Modal split and decoupling options – Paper 5

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Executive Summary

This paper is one of five papers on GHG reduction options for transport drafted under the EU Transport GHG: Routes to 2050? Project. This paper reviews the non-technical options related to transport demand and vehicle utilisation that could contribute to reducing transport’s GHG emissions, both up to 2020 and in the period from 2020 to 2050. It aims to provide a high-level summary of the evidence based on existing studies.

This paper covers the following options:
- Modal shift (both passenger and freight transport)
- Decoupling transport growth and GDP growth
- Improved logistics and vehicle utilisation
- Intelligent and advanced transport systems.

Most of the options covered in this paper are very closely linked to policy measures. The major cost of these options are usually not (just) technical cost but (also) the cost related to changing the behaviour of consumers and companies, e.g. the cost of higher travel times, less flexibility or lower transport volumes. Therefore it is not useful to calculate abatement cost in a traditional way. This explains why there are no abatement cost estimates available for the options concerned.

Below we summarize the main conclusions for each of these options

Modal shift
The GHG reduction potential of a shift between modes depends on the difference in GHG intensity (g per pkm or g per tkm) for the volumes that are shifted and on the potential volumes that can be shifted. Moreover, the overall impacts are also influenced by other impacts of modal shift policy like induced transport demand.

On average there are large differences in carbon intensity of the various freight transport modes. However, this has for a large part to do with differences in the type of goods (density, value), shipment size and requirements of the transport (e.g. speed, flexibility, granularity of the network). For the transport volumes that could be subject to modal shift, the differences between transport modes are generally much smaller than the average differences between transport modes. In addition, for a proper comparison it is crucial to look at entire transport chains rather than comparing the modes as such. Therefore the potential of modal shift is much smaller than the differences in these average carbon intensities would suggest.

For passenger transport, slow modes have clear GHG-advantages and in many cases also electric modes show relatively low GHG emissions, but this depends heavily on the electricity mix and vehicle utilisation rates. These modes have the highest potential in high-density urban areas. For freight transport, the potential depends a lot on distance and type of goods.

There are no reliable estimates available for the overall reduction potential of modal shift. Preliminary indicative estimates for the overall GHG reduction potential of modal shift for passenger transport ranges from 2 to 14% (for a shift from road to rail transport), depending on the assumptions. The shift from aviation to rail transport could in theory also reduce GHG emissions from passenger transport with a couple of percent. These estimates take account of both the differences in carbon-intensity and the market share that at the long run may be subject to modal shift. For freight transport the estimates found range from 4% to 23% reduction of total freight transport GHG emissions, with most of the estimates being at the lower end. Any potential of modal shift can only be achieved with policy intervention. It would require high investments and has the risk of rebound effects because of an increase in overall transport volume.

In the long run, all transport modes will become cleaner, safer and more fuel economic. This effect is likely to be larger for road transport, due to the slow turnover rate for ships, trains and aircraft. At the other hand, electric transport for example rail has an advantage as soon as a large
share of green electricity comes available. If all the electricity used is sustainably produced the CO₂ emissions drop to almost zero. For the other modes a suitable carbon-neutral energy carrier is as yet unavailable and may require large changes in vehicles and distribution infrastructure. Few assumptions can be made as to the nature of the improvements without a more detailed and technical description of the possibilities per transport mode.

Modal shift policy have the risk to interfere with curbing transport demand growth. Particularly infrastructure investments and subsidies can induce transport demand growth. In some cases, the benefits of modal shift were more than compensated by the growth in transport volume. Measures to mitigate this through ‘locking in’ the benefits are therefore required.

**Curbing down transport growth rates**
Transport demand growth is the main driver for the still strongly increasing GHG emissions of transport. Curbing the expected transport demand growth rates directly reduces GHG emissions. For passenger, the availability of faster and better transport modes leads to an increase in covered distances rather than in the reduction on time spent on travelling. Therefore, curbing passenger transport demand growth and increasing the average travel speed are generally incompatible. For freight transport, globalization and cost play also a key role.

There is wide range of policy instruments that can contribute to curbing transport growth:

- Urban planning, e.g. compact cities to avoid urban sprawl and spatial optimization of the location of industries and distribution centres.
- Transport pricing, e.g. infrastructure pricing: higher prices tend to curb down transport growth.
- Infrastructure policy: infrastructure investments have the risk to increase transport growth.
- Speed policy: reduction of travel speed, e.g. by lower speed limits, decrease transport demand.
- Other policies, e.g. taxes for buying/selling houses or all types of regulation that prevent or discourage local production.

The main barrier for curbing transport demand growth is the risk of adverse economic impacts. However, there are some example of measures that reduce transport demand but also have high net social benefits, like road pricing or abolishment of subsidies. Assessing the overall economic impact is a key precondition for these types of policy. It is not possible to quantify the potential of curbing transport demand growth, without considering policy instruments.

**Improved vehicle utilisation**
The overall potential of improvements in vehicle utilisation depends heavily on various developments and policies. Both private and public actors have an interest in improving vehicle utilisation in freight as well as in passenger transport.

There are many factors that constrain improvements in vehicle utilisation, varying from market-related, regulatory, inter-functional, infrastructural and equipment related constraints. Some of these constraints can be lifted by policy measures, whereas others need action from private actors. Important drivers to improve future vehicle utilisation are:

- A facilitating government providing the necessary infrastructure, the right incentive – for example pricing schemes that make variable costs visible and noticeable, and regulations that do not negatively influence vehicle utilisation improvement and
- ICT developments, which make it easier to cooperate and bundle in freight transport and easier to make carpool arrangement for passenger transport.

Autonomous developments have a huge impact on the way vehicle utilisation improvements in the future can occur or can be achieved. A main barrier for improvements in vehicle utilisation is the fact that often cooperation is required between many actors, which makes it more difficult in practice than it seems in theory.
Intelligent Transport systems (ITS)

Intelligent Transport systems (ITS) have the potential to contribute to GHG emissions reduction from transport. ITS covers all modes of transport but the emphasis tends to be on ITS for road transport. Until recently, not many studies into effects of ITS on GHG emissions were available, and much research is still needed to quantify the potential of ITS, especially of ITS that aim specifically to increase fuel efficiency and reduce GHG emissions.

Recent research indicates that ITS systems can help reduce GHG emissions substantially. A rough estimate based on (Klunder et al., 2009) would be a possible reduction of 15-25% (for road transport), by reducing the number of km driven, and optimising and homogenising speeds. It has to be noted that for this reduction to be realised, systems must be widely available and drivers must accept the system’s advice (e.g. with regard to the route or speed to be chosen) and be able to follow the instructions. The successful implementation of cooperative systems could increase the benefits. Apart from emissions in GHG emissions, ITS can also have a positive impact on travel time reliability, safety, air quality and traffic noise.

There are significant barriers to be overcome. Field operational tests, financial incentives or regulation can speed up the introduction of promising measures.

Finally, new, advanced transport systems can introduce additional flexibility into the transport system, helping travellers to choose the most environmentally friendly modes of transport to reach their destination.
1 Introduction

1.1 Topic of this paper

This paper is one of five papers on GHG reduction options for transport drafted under the EU Transport GHG: Routes to 2050? Project. These papers review the options – technical and non-technical – that could contribute to reducing transport’s GHG emissions, both up to 2020 and in the period from 2020 to 2050. This paper focuses on modal split and decoupling transport growth from GDP growth. The papers aim to provide a high-level summary of the evidence based on existing studies.

This paper was presented in draft form to a Technical Focus Group meeting (at which stakeholders were present) in July 2009 after which it has been updated on the basis of the discussion at the meeting and the comments and further evidence that were received.

1.2 The contribution of transport to GHG emissions

The EU-27’s greenhouse gas (GHG) emissions from transport have been increasing and are projected to continue to do so. The rate of growth of transport’s GHG emissions has the potential to undermine the EU’s efforts to meet potential, long-term GHG emission reduction targets if no action is taken to reduce these emissions. This is illustrated in Figure 1 (provided by the EEA), which shows the potential reductions that would be required by the EU if economy-wide emissions reductions targets for 2050 of either 60% or 80% (compared to 1990 levels) were agreed and if GHG emissions from transport continued to increase at their recent rate of growth. The figure is simplistic in that it assumes linear reductions and increases. However it shows that unless action is taken, by 2050 transport GHG emissions alone would exceed an 80% reduction target for all sectors or make up the vast majority of a 60% reduction target. This illustrates the scale of the challenge facing the transport sector given that it is unlikely that GHG emissions from other sectors will be eliminated entirely.

Figure 1: EU overall emissions trajectories against transport emissions (indexed)¹

![Graph showing EU overall emissions trajectories against transport emissions](image)

The extent of the recent growth in transport emissions is reinforced by Figure 2, which presents a sectoral split of trends in CO₂ emissions over recent years. Whilst the CO₂ emissions from other sectors have levelled out or have begun to decrease, transport’s CO₂ emissions have risen steadily since 1990. It should be noted that whilst Figure 2 is presented in terms of CO₂ emissions, very similar trends are evident for GHG emissions (in terms of CO₂ equivalent) since CO₂ emissions represent 98% of transport’s GHG emissions.

¹ Graph supplied by Peder Jensen, EEA
Figure 2: Carbon dioxide emissions by sector EU-27 (indexed)²

Notes:

i) The figures include international bunker fuels (where relevant), but exclude land use, land use change and forestry.

ii) The figures for transport include bunker fuels (international traffic departing from the EU), pipeline activities and ground activities in airports and ports.

iii) “Other” emissions include solvent use, fugitive emissions, waste and agriculture.

The vast majority of European transport’s GHG emissions are produced by road transport, as illustrated in Figure 3, while international shipping and international aviation are other significant contributors.

Figure 3: Greenhouse gases emissions by transport mode (EU-27; 2005)³

Note: The figures include international bunker fuels for aviation and navigation (domestic and international).


Recent trends in CO₂ emissions from transport are also expected to continue, as can be seen from Table 1 below. Between 2000 and 2050, the JRC (2008) estimates that GHG emissions from domestic transport in the EU-27 will increase by 24%, during which time emissions from road transport are projected to increase by 19% and those from domestic aviation by 45%. It is important to note that these projections do not include emissions from international aviation and maritime transport, which are also expected to increase due to the growth in world trade and tourism.

Table 1: CO₂ emissions projection for 2050 by end-users in the EU-27, in Millions tonnes of Carbon

<table>
<thead>
<tr>
<th>End user Category</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road transport</td>
<td>695</td>
<td>825</td>
<td>905</td>
<td>980</td>
<td>1002</td>
<td>1018</td>
</tr>
<tr>
<td>Rail</td>
<td>29</td>
<td>29</td>
<td>27</td>
<td>27</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Domestic Aviation</td>
<td>86</td>
<td>134</td>
<td>179</td>
<td>206</td>
<td>237</td>
<td>244</td>
</tr>
<tr>
<td>Inland navigation</td>
<td>21</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>810</td>
<td>988</td>
<td>1110</td>
<td>1213</td>
<td>1260</td>
<td>1299</td>
</tr>
</tbody>
</table>

Figures from the EEA (2008), illustrate the recent growth in GHG emissions from international aviation, as they estimate that these increased in the EU by 90% (60 Mt CO₂e) between 1990 and 2005; international aviation emissions will thus become an ever more significant contributor to transport’s GHG emissions if current trends continue. Furthermore, the IPCC has estimated that the total impact of aviation on climate change is currently at least twice as high as that from CO₂ emissions alone, notably due to aircrafts’ emissions of nitrogen oxides (NOx) and water vapour in their condensation trails. However, it should be noted that there is significant scientific uncertainty with regard to these estimates, and research is ongoing in this area.

Figure 4: Final transport energy consumption by liquid fuels in EU-27 (2005), ktoe

The principal source of transport’s GHG emissions is the combustion of fossil fuels. Currently, petrol (motor spirit), which is mainly used in road transport (e.g. in passenger cars and some light commercial vehicles in some countries), and diesel, which is used by other modes (e.g. heavy duty road vehicles, some railways, inland waterways and maritime vessels) in various forms, are the most common fuels in the transport sector (see Figure 4). Additionally, liquid petroleum gas (LPG) supplies around 2% of the fuels for the European passenger car fuel market (AEGPL,

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4 Taken from JRC (2008) Backcasting approach for sustainable mobility Luxembourg, EUR 23387/ISSN 1018-5593, Office for Official Publications of the European Communities.
5 Graph based on figures in DG TREN (2008), page 206
While the main source of energy for railways in Europe is electricity, neither of which are included in Figure 4. While, alternative fuels are anticipated to play a larger role in providing the transport sector’s energy in the future, currently they only contribute 1.1% of the sector’s liquid fuel use.

1.3 Background to project and its objectives

The context of the EU Transport GHG: Routes to 2050 is the Commission’s long-term objective for tackling climate change, which entails limiting global warming to 2°C and includes the definition of a strategic target for 2050. The Commission’s President Barosso recently underlined the importance of the transport sector in this respect by noting that the next Commission “needs to maintain the momentum towards a low carbon economy, and in particular towards decarbonising our electricity supply and the transport sector”. There are various recent policy measures that are aimed at controlling emissions from the transport sector, but these measures are not part of a broad strategy or overarching goal. Hence, the key objective of this project is to provide guidance and evidence on the broader policy framework for controlling GHG emissions from the transport sector. Hence, the project’s objectives are defined as to:

- Begin to consider the long-term transport policy framework in context of need to reduce greenhouse gas (GHG) emissions economy-wide.
- Deal with medium- to longer-term (post 2020; to 2050), i.e. moving beyond recent focus on short-term policy measures.
- Identify what we know about reducing transport’s GHG emissions; and what we do not.
- Identify by when we need to take action and what this action should be.

Given the timescales being considered, the project will take a qualitative and, where possible, a quantitative approach. The project has three Parts, as follows:

- Part I (‘Review of the available information’) has collated the relevant evidence for options to reduce transport’s GHG emissions, which was presented in a series of Papers (1 to 5), and is in the process of developing four policy papers (Papers 6 to 9) that outline the evidence for these instruments to stimulate the application and up take of the options.
- Part II (‘In depth assessment and creation of framework for policy making’) involves bringing the work of Part I together to develop a long-term policy framework for reducing transport’s GHG emissions.
- Part III (‘Ongoing tasks’) covers the stakeholder engagement and the development of additional papers on subjects not covered elsewhere in the project.

As noted under Part III, stakeholder engagement is an important element of the project. The following meetings were held:

- A large stakeholder meeting was held in March 2009 at which the project was introduced to stakeholders.
- A series of stakeholder meetings (or Technical Focus Groups) on the technical and non-technical options for reducing transport’s GHG emissions. These were held in July 2009.
- A series of Technical Focus Groups on the policy instruments that could be used to stimulate the application of the options for reducing transport’s GHG emissions. These were held in September/October 2009.
- Two additional large stakeholder meetings at which the findings of the project were discussed.

As part of the project a number of papers have been produced, all of which can be found on the project’s website, as can all of the presentations from the project’s meetings.

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1.4 Background and purpose of the paper

This paper is one of five “options” papers (Papers 1 to 5) that were developed under the EU Transport GHG: Routes to 2050 project. The aim of these papers was to review the technical and non-technical options that could contribute to reducing transport’s GHG emissions, both up to 2020 and in the period from 2020 to 2050. A series of papers (Papers 1 to 6) on “policy instruments” that could be used to stimulate the application and take up of these options was also developed. For the purpose of the project, we used the following definitions:

- **Options** deliver GHG emissions reductions in transport – these can be technical, operational or modal shift.
- **Policy instruments** may be implemented to promote the application of these options.

The options were reviewed in the following papers:

1. Technical options for fossil fuel based road transport.
2. Alternative energy carriers and powertrains.
3. Technical options for non-road transport modes.
4. Operational options for all modes.
5. Modal split and decoupling.

This paper is the fifth in this series of papers, all of which use evidence from existing studies to assess each of the options. It was presented in draft form to a Technical Focus Group meeting (at which stakeholders were present) in July 2009 after which it has been updated on the basis of the discussion at the meeting and any comments and further evidence received. This revised version of the paper can be found on the project’s website.

1.5 Structure of the paper

This paper covers the following options:

- Intelligent and advanced transport systems – chapter 2;
- Modal shift (both passenger and freight transport) – chapter 2.1;
- Improved logistics and vehicle utilisation – chapter 5;

Most of the options covered in this paper are very closely linked to policy measures. The major cost of these options are usually not (just) technical cost but (also) the cost related to changing the behaviour of consumers and companies, e.g. the cost of higher travel times, less flexibility or lower transport volumes. Therefore it is not useful to calculate abatement cost in a traditional way. This explains why there are no abatement cost estimates available for the options concerned.
2 Intelligent Transport Systems (ITS)

2.1 What are Intelligent Transport Systems (ITS)

Intelligent Transport Systems (ITS) include technologies in the transportation system such as information and communication technology, sensor technology and GPS. ITS covers a broad range of advanced systems or functionalities, for example traffic management, driver assistance systems, and traffic information systems.

ITS functionalities can be installed in vehicles, in the infrastructure, in nomadic devices, e.g. Functionalities may require service providers or traffic management centres to process raw data (e.g. information on traffic volumes and speeds) to advice (e.g. route advice) or control strategies (e.g. activating ramp metering to prevent congestion on motorways).

ITS innovates through the integration of existing technologies to create new services, in all modes of transport (road, rail, air, water). Systems and services are available for both passenger and freight transport.

ITS measures have, over the past decades, slowly become a part of transport policy. It is widely recognised that new infrastructure cannot solve all the problems associated with transport, such as accidents, congestion and emissions. ITS measures are regarded as relatively cheap (compared to building new roads) and flexible and are therefore of interest to many stakeholders.

Figure 5 shows the expected development of ITS. ITS started with solitary measures (e.g. local traffic management measures or in-car systems such as adaptive cruise control). With the realisation that the development and use of solitary measures are at their peak, the focus has shifted to network-wide approaches for e.g. traffic management. Advances in technology make this possible; however, this also requires improvements in data collection and processing methods and algorithm development. The benefits of network-wide approaches depend on 'joined up' and 'coordinated' the ITS measures will be.

After the network-wide approach, the next step is cooperative systems, in which the vehicles and infrastructure cooperate with each other (via vehicle-to-vehicle and vehicle-to-infrastructure communication). This means, for instance, that additional information becomes available about conditions further ahead, that the vehicle cannot yet sense with its own sensors. Cooperative systems are possible today but need time to become more sophisticated (and thus more effective). In 2050, traffic management is expected to be integrated with driver assistance and information systems. The added value of this is expected to be substantial, but not much is yet known about potential effects on GHG emissions.

Finally, it is expected that some new forms of transport will emerge between now and 2050.

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6 Those are devices that can be used in the vehicle but are not part of it, e.g. navigation systems that are not built in and can be taken out of the vehicle.
2.1.1 Examples of Intelligent Transport Systems

Driver assistance, advanced traffic management and cooperative systems

As ITS covers many different types of systems, with many different objectives, a very long list of examples could be provided. However, not all ITS are relevant in the light of GHG emissions, for instance, many advanced driver assistance and cooperative systems were developed as safety systems or systems aiming to improve throughput. Only a few driver assistance systems were developed with the aim of reducing fuel consumption and emissions. However, several of the safety systems originally designed with other objectives (e.g. safety), are expected (or have been shown) to have environmental benefits.

Table 2 gives several systems which could be considered relevant. However, not all of these systems will necessarily be relevant on the EU level [Klünder et al., 2009], since this depends on the (temporal and spatial) scale on which they can be applied; see the section on assessment of ITS.

Table 2: ITS systems with the potential to reduce fuel consumption and emissions.

<table>
<thead>
<tr>
<th>System group</th>
<th>Systems with (potential) environmental benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco solutions</td>
<td>Eco driving(^1) assisted by Energy use indicator and Gear shift indicator, Map-enhanced eco driving, Automatic engine shutdown, Fuel efficiency advisor, Tyre pressure indicator</td>
</tr>
<tr>
<td>Stand-alone (in-car) systems</td>
<td>(Adaptive) cruise control, Lane keeping assist, Emergency braking, Fuel efficient route choice, Pay As You Drive (PAYD), Speed Alert</td>
</tr>
<tr>
<td>Advanced traffic management</td>
<td>Congestion charging, Road charging, Dynamic speed limits, Dynamic traffic light synchronisation, Green waves, Slot management, Freight trip planning systems</td>
</tr>
<tr>
<td>Cooperative systems</td>
<td>Cooperative adaptive cruise control, Congestion assistant, Platooning, cooperative traffic lights(^2)</td>
</tr>
</tbody>
</table>

\(^1\) Eco-driving in itself is not an ITS, since the driver is not supported by technology. It is felt, however, that systems supporting the driver (e.g. map-enhanced eco-driving, which takes topographical and network information into account, can further increase the effectiveness of eco-driving.
Modal split and decoupling options  EU Transport GHG: Routes to 2050?
AEA/ED45405/Paper 5  Contract ENV.C.3/SER/2008/0053

2) Cooperative traffic lights could communicate a speed advice to an approaching vehicle to minimise driving dynamics, and vehicles could communicate their approach so that the traffic lights can optimise (the order of) green times.

Many of the systems in Table 2 are already on the market or will be on the market within a few years. As technologies (and data and algorithms) become increasingly advanced, ITS can become more effective in reducing GHG emissions. This can be due to optimisation for emissions (rather than for throughput or safety), but also due to general optimisation of traffic flows, which could result in fewer kilometres driven and more environmentally friendly driving behaviour, e.g. less congestion and fewer stops at signalised intersections. Further into the future, fully automated driving and the application of swarm intelligence could be introduced.

Travel and transport information services
Travel and transport information services can help travellers and logistics firms plan journeys in the most efficient way. There many route planners for road transport (passenger and freight transport). Also, many countries, regions and cities offer public transport journey planners. An increasing share offers the possibility to select the most fuel-efficient or environmentally friendly option. Most don’t however, offer intermodal travel options (an example of a planner that does can be found at www.9292ov.nl). There are intermodal freight transport planners, but most journey planners for passenger transport offer only a comparison between journeys by car or public transport at most, not an intermodal option. The challenge is to develop systems that offer seamless intermodal trip advice to the “connected traveller”. Travellers should be able to access information wherever they are, information that is relevant to the journey they want to make. This includes therefore (real-time) traffic information, such as information about congestion, incidents, events and weather conditions. Several issues need to be addressed in order to be able to develop useful, viable systems:

- Business and organisational models need to be developed (who will provide the information? Who will pay for it?).
- Standards (e.g. for data exchange) need to be developed.
- Large amounts of data need to combined into reliable advice that can be given in a very short amount of time.
- There are also issues w.r.t. privacy of the travellers.

There is a chicken-egg problem with the issues of business models and standards. Stakeholders may not see a viable business case when standards are lacking, and standards are not likely to be developed for systems that are still being developed. If a good standard is available, it offers everyone the opportunity to develop applications. An example of a standard used in public transport information services is the open Google Transit™ Feed Specification (GTFS), which is used by Bay Area Rapid Transit (USA) to offer official schedules, fares and other data in the open Google Transit™ Feed Specification (GTFS) (see http://www.bart.gov/schedules/developers/open.aspx).

Even with the issues identified above, there are still initiatives to improve and introduce new information systems. The i-Travel project (http://www.i-travelproject.com) is an initiative to identify currently available services and build on those. Its objectives are to identify (intermodal) use cases, perform stakeholder analyses, evaluate standardised technological and architectural options for an i-Travel service platform, create organisational models and business tools, carry out a feasibility and risk assessment and propose a “roadmap for seamless travel services”.

The “connected traveller” should, in the future, be able to make better decisions about every aspect of his journeys: choice of destination, mode(s) of travel, departure time and route. If more environmentally friendly travel options are attractive enough (e.g. in terms of costs, travel time, comfort and the ability to work on a journey), travellers may opt for those options more often than they would without the information. In the same way, it would become easier to plan freight transport using the most efficient, environmentally friendly options (in terms of modes used, freight traffic bundling etc.).
2.1.2 Assessment of ITS

GHG reduction potential
ITS have a number of different effects on the driving behaviour of individual vehicles and on traffic flows. The mechanisms via which GHG emissions are influenced are diverse and can be very difficult to assess, because often data with a high level of detail is required.

ITS can result in changes in the following:
- number of kilometres travelled;
- average speed;
- speed variation/dynamics / changes in the amount of congestion;
- traffic composition.

Until very recently, the main aims of ITS were the improvement of traffic efficiency (reducing congestion) and safety (accident avoidance and mitigation). However, some of the systems have also been shown to reduce emissions, and in the ITS community there is a growing interest in the potential of ITS to reduce environmental impacts of traffic. Table 2 presented several promising systems. In addition to those, there are safety systems that reduce the number of accidents, helping to reduce accident related congestion, which also benefits the environment. However, the effect of solving congestion is very small, as only a few percent of all kilometres driven in the EU is in congested conditions (accident related congestion as well as congestion by other causes such as bottlenecks and road works. This is even true in countries with relatively severe congestion problems, e.g. the Netherlands.

ITS aimed, purely, at reducing recurrent congestion have varying effects. If the ITS applied reduces travel times or increases travel time reliability, it is likely that the positive effect of the reduction in congestion is smaller than the negative effect of extra kilometres travelled (because a route has become more attractive). I.e. the overall impact of the measure is negative in terms of emissions reduction. One potential way of reducing this negative impact would be through the ‘locking in’ of the congestion reduction through measures such as road space reallocation and congestion or road charging.

In general, ITS that help reduce the mileage (e.g. measures associated with road charging, Pay As You Drive, fuel efficient routing) have a much larger impact on GHG emissions than those that primarily reduce congestion (e.g. Emergency Braking, slot management). ITS that influence driving dynamics on a large part of the road network can also have substantial effects (e.g. eco-driving, adaptive cruise control). Measures that work very locally (e.g. green waves) do not make a significant reduction to GHG emissions but can help improve local air quality and reduce noise annoyance.

For all but the highest average velocities, the measures to reduce vehicles dynamics, i.e., reducing accelerations and decelerations, will reduce the CO2 emissions, by 5% to 20%, for the same powertrain technology. The measures can range from adaptive cruise control, to intervehicle communication, to systems which prevent heavy trucks having to stop at junctions or traffic lights. A single stop of a 30 ton truck adds easily a kilogram or more to the total CO2 emission.

It has to be noted that many ITS have high potential impacts, which are difficult to reach in practice. Some reasons for this are:
- systems can be difficult to implement (see discussion on barriers below)
- it can be difficult to reach the high penetration rates of systems needed (in particular for cooperative systems)
- for high effectiveness of advisory systems, high compliance is needed

Availability of information about effects of ITS on GHG emissions
There are many ITS, and most have been evaluated in some form. However, many studies only produce qualitative results. Furthermore, results from quantitative evaluation (mostly the effects on traffic, but in some cases also effects on emissions) do not always provide a consistent picture, as the effects of ITS are highly dependent on local conditions (with respect to for example...
road geometry, weather, and driving behaviour). Only recently have monitoring systems and models become available with which the effects of ITS can be quantified accurately.

The recent study “Impact of Information and Communication Technologies on Energy Efficiency in Road Transport” (Klunder et al., 2009) examined a broad range of ITS w.r.t. their potential to reduce GHG emissions. In the analysis (based on available literature and scaling up of locally found effects to the EU level), the potential to affect traffic parameters (km driven, speeds etc.) as well as ease of implementation and expected level of compliance were assessed. Figure 6 shows the most promising systems in terms of their potential effect on CO₂ emissions. The potential CO₂ reduction is based on the maximum possible use of the system, i.e. a 100% penetration rate of an in-vehicle system, or application on all suitable roads and areas.

Figure 6  Ranking of promising measures on potential CO₂ effect (Klunder et al., 2009)

Some systems expected to be promising at first did not make the selection in the figure above. Intelligent Speed Adaptation (ISA) is an example. ISA systems face difficult implementation and compliance issues. However, if ISA is implemented widely and drivers comply with the lower speed limit (or are forced to comply, with mandatory systems), they can help reduce emissions (see paragraph 6.3 in paper 8 (Lower speed limits for road transport)).

N.B. While some documents on the future of ITS are available, very few look beyond 2020 and if they do, the descriptions of future systems are very generic and contain limited information on GHG savings. Possible reasons for this are the fast developments in ICT and the uncertainty around implementation.

Costs
The following costs need to be considered for the implementation and operation of ITS systems:

- hardware:
  - infrastructure (e.g. sensors/monitoring devices, variable message signs, computer servers, communication equipment)
  - vehicle (e.g. sensors, actuators, HMI, GPS, communication device)
- software:
  - algorithm / management & control strategies, software applications, standardisation
- personnel:
  - e.g. service provider or traffic management centre personnel, maintenance technicians
- PR/marketing
Infrastructural costs of ITS can be considerable (and installation may be costly as well). Costs vary from system to system. For in-vehicle systems, the same can be said. Current prices for in-vehicle systems range from a few hundred to thousands of Euros. Many of the systems that became available over the past years will become much cheaper in the coming decades, enabling more widespread use of advanced systems. However, new systems with high initial costs will keep emerging.

**Co-benefits**

ITS that reduce GHG emissions are also likely to reduce noise annoyance. This is because several ITS systems assist the driver to drive more smoothly and at more appropriate speeds. ITS systems can also have positive effects on travel time reliability, safety and driver comfort.

**Infrastructural requirements**

On the infrastructure side, ITS may require monitoring and data processing facilities, as well as the development of applications that process data to generate traffic management and information strategies. In the long term, the infrastructural requirements may decrease, when more systems will rely on in-vehicle applications and vehicle-to-vehicle communications.

**Barriers**

A large number of stakeholders is required for the implementation, on a large scale, of more advanced ITS. This means that there are complex organisational issues, legal issues (privacy and others and furthermore, in some cases, high initial investments. Business cases are often unclear (who pays for the system, who benefits?). This delays implementation and many systems do not make it past the trial stage. These barriers are significant for stand-alone systems but they are even more significant for cooperative systems.

Another issue is that not many quantitative impact assessment studies have yet taken place that prove the impact of ITS in terms of GHG emission reduction. Suitable assessment methods are scarce; however, more suitable modelling approaches are under development. In addition, it is difficult to obtain data with the temporal and spatial resolution needed. When estimations of effects for the EU level are needed, scaling up of results found under specific conditions or for specific regions is difficult, as driving behaviour varies across Europe.

N.B. Several Field Operational Tests are taking place in 7th Framework projects, such as SAFESPOT, CVIS, COOPERS, euroFOT, Telefot. Some of these projects consider environment effects. Results are not available yet, but will be become available over the next years.

**Uncertainties and main open issues**

As mentioned before, the transport community expects ITS to be very effective in solving a range of problems, including GHG emissions. ITS certainly offer many possibilities to manage traffic. But the effects of ITS are not very clear yet. There is a need for reliable and accurate effect estimations.

Whether ITS can meet the expectations in the future is hard to predict. Vision documents on future ITS are very general and do not offer much insight into the real potential of ITS. If intelligent transport systems are optimised for GHG emissions (for example Eco Driving Assistance, fuel efficient routing, road charging schemes, access restrictions for inefficient vehicles), effects could be much larger than with current ITS, but that might mean restrictions to travel that may not be acceptable.

Many scenarios are plausible for the development of ITS. In optimum conditions, much progress could be made within as short a time period as a decade. On the other hand, it may take significantly longer. For example, satellite navigation systems took many years to reach the current penetration rate, and a system like adaptive cruise control, which has been on the market for years, still has a very low penetration rate.
2.2 Advanced transport systems

Rapid urban transport systems
Wikipedia gives the following definition of rapid transit ([http://en.wikipedia.org/wiki/Rapid_transit](http://en.wikipedia.org/wiki/Rapid_transit)): "A rapid transit, metro(politan), subway, underground, or elevated (railway) system is an electric passenger railway in an urban area with high capacity and frequency, and which is grade separated from other traffic."
This definition includes 'traditional' systems like the metro, (hanging) monorail. The more advanced systems are called people movers or personal rapid transit.

People movers / Personal rapid transit
People movers are a fully automated form of rapid urban transport systems. Generally, the term people movers refers to systems serving relatively small areas such as airports, theme parks or business districts. If the vehicles used are very small (seating 2 to 6 passengers), the systems are called Personal Rapid Transit (PRT), which offers personal, on-demand non-stop transportation (e.g. the ParkShuttle in Capelle, The Netherlands). Currently, these systems need their own infrastructure.

New, flexible modes of personal rapid transport
In urban environments personal rapid transport could be attractive to a large number of travellers. Travel patterns are very diffuse, and in many regions it is difficult to operate traditional forms of public transport efficiently. There is therefore a need for relatively inexpensive, highly flexible personal transport systems that bring travellers as close to their destination as possible. Developments in information and communication technology can support the development of such systems. Several types of systems are already available or may become available soon; looking ahead to 2050 it can be expected that if these early versions of advanced personal rapid transport systems are successful, they will be followed by improved versions.

Some examples of vehicles that could be used for advanced personal rapid transport vehicles are:
- Cybercars
- The Segway
- small (buggy concept) cars

Given the current concerns about climate change and pollution, these systems would need to use clean vehicles. Several are under development; some are already operational.

Cybercars are environmentally friendly road vehicles with fully automated driving capabilities. A fleet of such vehicles forms a managed transportation system (a Cybernetic Transport System), for passengers or goods, on a network of roads with on-demand and door-to-door capability. This concept emerged in Europe in the early 1990’s and was introduced for the first time in the Netherlands in December 1997 for passenger transport at Schiphol airport. Since then, it has been developed under a number of European projects such as CyberCars, CyberMove, EDICT, Netmobil and CyberC3. New projects, also supported by the European Commission are now under way: CyberCars-2 and CityMobil (based on text found on the Cybercars website at [http://www.cybercars.org/index.html](http://www.cybercars.org/index.html) and the projects' websites). Cybercars are a form of personal rapid transport. Currently, they can only operate in low demand situations. Research projects are looking at how Cybernetic Transport systems can operate in situations with more interaction between vehicles. Cybernetic Transport Systems can be used in (urban) environments, to offer frequent transport to many destinations that cannot easily be accessed by other models of transport. for instance, it can replace cars on the last leg of a journey into a city centre.

A system like the Segway Personal Transporter is an even more flexible alternative for the automated systems. Segways can be used for access- and egress transport (e.g. to and from a train station). The Personal Urban Mobility and Accessibility Project (P.U.M.A. for short) seeks to develop an electric vehicle based on the Segway Personal Transporter. It will be a self balancing two-wheeled vehicle capable of reaching speeds of nearly 50 km/h. On a single charge, distances of up to 50 km can be travelled. A lithium battery is used It is expected to be able to communicate

Some environmentally friendly small cars (or buggy concept cars) are also being developed, such as the Mercedes-Benz F-CELL Roadster which has joystick control, a fiberglass body and hydrogen-electric fuel-cell power (source: http://jalopnik.com/5183567/mercedes-f-cell-roadster-hydrogen-powered-buggy-concept), or Fiat's Bugster, which will have an electric drive train and body panels made from natural fibres (source: http://www.autoracingdaily.com/news/other-motorsports/ fiat-bugster-a-plug-in-electric-car/ and many other websites). If concepts like these are coupled to the possibilities that ITS offer, many new and environmentally friendly concepts for personal rapid transit are possible.

### 2.3 Conclusions on intelligent and advanced transport systems

Intelligent Transport systems (ITS) have the potential to substantially reduce GHG emissions from transport. ITS covers all modes of transport but the emphasis tends to be on ITS for road transport. Until recently, not many studies into effects of ITS on GHG emissions were available, and much research is still needed to quantify the potential of ITS, especially of ITS that aim specifically to increase fuel efficiency and reduce GHG emissions.

Recent research indicates that ITS systems can help reduce GHG emissions substantially. A rough estimate based on (Klunder et al., 2009) would be a possible reduction of 15-25% (for road transport), by reducing the number of km driven, and optimising and homogenising speeds. It has to be noted that for this reduction to be realised, systems must be widely available and drivers must accept the system’s advice (e.g. with regard to the route or speed to be chosen) and be able to follow the instructions. The successful implementation of cooperative systems could increase the benefits.

Apart from emissions in GHG emissions, ITS can also have a positive impact on travel time reliability, safety, air quality and traffic noise.

There are significant barriers to be overcome. Field operational tests, financial incentives or regulation can speed up the introduction of promising measures.

Finally, new, advanced transport systems such as discussed in paragraph 6.2 can introduce additional flexibility into the transport system, helping travellers to choose the most environmentally friendly modes of transport to reach their destination.

### 2.4 References


3 Co-modality and modal shift

3.1 Introduction

Modal shift has been an important policy objective within the EU for many years. The objective was first formulated in the Sustainable Development Strategy (“SDS”, European Commission, 2001a). In the review of the T&E integration strategy in 2001 and 2002 (European Council 2001; European Council, 2002), the Council states that the modal split should remain stable for at least the next ten years, even with further traffic growth.

Modal shift was also one of the main objectives in the EU White Paper on the Common Transport Policy (CTP) “European Transport Policy for 2010: Time to Decide”. In this paper the Commission proposes a number of measures aimed at the modal shift. Also in the mid-term review of 2006, the issue of rebalancing the modes is still an important objective, but made more specific:

“Shifts to more environmentally friendly modes must be achieved where appropriate, especially on long distance, in urban areas and on congested corridors. At the same time each transport mode must be optimised.”

In these policy documents, the usual types of modal shift that are considered in freight transport are from road to rail, inland waterways or short sea (short sea shipping). For passenger transport, modal shift usually refers to a shift from aviation and passenger cars to rail, other types of public transport and non-motorised transport.

During the last decade, the focus has shifted from policy directly aiming at modal shift to the concept of co-modality. The latter aims at using the strength of each transport mode and developing the intermodal connections to make this possible.

In this chapter we do not assess whether or not policy aiming at modal shift or co-modality is desirable from a broad societal point of view, but rather focus on the contribution it could have on reducing GHG emissions from transport. From that perspective, the primary concern is what shifts between the market shares of the various transport modes could contribute to GHG emission reduction. Therefore, we do not distinguish between co-modality and modal shift, but just look at what changes in the overall modal split could contribute.

First we discuss modal shift in passenger transport: trends and projections in the modal split (section 3.2), comparison of transport modes on their CO₂ emissions per passenger-kilometre (section 3.3) and the potential and cost of modal shift (section 3.4). Next modal shift in freight transport is discussed in a similar way in section 3.5, 3.6 and 3.7. Finally, section 3.8 gives an overview of the conclusions on modal shift.

3.2 Trends and projections in passenger modal split

The observed trends and ‘business as usual’ projections for the modal split of passenger transport are shown in Figure 7. These graphs make clear that despite the existing policy, for developments since 1990 and the projections for the next two decades, the volumes of private road transport and aviation are increasing in absolute terms while the total volume of public transport modes is more or less constant. The results is that the relative shares of rail and bus are decreasing, while the shares of private road transport and aviation are increasing. So the modal split is not moving towards rail and other public transport modes, but rather the opposite is happening.
The increasing share of passenger car can be explained by the (real and perceived) advantages of private transport over public and alternative transport modes. Private transport is generally perceived as faster, more flexible (in particular outside urban areas), more comfortable and cheaper than public transport EEA (2006). Therefore, the main reasons behind the growing share of passenger cars are:

- Increased car ownership, particularly in the new EU member states.
- People need to combine tasks at increasing number of locations, driven by increasing participation of women in the labour market and an increasing amount of time spending to leisure activities. This asks for more flexible and faster means of transport which are generally met better by private cars than by public transport.
- The current transport costs structure (with high share of fixed vehicle costs rather variable costs linked to transport usage) does not contribute to remove the perception of private transport being cheaper than public transport. Car users generally only take the additional fuel costs into account when deciding on a trip. As a result, in many cases variable costs of car transport are lower than those of public transport.
- Spatial development: in the outskirts of urban areas, where public transport is much less accessible, accessibility to basic services by public transport, cycling or walking decreases. This leads to more car usage and subsequent traffic bottlenecks around and in cities. Hence, urban sprawl – the expansion of cities – could lead to greater car dependency and usage.

Without policy intervention, these trends are expected to continue. Car ownership may slow down because a saturation level is reached. A main driver will be the developments of average travel speed of the various modes. The impact of speed is further discussed in section 4.2.

The share of rail transport has remained stable since 1996. However, the regular rail connections have lost some share in favour of high-speed rail. Long distance rail transport competes with air transport and the rise of low-cost carriers has made regular rail transport less favoured for longer distances. Besides, international rail connections are still slowed down by border-crossings. High-speed rail lines are developing quickly to better compete with air transport, but prices and speed are decisive factors in the modal split. So high speed rail can only compete in cases where (door-to-door) travel times are close to those of aviation and prices are also competitive.
The growing share of air traffic is linked to a rapidly growing tourism industry and also an increase in international business travels. The high growth of low cost airlines has also contributed. In 2001 the share of air transport declined for the first time as a consequence of the terrorist attacks on the World Trade Centre in New York. Later, the war in Afghanistan and Iraq, and SARS added to the decline. The crisis forced the carriers into fierce competition to accelerate the recovery of the demand, and hence a hold to price increases. The number of flights declined in 2001 and 2002, but this decline was temporary in nature. In the period 2002-2004 the number of flights increased by 7% (Eurocontrol, 2004). The current decline in air travel because of the economic crisis may well be a temporary dip as well.

Walking and cycling are not included in Figure 7. In some cities, their shares are significant for short distances, particularly in urban areas. Research has shown that the main drivers for increased levels of cycling are the relative speed compared to other modes and the parking capacity and level of parking fees (Rietveld and Daniel, 2004).

3.3 Comparison of passenger transport modes

The impacts of changes in modal split on the overall GHG emissions of passenger transport is closely related to the differences in the carbon intensity of the various modes. A number of studies and models attempt to make a comparison between the CO₂ emissions of different transport modes. Some of these also project into the future. The TREMOVE model (T&ML, 2009) estimates the average transport performance of the different modes and uses emission factors to calculate the total CO₂ emissions and the emissions per passenger-km. The model makes projections until the year 2030. Figure 8 shows the average emissions for 31 European countries in 2030 for the most relevant modes. Note that the data are based on real life emissions of the expected average vehicle fleet in 2030 and include “Well To Tank” emissions.

Figure 8 Average CO₂ emissions for various transport modes according to TREMOVE

These projection do include some energy efficiency improvements in the various modes, like the 130 g/km targets for passenger cars. Additional energy efficiency increases in the longer future could be expected (like impacts of 95 g/km on test cycle for new passenger cars from 2020, hybrid buses or energy regeneration in rail transport modes). These improvements are not yet included. Also for the non-road modes further efficiency improvements and shifts to low-carbon energy carriers than included in the model, might occur at the long run.

CE (2003) showed that it is dangerous to compare just the overall average emissions of various transport modes, since modes operate at different markets with different characteristics. Environmental comparisons between transport modes only make sense for well-defined,
homogeneous and competing markets and for complete transport chains. If sound transport policy conclusions are to be drawn, moreover, analysis must move beyond the present to include the anticipated future environmental performance of the various modes of interest.

It needs to be considered that different modes are relevant for travel over short or long distances. For travelling short distances the public transport modes used are mostly limited by city/regional buses, tramways, subways and local trains. Personal transportation can be undertaken by car, motorcycle or moped or by zero emissions modes such as walking and cycling. For longer distances coaches, intercity trains, high speed trains and aircraft can be used, while mopeds, walking and cycling are unlikely.

Not only are some modes unpractical for long or short range transportation, the emissions can differ with range. CE (2003 and 2008) provide data for 2000, 2005, 2010 and 2020, comparing average emissions for relevant modes in short or long range transportation in the Netherlands. The 2008 study, called STREAM, was commissioned by the Dutch Ministry of Transport and the Ministry of Environment. The distinction between the ranges is especially important for car emissions. The average number of passengers for long distance travel by car is significantly higher than for short range transportation (on average 1.74 vs. 2.88 in the Netherlands according to CE, 2008). Also for rail transport, vehicle utilisation depends on the type of trains and distance.

The average emission per kilometre per person is considerably lower during long range transport than during short trips. Figure 9 and Figure 10 show the CO₂ emissions for different modes and travel ranges.

**Figure 9**  Average CO₂ emissions for short range passenger transport modes according to STREAM (including transport to mode access points)

![Average CO₂ emissions for short range passenger transport modes](image)

Source: CE Delft (2008)
Figure 10  Average CO2 emissions for long range passenger transport modes according to STREAM (including transport to mode access points)

Source: CE Delft (2008)

The main differences in approach between TREMOVE and STREAM are the distinction between long and short range and the way in which transport to and from the modes access point is settled. The differences in emissions resulting from long vs. short range transport mostly stem from a difference in degree of utilisation. As mentioned above this has a profound impact on the emissions (per passenger-km) of cars in the long range STREAM results.

Transport emissions from the trip to and from the access points (i.e. train stations and bus stops) are accounted to the mode with which it is performed in TREMOVE, while STREAM accounts it to the relevant public transport mode. For example if a trip consists of 10 km driving by car to the nearest railway station, 60 km by train and 10 minutes walking to the destination, TREMOVE would add 10 km to the transport performance by car and 60 km to rail and calculate the corresponding emissions. In the STREAM approach the emissions of the 10 km by car would be added to the emissions of the rail trip. The idea behind this approach is that transport users do always make an entire trip, which, particularly in the case of public transport and aviation of usually consists of a multimodal chain. When transport shifts from one mode to another, also the transport to and from access points should be taken into account.

When comparing the two studies there are some modes that show a high degree of agreement, but others that differ greatly. The emissions of personal motorised modes of transport (cars mopeds and motorcycles) of TREMOVE and STREAM (short range) are in good agreement considering that TREMOVE calculates a European average and STREAM is based on data for the Netherlands. The CO2-emissions for aircraft are also in good agreement. The additional high altitude greenhouse gas effects are not included in Figure 8, in Figure 10 they are marked CO2-eq.

The results for Bus and Passenger train (TREMOVE) cannot be directly compared with STREAM as the latter distinguishes more subtypes and transport ranges. Bus (TREMOVE) and Coach (Long range STREAM) are more or less in agreement and so are Passenger train (TREMOVE) and Intercity train (STREAM long and short range). The large differences between city/regional busses and coaches within STREAM is particularly because of the difference in average occupancy rates (13/14 passengers per city/regional bus compared to 38 passengers per coach).
Metro results disagree. This is caused by a difference in average degree of utilisation and energy mix of electricity generation. Because of these large differences between STREAM and TREMOVE on metro, we also include here some adapt from other sources. The carbon footprint of the London metro was estimated at 76 g/pkm (93 g/pkm when also the emissions from waste, employees etc. are included) (Transport for London, 2009). In this report, also a comparison with other metros in the world is included, which is shown below. This overview confirms the wide spread in CO\(_2\) emissions from metro. Most metro systems show CO\(_2\) emissions between 40 and 100 g/pkm. The two metro systems with the lowest CO\(_2\) emissions are Paris and Tokyo, which is because of the high share of nuclear power generation in France and Japan.

**Figure 11**  Average CO\(_2\) emissions per passenger-km of metro systems around the world

![Graph showing average CO\(_2\) emissions per passenger-km of metro systems around the world](image)

Source: Transport for London, 2009

The sensitivity to the degree of utilisation is dramatically apparent in Figure 9 and Figure 10. The emissions of personal motorised modes in the case of non average occupancy are indicated by the coloured shapes. A passenger car with four people in it can compete with all but the most advantageous public transport modes, while a car with only one occupant performs badly indeed.

With a degree of caution the results from the two studies can be summarised as:

1. Car and motorcycles emit more CO\(_2\) (per person-km) than most public transport modes but this is highly dependant on the degree of utilisation.
2. Public transit by rail outperforms that by bus with the exception of long range coaches.
3. When all emissions of a trip are accounted for, the difference between modes is not that great, except for walking and cycling and public transport modes in cases they have high average occupancy rates.
4. Emissions of travelling by aircraft are far greater than those resulting from travelling by a surface bound mode especially when all greenhouse gas effects are included.

Similar results can be obtained when comparing modes using present day trip based studies such as ECOpassenger (UIC, 2008) and (CIT, 2001).

From these results a rough estimation of the differences between transport modes can be estimated. Short range road transport dominates the transportation performance (see Figure 7). A shift from road to rail or tram/metro would therefore be most relevant. Another shift that may be advantageous is that from aviation to high speed rail.
Table 3 shows the reductions that could be obtained due to these shifts according to TREMOVE and STREAM.

<table>
<thead>
<tr>
<th>Reduction CO₂ emission</th>
<th>STREAM</th>
<th>TREMOVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>short range*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car to IC train</td>
<td>60%</td>
<td>67%</td>
</tr>
<tr>
<td>Car to metro</td>
<td>28%</td>
<td>93%</td>
</tr>
<tr>
<td>long range*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car to IC train</td>
<td>31%</td>
<td>67%</td>
</tr>
<tr>
<td>Air to High speed train**</td>
<td>76%</td>
<td>78%</td>
</tr>
</tbody>
</table>

* TREMOVE does not make the distinction
** TREMOVE does not have High Speed trains, regular trains used

Both STREAM and TREMOVE base their projections on business as usual scenarios (SE). STREAM assumes some (autonomous) improvements such as 130 g/km CO₂ for cars in 2020 and a yearly 0.75% efficiency improvement for aviation (see STREAM). Neither model takes into account possible ambitious climate policies or technical improvements with a large impact.

In the more distant future (>2030) all passenger transport modes are expected to become cleaner, safer and more fuel economic. However few assumptions can be made as to the nature of these improvements. If decarbonisation is the objective the electric rail modes have a strong advantage. If all the electricity used is sustainably produced the CO₂ emissions drop to almost zero. For the other modes a suitable carbon-neutral energy carrier is as yet unavailable and may require large changes in vehicles and distribution infrastructure.

A large increase of the share of aviation on the medium to long distances is predicted but whether this will occur depends, among others, on policy and oil prices.

One possible approach to estimate the effects on the long term is to assume that the autonomous improvements in vehicle performance as estimated in STREAM and TREMOVE can be extended to 2050. This will cause the emissions of personal vehicles (cars) to decrease more rapidly than the large capacity public transport modes. The overall effect is that the emissions (per passenger km) of all modes will decrease and the differences between modes will become smaller, hence diminishing the potential of modal shift.

A more technical approach takes into account the projections for all different modes. However such a comparison is not available from literature.

Besides the changes in CO₂ performance of the vehicles of the various modes, also developments in vehicle occupancy rates are a decisive factor in the differences in carbon intensity between transport modes. The impacts of modal shift to public transport modes with average utilisation is very different from a shift to public transport with high occupancy rates.

### 3.4 Potential for modal shift in passenger transport

In the previous section (Table 3) the raw potential of modal shift (the amount of CO₂ emission saved by changing from one mode to another regardless of practicality) was discussed.

Short range transport by car dominates the performance so a shift from car to rail and slow transport modes (walking and cycling) are the most relevant. An optimistic potential for the shift
from road to rail is 60-70 % emission reduction per passenger-kilometre. A less optimistic potential taking into account a longer range shift or a shift from car to metro (STREAM) would be 30% reduction due to the shift. These reduction rates are highly dependent on the efficiency improvements that will take place in the various transport modes as well as the developments in vehicle utilisation. Both are very uncertain, particularly for the period beyond 2020.

A shift from road to rail may not be possible or convenient for all trips. An estimation of the potential magnitude of shifts is needed to calculate the true potential. Road to rail modal shift potential was estimated by (ETC, 2008). Calculations could only be made for long range transport (between NUTS 2 regions). This is not the same as the designation “long range” in STREAM. In STREAM “long range” mostly excludes commuters while a daily commute between NUTS 2 regions is common.

To estimate the potential, four assumptions were made by ETC (2008):

1. Preconditions for rail infrastructure in all regions are upgraded to the level of highly populated areas
2. Travel time by train is equal or better than by car
3. Travel costs by train are better or equal than by car
4. On any specific line the capacity cannot be more than doubled by 2030

According to these assumptions the share of rail in long range passenger transport can increase from 10% to 17% of the transport volume of road and rail transport. This increase is assumed to be feasible by 2030 albeit with considerable effort.

In the long term (2050) the maximum potential might be estimated by disregarding the fourth assumption. In this case the maximum potential share increases from 17% to 33% of the total road and rail transport volume.

In the text box below, a rough estimation is made for the overall reduction potential of modal shift from road to rail in passenger transport. It ranges from 2 – 14% of the business as usual CO₂ emission from passenger road plus rail transport. It depends on the assumptions and only holds when the conditions mentioned above are met. In this paper we do not further discuss the policy and investments that would be required for such a modal shift; this is to be covered in one of the papers on policy instruments, however it is obvious that meeting the four requirements listed above would require huge policy interventions.

**Exemplary calculation of the total potential**

From the reduction potential of a shift from road to rail and the maximum possible increase in the share of rail in the personal transport performance a (very) rough estimate can be made of the total reduction potential. We assume the total increase in rail transport to be 33-10% = 23% of the total passenger transport volume by road and rail and the reduction potential of the shift from road to rail to be 60%. Because the share of road transport in passenger transport demand roughly equals its share in the related CO₂ emissions, the total CO₂ reduction potential can be calculated as:

\[23\% \times 60\% = 14\%\]

Hence a maximum reduction of roughly 14% CO₂ reduction of road plus rail emissions is possible by modal shift from road to rail.

A less optimistic view would be to assume that the share increases to 17% and the reduction of the shift is 30%. The total reduction potential would then be:

\[(17 - 10) \times 30\% = 2\%\]

The less optimistic approach would result in a reduction of only 2%
These estimates do not include other types of modal shift in the passenger transport market. The potential of a shift from aviation to rail depends heavily on the share of the expected air transport volume in 2050 that could be subject to such a shift. We have not found any projections for this potential. As an example, if 20% of the volume could be shifted and carbon intensity of rail would be 80% lower, the CO₂ emissions of aviation could be reduced by 16%. If in 2050 aviation would be responsible for 25% of GHG emissions from passenger transport, this would correspond to a 4% emission reduction of GHG emissions of passenger transport.

A third type of modal shift that may be of interest within the passenger market is shift to slow transport modes. This is particularly possible for short distance transport. To give indication, in the Netherlands, 15% of all passenger-kilometres was made on trips of less than 7.5 kilometre (CBS, 2009). The share of these trips that may be shifted to slow modes may in theory be very high, in practice it is more limited. However, hybrid types of vehicles like electric bicycles may at the long run well gain a significant market share in short distance transport. For the potential of modal shift to cycling and walking on European scale, no estimates were found. In dense urban areas this potential is usually higher than in rural areas, because:

- Economy of scale advantages in densely populated areas for public transport modes;
- Shorter distances make that also slow modes can be a true alternative to motorised transport.

### 3.5 Trends and projections in freight modal split

The trends and projections of the modal split of freight transport are shown in Figure 12. This graph makes clear that, like for passenger transport, both the developments since 1990 and the projections for the next two decades are an increasing share of road transport and decreasing shares of rail and inland waterway transport.

**Figure 12** Projection of the goods transport volume in EU-25

![Graph showing the projection of goods transport volume in EU-25](source: DG TREN)

This graph does not yet include the impact of the recent economic crisis. The crisis has a dramatic effect on freight transport volumes at the short run, but is also expected to have significant impacts at longer run (Fraunhofer-ISI, 2009). However, this crisis hits all transport modes and there is no evidence that it will affect the modal split at the long run.
EEA (2006) made an assessment of the freight transport trends and gives the following explanations:

- Road transport was able to take more advantage of the dismantling of trade barriers than rail transport was. Consequently, road transport becomes more competitive compared to rail transport with regard to international transport.

- The road sector is liberalised to a great extent (resulting in decreasing transport prices), while the inland waterway and rail sectors have only relatively recently been opened up for broad competition. In addition, the privatisation of railway companies has resulted in a cutback of tracks and higher transport prices, since transport revenues should fully compensate for costs now.

- Changing production structures (e.g. outsourcing) demand more and more for ‘just-in-time’ delivery of goods. Transport speed and flexibility are therefore of great importance. Despite congestion, road transport is often faster and more flexible than rail or water transport.

- The type of the goods transported plays an important role in mode choice. Perishable and high value goods require fast and reliable transportation – road transport is often the fastest and most reliable form of transport available, providing much flexibility with pickup and delivery points. On the other hand, the transport of bulk goods is less time dependent, and so for this type of goods the cheaper transport forms – rail and inland waterways – are preferred. Since the share of perishable and high value goods is rising in total tonne-kilometres, this can partly explain the strong position and increasing share of road transport.

- Due to changing spatial planning and infrastructure development, many destinations can only be reached by road and combined transport is only practised to a limited extent.

- The average tonne of goods carried by road travels about 110 km, a distance over which rail or inland waterways can hardly compete, in particular if road transport is needed to and from the points of loading. Moreover, there is a lack of standardisation of loading units and convenient and fast connections between inland waterways and rail. For short sea shipping the average tonne of goods is carried over 1430 km. Here, time is less an issue. The low price of shipping is probably of overriding importance.

### 3.6 Comparison of various freight transport modes

As is the case with personal transportation a number of studies and models attempt to compare the CO\(_2\) emissions of freight transport modes. Both the TREMOVE model (T&ML, 2009) and STREAM (CE, 2008) project into the future and estimates the CO\(_2\) emissions per ton-km. TREMOVE projects until the year 2030, STREAM until 2020.
Figure 13 shows the average emissions for 31 European countries in 2030 estimated by the TREMOVE model including “Well To Tank” emissions. Figure 14 to Figure 17 give the results of STREAM.
Figure 13  Average CO₂ emissions for various freight transport modes according to TREMOVE

Figure 14  Average CO₂ emissions for short range bulk freight transport modes according to STREAM (including transport to mode access points)
Figure 15  Average CO₂ emissions for long range bulk freight transport modes according to STREAM (including transport to mode access points)

![Long Range Bulk Freight Emissions](image)

Figure 16  Average CO₂ emissions for short range container transport modes according to STREAM (including transport to mode access points)

![Short Range Container Emissions](image)
Like for passenger transport, STREAM again distinguishes between short and long travel ranges and addition also bulk and container transport. The differences in emissions of the same mode between these ranges is far smaller than in passenger transport since the difference in average degree of utilisation is smaller. The main difference between the plots consist of the modes considered relevant for that range of transport. A further distinction is made between bulk goods and containers, here the difference in utilisation is greater. Neither STREAM nor TREMOVE include air freight in their graphs because the CO₂ emissions are an order of magnitude greater than the other modes.

Overall the agreement between the two studies is very good, certainly considering that TREMOVE calculates a European average and STREAM is based on data for the Netherlands. The emissions for non road modes in TREMOVE are generally lower than in STREAM. One of the reasons for this is that TREMOVE does not attribute the transportation to and from the access point of the non road mode to the total emissions of the mode, nor does it add emissions during transfer. STREAM does account these emissions to the non road mode and as a result reports higher emissions. The main conclusions from these studies are:

1. Higher capacity vehicles have lower emissions that lower capacity crafts.
2. On average rail has lower emissions than most modes except the higher capacity ships.
3. Road transport emissions are on average the highest compared to the other modes (except air freight), but the logistic characteristics are decisive.
4. The emissions from air freight are an order of magnitude greater than surface bound modes.

The differences between the various modes are, at least partly, explained by the types of good carried and the markets the various modes operate in. The main differences are:

- The density of the goods carried by rail in inland waterways is on average much higher than on road.
- High value and low-density goods are mostly transported by road transport.
- Road transport is dominant for transport with high requirements regarding speed.
- Urban distribution is almost entirely done by road transport.
These differences should be recognized when interpreting the differences between the various modes. In STREAM some of these differences have been taken into account by including emissions to and from access point of the non road mode and by distinguishing short and long distance transport and bulk and container markets.

The emissions of inland barges or sea freight depend strongly on the size of the vessel and the route taken (for instance up or downstream) therefore a shift from road to rail is evaluated here. Another shift that may be relevant is that from air freight aviation to road or rail. Table 4 shows a rough estimate of the reductions that could be obtained due to these shifts according to TREMOVE and STREAM. It should be noted that these percentages show averages and that differences in specific cases may be much smaller because of the impacts on vehicle utilisation.

### Table 4 Indication of differences in emissions for freight transport modes

<table>
<thead>
<tr>
<th>Reduction CO₂ emission</th>
<th>STREAM (%)</th>
<th>TREMOVE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy duty truck to rail</td>
<td>55%</td>
<td>78%</td>
</tr>
<tr>
<td>Articulated lorry to rail</td>
<td>35%</td>
<td>66%</td>
</tr>
<tr>
<td>Air to Articulated lorry</td>
<td>89%</td>
<td>*</td>
</tr>
<tr>
<td>Air to rail</td>
<td>93%</td>
<td>*</td>
</tr>
</tbody>
</table>

* Data not available

The relatively high emissions of trucks are mostly due to the degree of utilisation. The other modes show generally higher average load factors (expressed in percentage of the maximum load in tonnes). If a large modal shift were to occur between road to another mode this (lack of) efficiency should be considered. It is likely that together with the goods also lower vehicle utilisation rates are shifted from road to competing modes. The effects on emissions would then be smaller than predicted on basis of the differences stated in the studies discussed here.

Both STREAM and TREMOVE base their projections on business as usual scenarios. Neither model takes into account possible ambitious climate policies or technical improvements with a large impact. No or very little energy efficiency improvements for the various freight modes were assumed.

In the future freight modes are expected to become cleaner, safer and more fuel economic. This effect is likely to be larger for trucks, due to the slow turnover rate for ships, trains and aircraft. At the other hand, electric transport has an advantage as soon as a large share of green electricity comes available. Few assumptions can be made as to the nature of the improvements without a more detailed and technical description of the possibilities per transport mode.

A more technical approach takes into account the projections for all different modes. However such a comparison is not available from literature.

### 3.7 Potential for modal shift in freight transport

Like for passenger transport, the GHG emission reduction potential of modal shift depends on the potential volume that can be shifted and the differences in GHG-efficiency.

From the previous paragraph the potential of shifting a transport flow from road to rail can be 35-55% (taking the approach from STREAM that attributes emissions from transfer and transportation to and from access points to the rail emissions). However, as stated before, the differences in the cases of modal shift may be smaller.
Only part of the freight transport market might be subject to modal shift. Some modes are in competition for transport of certain commodities but in many cases modes are complementary. A shift from road to rail is not possible or convenient for all commodities and transport relations. The transport volume that could be shifted from road to rail is estimated by (ETC, 2008). They estimate that the transport volume that can shift from road to rail within Europe can be 9% of the current (2006) transportation by road (in Tonne-km) This amounts to an increase in rail freight by 362 billion tonne kilometres. A note is made that in some EU countries this would require a very large effort and it is therefore unlikely to be achievable by 2030. In the long term (2050) this maximum potential might be obtained, but would require high investments.

The potential from other modes is included in (WEF, 2009). The main shifts regarded in this study are:
- Intercontinental air to ocean freight;
- Short haul air to road transport;
- Long distance road transport to rail and barges.

In total a global CO₂ reduction potential of about 23% within these categories is estimated with a medium feasibility.

Other sources come with much smaller potentials. CE (2003) shows that doubling the share of rail in EU freight transport would result in only 1 to 2% CO₂ emission reduction. (ZEW, 2008) calculates the potential CO₂ emission reduction of two policy measures to stimulate modal shift from road to rail in Germany. The most ambitious measure was calculated to result in an increase of rail demand of 8% facilitating a emission reduction of 4%. The study also remarks that modal shift does not always cause a CO₂ emission reduction. In some cases emissions appeared to increase because the cheapest rail chain was far longer than the distance travelled by road. The overall conclusion of (ZEW, 2008) is that policies to stimulate modal shift for freight are an inefficient method to reduce CO₂ emissions. This opinion is shared by among others by (PRC, 2007) and (KiM, 2007). At the other hand, other advocate modal shift as an important part reducing GHG emissions from transport or reducing negative side effects of transport more in general.

**Exemplary estimation of the total potential**

From the reduction potential of a shift from road freight to rail and amount of shiftable trips a (very) rough estimate can be made of the total reduction potential. Assuming that 9% of the transportation performance by road can be shifted to rail (like estimated by ETC, 2008) and the reduction potential of the shift from road to rail is 40% (assuming a majority of articulated lorries). The total reduction potential is:

\[ 9\% \times 40\% = 4\% \]

Hence a 4% CO₂ reduction is possible in Europe by modal shift from road to rail which is in agreement with (ZEW, 2008).

### 3.8 Conclusion modal shift and co-modality

Shifting transport volume from modes with relatively high carbon intensities to modes with lower carbon intensities may in principle contribute to GHG emission reduction. The GHG reduction potential of such a shift depends on the difference in GHG intensity (g per pkm or g per tkm) for the volumes that are shifted and on the potential volumes that can be shifted. Moreover, the overall impacts are also influenced by other impacts of modal shift policy like induced transport demand.

On average there are large differences in carbon intensity of the various freight transport modes. However, this has for a large part to do with differences in the type of goods (density, value), shipment size and requirements of the transport (e.g. speed, flexibility, granularity of the network). For the transport volumes that could be subject to modal shift, the differences between transport
modes are generally much smaller than the average differences between transport modes. In addition, for a proper comparison it is crucial to look at entire transport chains rather than comparing the modes as such. Therefore the potential of modal shift is much smaller than the differences in these average carbon intensities would suggest.

For passenger transport, the differences within transport modes are often as high as the differences between the various modes. Slow modes have clear GHG-advantages and in many cases also electric modes show relatively low GHG emissions, but this depends heavily on the electricity mix and vehicle utilisation rates.

Only part of all transport volumes could be subject to modal shift. For passenger transport, slow modes and carbon-efficient public transport with high vehicle utilisation rates have the highest potential in high-density urban areas. For freight transport, the potential depends a lot on distance and type of goods.

There are only very few estimates for the overall GHG reduction potential of modal shift. This potential depends heavily on various developments and policies, in particular:

- Development of the CO\(_2\) performance of the individual modes;
- Spatial developments;
- Infrastructure development of road and non-road modes;
- Efficiency improvements and interconnectivity of intermodal networks (e.g. border crossings);
- Travel times of the various modes;
- Travel costs of the various modes.

There are no reliable estimates available for the overall reduction potential of modal shift. Preliminary indicative estimates for the overall GHG reduction potential of modal shift for passenger transport ranges from 2 to 14\% (for a shift from road to rail transport), depending on the assumptions. The shift from aviation to rail transport could in theory also reduce GHG emissions from passenger transport with a couple of percent. These estimates take account of both the differences in carbon-intensity and the market share that at the long run may be subject to modal shift. For freight transport the estimates range from 4\% to 23\%, with most of the estimates being at the lower end. Any potential of modal shift can only be achieved with policy intervention. It would require high investments and has the risk of rebound effects because of an increase in overall transport volume.

In these estimates, long term developments in emission levels of the various transport modes (beyond 2020) have not yet been taken into account. It is to be expected that all transport modes will become cleaner, safer and more fuel economic. This effect is likely to be larger for road transport, due to the slow turnover rate for ships, trains and aircraft. At the other hand, electric transport for example rail has an advantage as soon as a large share of green electricity comes available. If all the electricity used is sustainably produced the CO\(_2\) emissions drop to almost zero. For the other modes a suitable carbon-neutral energy carrier is as yet unavailable and may require large changes in vehicles and distribution infrastructure. Few assumptions can be made as to the nature of the improvements without a more detailed and technical description of the possibilities per transport mode.

Modal shift policy have the risk to interfere with curbing transport demand growth. Particularly infrastructure investments and subsidies can induce transport demand growth. In some cases, the benefits of modal shift were more than compensated by the growth in transport volume. Measures to mitigate this through ‘locking in’ the benefits are therefore required.

In addition, there is the risk of undesirable modal shift. A famous example is the shift from slow modes to bus in the case of some free public transport schemes.

Barriers for modal shift include:

- the high investments needed for improving rail and waterway networks;
- the intrinsic advantages of road transport in the emerging transport markets (e.g. container transport, leisure travel), because of it higher speed, flexibility and connectivity.
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4 Decoupling transport growth and GDP growth

4.1 Introduction

The growth in transport volume is an important driver behind the growth in GHG emissions. GHG reduction policy could include instruments that reduce the transport growth rates. Limiting the growth in transport can also be regarded as one of the options for reducing emissions, and EU Transport policy makers have recognised this. The Common Transport Policy of 2001 included the decoupling transport growth from GDP growth as one of the main policy objectives.

In this chapter we discuss this option for passenger transport in section 4.2 and for freight transport in section 4.3.

4.2 Curbing passenger transport demand growth

In this section, the following issues are discussed:
- Trends in decoupling of transport growth and GDP growth (section 4.2.1);
- Drivers behind passenger transport volume growth (section 4.2.2);
- Transport speed and transport volume (section 4.2.3);
- Teleworking and teleconferencing (4.2.4);
- Link with policy instruments (section 4.2.5);
- Cost and benefits of curbing passenger transport demand growth (section 4.2.6).

4.2.1 Trends in decoupling of transport growth and GDP growth

In previous decades passenger transport has been growing steadily. Figure 18 shows the trend from 1995 till 2007. GDP growth is generally regarded as an important driver behind transport growth. In the light of the decoupling objective, EEA monitors the relation between GDP growth and transport growth. This is also shown in Figure 18, making clear that GDP grows faster than passenger transport volume. So, in the period 1995-2007 there was a decoupling of passenger transport growth from GDP growth. In the mentioned period some EU countries had decreasing or even negative growth rates.

**Figure 18** Passenger transport growth compared with GDP growth

Source: EEA 2008
The relationship between GDP growth and transport growth differs per country, as illustrated by Figure 19. This graph makes clear that there is no clear correlation between transport growth and GDP growth. Countries with a high economic growth rate do not necessarily show high transport growth rates.

Figure 19  Correlation growth GDP and passenger transport


Note: The figure shows the correlation between growth in the economy and growth in passenger transport. The correlation is visible from the distribution, but there is also a relatively broad range of different economic growth rates which can lead to the same growth in passenger transport.


Source: EEA 2006

4.2.2 Drivers behind passenger transport demand growth

To be able to curb the growth of passenger transport, it is important to know the driving factors behind it. To illustrate these factors, a conventional view of these factors largely shared among transport experts, is presented and elaborated upon below.

This view was provided at the International ECMT Seminar “Managing the Fundamental Drivers of Transport Demand” by Arie Bleijenberg, of the Netherlands Ministry of Transport, Public Works and Water Management (ECMT, 2002). According to Bleijenberg the growth that has taken place in transport has been the result of the fact that travelling has become faster, cheaper, more comfortable and reliable. This allowed for the impressive mobility growth we have experienced. Cheap and abundant energy, mainly in the form of fossil fuels, was the single most powerful reason for such impressive development of mobility, as it was also for the take-off of economic development.

The shift to ever faster modes of transport has resulted in an enormous increase in transport volume as the time persons spent on travelling has nearly stayed the same. In the same amount of time it became possible to reach further destinations. Therefore the main driver of the growth in passenger travel appears to be the increase in average speed.
The increase in speed is induced by various drivers. A conceptual model of the relations of the underlying drivers on passenger transport growth is presented in Figure 20.

**Figure 20  Transport speed as a driver of passenger transport growth**

![Diagram showing the conceptual model of transport speed as a driver of passenger transport growth.](image)

The following forces made the switch to faster transport modes possible:

- **Technological improvements**, each travel mode has become faster, cheaper and more comfortable by innovations such as the internal combustion engine, airplanes and the creation of motorway networks.
- **Increasing purchasing power**, as a result of economic growth, allowed people to buy faster transport modes.
- **Social forces** influence the shift to faster travel. It generally takes time before new (transport) technologies are accepted and fully adopted. In addition, the social acceptance (i.e. status) and emotional attitude might influence the modal choice of people.
- **Reductions in travel costs** promoted the shift to faster modes. Figure 21 shows this reduction in costs for the past century for different modals in the period 1900-1960.

**Figure 21  Average costs of passenger travel (in 1990 euro per km)**

![Graph showing average costs of passenger travel](image)

*Source: ECMT, 2002*

Following this “travel speed” approach, a projection for the future has been made in the ECMT paper. As shown in Figure 22, passenger mobility will continue to grow and aviation – the fastest mode of transport - will become the dominant mode between 2030 and 2050.
When changing the scope from (western) society as a whole and trying to explain the growth in mobility on a more detailed (country) level, the following factors have to be taken into account. These factors differ for different countries and influence the demand for transport.

- Population growth and ageing
- Urbanization
- Households size
- Economic growth (GDP per capita)
- Fuel prices
- Technology (improved vehicle efficiency; Information Technology impact “in” and “on” transport)
- Workforce participation rates (affected by ageing and gender)
- Vehicle ownership
- Disposable income
- Transport infrastructure
- Spatial and urban planning

As discussed above, the average speed of travelling is an important indicator in predicting and explaining the growth in personal travel. Therefore, in the next section the relationship between the two is further elaborated.

### 4.2.3 Travel speed and transport volume

According to different studies (Levinson, 1995; Lawton, 2001) the time a person spends on travelling will stay nearly the same throughout the years (60-70 minutes per full day). Levinson (1995) states that this effect is the same for different countries. The time spent on travelling seems to be indifferent to the transport possibilities and has been constant for decades. It seems as if the average person is not willing to spend more then little more than an hour on travelling. The effect of this phenomenon is that speed increases in transport will ultimately lead to increases in the distance travelled. The total travelled distance will increase as the persons can cover greater distances in the same amount of time.

The availability of faster and better transport modes has indeed led to the increase in covered distances and not in the reduction on time spent on travelling (Lawton, 2001; Duany 2000; Cervero, 2001).

To illustrate this effect the development in average travelling distances in France in the period 1800-2000 is presented in Figure 23. The average distance covered in passenger transport per person per full day increased from a few kilometres in 1800 to 40 kilometres in 2000. The dominant mode of transport shifted from walking and horses to the train and eventually the car.
Technological developments, in combination with growing income, allowed people to buy faster modes of transport over time.

**Figure 23**  Travelling distance per person per full day 1800-2000 (excluding walking; France)

![Graph showing travelling distance per person per full day 1800-2000 (excluding walking; France)](image)

Source: ECMT, 2002

A more recent example, the Dutch mobility situation in the period 1994-2007, confirms that travel time budgets are more or less constant over time. From CBS (Statistics Netherlands) data it can be concluded that in the Netherlands in mentioned period almost no fluctuation occurred in the average travelling time (-1%).

Figure 24 illustrates these developments of the Dutch average travel time per person per day. In the figure it is visible that the time spent on travelling remains almost constant (61.5 minutes in 1994 against 60.7 minutes in 2007). On the other hand however, the travelling speed increased by 7%. The result of this almost constant travelling time and the increase in average speed was a 6% increase in average covered distance.

**Figure 24**  Development of the mean travel time per full day per person (1994 = 100).

![Graph showing development of the mean travel time per full day per person (1994 = 100).](image)

Bron: CBS, 2009 (Dutch Statistics Agency)

This effect is likely to work both ways; a decrease in the travelling speed will lead to a decrease in the distance travelled as the distance a person is able to cover in the same amount of time (60-70 minutes) decreases. On the short run travel time budgets may not be constant, as travel behaviour can not always be changed immediately.

With the constant time budget for passenger transport, it is important to realize that curbing transport demand growth and increasing the average travel speed are incompatible.
4.2.4 Teleworking and teleconferencing

Teleworking is often mentioned as an opportunity for reducing transport demand. Teleworking reduces commuting traffic. However, it also has some rebound effects:
- CO$_2$ emissions from heating at home increase.
- Average commuting distances increase in the long run, because of the lower number of days that need to be travelled to work and people tend to accept longer travel times per day.

Teleworking has the advantage that it reduced cost and it also has some co-benefits, like improved labour, lower illness rates; higher attractiveness of employers.

In CE (2008) some exemplary calculations have shown the possible impacts of teleworking in the Netherlands. With a commuting distance of 45 km (one way), the net effect of working from home is a CO$_2$ reduction of about 40%, taking into account the average heating over the year. For shorter commuting distances, the relative impact of the heating becomes larger; at a commuting distance of about 25 km (one way) the net reduction is zero. Moreover, in these calculations, the possible increase in commuting distances were not yet included. At the other hand, when considerable number of employees make use of teleworking, also the office capacity may in some cases be reduced.

The reduction potential of teleworking depends on:
- CO$_2$ emissions from working at home (in the long run, these may be lower because of more energy efficient heating/cooling of houses);
- Impact on average commuting distance.

There is not enough information available for a reliable quantification of the reduction potential. However, given the rebound effects, the overall contribution is expected to be small.

Another interesting development that can potentially reduce passenger transport demand is teleconferencing. The rebound effects of teleconferencing are likely to be smaller than of teleworking. Until now, teleconferencing is not yet used very widely, but with technological improvements this is likely to change in the next decades. When it is perceived as a appropriate alternative for a live meeting, it may well help to reduce long distance transport, in particular air travel. No quantifications have been found for the CO$_2$ reduction potential of teleconferencing.

4.2.5 Policies that can contribute to curbing passenger transport demand growth

Historically, transport policy has generally aimed at facilitating transport growth and influencing the type of growth rather than trying to limit the growth itself. The various drivers of passenger transport demand growth make also clear what type policies can curb the demand growth. In principle these are measures that influence travel speed and/or travel cost.

The policy instruments available can be divided in the following segments:
- Infrastructure: The capacity of infrastructures is an important factor in the transport demand. Less capacity (growth) will results in increasing travel times. This will ultimately result in a decreasing (growth of) transport demand.
- Speed: Transport volumes can be controlled by the speeds measures. Speed limiting measures will on average result in increasing travel times. The increased travel times will ultimately result in a decrease in the transport demand (growth).
- Urban planning: The demand for transport can be influenced by urban planning. The demand for example can be reduced when cities are being built in such a way that all basic facilities are situated in the neighbourhood and can be easily reached by slow transport modes.
- Pricing options: options aimed a discouraging transport or particular modes of transport due to the cost increase. Pricing options that increase the variable cost of car use can
help to curb passenger transport growth. Variabilisation of the fixed car taxes in the Netherlands into a kilometre charge are expected to reduce transport volume by 15% and have high net social benefits, particularly because of reducing congestion costs (CE Delft, 2008).

In addition to these measures that are directly related with transport, also measures in other sectors can influence transport demand. Examples are tax levels for buying/selling a house and policies aimed at teleworking. The various policies are further discussed and elaborated in the set of papers on policy instruments (Paper 6, 7, 8 and 9).

4.2.6 Cost and benefits of curbing passenger transport demand growth

GDP growth and passenger transport demand growth are not well correlated, so decoupling the two seems a feasible option. However, curbing transport growth may still result in economic cost. The level of the overall cost depend on the various effects, like reduced mobility, increased travel times and the cost of implementing the policy measure. At the other hand, demand reduction has various type of benefits. These include, besides reduced GHG emissions, co-benefits like reduced air pollution, noise, accidents, fuel cost, infrastructure cost and congestion. The level of the cost and benefits of transport volume reducing policy depend heavily on the specific policy measure.

The cost of reduced mobility and increased travel times depend on the travel purpose. People travel for a wide variety of reasons, motivations range from work related to leisure related transport. However these different types of journeys represent different economic values. An indication of the value of a trip is the Value of Travel Time which expresses the (changes in) time spent on a journey (travelling and waiting) in an economic value. In these values the costs for persons (personal travel) and businesses (commuting, business travel) of time spent on travelling (paid as well as unpaid) are expressed (Victoria Transport Policy Institute, 2009). Parameters in determining the costs and benefits of a journey are the trip purposes, modes and journey lengths.

Table 5 shows that the valuations differs for the different types of journeys and the different transport modes. Looking at the valuation of the different types of journeys people tend to value their time the most for work related travelling and for longer commuting trips. At the modal level people tend have the highest VoT for plane travel followed by car and train travel and the least for bus travelling.

Table 5 Value of Time for passenger transport.

<table>
<thead>
<tr>
<th>Sector/purpose</th>
<th>Unit</th>
<th>Car/HGV</th>
<th>Rail</th>
<th>Bus/Coach</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger transport</td>
<td>€2002/passenger, hour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work (business)</td>
<td></td>
<td>23.82</td>
<td>19.11</td>
<td>32.80</td>
<td></td>
</tr>
<tr>
<td>Commuting, short distance</td>
<td></td>
<td>8.48</td>
<td>6.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuting, long distance</td>
<td></td>
<td>10.89</td>
<td>7.83</td>
<td>16.25</td>
<td></td>
</tr>
<tr>
<td>Other, short distance</td>
<td></td>
<td>7.11</td>
<td>5.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other, long distance</td>
<td></td>
<td>9.13</td>
<td>6.56</td>
<td>13.62</td>
<td></td>
</tr>
</tbody>
</table>

* Short distance values presented by HEATCO (70% of long distance values) have been removed, because short distance air transport (below 50 km) does not happen.

Source: HEATCO, 2006 (Deliverable 5: Tables 0-6 to 0-8)

An example of the net economic impact of reducing transport volume can be obtained from cost benefit analysis that have been carried out for speed limits on motorways. Rietveld et al (1996) estimated that the optimal speed limit on motorways in the Netherlands, by expressing all cost and benefits in monetary terms. He concluded that the optimal speed is around 90 km/h. More recently TML (2009) has calculated the optimal speed on Belgium motorways, from a macro-economic perspective. They concluded that the optimal speed limit is about 110 km/h. TML took into account the cost of increased travel times and the effects on GHG emissions, air pollutant emissions and accidents. No changes in transport demand nor savings in fuel cost and
infrastructure cost were included. Therefore the optimal speed is likely to be lower. This suggests that speed reduction leads to net social benefits.

4.3 Curbing freight transport demand growth

Like for passenger transport, also for freight transport, curbing demand growth can contribute to reducing GHG emissions. A decreasing demand growth for freight transport will result in economic (co)benefits but of course also economic costs. The net cost can be higher or lower than other GHG reduction options. This depends a lot on the policy instruments used.

Policy instruments can have various impacts on freight transport demand. While some instruments increase demand growth, others result in decreasing freight transport growth rates. This can in some cases have a large impact on the effectiveness of policy instruments regarding GHG reduction. For these reasons it is important to assess the mechanisms behind freight transport demand growth and possible reduction of this growth.

The structure of this section is similar to the previous one; the following issues are discussed:
- Trends in decoupling of freight transport growth and GDP growth (section 4.3.1);
- Drivers behind freight transport volume growth (section 4.3.2);
- Link with policy instruments (section 4.3.3);
- Cost and benefits of curbing freight transport demand growth (section 4.3.4).

4.3.1 Comparison of member states on freight transport volume per capita with the GDP per capita

Over the last decades, freight transport has constantly been growing, even stronger than passenger transport. Also in the period to 2050, freight transport growth is expected to outpace passenger transport growth.

The EEA reports show that freight transport demand has regularly outgrown the economy. In Figure 25 it can be clearly seen that the transport has regularly grown faster than the economy (GDP) (EEA, 2008).

\[\text{Figure 25 Decoupling levels freight transport}\]

On the long run GDP of western economies grow with an average 2.5% a year. This growth, however, does not equal the growth in physical terms (tonnes goods weight). The physical growth
of our economies is roughly estimated at 1% a year. The divergence between economic growth and physical growth reflects the structural changes in western economies: from industrialization towards services and knowledge-based economies. This phenomenon is known as “dematerialization” of the modern economies.

On the short run the increasing centralisation of production processes (longer hauls) and the introduction of just in time production (more frequent hauls) processes have led to a growth in freight transport which is larger than the growth physical growth and even larger than GDP growth. The EEA (2008) also mentions improved transport efficiency and removal of intra EU transport barriers as reasons for the achieved growth.

In Figure 26 the relationship between economic growth and transport growth for the period 1991-2001 is given for various member states. Just like for passenger transport growth, also freight transport growth is not well correlated to GDP growth. Apparently it is possible to have a high economic growth with a modest growth of freight transport volumes. Many of the member states that show the highest level of decoupling for freight transport, also had relatively high decoupling of passenger transport (UK, Netherlands, Finland, Sweden, Germany). It should be noted that this comparison does not included ‘embedded’ GHG emissions: member states can have a relatively high GDP growth with relatively low transport growth rates when a large share of transport intensive products are just imported and produced elsewhere. At the other hand, this comparison makes clear that there exist various pathways of economic growth and that some are more transport intensive than others.

Figure 26  Correlation growth GDP and freight transport

Source: EEA, 2005

4.3.2 Drivers behind freight transport demand growth

To understand how freight transport demand growth can be influenced, the main drivers of freight transport are presented:

- The increasing penetration of Just in Time production in all sectors has resulted in an increase in hauls (each tonne of final product is moved more often in the production chain).
The concentration of production and inventories has resulted in an increase in the average haul distance. Goods are being moved more frequently and over longer distances.

The increased purchasing power (income growth) allows consumers to choose from a large variety of consumption goods. Goods that are increasingly sourced globally.

Western economies are characterized by a move from production economies to knowledge service based economies, this phenomenon is also known as the dematerialization of the economy.

The economies of lean-production processes, as firms minimize their total production costs by searching for economies of scale in production and distribution, locational advantages and reduced costs for warehousing – all factors which stimulate just-in-time deliveries and more freight transport activity.

If transport costs decrease, companies will use more transport in the optimum thereby save money on warehousing and production costs.

A conceptual model of the influence of these drivers on transport growth is presented in Figure 27.

**Figure 27 Drivers of freight transport growth**

The future demand for freight transport will be determined by the broader societal developments. These broader developments have to be taken into account when developing and assessing policy that could contribute to curbing freight transport growth.

### 4.3.3 The relationship between policy and freight transport demand growth

A number of options can be identified that have an important impact on freight transport growth rates. They could be designed in such a way that they support unlimited freight transport growth or in a way that freight transport growth rates are curbed down. It is not our goal to provide a complete list of all the different policy instruments that influence transport growth and could contribute to a reduction. Instead we focus on the generic options available.

The policy instruments available can be divided in the following segments.

- **Urban planning:** The demand for freight transport can be influenced by urban and spatial planning. Production, distribution centres as well as urban areas can be planned in special areas as to resemble the most optimum distribution situation. Also policy aimed at limiting physical distances between production and consumption can reduce transport growth.

- **Pricing options:** Pricing can discourage freight transport or particular modes of transport. Options like road pricing may to some extent contribute to curbing freight transport
growth. At the contrary, subsidies generally lead to lower transport cost and therefore to higher transport growth rates.

- Infrastructure: The capacity of infrastructures can be an important factor in the freight transport demand. Less capacity results in increasing travel times and ultimately in decreasing transport volume.
- Speed: Freight transport volumes are affected by the speeds measures. Speed limiting measures will on average result in increasing travel times. The increased travel times will ultimately result in a decrease in the demand for transport. However, it is unclear whether the clear link between travel time and transport volume that exists in passenger transport, also exists in freight transport.
- Other policies: e.g. regulation that prevents or discourages domestic or local production.

4.3.4 Cost and benefits of curbing freight transport demand growth

As discussed the time consumed by travelling can be expressed in an economic value. This Vale of Time (VoT) is frequently used to determine the costs of congestion. In freight transport they determine these costs are not determined on basis of the passengers but on the haul. In freight transport the value is expressed on a ton/hour basis. In the VoT in freight transport the parameters are mode and commodity type. The VoT for Heavy goods vehicles as recommended by HEATCO (2005) is 2.5 times higher then that of Trains. The VOT in commercial transport contains all components of a full cost calculation including vehicle provision, personnel, fuel and second-order effects on customers. The difference between road and rail reflects the fact that goods shipped by road have on average a higher economic value than in the case of rail transport and are more often time-critical.

The net societal cost or benefits of reducing the freight transport growth is heavily dependent on the policy measure with which this is induced. In cases where the external cost of freight are higher than the taxes and charges paid by transport users, it is likely that measures that reduce transport demand growth can have net benefits.

4.4 Conclusion on curbing transport demand growth

It is not possible to quantify the potential of curbing transport demand growth, without considering policy instruments. Therefore in this chapter no reduction potentials could be quantified.

For passenger, the availability of faster and better transport modes leads to an increase in covered distances rather than in the reduction on time spent on travelling. Therefore, curbing passenger transport demand growth and increasing the average travel speed are generally incompatible. For freight transport, globalization and cost play also a key role.

There is wide range of policy instruments that can contribute to curbing transport growth:
- Urban planning, e.g. compact cities to avoid urban sprawl and spatial optimization of the location of industries and distribution centres.
- Transport pricing, e.g. infrastructure pricing: higher prices tend to curb down transport growth.
- Infrastructure policy: infrastructure investments have the risk to increase transport growth.
- Speed policy: reduction of travel speed, e.g. by lower speed limits, decrease transport demand.
- Other policies, e.g. taxes for buying/selling houses or all types of regulation that prevent or discourage local production.

The main barrier for curbing transport demand growth is the risk of adverse economic impacts. However, there are some example of measures that reduce transport demand but also have high net social benefits. Examples are the introduction of road pricing in cases where external cost are
not yet fully internalised or abolishment of subsidies. For policy that reduce transport growth, assessing the overall economic impact is a key precondition.

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5 Improved logistics and vehicle utilisation

5.1 Introduction

Improving vehicle utilisation has been an important policy objective for years. This is also one of the most important logistical objectives of many companies. Increasing vehicle utilisation and therefore reducing the number of (empty) kilometres is not only good from an environmental perspective; it also helps to relieve congestion on many (urban) roads and highways.

In this chapter we first discuss the trends in vehicle utilisation in freight transport (section 5.2.1), the drivers behind these trends (section 5.2.2), examples of initiatives to improve vehicle utilisation (section 5.2.3) and an overview of policy possibilities that can contribute to improving the vehicle utilisation in freight transport (section 5.2.4). Next, we discuss vehicle utilisation for passenger transport in a similar way (see sections 5.3.1 - 5.3.3).

In section 5.4 we discuss possible future developments in the vehicle utilisation based on explorative scenarios for mobility in 2030-50. Four scenarios are formed based on two uncertainties; i.e. the policy impact (either strong or weak) and the social-cultural values (either individual or collective). Finally, section 5.5 gives an overview of the conclusions on vehicle utilisation.

5.2 Vehicle utilisation in freight transport

5.2.1 Trends in vehicle utilisation in freight transport

Road

Figure 28 shows the trend in freight transportation; over the last three decades the amount of truck kilometres running empty has decreased, which means that the trucks are used to transport cargo more efficiently.

Figure 28 Proportion of truck-kilometres run empty in the UK: 1973-2003 (vehicles >3.5 tonnes gross weight) (McKinnon, 2007, based on DfT, 2004)

For the remaining truck kilometres, the kilometres in which the vehicles carry cargo, the average load factor is between 0.6 and 0.7. In the Netherlands, around 50 million road transport trips with
vehicles over 3.5 tonnes were undertaken in 2007. Next to this, around 225 million road transport trips are undertaken by smaller vans. The vehicle utilisation rate was 69.2% for outsourced transport in 2007, while for own transport it was 63.5%.

<table>
<thead>
<tr>
<th>% Road trips with loads in the Netherlands</th>
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<tr>
<td>Own transport</td>
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Legend:
Own transport = transport by manufacturers, traders, retail, etc. INCLUDING van transport
Outsourced transport = transport by road haulage companies
Source: NIWO and CBS 2008

The conclusion from this data is that over 4 years the change in the vehicle utilisation rate in the Netherlands has not changed much. This is also the case for the UK (see DfT, 2008). However, there have been substantial changes in especially the vehicles utilisation rate in own transport. The reason is not entirely clear, but it is suspected that the utilisation of vans is causing the changes. The current economic crisis is hitting road transport strongly, especially in vulnerable sectors like automotive and building. There are examples of large logistics service providers in the Netherlands where up to 1/3rd of all vehicles are standing still at the moment.

Other modes
Road transport is the dominant transport mode and initiatives to increase the shift to other modes are dealt with in another section of this paper. Therefore, we mainly focus on road transport. For the other modes we see the following trends in vehicle utilisation:

The utilisation of container ships world wide has falling dramatically in the past 6 months. In October 2008, less than 2% of all container ships were idle, while in April 2009 more than 10% of all container ships are in the docks and not used. This represents more than 1.2 million TEU of capacity (source: AXS Alphaliner Newsletter 2008 and 2009). Also, the container ships that are sailing the seas usually have a utilisation rate of around 80% or less, which was higher before the financial crisis. This underutilisation of container ships is expected to grow worse from the autumn of 2009 on, because many new and large container ships are ordered and will be delivered then. However, with the current economic crisis it is not expected that there will be enough trade for all of them. This will result in low ship utilisation and a low load factor for the ships. The question remains how the vehicle utilisation will develop, it is expected that the utilisation will be low for the next few years.

The share of rail compared with other modes in freight transport will increase. Hub and spoke system is intensively used through out Europe. The facilitators of this trend are the EU policy (e.g. a European network of rail freight corridors through cross-border cooperation) and the development of advanced high-speed rail. The amount of long-distance freight traffic would be significantly reduced by improved logistics (resulting in higher load factors), and by greater use of rail-based modes. Rail freight vehicles would very likely become longer, bigger and more energy efficient.

For air and rail, vehicle utilisation has also decreased. Logistics service providers are trying to prevent this by taking vehicles temporarily out of the market. The actual vehicle utilisation rate thus will fall less than could be expected.
5.2.2 Drivers behind these trends

McKinnon (2004) indicates several factors that constrain vehicle utilisation (see Figure 7). They can be classified as market-related, regulatory, inter-functional, infrastructural and equipment-related. For example, the vehicle utilisation is influenced by regulations. For example, many cities have vehicle weight restrictions or local authorities use time-access windows that force carriers to deliver stores during a short time-period usually in the morning hours. Because of these regulations, carriers need more vehicles to deliver goods to locations in different stores, resulting in an increase in the number of kilometres (and CO₂ emissions) and a decrease in vehicle utilisation (see Quak, 2008). Another example of a constraint that influences the vehicle utilisation is the incompatibility of vehicles and products. For example, some products have to be transported at low temperatures (e.g. milk) and other not. It is difficult to combine these different temperature flows in one vehicle. Other examples of constraints for vehicle utilisation can be derived from Figure 7.

Addressing one of these constraints would make an improvement in vehicle utilisation possible.

![Classification of the constraints on vehicle utilisation (McKinnon, 2004)](image)

McKinnon (2006) finds several drivers that explain the improvements in vehicle utilisation during the previous decades. The length of the haul increased, which implies that the return trips are also longer. Therefore, carriers have a higher incentive to find a return load. The truck operating costs per kilometre decreased, which results in a higher emphasis on the reduction of empty running and therefore in an increasing effort to increase vehicle utilisation. Next, the organisation of many transport changed over the years. Figure 30 shows the changing role and organisation of transport in supply chains. In the seventies the suppliers supplied stores, however since the eighties we see a centralisation stage, in which suppliers supply only a few distribution centres with full truck loads (FTL) and from there the retail organisation supplies stores with goods from several suppliers combined in one vehicle.
Next, we see an increase in multiple drop rounds, which results in better vehicle utilisation (see McKinnon, 2006). McKinnon (2006) mentions two other drivers that explain the improved vehicle utilisation over the last decades; the use of load matching services and more attention for reverse logistics. The increased attention for reverse logistics (and related concepts, such as closed-loop-supply-chains) results from the increasing scarcity of raw materials, so re-using materials becomes more attractive. Next, regulation on recycling and packaging waste is introduced and more products are retrieved at the end of life (i.e. refrigerators) according to EU-directives. Other drivers to improve vehicles utilisation are:
- Need for cost savings by utilising existing vehicles capacity (i.e. fixed costs) better, and thus have less transport cost per product (which is an important driver in a market with over-capacity).
- More cooperation between logistics service providers in bundling transports.
- More emphasis on sustainable transport through retaining networks.

5.2.3 Examples of initiatives to improve vehicle utilisation

There are several examples of initiatives that aim at improving vehicle utilisation.

- Improving the load factor. TNO (2009) shows that carriers already constantly try to improve the vehicle load factor. This can be achieved by putting more in one vehicle, for example by using long and heavy vehicles (LHV) or by using a double loading floor, so that one can carry twice as many pallets as with only one loading floor. Other examples of improving load factor initiatives are to use any empty room in a truck; if a truck is filled with roll containers, the space above the containers is empty. It is possible to put extra boxes on the containers. However, it takes more time to load and unload, and the costs for these activities might outweigh the gains from improved vehicle utilisation. Combining heavy products with volume products also improves vehicle utilisation, for example in the building sector, some materials are really heavy (for example stones or tiles), with the result that a truck is ‘full’ when the maximum weight is reached. However, for most of the time, there is still plenty of room in the truck. Other materials take a lot of room (for example isolation-materials), and trucks does not exceed the maximum weight, but is filled easily. By combining these materials the overall utilisation increases.
- Use of ICT – the smart use of ICT could increase vehicle utilisation considerably and there are policies that can stimulate ICT related improvements. First of all, ICT makes matching in loads (for example to find return loads) and carriers easier. It also makes cooperation and bundling (see next bullet-point) between companies easier. Next, advanced planning systems
are better able to cope with the uncertainties of today’s demands (see also constraints in Figure 7). Real time planning makes it easier to implement new orders at appropriate locations in vehicle roundtrips and to make efficient roundtrips in case unexpected events occur, e.g. an accident (see for example Moonen, 2009).

- Bundling of products. There are several forms of bundling; this is possible at a horizontal level, e.g. bundling of volume of similar parties in the supply chain, such as carriers or shippers and at a vertical level, e.g. integrate primary and secondary distribution (see Figure 31). Bundling already happens at distribution centres, which is bundling at the origin. There are also several initiatives to bundle goods at the destination, for example urban consolidation centres (see Van Rooijen and Quak, 2009) – see for more information the overview of policies in section 5.2.4.

Figure 31  Different ways to consolidate and improve vehicle utilisation

- Improving the route planning, so that trucks make the most efficient roundtrips. Software packages are available to help companies plan their deliveries and take constraints in account, such as local authorities’ regulations, congestion, etc.
- Reduce mistakes in the deliveries and ‘no-answers’, this will improve the overall vehicle utilisation. In case of mistakes, or in case of ‘no-answer’ a delivery has to be made again with the same goods.
- Reduce the delivery frequency (for LTL deliveries, less than truckload), Figure 7 shows that JIT (Just In Time) deliveries are a constraint to vehicle utilisation. Vehicle utilisation improves by decreasing the delivery frequency (and so increasing the amount of goods delivered per delivery). This reduces the number of kilometres as well.
- Outsourcing transport activities, in case more shippers outsource transport public carriers can combine supplies from many shippers, and so get a network with a higher drop density. This results in higher vehicle utilisation.
5.2.4 Overview of policies that can contribute to improved vehicle utilisation

The examples mentioned before are mainly in the private sector. Vehicle utilisation and improvement in vehicle utilisation are mainly accomplished by private companies. However, there are also policies that can contribute to improved vehicle utilisation:

- Relaxation of or removing of regulations. Figure 7 already showed that regulations could be a constraint on the vehicle utilisation. In the figure, health and safety regulations, vehicle size and weight restrictions, and goods handling requirements are mentioned. The cabotage regulation is another example. Obviously, many regulations are introduced for valid reasons, however sometimes the have unintended negative effects on the vehicle utilisation. For example, vehicle weight and size restrictions often result in lower vehicle utilisation and in an increase in truck-kilometres (see Quak, 2008).

- Pricing schemes and polluter pays policies. This is an area where a number of transport policy initiatives are being carried out, including infrastructure charging and internalising external costs. In the trends we argued that one reason for improved vehicle utilisation over the years was that gains per truck kilometre decreased, due to a lower cost-price per kilometre in the transport market, which forced the carriers to organize their transport more efficient in order to be profitable. By road pricing the cost per kilometre driven increases, which is an incentive for carriers to reduce empty kilometres. Most of the time the road price for the non-empty kilometres is paid for by the principal, but the carriers have to pay the road price for their empty kilometres themselves. Example like the German LKW Maut suggest that road pricing schemes, in particular, encourage carriers to reduce empty kilometres. Increasing fuel prices might have similar results.

Other policies that might contribute to improved vehicle utilisation are:

- Improvements in road telematics (policy could stimulate innovation in that direction and define standards).
- Implementation of the international organisation of rail transport, so that border-crossing rail transport is easier to organise and the utilisation of rail infrastructure for goods transport increases (see section on modal shift).
- Creation or stimulating the set-up of (a network) of urban distribution centres – although there are not many initiatives that have succeeded in this area in the past (see Quak, 2008), urban distribution centres could improve vehicle utilisation. The idea of consolidation centre initiatives is to split up the freight transport into two parts: the part inside the city and the part outside the city (see Figure 32). Transhipping at the city border, resulting in a split up of the transport, making it possible to benefit from the advantages of large vehicles for long haul transport outside the city without having disadvantages of these large trucks in the urban area, e.g. pollution and traffic safety issues. Next, smaller trucks transport the goods to outlets in the city after transhipment in a consolidation centre. An extra advantage is that the small trucks can be fully loaded in the consolidation centre, which results in a minimum number of vehicles entering the city. Depending on the load factor of the large vehicles that are replaced by the small ones, it may take more small vehicles to replace the large vehicles, which could increase the number of vehicles in the city. In some initiatives environmentally friendly vehicles are used to make the final delivery from the consolidation centre to the stores.
5.3 Vehicle utilisation in passenger transport

5.3.1 Trends in vehicle utilisation in passenger transport

Utilisation efficiency is one of the main parameters that determine energy, emissions and efficiency. A high occupancy rate in passenger cars and buses has relatively little impact on overall vehicle weight, and therefore on energy consumption, but could have a significant impact on the total number of vehicle movements and therefore on emissions. For vehicle utilisation of passenger transport we mainly focus on road transport, since this is by far the dominant mode.

Air transport
For air transport, in particular, managing vehicle utilisation is the core business. This has resulted in the use of advanced revenue management practices. Figure 34 shows the latest trends in the
development of the passenger load factor (PLF, i.e. a measure of how much of an airline’s passenger carrying capacity is used. It is passenger-kilometres flown as a percentage of seat-kilometres available. This is a measure of capacity utilisation). The utilisation is about 0.75, the trend is decreasing (mainly due to the current financial crisis).

Figure 34  International Passenger Load Factor (PLF) for airlines (IATA, 2009)

Road transport

The average passenger load factor, as an indicator for vehicle utilisation for passenger cars is considerable lower. The average number of occupants per car has fallen slightly, from 1.60 in 1995/97 to 1.58 in 2006 (see Figure 7). Assuming that on average a passenger car has (at least) four seats, the average for passenger cars load factor (in the UK) is slightly under 0.40, which is almost half of that in the airline industry.

Figure 35  Average car occupancy: 1995/97 to 2006, Great Britain (DfT, 2008)

In 2006, 60 per cent of cars on the road had only one occupant and the vast majority (i.e. 85%) of both commuting and business car trips had only the one occupant (DfT, 2008). Car occupancy varies according to the purpose of the trip. The highest occupancy rates in 2006 were for
holiday/day trips and education (2.0 persons per car). The lowest rates were for commuting and business travel (1.2 persons per car), see Figure 36.

**Figure 36**  Average car occupancy by trip purpose: 2006, Great Britain (DfT, 2008)

![Average car occupancy by trip purpose](image)

Figure 37 shows that the vehicle utilisation of passenger cars decreased over the last decades, but stabilised since about 2003 (which corresponds to Figure 35). To improve vehicle utilisation the focus should be on business trips (by passenger cars) and commuting trips.

**Figure 37**  Evolution of occupancy rates in passenger transport (AEA, 2005; CBS, 2005; DFT, 2005; MDCR, 2002; NS, 2004)

![Evolution of occupancy rates in passenger transport](image)

**Public transport**

Information on load factors in rail and bus transport is in limited availability due to its monopolistic history. There is also a tendency to privatise bus companies, routes that are unprofitable (potentially those with lower utilisation rates) can therefore be closed. This can result in higher occupancy rates and corresponding improvements in usage efficiency.
Subsidies can be provided to both rail and bus transport since it is recognised that underutilised routes (for example those operating on Sundays) can still perform important social roles.

The occupancy rate for rail increased in the Netherlands by more than 30% between 1980 and 1998. This is probably due to improved efficiency in combination with the increasing congestion on roads. Figure 37 shows that after 2003 there is a small decline. Obviously, the occupancy rates vary between trains, time of day and country but on average occupancy is around 35 % full. The occupancy rate of high-speed trains is generally higher, varying for different countries and connections. For example 80 % for the Paris–Lyon TGV and about 50 % on average for the German ICE (EEA, 2005).

5.3.2 Drivers behind these trends

Figure 37 shows that the occupancy rates for passenger cars over a longer period are declining. This could be a result of greater individualisation of society, declining household sizes and increasing car ownership. But is also due to increased use of cars for commuting where occupancies typically are low (Figure 37).

The basic trends show that vehicle utilisation is quite high in the airline industry, and low for the passenger transport. (Obviously, the financial crisis has impacts on the load factor for airline seats, but still the utilisation is high in comparison to passenger road transport). For the last decades, we see a decrease in the vehicle utilisation in road passenger transport. More and more, people depend on their cars for every-day activities, such as shopping, bringing children to schools, etc. The landscape and urban planning develops in such a way, that people need their cars for these activities.

5.3.3 Overview of policies that can contribute to improved vehicle utilisation and examples

Car sharing and Car Clubs

Measures to increase occupancy rates include schemes for favouring vehicles with more than one passenger (through-traffic privileges) and initiatives to promote car sharing, for instance “Greenwheels” in the Netherlands. With a subscription on Greenwheels drives don’t own their own car but share a car with other participants for a particular time.

Figure 38 Greenwheels

Measures to increase occupancy rates through – traffic privileges; e.g. privileged roads, commercials and carpool (car sharing) facilities have had limited success. Despite the results some Member States have developed special policies to improve the occupancy rates of passenger cars. For example:

- Sweden: occupancy rate plus 5%.
- Denmark: promotion of car sharing due to sharing tools, automatic toll systems, ecc).
- Italy: Firms are obliged (with more than a given number of employees) to have a mobility manager to promote vehicle sharing.
Revenue management by airlines

The success of airline-companies relies on their ability to extract the maximum profit from a fixed amount of goods or services. The total costs are nearly unaffected by the number of units sold. In order to maximize revenues, airline industries use sophisticated demand management techniques, known as revenue management. Exploiting differences in product valuations between customers, over time and for different product variants is at the core of revenue management. The airline industry is the poster child example of successful revenue management with enormous revenue increases reported (Marmorstein et al. 2003). The key idea is that one offers different ‘products’ to different customer segments to serve a bigger market and to extract more revenues. The example is the distinction between business and tourist travellers in the airline industry. In general, tourist class travellers are more flexible and more price sensitive than business class travellers. Therefore, the airline targets these segments with distinct product types, both in terms of price and booking restrictions (e.g. the cancellation policy, Saturday-night stay). Varying ticket prices based on the amount of chairs available is also an example of airliner’s revenue management. For public transport, costs per seat are also highly sensitive to vehicle utilisation, and therefore the example from the airlines might be useful for public transport from a utilisation point of view. These revenue practices are also practised ensuring a high utilisation of high speed trains.

Other initiatives have not really shown great results on a large scale, such as carpooling and park & ride locations to continue by for example public transport.

Other measures

Policy measures and initiative to improve vehicle utilisation:

- Pricing schemes
- Encouragement of carpooling: “carpooling reduces the costs involved in repetitive or long distance driving by sharing cars, sharing rental charges, or paying the main car owner. Some countries have introduced high-occupancy vehicle (HOV) lanes to encourage carpooling and use of public transport, to combat rising traffic congestion. In wartime, carpooling was encouraged to save oil. In reducing the number of cars on the road, carpooling decreases pollution and the need for parking space, and in a global perspective, reduces greenhouse gas emissions. Shared driving carpooling can also reduce driving stress. No money changes hands, but a mutual benefit still exists between the driver and passenger(s) making the practice worthwhile. In some cases, companies or local authorities will introduce facilities to encourage private carpooling, often as part of wider transport programs. These can include central listing facilities, defined pick-up points, preferential parking and general advice. This has increased through use of the Internet, mobile phones and other software support systems. A third party rideshare agency may also provide services to enable one off or regular carpooling in defined areas. In the “dynamic ridesharing” concept, a separate system performs a carpool match automatically for approval by the travellers” (http://www.dft.gov.uk/pgr/sustainable/cars and also Wikipedia, 2009).
- Car-free urban centers, resulting in better vehicle utilisation in public transport.

Vehicle utilisation improvement is more a freight transport than a passenger transport issue. Initiatives normally focus more on attracting passengers to public transport or to use other transportation means, such as bicycles or walking, than on improving the vehicle utilisation of passenger cars. These other issues are dealt with in another section of this paper. Some policy measures that are discussed in section 5.2.4 can be translated to passenger transport (for example a city consolidation centre is comparable to a park & ride location at the city border that makes a transfer to public transport easier). We decided not to repeat the policy measures and initiatives in this section, but to encourage the reader to make to translation from freight transport to passenger transport him or herself.
5.4 Vehicle utilisation in the future

In TNO (2009b) four explorative possible scenarios for the future were developed to make an estimate on how the future of mobility might look like. These four scenarios are all equally likely. The interesting thing is that the mobility system, and with that the development of the vehicle utilisation, in the future is very different in these scenarios. In this section we shortly discuss the potential impact of the uncertainties of the future on the development of the vehicle utilisation in the future.

The four scenarios are designed on based on two axes, i.e. the governmental impact (either strong or weak) and the social-cultural values (either individual or collective), see Figure 39. In a future with a strong government and individually driven society we expect no acceptation of collective transport systems and a government that privatises non core-activities, such as the road infrastructure. In this scenario we expect an increase in transport, and the main driver for increased vehicle utilisation will be for freight transport the companies themselves. By organising logistics more efficiently they can perform better than their competitors. For passenger transport we would see an increase in the utilisation of public transport due to the high costs for using private cars (e.g. toll that is especially high during peak hours, environmental taxes etc.) for the people with a lower income and the use of large luxurious cars for higher incomes and business travel, improvements in utilisation rates for this class would be low.

In the situation in which there is a strong governmental impact and collective values (scenario 2 in Figure 39) we expect a different development of utilisation. In this scenario mobility will be based on collective systems that match and optimise for both passenger and freight transport. This means that, in this case the vehicle utilisation would be very high, for passenger transport this means good and frequent public transport and connections, the use of shared cars and an increase in travel time. For freight transport we see large vehicles that deliver goods between consolidation centres and from there efficiently to end-customers (such as stores). For freight transport as well, improvements in vehicle utilisation results in a decrease in delivery times (not in reliability though).

In a situation with a weak governmental impact and a society that is individualistic, we see social divide. On the one hand there is the richer group that uses large cars and drives priority (no congestion) ways, and on the other hand we see a poorer group that uses older cars to travel. People rely on their cars to go shopping and to work, since there is hardly public transport. The vehicle utilisation for passenger cars is low, but since most people can afford only small cars the
utilisation rate for passenger transport by road increases. Congestion is huge. For freight transport we expect increased vehicle utilisation, not because of cooperation and bundling, but due to the use of large vehicles (LHV).

Finally, in the fourth scenario – collective social values and a weak governmental impact (see Figure 39) we expect less transport since activities are regionally focused. Private transport means are shared with others in the community, which results in a transport prevention, car sharing and carpooling, both in passenger and in freight transport. Good infrastructure and public transport is lacking, so the existing (but old) means are used better.

This section and the short description of potential developments in mobility in the future, and the resulting developments in vehicle utilisation shows that there are many possibilities for improving vehicle utilisation in the future, but that these possibilities are different for various autonomous future developments that influence the mobility-system as well.

5.5 Conclusions

The overall potential of improvements in vehicle utilisation depends heavily on various developments and policies. Both private and public actors have an interest in improving vehicle utilisation in freight as well as in passenger transport.

There are many factors that constrain improvements in vehicle utilisation, varying from market-related, regulatory, inter-functional, infrastructural and equipment related constraints. Some of these constraints can lifted by policy measures, whereas others need action from private actors. Important drivers to improve future vehicle utilisation are:

- A facilitating government providing the necessary infrastructure, the right incentive – for example pricing schemes that make variable costs visible and noticeable, and regulations that do not negatively influence vehicle utilisation improvement and
- ICT developments, which make it easier to cooperate and bundle in freight transport and easier to make carpool arrangement for passenger transport.

The four future scenarios show that autonomous developments have a huge impact on the way vehicle utilisation improvements in the future can occur or can be achieved. The revenue management example of the airline industry, where we see high vehicle utilisation, shows that in some cases there are tools to improve utilisation. The airliner’s main interest is in having high vehicle utilisation, since the vehicle utilisation determines its profitability. This is also the case for some logistical companies, and we learned that these companies that usually compete on costs and therefore also on logistical efficiency, strive for a high vehicle utilisation. Apparently, similar incentives are lacking for road passenger transport, where the vehicle utilisation is low.

A main barrier for improvements in vehicle utilisation is the fact that often cooperation is required between many actors, which makes it more difficult in practice than it seems in theory.

5.6 References


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