD	World Business Council for Sustainable Development

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