

# Keep Moving, Towards Sustainable Mobility



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Bert van Wee (Ed.)



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Tel.: +31 70 33 070 33

Fax: +31 70 33 070 30

e-mail: [sales@budh.nl](mailto:sales@budh.nl)

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# Preface

Miranda Schreurs and Henry Meijdam

Societies are seeking a better balance between human well-being, the quality of the environment and economic profit. Sustainable mobility is a major challenge in moving towards a more sustainable society. Overall emissions in the European Union have been declining since 1990. However, emissions caused by the transport of people and goods continue to rise steadily, making the transport sector a prime source of greenhouse gases in the EU. The share of transport in total European emissions is expected to increase from 20% today to 50% in 2050. It is imperative to reduce emissions, as stated in the 'Roadmap for Moving to a Competitive Low-Carbon Economy in 2050'. This goal must be accomplished without restricting our freedom of movement which remains of prime importance to society as a whole. Herein lies one definition of sustainable mobility: the current freedom of movement with the lowest possible carbon emissions.

Through this book and the EEAC/RLI<sup>1</sup> conference in October 2012, we wish to provide a selection of state-of-the art knowledge about sustainable mobility. That knowledge will be drawn from many disciplines, notably social sciences, economics, engineering, and (urban) planning. We devote particular attention to behavioural aspects, considering both consumers and companies. The book describes selected mobility-related trends and specific European issues, and examines how governments have responded to date. It also includes a discussion of proposals for action to enable national governments to facilitate societal initiatives and encourage sustainable mobility. The authors were invited to write essayistic on the matter to enhance discussion and bring up new ideas.

Achieving sustainable mobility is a complex task that must be pursued by means of a complex system comprising many different actors and policy domains. It calls for a fully integrated approach in which all challenges are interlinked. This book will allow readers to sample knowledge from several relevant disciplines.

1 The Councils for the Environment and Infrastructure (RLI) advise the Dutch government and Parliament on strategic issues that are concerned with our overall living and working environment. The formal councils offer solicited and unsolicited advice on long-term issues of strategic importance to the Netherlands in an international context. EEAC stands for the network of European Environmental and Sustainable Development Advisory Councils. In European countries, Advisory Councils.

Hopefully, it will fuel the wider political and societal debate about sustainable mobility. Most readers will have more than a passing interest in the subject matter. Many will be directly involved in research, others in policy making. We hope that the knowledge provided will help to make those policies more effective and better coordinated at the European level. Our aim is not to produce a 'primer' on sustainable mobility, but to offer an inspiring sample of current knowledge which will help the reader to articulate policies with renewed energy.

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# Defining the Policy Challenge

Bert van Wee

**The transport system has many advantages for individuals, households and the wider society. Cars, public transport and slow modes provide access to many locations of opportunities (jobs, shops, family and friends, schools, universities, recreational locations, etc.). Since World War II in many European countries, the share of the car in passenger kilometres has rapidly increased. The car is often a convenient way to travel, offering door-to-door access. In Western countries, in the past century, most households have at least one car. In most western countries, the number of cars per 1,000 people is above 450 (Schäfer et al., 2009). Since World War II, freight transport volumes (expressed in tonne kilometres) also have rapidly increased, allowing companies to buy and sell more or less world wide. Trends in passenger and freight transport largely result from demographic trends (increase in population size and a trend towards smaller households; ageing), economic trends (mainly, income increases allowing more people to buy and use a car and to fly), the development of 'better' transport systems (extensions of road and [to a much lesser extent] [high speed] rail networks, airline services) and changes in land use patterns (decentralization, suburbanization).**

However, increasing transport levels come at a cost, both at the individual level and for the society. These costs partly challenge the sustainability of the transport system. At the individual level, a lack of (road) safety is a major drawback, as well as the related lack of exercise due to non-active travel. At the level of society, a wide range of environmental impacts of car use exist, ranging from climate change and depleting resources at the global level to local air pollution and noise nuisance at the local level. Policy makers have recognized the drawbacks for society for decades and have introduced regulations of emissions of air pollutants and noise emissions, and for concentrations of pollutants (that result from emission of transport and other sources). More recently, the European Union has introduced policies to reduce CO<sub>2</sub> emissions of the transport system. Not only environmental concerns are high on the policy agenda, so are social concerns. Increasing car ownership levels have contributed to the disappearance of many local shops and services. Road and rail infrastructure can be a barrier for people

and animals. Owing to these and other changes in the transport and land-use system, some groups of people have become socially excluded (*e.g.* Stanley and Lucas, 2008; Lucas, 2012) – the topic of social exclusion is on the policy agenda of several EU member states, the United Kingdom and France being among the first to pay attention to these problems. Finally, safety is high on the agenda of policy makers and researchers for several decades now – safety impacts are important for both the economic and the social impacts of the transport system – see below.

During the past two decades, the topic of sustainable mobility has increasingly received attention of policy makers and researchers. Sustainable mobility can relate to balancing economic, environmental and social impacts of the transport system, but also to intergenerational issues (see below). For several reasons, we think the topic will in the future become even more relevant because policy makers face major challenges. Firstly, the depletion of oil and related fluctuations in prices make the transport system very vulnerable – it almost completely relies on oil-based fuels. Secondly, it becomes more and more likely that climate changes occur and that man contributes significantly to these changes. Policy makers, also at the EU level, have decided to try to reduce the impact of human-caused emissions of greenhouse gases (GHG; including CO<sub>2</sub>). Note that climate change is not the only environmental challenge for policy makers, but it is probably the toughest. In addition, noise levels have hardly reduced over the past decades, despite the introduction of noise emissions regulations for road vehicles. Air pollution has decreased, but even below the air quality standards for particulate matter (PM) severe health impacts occur. Thirdly, in addition to these effects, we seem to have entered a new era with respect to attitudes towards mobility or at least car use. Car use is saturating in several EU and other western countries (*e.g.* Metz, 2012 – see the essay of Litman). Young people in at least some countries (*e.g.* Germany and the United Kingdom) seem to be less oriented towards the car than equally old people a few decades ago. These trend changes raise many important questions: Will new road infrastructure be as beneficial for society as expected, based on models ignoring these changes? Will congestion levels increase as rapidly as in the past decades and according to the transport models used to forecast them? Can we expect an increase in the popularity of traveling by public transport because (young) people want to be online?

The trends in environmental and social impacts of transport, and in society, raise huge challenges for policy makers. The share of the transport sector is expected to increase to about 50% by 2050 (see the essay of Hajer, Hoen and Huitzing), whereas a strong reduction in GHG emissions is needed to reduce climate change to an acceptable level. It is clear that without policy interventions we cannot expect a strong reduction in the use of fossil fuels and CO<sub>2</sub> emissions. On the other hand, policies based on only measures that seem to be acceptable for policy makers and other actors will be by far not enough to meet ambitious

targets for CO<sub>2</sub> emissions and other targets. Therefore, the point of departure of this book is that policy makers face a major challenge if they want to move towards sustainable transport. History has shown that many ideas to implement unconventional policies have been presented, but real world implementations are relatively scarce. Important exceptions to the general rule of 'difficult implementations' are the introduction of road pricing and congestion charge schemes in London, Stockholm, Norwegian cities, Malta, Singapore and other cities (see, for an overview of recent research in the area of pricing [Verhoef et al., 2008], and public transport-based transport systems [often supported by land use policies] such as in Curitiba [Brazil] and Karlsruhe [Cervero, 1999]).

## 1. This Book: Aims and an Overview

This book aims to inspire policy makers and other professionals working in the area of sustainable transport by providing them lessons learned, ideas, data, trends and concepts. It includes seven essays written by well-respected authors. The book, therefore, is not a comprehensive scientific book covering the topic of sustainable transport. And although some authors share opinions on specific topics, not all authors agree upon all aspects of sustainable transport. The emphasis of this book is on environmental impacts – social and safety impacts receive less attention. We think that in the long run the environmental impacts and oil dependency are the toughest topics to address by policy.

*Phil Goodwin* discusses in his chapter theoretical concepts, the definition of sustainability and backgrounds of mobility. He argues that it is not a problem that distinguished authors in this book use different definitions – these differences do not represent an obstruction to agreement on vital, radical and achievable policies. If there are differences in definitions, potential conflicts are resolved easily in those cases where the same policy instruments have positive effects on all, or most, of the potentially competing objectives (due to different definitions). Goodwin stresses that there are some policies and projects on which there is a very broad agreement that they can be good for congestion reduction, efficiency, the economy, equity and the environment. It is identifying which policies these are, and how they may be implemented, that makes the movement towards sustainable transport systems achievable. In addition to discussing definitions, Goodwin argues that the focus has too much been on mobility, not on accessibility. The aim of the transport system is not to increase passenger kilometres travelled, but to provide access to (potential) destinations. This access should be low-impact. Reducing the impact of access can imply a reduction in car use. This does not have to be a problem. Goodwin states that it is clear that in many of the areas that have reduced car use most are not the impoverished or troubled ones – they are rich, economically successful cities, such as London, Paris, Munich, Strasbourg and Freiburg.

*Todd Litman* gives an overview of trends in mobility and their implications for sustainability. He summarizes some recent publications that show that per capita vehicle travel has peaked in most developed countries. He states that the reasons are demographic and economic trends, including aging population, rising fuel prices, increasing urbanization and associated traffic and parking congestion, improving transport options, increasing health and environmental concerns and changing consumer preferences. In line with Goodwin, he also argues that in many situations a shift of resources from accommodating car travel to improving alternatives is needed. And he also shares Goodwin's opinion that the transport system should provide access, not mobility (expressed in kilometres). Litman argues that the current planning process, and resulting transport system, however, is biased towards motor vehicles and ignores the negative impacts this can have. Next he discusses technologies. Although technologies in the past have improved motor vehicle performance, newer transport innovations improve alternative modes (including teleworking) or allow more efficient pricing. He then discusses evaluations of transport policy options, arguing that these are often biased. For example, parking costs are often ignored, as well as costs of induced travel due to motorway expansions. The shortcomings mainly result from the models used. Again in line with Goodwin, he stresses the importance of win-win policies and planning and gives several options of such policies.

But even if car use would have already saturated or will saturate in the coming one or two decades, and even if policies and planning would shift away from the car, car use will still have the largest share in passenger kilometres in the next decades. Therefore, technological changes reducing the impact of cars will probably result in the largest reduction of environmental pressure of passenger mobility. *Joan Ogden* gives an excellent and easy-to-understand overview of the state of the art and expectations with respect to several alternatives for the current transport system, with an emphasis on light duty vehicles (including cars) and alternative fuels. She explains how options for fuels/energy can be linked in multiple ways to options for energy carriers. Energy can originate from oil (conventional and unconventional), natural gas, coal, biomass, solar/wind/hydro and ocean and nuclear energy. These sources can be converted to gasoline, diesel (oil), synthetic liquids (oil, natural gas, coal), methane (natural gas, coal), ethanol (biomass), electricity (all sources) and hydrogen (all sources). These energy carriers can provide energy to internal combustion engine vehicles, hybrid electric vehicles (HEVs), plug-in HEV (PHEVs), battery electric vehicles (BEVs) and fuel cell electric vehicles. Next Ogden gives an overview of the state of the art for alternative fuels and vehicles. One of her conclusions is that a significant penetration of BEVs and PHEVs will make only a minor contribution to total electricity demand. The main near-term infrastructure needs are new in-home chargers plus some public fast chargers. She also discussed infrastructure investments of some technological options. For the United States, costs for

infrastructure and vehicles probably are 10s or 100s of billions of dollars, but the alternative of the petroleum-based fuel supply also has significant costs, that probably are much higher: the total expenditure for oil and gas refining and delivery infrastructure in North America is projected to be about 1 trillion dollars between 2007 and 2030, and over 6 trillion dollars globally. She argues that it is likely that there will be no single fuel or vehicle of the future. Rather, we will see a diverse mix of fuels in different regions and transport applications. By 2050, especially, the large-scale use of renewable liquid fuels and electric drive trains can be expected. Because the related transitions will take long, and uncertainties are large, she states that a portfolio strategy, combining energy efficiency improvement of current vehicles, travel reduction and adoption of alternative fuels and vehicles, is the best way forward. In addition, she suggests a series of city scale demonstrations – these are needed to accelerate technology learning at the system level. But, if it is not clear what the best options are, what then to do? If it is not clear how the future should look like, should policy makers wait and see? Ogden argues that the answer is ‘probably not’. We already have the technical capacity to build zero or near zero emission vehicles and produce low or zero carbon fuels. And the urgency of climate change problems means that we have to implement alternatives for carbon quickly. She next gives an overview of the major critical technical areas for improvement. She concludes that policy makers should on the one hand increase the efficiency of internal combustion engine vehicles and bring low-carbon biofuels into use. On the other hand, they should implement a strong programme of support to nurture emerging electric drive transportation technologies (batteries and fuel cells). Ogden states that perhaps the greatest need now is for strong and consistent policies, and roadmaps and strategies showing how stakeholders can coordinate to make feasible steps towards a sustainable transport future.

A specific category of technology is information and communication technology (ICT). In his essay, *Peter Sweatman* discusses the link between ICT and sustainable mobility and argues that ICT impacts the demands placed on transport as well as the efficiency with which we meet those demands. On the demand side, technology encourages our citizens and organizations to access services remotely, including remote learning, teleworking and telecommuting, and to interact socially without physical, face-to-face presence. On the demand side, ICT will make the transport system more efficient. It will, for example, increase safety, smoothen traffic flows and reduce congestion, increase (freight) load factors, encourage eco-driving and contribute to the implementation of road pricing. At the vehicle level, it will improve the efficiency of several options for powertrains (see the essay of Ogden). How will this happen? Many actors are involved to make the transport system more ‘intelligent’ via ICT. The automotive industry and its suppliers are of key importance. Other actors include the intelligent transportation systems (ITS) industry, the ICT industries, freight

industries, transit industries and infrastructure managers at the state, regional and local levels. Also consumers become increasingly important: they evolve from being purchasers and users of transport products to being consumers of transport services. Consequently, consumers will interact more frequently with a range of transport enterprises. Sweatman discusses the links between ICT and transport largely from a US perspective. He states that in the United States the strong regulatory flavour of federal departments of transportation has not been conducive to collaborative action with the automotive industry. In addition, the required ITS partnership between industry and government is also complicated by the diverse industry sectors and levels of government that need to be involved. Sweatman recognizes differences between the United States and Europe: in the United States, safety improvements, through crash avoidance, dominate the discussion, whereas Europe tends to have broader objectives that include safety, traffic efficiency and reduced environmental impact. Sweatman also discusses sustainable mobility. He argues that the transport system ultimately needs to be resilient – able to flourish under multiple forms of internal and external threat – an aspect that is often overlooked in discussions on sustainable mobility. Linking ITS to sustainability, he argues that the ability of ITS applications to play a major role in sustainable mobility may be expressed in two important characteristics brought to light in this discussion: (1) the reliability of the technology in delivering accurate information in a way that is immediately understood by the user and (2) the strength in influencing decision processes, behaviour and the subsequent impacts on sustainability. Sweatman discusses the role of ICT and ITS in future transport systems, including electric vehicles, mode choice and telecommunications. He argues that a common, multi-purpose, open-source platform for transport system communications needs to be established. An important policy conclusion is that policy makers need to do much more to plan for the ITS platforms of the future, an important reason being that independent authority will be needed to ensure that access is provided to private and public entities, that consumers have control over their data and that ITS platforms operate in a stable and reliable manner.

Although technological change very likely needs to bring the largest reduction in environmental pressure, behavioural changes may also contribute. Such changes can be the result of 'forced upon measures' (such as road closures and the introduction of car free zones) or of voluntary changes. On the basis of a behavioural perspective, *Tommy Gärling and Margareta Friman* discuss voluntary reduction of private car use. Although they do not provide the reader with a ready-to-implement recipe, their essay provides several useful insights that are well founded in literature. A first question they raise is, *Does having environmental protection attitudes and values make car users reduce car use?* On the basis of the theory of reasoned action and the theory of planned behaviour, they conclude that the answer to the question is yes, but not to any larger extent. Next they raise the question:

*How and why do car users respond to transport policy measures aimed at changing their car use?*

To answer this question, they present a theoretical framework grounded in self-regulation theories in cognitive and social psychology. They assume that people seek and select options that lead to the attainment of the goal they have set. A goal could be a reduction in car use. They also assume that people's choices are made sequentially over time, implying that people evaluate benefits and costs of alternatives over time. On the basis of these assumptions, it is important for policy makers to understand how (potential) policy measures will affect car use reduction goals. Secondly, it is important to understand the degree to which the policy measures facilitate or prevent that the goals people have set are attained. Gärling and Friman next raise the question: *Are voluntary changes in car use effective?*

On the basis of several papers describing real world cases, they conclude the answer probably is yes. Key for the effectiveness of voluntary changes seems to be firstly that people form plans. Customized information about alternative travel modes facilitates the formation of such a plan. To summarize their findings, they conclude that voluntary changes are unlikely unless (1) car users form an intention to change, for instance, due to increasing car costs or that they are persuaded to feel responsible for contributing to the protection of the environment, (2) acceptable alternatives are available and (3) society and important others approve change or disapprove non-change.

Now that several authors have presented building blocs, how could all the pieces of the puzzle of sustainable transport come together? In his essay, *Arie Bleijenberg* presents a challenging and provocative vision on how to achieve sustainable mobility. He does not exclude any impact of voluntary change, as discussed by Gärling and Friman, but he argues that between two-thirds and three-quarters of the required reduction in CO<sub>2</sub> emissions from transport can be achieved by clean technology: very efficient vehicles in combination with low-carbon energy. Such reductions can only be obtained if policy makers develop adequate, though difficult to implement, policies – a conclusion that matches the essay of Ogden. Bleijenberg states that policies should be technology neutral – policy makers should not, for example, 'choose' a specific drive train. A problem occurs because the lobby for 'clean technologies' is rather weak, unlike the policies for mainstream technologies. Between one-quarter and one-third of the CO<sub>2</sub> emission reduction needed can be achieved by making transport policies more economic. Bleijenberg argues that combating congestion is not the right compass for transport policy; it's the increase of average vehicle speed that made the transport system unsustainable in the first place. Rather the economic focus should shift to improving accessibility, being the combination of nearness and speed. Note that the focus on accessibility is also addressed by Goodwin and Litman. Nearness implies urbanization and high densities.

High-density urban areas increase the competitiveness of public transport because average car speed drops significantly in these areas. Another ingredient for economic transport policies is setting the prices 'right'. Bleijenberg argues that transport policies of the past decades were to a large extent based on wishful thinking about reductions in mobility growth and a model shift away from road transport. He also criticizes green lobby groups: it looks as if many greens are more interested in changing mobility patterns and reducing mobility growth than in reducing pollution itself – it is a change in life style they primarily aim for, more than a reduction in pollution.

Having a vision is important, but how to materialize it? Who should do what to implement it? What is the role of governments? In their essay, *Maarten Hajer, Anco Hoen and Hiddo Huitzing* elaborate on such questions. They argue that most policy frames consider the car as the default option. They state that the question is not *if* trends in the environmental impact of the transport system legitimizes government intervention, but *what sort of intervention* can be envisaged. They state that 'out-of-the-box' thinking is required. They present a perspective that may help to find new strategies to reduce the environmental impact of cars. Like Bleijenberg, they conclude that policies so far have failed to address the problems. And in line with Bleijenberg they argue that roughly 80% of the required CO<sub>2</sub> emission reduction should come from fuels and vehicle technologies; behavioural change can attribute some 20%. Before presenting their ideas, Hajer, Hoen and Huitzing first discuss measures so far. Successful measures include road pricing and congestion charging, emissions regulations and purchase tax incentives. Counter productive measures include free public transport and financial compensation for commuters. In their alternative approach, Hajer, Hoen and Huitzing stress the importance of power, of learning via variation and selection, and the role of experiments. They do emphasize that the traditional roles of the government, defining goals, infrastructure provision and creating rules and regulations are needed but not sufficient. In addition, coalitions need to be formed, in which governments participate, recognizing social and cultural forces. They then present six important ingredients for their approach: (1) the importance of framing: or society should be based on the frame of endless supply of energy (renewables); (2) smart solutions such as efficient vehicles; (3) global justice: western countries should perhaps share patents and technology with developing countries; (4) autonomy: renewables create autonomy and reduce dependency on geopolitical unstable regions; (5) endless supply: some sources of renewable energy are unlimited; we only have to find ways to harvest them. What should governments do in their approach? Governments should be predictable, change the default away from consumption of fossil fuels, and make regulations dynamic (only the top 10 or 20 vehicles should be entitled to tax reductions); (6) use financial instruments: put a price on CO<sub>2</sub> emissions, stimulate citizens to share cars, and learn through variation and selection. To be able to learn that way they should

set targets, monitor progress and show differences in performance. Over time the strategy should remain, but the tactics may change: policy must be adaptive.

## 2. Growing Pains

What can policy makers learn from the essays? Do they merely have to be bold and make unpopular choices? Although the authors in this book display a range of different views, I would conclude that this book offers a message of hope. The hope that policy makers have the audacity to build on the available instruments and are able to find the right frames to use them. By far the largest contribution in the reduction of CO<sub>2</sub> emission of cars, and probably the whole transport system, should come from vehicle technology and (renewable) fuels. And the technology is already available. A shift from fossil fuels to renewables, and from current cars to those with much lower CO<sub>2</sub> emissions, is very costly though, but in the long run (say up to 2050) the conventional fossil fuel system – most likely – costs even more. A strong reduction in CO<sub>2</sub> emissions without fierce and consistent policies, at the European Union and national level, is an illusion. Conventional policies have been completely insufficient. A viable policy frame is already offered. The transport system should primarily provide access to destinations, implying a shift away from mobility measured in passenger kilometres and fighting congestion (though reducing congestion is beneficial for society) and a shift towards a (urbanised) transport system that also gives way to other, more sustainable modalities. A final personal note: As Phil Goodwin already points out so eloquently in his chapter, this book is about the journey, not the destination. I think the problem of the transition to a low-carbon transport system is not the ‘after transition’ system itself, but the transition phase itself – *the pain is in the change*.

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# Keep Moving Towards Sustainable Mobility – What Does It Mean?

# 01

## Theoretical Concepts and Background of Mobility

Phil Goodwin

**This book, and the conference in Rotterdam at which it is launched, have chosen the general theme ‘keep moving towards sustainable mobility’ – only five words but with many layers of meaning. ‘Keep moving’ expresses the idea that transport is, and will continue to be, essentially about movement: a simple reminder that modern societies have a kinetic energy consisting of the bustle of trade and transfer and connection, of people and things, and always will. ‘Towards’ in the title is a word with a hidden meaning: a reminder that the goal of improving transport is a journey, not a destination – there will never be a final, complete, perfect transport system, and trying to design one is a useful mental exercise but not a realizable utopia. Societies change. The cranes on the horizon of a city such as Rotterdam are not temporary, but a machine for continual change.**

The two versions of the title (with and without punctuation after the first two words) are a sort of word game, a delight to those who enjoy language: ‘Keep moving – towards sustainable mobility’ emphasises that movement is a continuing part of the sustainable manifesto. ‘Keep moving towards sustainable mobility’ emphasizes the need for continuing effort and policy rather than a one-off initiative.

And the two key words ‘sustainable mobility’ represent a much discussed ambition, an agenda for transport planners and politicians, which is subtle and profound. Analysts have wrestled with definitions, as scientists always do, to try and make them at the same time unambiguous, useful and universally agreed upon. It is defining these two words that is the main task of this chapter.

The search for perfect, comprehensive definitions has not been completely successful. Indeed, the political opponents of sustainable mobility sometimes suggest that the words, being used in rather different senses by different people, must represent a confusion of thought and therefore inconsistent objectives. Even within this book, the authors of different chapters have used the words ‘sustainable’ and ‘mobility’ in rather different senses, and reflect a range of different views about the most effective policy instruments and the possibilities of success.

The purpose of this chapter is to explain that there are perfectly sensible reasons why this range of definitions has happened, to clarify the senses used and to argue that through that clarification, *the differences in definition do not represent an obstruction to agreement on vital, radical and achievable policies.*

## 1. Defining Sustainability

In its origin, sustainability was a simple, elegant and practical concept developed for the planning of forestry. The needs of pre-industrial economies relied heavily on trees to produce wood for building, manufacturing, fuel and many by-products. To be sustainable, it was necessary that one new tree should reach maturity to replace each tree that was cut down for use. There were some rather obvious practical complications – you need to plant extra to allow for the seedlings that do not reach maturity, for example, and some trees will be unsuitable because of disease or pattern of growth – but the underlying idea is clear: Forestry can be sustained indefinitely into the future only if this condition is met. If too few new trees are planted to replace the ones that are used, the activity is not sustainable; literally, it cannot be sustained.<sup>1</sup>

It is helpful to keep that basic idea always in mind when considering the more recent complications. The Brundtland Commission<sup>2</sup> provided the now most widely used general definition of sustainability, intended to be applicable to all processes that use limited natural resources:

meeting the needs of the present without compromising the ability of future generations to meet their own needs.

This definition has the same idea of an implied ‘contract’ between the present and the future, the commitment to think of the long-term consequences of present actions. The idea of a balance or social contract between present and future populations is inherent to the focus of sustainability as a process over time: but it lends itself to extension into ideas of a similar balance geographically (different regions of the world; cities and countryside) or socially (different classes, income groups, age, gender, etc.), which have been given different emphasis as discussed below.

There is a direct parallel between the classic forestry definition and the contemporary problem of using fossil fuels, which are, inherently, in large but limited supply. Once the world’s oil is used, it is finished, and therefore every tonne of oil that is used requires that an equivalent ‘tonne’ of some other fuel will be found, as modified by the changing pattern of the demand for fuel itself.

1 Although wood no longer has the same central significance that it once had, nevertheless the importance of trees remains, at a world level, in the issue of the rain forest and what will happen to it.

2 World Commission on Environment and Development (the Brundtland Commission), *Our Common Future*, Oxford University Press, Oxford, 1987.

But the parallel between the modern problem of oil and the classic one of a forest is not perfect, because other complications have forced themselves upon our attention. Sustainability of fuel supply is not *only* a problem of developing new sources of power at the same time as using up the oil, because it becomes clear that the same concept of a process that can be sustained indefinitely into the future requires that other conditions are met as well. Using fossil fuels releases carbon dioxide, which affects the climate, which in turn means that present and expected patterns of production and life cannot be continued. A shift from one fuel source to another affects not only the amount of energy but also its availability in different places, so that the security of supply to one country or region may be under threat. The combined effects of climate change and energy location mean that some populations will be under much more stress than others, causing political instability and potential population movements, which cannot easily be managed in a world of national frontiers and competing interests. Solutions to any one of these aspects will generally cost money, and therefore the question of whether that money can continue to be provided has to be addressed.

These complications meant that the simple concept of productive sustainability has inevitably developed into a host of other sustainabilities. This is seen in the World Bank definition, developed for its 1996 strategy 'Sustainable Transport' and expanded in its 2008 update:<sup>3</sup>

Economic and financial sustainability requires that resources be used efficiently and that assets be maintained properly. Environmental and ecological sustainability requires that the external effects of transport be taken into account fully when public or private decisions are made that determine future development. Social sustainability requires that the benefits of improved transport reach all sections of the community.

Therefore, policies may now be scrutinized according to whether they are politically sustainable, socially sustainable, geographically sustainable (*i.e.* both globally and locally), demographically sustainable or economically sustainable. From the point of view of transport and planning, it is not enough to consider the fuel used for movement; it is also necessary to consider the effects of transport decisions on the sustainability of housing; local and regional economies; the location of schools, hospitals, shops and workplaces; the differential impacts on those with and without their own private transport.

3 The International Bank for Reconstruction and Development/The World Bank (2008). 'Safe, Clean and Affordable'. This definition is immediately followed by the sentences "It is necessary to redefine the role of governments in the transport sector – the focus in transport policy must shift toward a market-based approach with the private sector taking on more of the responsibility for providing, operating, and financing transport services and infrastructure". Not all agencies agree that a shift from the public sector to the private sector is an inherent condition for sustainability, though clearly it has considerable influence at the present time.

The problem is that in its journey from the pure simplicity of planting enough trees to replace those we use in a forest to the multiple dimensions of modern analysis, we gain something and we lose something. We gain a flexible tool that in principle can be applied to all processes that use resources and have an impact on the world, a reminder that the world is complex, and we are foolish if we ignore those complications. But we lose the clarity of explanation, especially when – for perfectly sensible reasons – different analysts naturally choose to focus on a different subset of all the possible dimensions of sustainability that could apply.

Thus we can approach the definition of sustainability historically; a very simple origin, with progressive layers of meaning attached as the simple concept is applied to more dimensions. There may appear to be differences because different authors focus more or less on those aspects necessary to their themes, but the underlying consistency is there, and the problem becomes one of weighing a number of objectives in the balance and deciding how to get the best practical outcome. So some authors may choose to focus on a single aspect of sustainability as the most important – carbon emissions, for example, while inevitably recognizing that other criteria will also be important in decision-making. Other authors may decide to define sustainability as the combined total of all the different elements, environmental, economic, political and so on.

Approaching the definition of sustainability in this way has important consequences. The first is logical. At first sight, this has the potential for conflict – conflicts between sustainability and other objectives, in the first approach, or conflicts between the different elements of sustainability in the second. These may use different language, but they are logically identical: It does not make any practical difference whether one describes such conflicts as between ‘sustainability and other goals’ or between ‘the different elements that together constitute sustainability’. They remain potential conflicts and have to be resolved.

The second consequence is even more important, and political. *This is that the potential for conflict arising from different priorities and definitions is resolved easily in those cases where the same policy instruments have positive effects on all, or most, of the potentially competing objectives.*

The policy issues of how to achieve sustainability in transport depend crucially on whether the first property (conflict between different objectives and elements of sustainability) or the second (potential for the same policies to contribute to all the major objectives) applies. This tension is often seen in discussions of some large-scale infrastructure projects of a type that have manifestly negative effects on the environment (e.g. those roads or airports that provide for an expansion of travel patterns with high use of fossil fuels) but arguably favourable effects on

the economy (e.g. with claims that they generate employment, economic growth or public or private revenue streams). Taking the claims at face value, there then appears a choice between ‘the economy and the environment’ or – which expresses the same conflict in different words – a choice between ‘economic sustainability and environmental sustainability’.

It does need to be said that there is often a difference between the language in which projects and policies are supported and the underlying reality. In a political context where the need for ‘sustainability’ has been widely agreed, there are obvious advantages in canvassing support for a controversial project by using the word ‘sustainability’ persuasively in its prospectus, and there are specialists in providing arguments of this form. They are not always valid. Indeed one of the necessary technical skills of the transport planner has to be to ‘read between the lines’ of volumes of argument and statistics to distinguish valid and invalid claims for projects and policies.

Not all analysts agree on the outcome of these studies. This applies particularly to the largest infrastructure investments, where there are great commercial interests at stake, and differences of view about – for example – whether improved transport links between a rich and a poor area are more likely to benefit the dominance of the one or the development of the other.

But remarkably, there are *some* policies and projects in the transport sector on which there is now a very broad agreement that they can be good for congestion, efficiency, the economy, equity and the environment. It is identifying which policies these are, and how they may be implemented that makes the movement towards sustainable transport systems achievable.

If this proposition is true, it is the most important single understanding which this book can offer to the transport debate. Therefore, we return to the proposition after considering the second main issue of definition: what do we mean by mobility?

## 2. Defining Mobility

The problem with the word ‘mobility’ is quite different. Although in a dictionary sense there is some sort of common meaning – ‘the ability to move’ – this does not actually help much. The reason is that ‘mobility’ is a chameleon word, taking on different shapes and meanings according to the disciplines of research.

In biology, mobility has been used as one of the basic definitions of the existence of life, especially in distinguishing between animals and plants. In sociology and political science, social mobility is seen as a feature of open

societies, and a necessary condition for fair distributions of wealth and income. Freedom of movement is seen as a fundamental human right. Economists see the unimpeded movement of labour and capital as being part of the dynamic of competition and efficiency. Social geography has constructed an abstract theory of mobilities. Mobility is at the heart of the evolution of the human gene pool, and its spread, over many millennia, throughout the world. In medical science, mobility is applied to the functioning of joints and muscles, and the social services see the problem of mobility as the property of a person, particularly acute owing to aging or illness.

This is not a case of a simple concept growing to become applied to a wider range of issues. These are different meanings of the same word.

Many but not all of these cases share an unstated sense of moral and ethical approval: 'mobility is good, whatever it means'. This may be seen by considering how rare are the cases where the converse, immobility, is seen as a desirable characteristic – mostly in a negative context such as concealment from danger or resistance to change. But at the same time, there is a growing unease with some aspects of mobility, seen in the coining of a new word, *hypermobility*. There are cases where unimpeded movement seems to have negative consequences, or at least ones whose impacts are contested and cannot be assumed to be unambiguously good. These have included, for example, the geographical colonization of the world; imperial relationships between developed areas and their suppliers of raw materials and cheap manufacturing capacity; population movements due to economic and demographic pressures that now take place in days and weeks rather than decades and centuries, resulting in stresses that governments respond to by barriers, camps and police action; flight patterns that mean that diseases can in theory spread around the globe within hours; patterns of movement within cities that result in serious problems of congestion, pollution, obesity and loss of life.

This has resulted, in application to transport, in the recognition that mobility cannot be simply asserted as an *unlimited* good – the more the better. 'Keep moving' is helpful only if it is sensibly and carefully defined with reference to the quality, type, location and consequences of mobility.

At the heart of all, this is a single mistake, made far too widely in discussions of transport, which is the error that the measure *person kilometres travelled* has been used as an indicator of the benefits of travel and *tonne kilometres moved* as an indication of the economic benefits of freight. This has been misleading both in practice and in the theoretical structures of transport project appraisal. It replaces a fundamental understanding of what people want to travel for by a superficial and distorted quantitative measure. Paradoxically, it is made even

worse by the desirable scientific qualities that person or tonne kilometres are easy to define, relatively easy to measure and unambiguous.

Recognition of the distortion is not new – it underpins a long-standing (though sometimes rather mystifying) debate about the *difference between mobility and accessibility*, and why that is important.

### 3. The Traditional View

Using the simplified approach that mobility is measured by distance travelled, there has been an implicit assumption that the more movement the better. In theory, as people travel farther, they have a greater choice of destinations and hence a better match with their needs and interests. As goods are moved for longer distances, there is a wider choice of products, at a cheaper price because of economies of scale as different regions specialize in producing what they are best at. All movement incurs a cost, of course, and therefore elaborate methods have been developed for providing the methods of transport people want to use at the minimum economic and social cost and providing the goods they want with the maximum efficiency in terms of production, distribution, exchange and delivery. In an ideal world, the convergence of public policy and commercial interest would ensure that all methods of public and private transport would operate smoothly and in harmony for the public good and private income. Economic history indicates that the growth of economies is intrinsically related to the efficiency of their transport.

### 4. Rethinking Mobility

The problem with the description above is that it breaks down in an imperfect world, especially when short-term individual or company interests lead to unpleasant longer-term effects. The growth of mobility, as a general concept, becomes translated into the growth of traffic, and, above all, dependence on private car use, which brings environmental pollution, economically wasteful congestion, problems of health and safety and a dynamic development of land use where local opportunities are impoverished and people are forced to travel further and further even if they would prefer not to.

So while the traditional view of mobility tended to assume that physical movement was inherently beneficial, the excessive growth of car use in pursuit of this movement has led to congestion, pollution, economic inefficiency and a poor quality of life. *A wider concept of sustainable mobility needs to be based on efficient and low-impact access to goods and services and participation in social activities.*

There are important cases where this can be better achieved with less physical movement, not more. A superficial analysis might see policy emphasis on local facilities, shops, short distance trips, the health of local town centres and neighbourhoods, the role of the pedestrian, as being in conflict with the imperatives of a global economy. What sustainable transport tells us is that this is not true. Quality of life and economic efficiency both depend on what happens at the local level.

### 5. A Historical Narrative: The Evolution of Policy About Mobility

A large part of the mobility history of the 20th century was composed around the following propositions:

- Cars are faster and more desirable method of transport than any other, for most local and medium distance travel.
- Rising incomes will inevitably lead to more car use.
- Therefore the core duty of public policy is to provide roads and other infrastructure thought to be necessary for increased car use.
- Doing so will provide people with greater mobility, better lives and more efficient economies.

This approach broke down essentially because it was not successful under any of the different definitions of sustainability. Early in the development of sustainable transport policies, it became clear that the forecast increases in motorized traffic could not be accommodated by road-building, and therefore there would be increasing pressure on available road space, with resulting congestion, increased environmental impact, and problems of health, safety and economic inefficiency. The various policies developed to cope with this mostly addressed personal movement (better public transport, walking and cycling, including reallocation of road space from cars to these modes; pricing; cultural shifts; land use planning, etc.). In particular, there have been substantial successes since the 1970s and 1980s, including:

- Shifting the balance of power from vehicles to pedestrians in the woonerven in urban residential areas in the Netherlands;
- Pedestrianisation of town centres especially in Germany (and the extension of the pedestrian area into the inner cities by *verkehrsberuhigung* or traffic calming);
- Interest in road pricing mostly in the UK and Scandinavia (of which London and Stockholm were later implemented on a substantial scale);
- A reinvestment in public transport to reverse its declining role most marked in France, Italy and Spain;

- More recently a substantial regrowth of interest in cycling supported by new infrastructure, priority use of existing roads, inventive access schemes of which the largest is in Paris, and towns such as Gent and Cambridge, which are sometimes called 'cycle cities';
- In the UK, particular emphasis has been placed on a set of policy instruments formerly called 'soft measures', involving encouraging behaviour change by travel planning at the level of the workplace or household and
- International agreement to try to use regulation and market pressures to increase the fuel efficiency and cleanliness of vehicles.

It must be recognized that the implementation of these policies has not always been consistent, and rarely have all the policies been implemented together. Some of the differences in tone that the chapters of this book adopt reflect differences in the experiences of the authors' home cities and countries. But nevertheless there is one very important new phenomenon that is now under investigation: The proposition that is now under serious discussion is that we have now entered a 'second phase' of sustainable mobility, often known as 'peak car', whose features are quite different. Forecasts of large increases in car use are now no longer credible. Car traffic growth *has already ceased or substantially slowed in most developed economies*, and in some there are signs of significant decreases, especially in larger towns and cities, and with a timing that precedes the current economic crisis and is therefore not mainly due to it.

The debate on this question is at the cutting edge of assessment of what sustainable transport policies have achieved, and where they can go next. There is no consensus on the reasons and the prognoses, with some authors arguing that what we currently see is a temporary pause due to the world economic crisis, with growth expected to resume when the economic situation improves, and others arguing that we are even now in the middle of a historic shift in the culture of mobility, giving great possibilities of success. In specific analyses, the reasons that have been advanced for the shift in trends that we see (with at least some evidence on all of them) are listed in Table 1.

What is now clear is that many of the areas that have reduced car use most are not the impoverished or troubled ones – they are the rich, economically successful cities with growing economies and improving quality of life, for example London, Paris, Munich, Strasbourg, Freiburg. While the future is of course uncertain, there are now really serious possibilities of a structural change in the long-term transport trends that have been unfavourable to sustainability. It used to be the case that every discussion of transport and the environment had phrases such as 'transport is the most challenging sector', but the mood now is distinctly different in many countries, with examples of great success and change.

Factors thought to explain reduced car use in successful cities and some advanced countries	
Traditional 'economic' factors of prices and incomes	General economic conditions
	Fuel prices, cost of learning to drive, acquire and run cars, congestion charging, insurance costs
	Fares subsidies on public transport
	Changes in regulation, taxing and funding of company cars
	Decoupling of income growth from travel growth
Changes to the relative quality and reliability of travel	Improvements in public transport, due to priority access to infrastructure and better operations
	Congestion
	Provision of cycle lanes and other support
	Pedestrianization of town centres and traffic calming in residential areas
	Development of urban rail systems with consequential impacts on property values and attractiveness of locations well served by public transport
	Reallocation of road capacity from car to wider pavements, priority lanes, etc.
	Parking conditions and policy
Developments in land use planning	Redevelopment of brown-field sites and inner city areas with high densities
	Retail and service development favouring urban localities rather than out-of-town sites
	Inner city development of a type that becomes preferred by higher income groups and opinion formers, changing fashions away from suburbs
	Better understanding of economic benefits of public realm improvements
New patterns of work, shopping, entertainment and leisure	Shift of certain categories of what has traditionally been considered as 'personal' travel to 'commercial' travel, notably in home delivery of some goods previously been transported by car
	Telecommuting, high-technical versions of home working
	Shifts of some travel from car to air, and from air to train
	Reduction in traditional forms of car dependence, including by development of new patterns of car use moving away from traditional ownership to various sharing, leasing or renting schemes
Direct and indirect effects of technologies providing mobile Internet access	Opportunities for entertainment, social contact and productive work during travel, tending to favour public transport more than car use
	Better travel planning, including recovery from disruption

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Factors thought to explain reduced car use in successful cities and some advanced countries	
New social/technical patterns and preferences seen as influences on behaviour	Travel time budgets, especially in the context of natural saturation level
	Application of 'smarter choices' programmes
	Cultural and psychological shifts including a cooling or disappearance of the 'love affair with the car'
	Concern with motivations less favourable to the car (notably environmental impacts and personal health)
	Various different forms of e-commerce (tele-commuting, on-line shopping, virtual conferences and meetings) and e-leisure (social networks, virtual worlds) especially associated with mobile commuting (which in turn is more favourable to public transport use than car driving)
	Social changes such that the driving licence as a key rite of passage into adulthood no longer has the universality it had seemed to be acquiring, especially among young men whose propensity to learn to drive and buy a car has reduced in many countries
	Decline of the status, fashion, social esteem, implicit sexuality and 'buzz' of car ownership and use, and their replacement by other products and icons
	Changing demographic structures and lifestyles, including those which affect the longevity of particular life-cycle stages and the locations where people prefer to spend them, e.g. shifts from inner cities to suburbs of young couples, returning to cities when their children leave home
	Growth of immigrant numbers (in the broadest sense) who bring different cultural attitudes and habits of travel to their new homes, whose effects may go in either direction depending on the specific two cultures concerned
	Shift in the direction of transmission of attitudes, i.e. from children to parents
	Complex balance of aging and gender effects, such that women are catching up with the car access of men, men are catching up towards the longevity of women, both are living longer with a tendency to keep on with car use in the early years of retirement but then to have a longer period of life when it is less easy to sustain car use and the skills which go with it

Table 1. Factors thought to explain reduced car use in successful cities and some advanced countries.

Although the discussion has mainly been about personal travel, it has ramifications on freight logistics also. In the first phase of replacing 'predict and provide' by 'demand management', while there was pressure for freight transport also to improve its efficiency and become cleaner, but there was little scope for large-scale support from public policy, which was addressed mainly to restrictions on lorry traffic, together with improvements in logistics, so that fewer vehicles, if possible, could deliver a greater volume of goods.

In the new situation, there will be increasing scope for substantial re-allocation of road space not only from cars to buses, bicycles and pedestrians, but also to essential goods, service and emergency vehicles. One of the rationales for doing so is that one of the driving forces behind the reduction of car traffic has been

the transfer of a proportion of ‘personal’ movements to ‘goods’ movements, as Internet shopping with home delivery replaces a part of car-based personal shopping: fewer cars, but more vans. Big stores had a logistic function of transferring goods from a few lorries to many cars. But increased home delivery changes the pattern of flows. This directly affects the final stage of the logistic chain, but it has knock-on effects to earlier stages, including factory-to-warehouse whose location will be different if they are feeding to delivery vans rather than shops and may give new life to the idea of urban transshipment depots whose success has not, until now, lived up to hopes.

Thus future traffic flows are likely to require more lorries and vans, which will be made possible by a greater reduction in cars. The result is not only environmentally helpful, it is also economically more efficient and enables a higher quality of life and the growth of towns.

## 6. Conclusion

The discussion of definitions suggests that the potential conflict between competing objectives within a broad definition of sustainability (or between a narrow definition of sustainability and other objectives) can be resolved in practice by the existence of a specific set of practical policies that usefully contribute to all the major objectives – including that of improving mobility, provided that it is not defined in terms of the crudest measures of miles travelled by vehicles.

Sustainable mobility is now seen as a philosophy of providing for quality in movement rather than simply quantity and of enabling the best achievable standards of participation in social and economic activity at the same time as reducing the amount of unnecessary or damaging movement by unsuitable methods in unsuitable places. It will require committed politicians and professionals, and support from engaged and thoughtful citizens, but it does, now, accord with the spirit of the times, and can deliver significant environmental and economic advantage. This is an outlook of great potential.

# Current Mobility Trends – Implications for Sustainability 02

Todd Litman

**This chapter investigates current mobility trends and their implications for sustainability. It discusses factors that affect transport demands (the amount and type of travel that people would choose in a particular situation) and how demographic and economic trends affect these demands. During most of the last century, motor vehicle travel grew steadily in most developed countries. During this period, it made sense to invest significant resources in expanding roads and parking facilities, so this became the focus of transport planning. However, per capita vehicle travel has peaked in most developed countries because of demographic and economic trends, including aging population, rising fuel prices, increasing urbanization and associated traffic and parking congestion, improving transport options, increasing health and environmental concerns and changing consumer preferences.**

Motor vehicle travel imposes significant economic, social and environmental costs. An optimal transport system provides diverse mobility options and incentives to use the most efficient option for each trip, taking into account all benefits and costs. This implies that in many situations, it makes sense to shift resources currently devoted to accommodating automobile travel to improving alternative modes, in order to respond to changing consumer demands and to reduce problems that result from excessive automobile dependency. This chapter explores the implications of these changing demands and priorities on transport policy and planning decisions. It discusses ways to evaluate various transport benefits and costs, and the degree that these are considered in conventional planning. This analysis indicates that current planning is biased in various ways that favour mobility over accessibility and automobile travel over other modes. It discusses potential policy and planning reforms needed to better respond to user demands and help achieve sustainability goals.

## 1. Introduction

During the 20th century, motor vehicle travel grew steadily in most developed (industrialized) countries. During this period, it made sense to invest significant resources to accommodate this growth. However, travel demands (the amount and type of travel that people would choose in a particular situation) are changing. Per capita vehicle travel has peaked in most developed countries, and there is growing awareness of the problems that can result from excessive automobile dependency. It is time to reconsider some basic assumptions (Asian Development Bank, 2009). A *paradigm shift* (a change in the way problems are defined and potential solutions are evaluated) is occurring in the transport planning field, as summarized in Table 1. It is important that people involved in transport policy and planning activities understand this shift.

	Old paradigm	New paradigm
<b>Definition of transportation</b>	<i>Mobility</i> : movement of people and goods	<i>Accessibility</i> : ability to access goods, services and activities
<b>Planning objectives</b>	Maximize mobility, minimize time and monetary costs	Maximize accessibility, cost efficiency and user options. Respond to consumer demands
<b>Impacts considered</b>	Travel time, vehicle operating costs, risk, and some pollution emissions	Various external, indirect and non-market impacts, including negative effects of vehicle traffic on non-motorized travel, land use impacts, health and social equity objectives
<b>Options considered</b>	Primarily road and parking facility improvements, and major transit improvements on some urban corridors	Multiple modes (walking, cycling, ride-sharing, automobile, public transit, and telework) and demand management strategies (road space prioritization, pricing reforms, smart growth land use policies)
<b>Consideration of travel demands</b>	Focuses primarily on automobile travel demand. Seldom applies transportation demand management	Considers demand for all modes, including latent demands. Often considers transportation demand management solutions
<b>Performance indicators</b>	Vehicle travel speeds, vehicle operating cost per person-mile, roadway level-of-service	<i>Accessibility</i> : number of opportunities people can reach within a given time and money budget. Service quality of various modes
<b>Favored improvements</b>	Projects that increase motor vehicle travel speeds	Policies and projects that increase transport system efficiency and diversity

Table 1. Comparing transport planning paradigms (Litman 1999).

This table compares the old and new transport planning paradigms. The new paradigm is sometimes considered sustainable transport planning.

The old paradigm defines *transport* based primarily on *mobility* (physical travel), which assumes that society's goal is to increase travel speed and distance. However, mobility is seldom an end in itself; the ultimate goal of most transport is *accessibility* (or *just access*), which refers to people's ability to reach desired goods, services and activities (together called *opportunities*) (Chapman & Weir, 2008; Litman, 2003). Many factors affect accessibility including the quality of mobility options available (the ease of walking, cycling, automobile travel, public transit and taxi services), the location of destinations (the distance between homes, worksites, schools, shops and parks), path and roadway connectivity and the quality of mobility substitutes such as telecommunications and delivery services.

Planning decisions often involve trade-offs between different types of access. For example, roadway expansions tend to improve automobile access but reduce access by non-motorized modes. Bus-lane and bike-lane development often requires reducing traffic or parking lanes. Land use patterns that maximize automobile access, with activities located along major roadways and abundant parking supply, are generally difficult to access by other modes. It is important that decision-makers understand the full impacts of such decisions, including the negative impacts that unintentionally result from efforts intended to improve motor vehicle travel.

An efficient and equitable transport system is diverse, so travellers can choose the best accessibility option for each type of trip. This means, for example, that walking and cycling are convenient and safe for local errands, high-quality public transit is available for efficient travel on major travel corridors, and automobiles can be used to reach dispersed destinations or carry loads. To the degree that current planning practices favour mobility over accessibility and automobile travel over other modes, they result in excessively automobile-dependent communities, forcing people to drive more than overall optimal.

The current planning process is biased in many, often subtle ways. For example, transport system performance is often evaluated primarily on the basis of roadway level-of-service, which reflects automobile travel speed and affordability. This justifies roadway expansion to improve motor vehicle accessibility, but ignores the negative impacts this can have on other accessibility factors. By evaluating only impacts on motor vehicle accessibility while ignoring many of the negative impacts that result from wider roadways, this type of performance evaluation often results in economically excessive roadway expansion and inadequate investment in alternative modes. Similarly, generous minimum parking requirements, and traffic impact analysis that impose higher costs on compact, infill development, create more sprawled, less walkable and transit-oriented communities than would otherwise occur. More optimal planning

requires more comprehensive and multi-modal analysis. For example, project and policy analysis should account for the increased transport costs that result if wider roads and increased motor vehicle traffic force residents to drive for local trips that could otherwise be made by non-motorized modes, and the reduction in accessibility that would result from sprawled land use development.

The old transport planning paradigm tends to reflect an engineering perspective: It optimizes for one primary objective, mobility. The new paradigm tends to reflect an economic perspective: It recognizes that planning should consider diverse objectives, impacts and options.

By applying accessibility-based planning, the new paradigm greatly expands the variety of solutions that can be applied to transport problems, which can increase cost efficiency and total benefits. For example, with the old paradigm, the only solution to traffic and parking congestion problems is to expand road and parking facilities, which is costly, and by increasing total vehicle travel tends to exacerbate other traffic problems. The new paradigm allows consideration of other solutions, including improvements to alternative modes, incentives to use alternatives, and smart growth land use policies that reduce the amount of vehicle travel generated in a community. These solutions are often more cost effective and beneficial overall.

The new planning paradigm requires comprehensive understanding of transport demands to determine the types of facilities and services users want, and how they would respond to transport system changes. For example, the new planning paradigm recognizes the possibility of latent demand for alternative modes, that is, people would sometimes prefer to drive less and rely more on walking, cycling and public transport, if given suitable options. This information can be used to design effective demand management strategies, such as improvements to alternative modes, efficient transport pricing, and smart growth land use policies, in order to achieve planning objectives such as congestion reduction, cost savings, improved public safety and health and environmental protection. The following section discusses this issue.

## **2. Factors Affecting Transportation Demands**

Various factors affect transport demands, as summarized in Table 2. These factors can help predict how demographic and economic trends will affect future travel demands, and they can be used to better respond to user needs and to develop demand management programmes that increase system efficiency.

Demographics	Economics	Prices	Transport options	Service quality	Land use
Number of people (residents, employees and visitors)	Number of jobs	Fuel prices and taxes	Walking	Relative speed and delay	Density
Incomes	Incomes	Vehicle taxes & fees	Cycling	Reliability	Mix
Age/lifecycle	Business activity	Road tolls	Public transit	Comfort	Walkability
Lifestyles	Freight transport	Parking fees	Ridesharing	Safety and security	Connectivity
Preferences	Tourist activity	Vehicle insurance	Automobile	Waiting conditions	Transit service proximity
		Public transport fares	Taxi services	Parking conditions	Roadway design
			Telework	User information	
			Delivery services	Social status	

Table 2. Factors that affect transport demand (Litman 2008). This table indicates various factors that affect transport demand, which should be considered in transport planning and modeling, and can be used to manage demand.

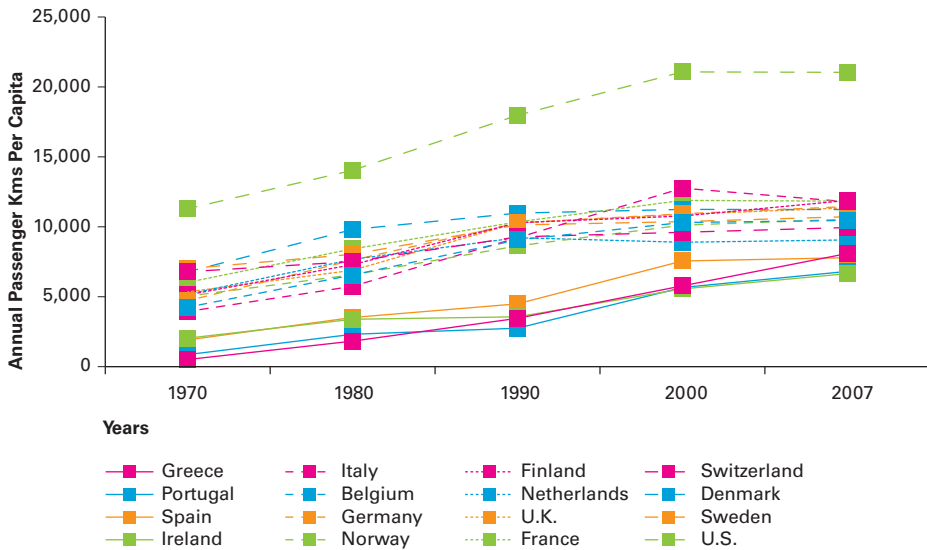


Figure 1. International Vehicle Travel Trends (EC 2007; FHWA, Various Years). Per capita vehicle travel grew rapidly between 1970 and 1990, but has since leveled off and is much lower in European countries than in the U.S.

This is important and timely because current demographic and economic trends are significantly changing travel demands (Goodwin, 2011; Litman, 2006; Metz, 2010; Millard-Ball & Schipper, 2010). Per capita motor vehicle travel grew rapidly during most of the 20th century but recently peaked and declined slightly in most developed (industrialized) countries, as illustrated in Figure 1. The level at which vehicle travel peaks varies, depending on transport and land use policies; low fuel prices, abundant highway expansion and low-density land use development result in two to three times as much per capita vehicle travel in the United States as in other wealthy countries. This indicates that our transport policies and planning practices will need to change in order to respond to future needs and preferences, and demand management strategies can help achieve strategic planning objectives, such as reducing traffic congestion, accidents, energy consumption and pollution emissions.

Several specific factors have contributed to the peaking of vehicle travel:

*Motor vehicle saturation.* Motor vehicle ownership and use grew steadily in most developed countries during the 20th century. In many areas, there is nearly one motor vehicle for every licensed driver and most travel is by automobiles. In those situations, people have little reason to own more vehicles and little opportunity to drive more annual kilometres.

*Wealth effect.* As households become wealthier, their vehicle ownership tends to increase, but at a declining rate (Dargay, Gately & Sommer, 2007). International data indicate that below about \$10,000 annual income per capita (2002 U.S. dollars), automobile ownership and annual kilometre rates tend to increase about twice as fast as income growth, but at higher incomes growth rates level off and eventually saturate (Millard-Ball & Schipper, 2010). Karlaftis and Golias (2002) find that households' purchase of their first vehicles depends primarily on socioeconomic factors (employment and income), but additional vehicles depend on the quality of access options available, making multiple household vehicle ownership rates responsive to transport and land use planning decisions.

*Aging population.* People tend to reduce their vehicle travel by 40-60% after they retire and by more as they age into their 70s, 80s and 90s.

*Rising fuel prices.* Higher fuel prices tend to reduce vehicle travel, particularly over the long run (long-term effects tend to be three times greater than short-term effects). Real (inflation-adjusted) fuel prices have increased during the last decade, and high prices are expected to continue into the future.

*Increased urbanization.* Urban area residents tend to drive 20-60% less than they would in automobile-oriented, suburban and rural locations. Urbanization has

increased in most countries, both from migrations to urban areas and because many suburbs are becoming more urbanized. Current real estate trends tend to favour urbanization (Litman, 2010). Surveys indicate that an increasing portion of households would choose smaller-lot, urban home locations if they provide better travel options (better walking, cycling and public transit), more local services (nearby shops, schools and parks) and shorter commute distances (Myers & Ryu, 2008; Urban Land Institute, 2009).

*Improving transport options and incentives.* Many communities are improving walking and cycling conditions, rideshare and public transport service quality and telecommunications and delivery services, and are implementing various transportation demand management strategies to encourage use of efficient transport options. This is increasing use of alternative modes and mobility substitutes such as telecommuting and Internet shopping.

*Changing consumer preferences.* The younger generation appears to place less value on vehicle ownership and suburban living (Santos, McGuckin, Nakamoto, Gray, & Liss, 2011). Car ownership and travel declined, and use of other modes increased, among German and British 20- to 29-year-olds (Kuhnimhof, Buehler, & Dargay, 2011). Sivak and Schoettle (2011) find that, controlling for other factors, an increase in Internet use is associated with a decline in drivers' licence rates, suggesting that telecommunications substitutes for physical travel.

*Increased health and environmental concerns.* Although largely anecdotal, there is evidence that many people would prefer to drive less and rely more on alternative modes owing to health and environmental concerns. These issues also affect public policy, resulting in energy conservation and emission reduction, and active transport encouragement programmes in many jurisdictions.

As people become wealthier, they tend to be less price sensitive and more sensitive to service quality. In the past, this usually resulted in shifts from basic public transit (such as buses operated in mixed traffic) to personal automobile travel. However, it sometimes has other effects. For example, some households use additional wealth to purchase more accessible homes (in more central, walkable neighborhood) or to travel by high-quality public transport (such as express buses or trains). This implies that some travellers would shift to more efficient alternatives if their quality was improved. For example, it is possible that some relatively wealthy people could shift from driving to public transit if it had amenities such as comfortable seats, on-board Internet access and refreshment services.

Although impacts vary, there is now good evidence to indicate that in most developed countries total vehicle travel has peaked, and in many communities

there is latent demand for alternatives: Many people would prefer to drive less and rely more on alternative modes, provided that they are convenient, comfortable, safe and affordable.

Existing transport demand models are poor at accounting for these factors. There is research on the effects that individual, demographic, income, price and land use factors have on travel activity, but many of these factors interact, making it difficult to predict future travel demands, particularly over the long run. For example, we can predict that people usually reduce their annual vehicle travel when they retire, and we can also predict that future generations of retirees will probably drive more annual kilometres than they did in the past. We can also predict that the amount that people reduce their driving will depend on the quality of alternatives, where they live, and future fuel prices. However, it is difficult to predict exactly how these various factors will interact.

It is also difficult to predict future freight travel demands. During the last several centuries, shipping costs declined steadily, stimulating increased freight volumes (Figure 2). Over time, the scale and efficiency of marine, rail and truck transport increased. Containerization, intermodalism, deregulation and various technical and logistical improvements continued to reduce shipping costs and to increase speeds, particularly for long-distance travel. Unit costs often declined by an order of magnitude during the last century. Although such improvements are likely to continue, particularly increased use of information technologies to automate and optimize flows, future cost reductions will probably be more modest and may be

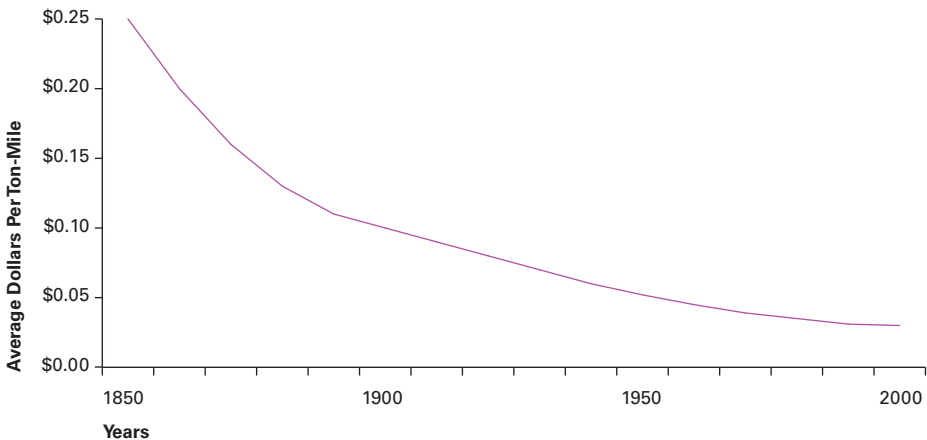


Figure 2. Railroad freight costs (Garrison & Levinson 2006, p. 290). Shipping costs per ton-mile declined significantly during the last 150 years.

offset by increased fuel prices, particularly for truck transport. When transport costs are a major portion of total retail prices, transport cost reductions significantly increase sales and shipping volumes, but further cost reductions have less impact.

As a result, freight transport demand will probably continue to grow, particularly on high-volume routes, but the growth will probably be at a lower rate than during the last half century, particularly for intraregional shipping.

Similarly, long-distance travel, particularly personal air travel, tends to be sensitive to price and income (Dargay, 2010; InterVISTAS, 2007). As a result, total worldwide air travel demand is likely to continue growing in the future, particularly from developing countries, but the growth rate may decline if fuel prices continue to increase.

This suggests that both freight and long-distance air travel demand growth will result primarily from increased demand by developing countries and will be concentrated on major corridors where scale economies can maintain low prices despite rising fuel prices. For example, there may be further growth in freight and air travel volumes between Asia, the Americas and Europe, but less growth, and possibly declines, on many routes within Europe. Much of this growth will probably be met through increased efficiencies, such as larger jets and ships, and faster loading. Although some large airports and ports may continue to experience congestion, others may experience overcapacity. It will be important to identify appropriate niches on the basis of competitive advantages and strategic planning and to avoid overbuilding freight and airport capacity.

### 3. New Technologies

It is worth considering how future technological improvements are likely to affect transport demands. Past technological innovations (better vehicles, drive systems, roadway designs, logical management) improved motor vehicle performance (power, speed, safety, reliability and comfort), which reduced costs (money, time, discomfort and risk per kilometre of travel) and increased travel demand. Many newer transport innovations improve alternative modes or allow more efficient pricing. Table 3 categorizes technologies according to their vehicle travel impacts. More new technologies are likely to reduce rather than to increase vehicle travel. The mobility effects of specific new technologies are discussed on the next page.

#### **Telework**

Telework refers to the use of electronic communication to substitute for physical travel, including commuting, business activities and errands such as shopping and banking.

Increases motorized travel	Mixed mobility impacts	Reduces motorized travel
Increased fuel efficiency and cheaper alternative fuels  Increased vehicle comfort  Automated driving	Electronic vehicle navigation  Improved traffic signal control	Telework (electronic communication that substitutes for physical travel)  Improved road and parking pricing  Improved transit user information  Transit service improvements  Improved rideshare matching  Improved delivery services  Improved carsharing services

Table 3. Travel impacts of new transport technologies (Litman 2006). Some new technologies tend to increase vehicle travel, others tend to reduce it.

There is evidence that Internet shopping is replacing some physical trips (Santos et al., 2011). The Internet can also increase potential travel demand, for example, by helping people make and maintain long-distance friendships.

**Intelligent Transportation Systems**

Intelligent Transportation Systems (ITS) apply computers and electronic communication to improve transport services. Although ITS research initially focused on automated driving, which probably would increase vehicle travel, implementation of this strategy has been slow. So far, ITS successes have consisted primarily of driver information and navigation services, transit user information, transit priority systems and better road and parking pricing, which tend to reduce rather than to increase motor vehicle travel.

**New Modes**

Some new modes could develop during the next century, such as Personal Rapid Transit (PRT), Magnetic Levitation (Maglev) trains, flying cars, Segways and their variants. There may also be new transport services, such as commercial space travel and more underwater tunnels replacing ferry travel. Their overall impacts are likely to be modest since they serve only a small portion of trips. For example, even if Maglev technology is perfected, it is only suitable for medium-distance (50-500 km) trips on heavy traffic corridors. It may increase long-distance commuting in a few areas, but have little effect on other travel. Only if Maglev systems stimulate transit oriented development (compact communities designed around transit stations) is overall travel likely to change, and this will result from land use changes, not the technology itself.

Usually considered	Often overlooked
Financial costs to governments	Downstream congestion impacts
Travel speed (reduced congestion delays)	Traffic impacts on non-motorized travel
Vehicle operating costs (fuel, tolls, tyre wear)	Parking costs
Per-km crash risk	Vehicle ownership and mileage-based depreciation
Project construction environmental impacts	Indirect environmental impacts
Per-km air and noise emissions	Strategic land use impacts
	Transportation diversity value (e.g., mobility for non-drivers)
	Equity impacts
	Impacts on physical activity and public health

Table 4. Scope of conventional planning analysis. Conventional transportation planning tends to focus on a limited set of impacts.

Similarly, Segways are unlikely to affect overall travel unless implemented with urban design and traffic management changes to favour local, slower-speed modes over automobile traffic.

**Alternative Fuels**

Various alternatives may replace petroleum as the primary vehicle fuel, but virtually all currently being developed will be more expensive than what petroleum cost in the past, and most alternatives impose their own problems, such as the high carbon content of petroleum produced by tar sands and coal liquefaction, and the economic and environmental costs of increasing electrical production to power electric vehicles. As a result, alternative fuels are unlikely to reduce future vehicle operating costs.

**4. Comprehensive Evaluation**

Conventional transportation planning tends to consider a relatively limited set of benefits and costs when evaluating transportation policies and projects, as summarized in Table 4. For example, conventional transport project economic evaluation models such as MicroBenCost and HDM4 were originally developed to evaluate specific highway projects, and so they only consider project costs and marginal changes in travel time, vehicle operating costs, accidents and sometimes pollution emissions. These models generally ignore parking costs, and therefore the parking cost savings to businesses if more of their employees and customers arrive by alternative modes, nor do they consider

vehicle ownership costs and therefore the savings to households that result from improved mobility options. Most models ignore the induced vehicle travel that results from urban highway expansion and from fuel and parking subsidies, and the incremental congestion, accidents and pollution that results. Most evaluation models seem to assume that everybody (or at least, everybody model makers consider important) has the ability to drive and so assign no value to transport policies and programmes that improve accessibility for non-drivers.

Planning objective	Definition	Consideration in conventional planning
Increased user convenience and comfort	More convenient and comfortable conditions for transport system users, including better walking and cycling conditions, and better transit service	Although often recognized as desirable, not generally quantified or included in benefit-cost analysis
Congestion reduction	Reduced delays, and associated reductions in travel time, fuel costs and pollution emissions.	Motor vehicle congestion costs are widely recognized and quantified, but delays to non-motorized travel (called the “barrier effect”) is generally ignored
Roadway cost savings	Reduced costs for building and maintaining roadways	Generally considered
Parking cost savings	Reduced costs for building and maintaining parking facilities	Generally ignored
Consumer cost savings	Reduced costs to users to own and operate vehicles, and for public transit fares.	Operating cost savings are generally recognized but vehicle ownership savings are generally ignored
Reduced traffic accidents	Reduced per capita traffic crashes and associated costs	Crash risk, measured per vehicle-mile, is often considered, but impacts of changes in vehicle mileage are generally ignored
Improved mobility options	Improved quantity and quality of transport options, particularly affordable modes that serve non-drivers	Sometimes recognized as a planning objective but seldom quantified or included in formal economic evaluation
Energy conservation	Reduced energy consumption, particularly petroleum products	Sometimes recognized
Pollution reduction	Reduced emissions of harmful air, noise and water pollution	Sometimes recognized. Generally measured per vehicle-km.
Physical fitness and health	Improved physical fitness and health, particularly more walking and cycling by otherwise sedentary people	Not usually considered in the past. Sometimes recognized now, but seldom quantified
Land use objectives	Support for various land use planning objectives	Sometimes recognized as a planning objective but seldom quantified or included in formal economic evaluation

Table 5. Comprehensive planning objectives (Litman 2011).

“Planning objectives” are desirable outcomes, the opposite of “problems.” This table lists various transport planning objectives and the degree they are considered in conventional planning.

As a result, such models are unsuited to evaluating decisions that involve choosing between alternative modes or for evaluating demand management strategies. For example, if used to compare a highway expansion project, a transit improvement project and congestion pricing, they will fail to account for the parking cost savings to governments and businesses that result if commuters shift from driving to alternative modes, and the cost savings that can result if improved public transit service allows some households to reduce their vehicle ownership.

Planning objective	Roadway expansion	Fuel efficient vehicles	Improve transport options	Price reforms
User convenience and comfort	•		•	•
Congestion reduction	•		•	•
Improved pedestrian access			•	•
Roadway cost savings			•	•
Parking cost savings			•	•
Consumer cost savings		Mixed	•	Mixed
Reduced traffic accidents			•	•
Improved mobility options			•	•
Energy conservation		•	•	•
Pollution reduction		•	•	•
Physical fitness & health			•	•
Land use objectives			•	•

Table 6. Comparing strategies (Litman 2011).

(• = Achieve objectives.) Roadway expansion and more fuel efficient vehicles help achieve relatively few objectives. Improving transport options and transport pricing tend to achieve a broader range of objectives.

This is not to suggest that these additional objectives and impacts are totally overlooked in the planning process. They are sometimes considered qualitatively or during public comment. However, they are not generally considered in economic evaluation, when calculating net benefits, and so receive less weight. This biases planning towards mobility over accessibility and automobile improvements over alternatives. More comprehensive transport planning analysis considers a wider set of planning objectives and impacts. Table 5 identifies a set of planning objectives and discusses the degree to which they are considered in a conventional planning process.

Many transport improvement strategies can achieve only a few of these objectives. For example, expanding highways increases user comfort and reduces traffic congestion, and increasing vehicle fuel efficiency conserves energy and pollution emissions and provides fuel savings. Some strategies provide a broader range of benefits. Table 6 compares the range of planning objectives achieved by various strategies.

Some studies have quantified and monetized (measuring in monetary units) these impacts, as indicated in Figure 3. This allows the costs of various different vehicles, travel modes and travel activities to be compared. These impacts can be categorized in various ways. In general, impacts that are variable (they increase with the amount that a person travels) and internal (borne directly by users)

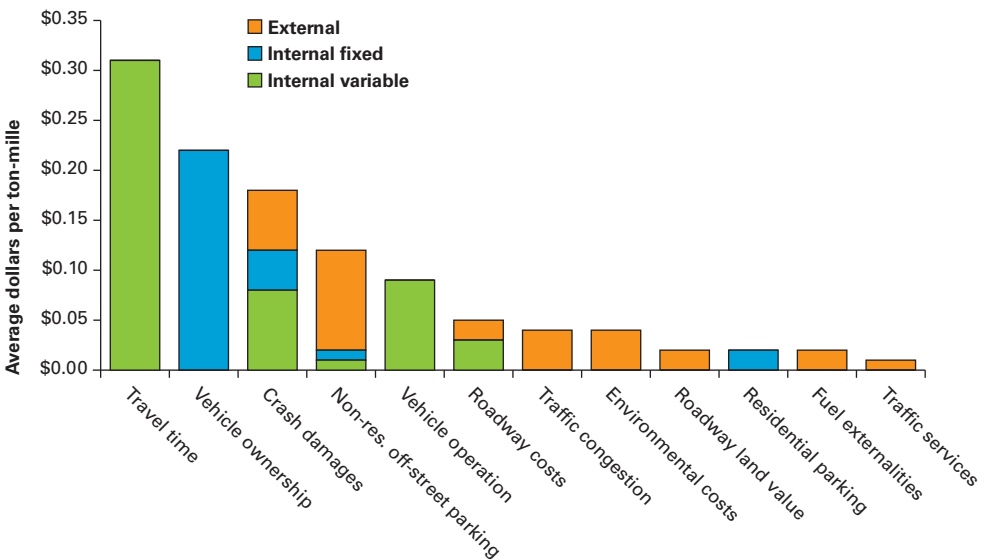


Figure 3. Per-mile costs of automobile use (Litman 2009). This figure illustrates the estimated costs of motor vehicle ownership and use, averaged per vehicle-mile.

are most efficient and equitable. This analysis indicates that a major portion of automobile travel costs are inefficient and inequitable. Traffic congestion and air pollution, the costs that tend to receive the greatest consideration in transportation planning, are modest in magnitude overall. A policy or programme that reduces congestion or pollution but results in even modest increases in other costs, such as vehicle ownership, road and parking facility costs or crashes, is likely to harm society overall.

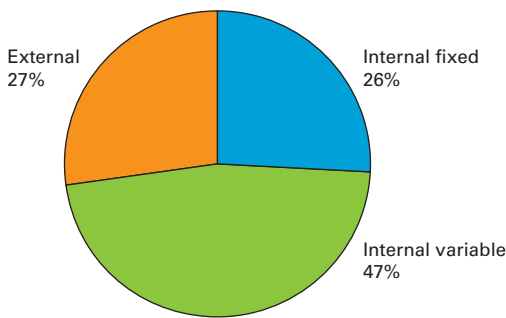


Figure 4. Average distribution of automobile costs (Litman 2009). Less than half of the total costs of automobile use are internal-variable.

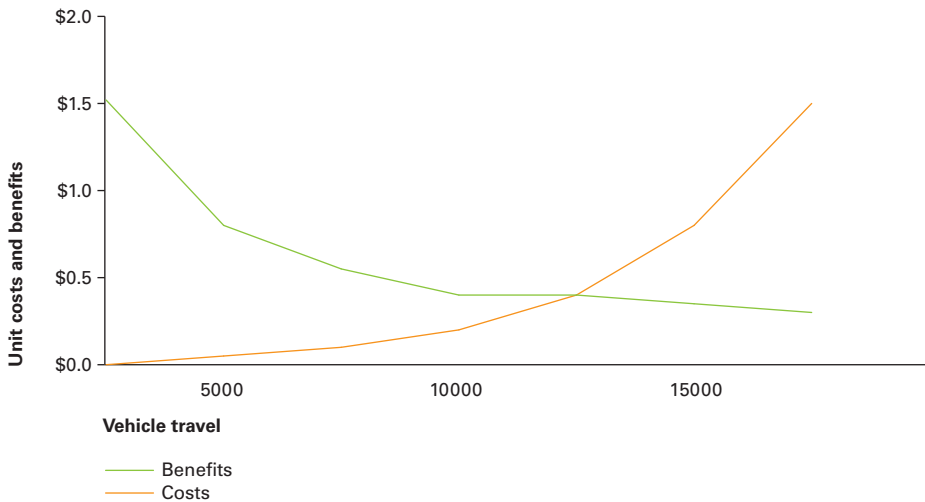


Figure 5. Motor vehicle use conflicting cost curves. Although some vehicle trips have very large benefits, the benefit curve (or demand curve) declines with increased vehicle travel. Costs, however, increase, particularly as the system becomes congested. As a result, beyond a certain point, marginal costs exceed marginal benefits, so society is better off with reduced vehicle travel.

Name	Description	Transport Impacts
Least-Cost Planning	More comprehensive and neutral planning and investment practices	Increases support for alternative modes and mobility management
Mobility Management Programs	Local and regional programs that support and encourage use of alternative modes	Increases use of alternative modes
Commuter Trip Reduction (CTR)	Programs by employers to encourage alternative commute options	Reduces automobile commute travel
Commuter Financial Incentives	Offers commuters financial incentives for using alternative modes	Encourages use of alternative commute modes
Fuel Taxes - Tax Shifting	Higher fuel and vehicle taxes	Reduces fuel consumption and vehicle travel
Pay-As-You-Drive Pricing	Converts fixed vehicle charges into mileage-based fees	Reduces vehicle mileage
Efficient Road Pricing	Charges users directly for road use, with rates that reflect costs imposed	Reduces vehicle mileage, particularly under congested conditions
Parking Management	Various strategies that result in more efficient use of parking facilities	Reduces parking demand and facility costs, and encourages use of alternative modes
Parking Pricing	Charges users directly for parking facility use, often with variable rates	Reduces parking demand and facility costs, and encourages use of alternative modes
Transit and Rideshare Improvements	Improves transit and rideshare services	Increases transit use, vanpooling and carpooling
HOV Priority	Improves transit and rideshare speed and convenience	Increases transit and rideshare use, particularly in congested conditions
Walking and Cycling Improvements	Improves walking and cycling conditions	Encourages use of nonmotorized modes, and supports transit and smart growth
Smart Growth Policies	More accessible, multi-modal land use development patterns	Reduces automobile use and trip distances, and increases use of alternative modes
Location Efficient Housing and Mortgages	Encourage businesses and households to choose more accessible locations	Reduces automobile use and trip distances, and increases use of alternative modes
Mobility Management Marketing	Improved information and encouragement for transport options	Encourages shifts to alternative modes
Freight Transport Management	Encourage businesses to use more efficient transportation options	Reduces truck transport
School and Campus Trip Management	Encourage parents and students to use alternative modes for school commutes	Reduces driving and increases use of alternative modes by parents and children
Regulatory Reforms	Reduced barriers to transport innovations	Improves travel options
Carsharing	Vehicle rental services that substitute for private automobile ownership	Reduces automobile ownership and use
Traffic Calming and Traffic Management	Roadway designs that reduce vehicle traffic volumes and speeds	Reduces driving, improved walking and cycling conditions

Table 7. Win-win strategies (IGES 2011; Litman 2011).  
There are various Win-win strategies, which encourage more efficient transportation.

On the other hand, a congestion or pollution reduction strategy becomes far more valuable to society if it also reduces these other costs. This emphasizes the importance of finding solutions that provide multiple benefits.

Figure 3 presents these costs measured per vehicle mile. Figure 4 summarizes the total of these costs, indicating that approximately a quarter of all automobile costs are external, and another quarter are external-fixed (users must pay them regardless of how much they drive).

The motor vehicle transport provides significant benefits, but like most goods, benefits diminish marginally because consumers are rational enough to choose more benefit travel before less beneficial travel. For example, if some vehicle trips are very beneficial, consumers will choose them even if prices are high, but will forego vehicle trips that provide little benefit or have good substitutes. Costs, however, tend to increase, particularly once a system becomes congested, as illustrated in Figure 5. As a result, beyond a certain level, increased vehicle travel imposes more costs than benefits. At that point, society benefits from demand management strategies that reduce lower value while allowing higher value vehicle travel.

## 5. Strategies for More Sustainable Transport

Several “win-win” policy and planning reforms, summarized in Table 7, can help create more efficient transport systems by improving resource-efficient transport options and giving travellers incentives to choose the most efficient option for each trip. They tend to reflect market principles, including comprehensive evaluation, consumer sovereignty and efficient pricing.

## 6. Performance Evaluation

*Performance evaluation* refers to a monitoring and analysis process to determine how well policies, programmes and projects perform with regard to their intended goals and objectives. *Performance indicators* (also called *measures of effectiveness*) are specific measurable outcomes used to evaluate progress towards established goals and objectives (Dhinghi, 2011; Joumard & Gudmundsson, 2010). More comprehensive transport planning requires multi-modal performance indicators, such as those listed in Table 8.

It will be useful for international transportation professional organizations to develop more consistent data collection practices to support more comprehensive and multi-modal performance evaluation (Bongardt, Schmid, Huizenga, & Litman, 2011; Litman 2007; Global Transport Intelligence Initiative; Sustainable Transportation Indicators, 2008).

Mode	Service quality	Outcomes	Cost efficiency
Walking	Sidewalk/path supply Pedestrian LOS Crosswalk conditions	Pedestrian mode split Avg. annual walk distance Pedestrian crash rates	Cost per sidewalk-km Cost per walk-km Cost per capita
Cycling	Bike path and lane supply Cycling LOS Path conditions	Bicycle mode split Avg. annual cycle distance Cyclist crash rates	Cost per path-km Cost per cycle-km Cost per capita
Automobile	Roadway supply Roadway pavement condition Roadway LOS Parking availability	Avg. auto trip travel time Vehicle energy consumption and pollution emissions Motor vehicle crash rates	Cost per lane-km Cost per vehicle-km User cost per capita External cost per capita
Public transit	Transit supply Transit LOS Transit stop and station quality Fare affordability	Transit mode split Per capita transit travel Avg. transit trip travel time Transit crash and assault rates	User cost per pass.-km User cost per capita Subsidy per capita
Taxi	Taxi supply Average response time	Taxi use Taxi crash and assault rates	Cost per taxi-trip External costs
Multi-modal	Transport system integration Accessibility from homes to common destinations User survey results	Total transportation costs Total average commute time Total crash casualty rates	Total cost passenger-km Total cost per capita External cost per capita
Aviation	Airport supply Air travel service frequency Air travel reliability	Air travel use Air travel crash rates	Cost per trip External costs Airport subsidies
Rail	Rail line supply Rail service speed and reliability	Rail mode split Rail traffic volumes Rail crash rates	Cost per rail-km Cost per tonne-km External costs
Marine	Marine service supply Marine service speed and reliability	Marine mode split Marine traffic volumes Marine accident rates	Cost per tonne-km Subsidies External costs

Table 8. Multi-modal performance indicators.  
This table illustrates various types of performance indicators.

## 7. Conclusions

The 20th century was the period of automobile ascendancy. Between 1900 and 2000, automobile travel grew from almost nothing to becoming the dominant transport mode in most economically developed regions. During this time, it made sense to devote significant resources to accommodating increased vehicle travel demand. Much of our current transport policies and planning practices developed during that period. This analysis indicates that current transport

policies and planning practices are biased in ways that favour mobility over accessibility and automobile travel over other modes. This has created automobile-dependent transportation systems and economically excessive motor vehicle travel, which exacerbates various economic, social and environmental costs. These existing policies and practices are unsuited to solve future problems.

A number of current trends are reducing demand for automobile travel and increasing demand for more alternatives. This is not to suggest that everybody wants to give up automobile travel completely, but this analysis indicates that at the margin – compared with their current transport patterns – many people would prefer to drive less and rely more on alternatives, provided they are convenient, comfortable, safe and affordable. Freight and air travel may continue to increase in the future, particularly on major corridors, provided that prices remain low, although how much is difficult to predict.

In the past, as people became wealthier, their motor vehicle travel tended to increase. This is no longer true. Most developed countries have reached vehicle saturation. The level at which automobile ownership and use peaks depends on transport and land use policies; automobile-oriented policies (such as generous roadway capacity, poor walking and cycling conditions, inferior public transit service, low fuel and parking prices and sprawled land use development) cause vehicle travel to peak at high levels (more than 20,000 annual kilometres per capita), but if policies are more multi-modal, the peaks will be much lower. Some cities have demonstrated that relatively wealthy people will walk, bicycle and use public transit, provided they are of high quality.

Although motor vehicle travel provides significant benefits, like most goods, these diminish marginally. Motor vehicle travel also imposes significant costs, including many that are external, indirect and non-market. A more efficient transport system offers travellers a diverse range of accessibility options, with incentives to use the most efficient option for each trip. A number of “win-win” transportation policy reforms can help correct existing market distortions, resulting in a more diverse and efficient transport system. These strategies ensure that higher value trips can be made conveniently and efficiently while preventing lower-value vehicle travel that imposes more costs than benefits.

These reforms are justified on market principles, including comprehensive evaluation, consumer sovereignty and efficient pricing. Because they provide multiple benefits they can gain broad support from diverse interest groups. It will be important to educate stakeholders about the principles of sustainable transport planning and the full potential benefits of win-win solutions.

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# Modalities and Technical Advancement

# 03

Joan Ogden

**Making a transition to a sustainable transportation system requires fast-moving success on three fronts: improved energy efficiency, reduced travel demand and adoption of low carbon fuels that can be produced from widely available primary sources. There are technical approaches that could help move closer to each of these goals. By combining these approaches, recent studies suggest it would be technically feasible to significantly reduce transportation greenhouse gas (GHG) emissions and diversify away from dependence on petroleum over the next few decades. But actual progress towards these goals has been slower than the technical potential suggests, because of an array of complex transition issues. The way forward is not obvious, posing daunting challenges to policymakers seeking a more sustainable transportation future.**

In this chapter, we examine the technical options for meeting sustainability and energy security goals in the transport sector, with an emphasis on light duty vehicles (LDVs) and alternative fuels. The goal is to inform policymakers about the technical prospects for moving forward with different alternative fuel options. LDVs are key to successfully transforming the transportation sector. They are the biggest energy users and are widely regarded as the most difficult challenge, because of the complex interplay between consumer behaviour, technology development and policy. Many analysts feel that if we can achieve major changes in the light duty fleet we can do it for the rest of transportation. This chapter also focuses on low carbon alternative fuels because ultimately their adoption will be required to reach very deep cuts in GHG emissions and oil use.

Each fuel faces different challenges, and we discuss barriers to their implementation. It is likely that there will be no single fuel or vehicle of the future. Rather, we will see a diverse mix of fuels in different regions and transport applications. Given the long time frame involved in transitions and the uncertainties, we assert that a portfolio strategy, combining energy efficiency improvement, travel reduction and adoption of alternative fuels and vehicles, is the best way forward. Further, we propose that a series of city-scale demonstrations are needed now to accelerate technology learning at the system level, if we are to meet ambitious

goals for low carbon transport by 2050. The chapter first presents an overview of transport sector energy supply and demand. We present technology assessments for alternative vehicles and fuels, including biofuels, electricity, hydrogen, natural gas and unconventional fossil fuels. We examine how these options might be combined to reach societal goals, and analyse the thorny transition issues that surround alternative fuels. Finally, we present insights on transition timing, costs and benefits and possibilities for near and long-term actions towards a sustainable transport sector.

### 1. Improved energy efficiency

Global demand for mobility is growing rapidly, with the number of vehicles projected to triple by 2050 (IEA, 2009). Growth is especially fast in the developing world, where the number of vehicles is increasing by 5-6% per year. Today LDVs consume about half of the total transport fuel worldwide, with heavy duty vehicles (HDVs) accounting for 24%, aviation 11%, shipping 10%, and rail 3% (IEA, 2009) (Figure 1).

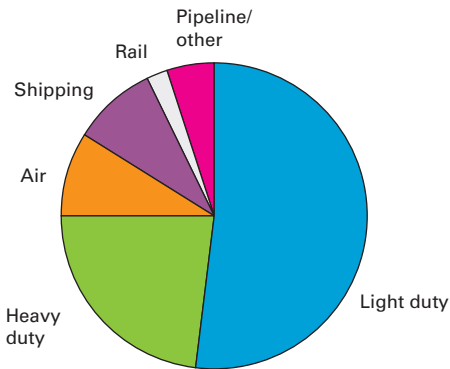


Figure 1. Fraction of global transport energy use in 2005. Source: IEA (2009). Possible Vehicle Type – Fuel Source Combinations

Energy supply is a critical concern for the transport sector. Today about 94% of transport fuels come from petroleum sources, about 70% of which is imported by the countries where it is used (IEA, 2009). Costs for conventional crude oil are rising, and direct substitutes for petroleum (such as unconventional oil from oil shale and tar sands or liquid biofuels) face economic, technical and environmental challenges.

Direct combustion of fossil fuels for transportation accounts for a significant fraction of global primary energy use (18%), air pollutant emissions (5-70%, depending on the pollutant and region) and GHG emissions (22% on a well-to-wheels basis) (IEA, 2010). Although improved energy efficiency in buildings or low-carbon electricity generation might offer lower-cost ways of reducing carbon emissions in the near term, decarbonizing and improving the efficiency of the transport sector will be critically important to achieving the long-term, deep cuts in carbon emissions required for climate stabilization (IEA, 2010).

To help meet future goals for both energy supply security and GHG reduction, oil use would need to be substantially reduced over a period of several decades. Recent studies (European Commission, 2011; IEA, 2010; McCollum & Yang, 2009; NRC, 2008) suggest that a combination of approaches, namely reduction of travel demand, higher efficiency and replacing petroleum-based fuels with low or near-zero carbon fuels, will be needed to accomplish 50-80% reductions in transport-related GHG emissions by 2050 (compared with current values) while meeting the projected growth in demand (IEA, 2009). In this chapter, we concentrate on the technical prospects and challenges for large-scale development of alternative vehicles and fuels.

## 2. Technical Options for Sustainable Transportation

We now review the technical prospects for each of the three general approaches to reducing oil use and GHG emissions, with a focus on alternative fuels and vehicles.

### Reduction of Travel Demand

It might be possible to reduce vehicle kilometres travelled by enacting policies to encourage mode switching: greater use of car-pooling, cycling and walking, combining trips, or telecommuting. City and regional 'smart growth' practices could reduce GHG emissions as much as 25% by planning cities so that people do not have to travel as far to work, shop and socialize (Eaken & Goldstein, 2008; European Commission, 2011; Johnston, 2007).

### Higher Efficiency

*Shift to more energy-efficient modes of transport.* Overall transport sector efficiency could be improved by shifting to more energy-efficient modes of transport, such as from cars to mass transit (bus or rail) or from trucks to rail or ships (IEA, 2009). The importance of regional planning and adoption of emerging Intelligent Transportation technology has been highlighted in several recent reports (European Commission, 2011).

*Improved energy efficiency of vehicles.* Vehicle efficiency improvements could be achieved by reducing vehicle weight, aerodynamic streamlining and improving the designs of engines, transmissions and drive trains. Examples include hybrid electric vehicles (HEVs), turbo-charging of internal combustion engines (ICEs) and downsizing of installed vehicle engine power. Electric drive vehicles, employing either batteries or fuel cells, can be two to four times more efficient than their ICE counterparts (Kromer & Heywood, 2007; NRC, 2008) (see Figure 3). Electric drive vehicles have higher efficiency because electric motors and fuel cells are more energy efficient under typical driving conditions than gasoline or diesel internal combustion engines. However, both electricity and hydrogen must be made from some other form of energy. The energy losses in making electricity or hydrogen are generally higher than for oil refining, and must be counted. Still the overall energy efficiency is greater for electric or hydrogen, even when the whole pathway is considered.

For light commercial trucks where high speeds are not needed, smaller more efficient engines may be sufficient and could result in lower GHG emissions. In the HDV sub-sector for freight movement, and in aviation, there are also potentially significant energy efficiency improvements (Sims et al., 2011).

### **Technical and Economic Prospects for Adoption of New Types of Vehicles and Low Carbon Fuels**

The context for alternative fuels is rapidly changing due to energy security, oil price volatility and climate change concerns, and a host of policy initiatives in Europe, North America and Asia are driving towards lower carbon fuels and zero-emission vehicles. Here we review the technical potential for new types of vehicles and fuels.

#### **Overview of Possible Transportation Fuel and Vehicle Pathways**

Although our current transportation system is based almost exclusively on petroleum and the internal combustion engine, there are many other possibilities. A variety of more efficient vehicles (including those with hybrid drive trains and fuel cells along with battery electric vehicles [BEVs]) and alternative fuels (including compressed natural gas [CNG], ethanol, methanol, DME, F-T diesel, electricity and hydrogen) have been proposed to address climate change and energy security concerns (Figure 2).

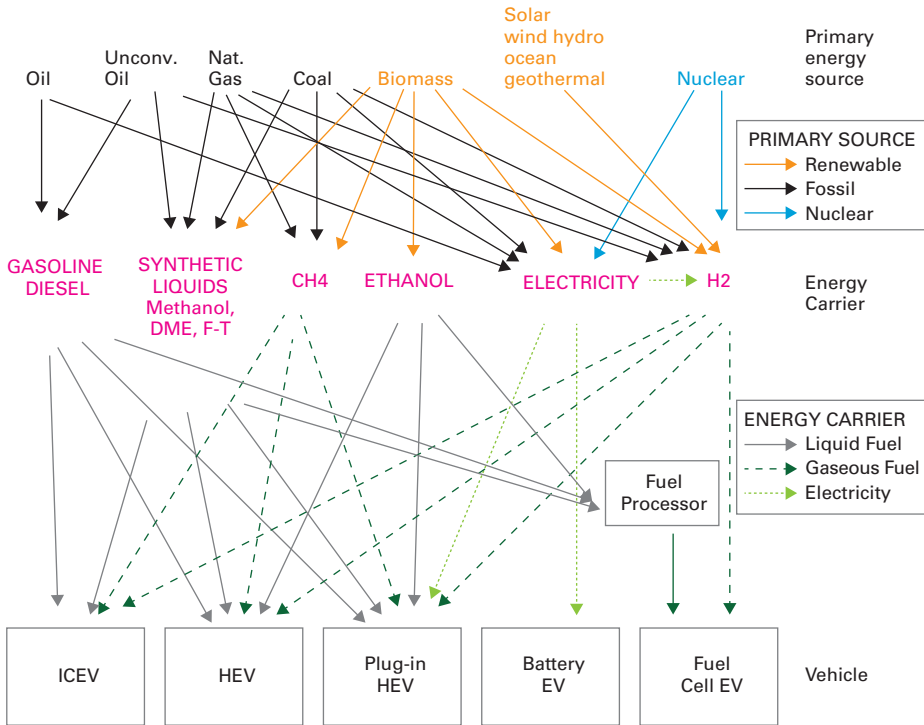


Figure 2. A variety of combinations of vehicle types and fuel sources are possible to meet our transportation needs. Possible fuel/vehicle pathways are shown here, with primary energy sources at the top, energy carriers (fuels) in the middle and vehicle options at the bottom. F-T, Fischer-Tropsch process; ICEV, internal combustion engine vehicle; HEV, hybrid electric vehicle; EV, electric vehicle. Source: Ogdén and Anderson (2011).

**Current Status of Alternative Fuels**

Alternatives to the internal combustion vehicles that run on petroleum-based fuels have had limited success thus far. Internal combustion engine vehicles (ICEVs) are currently more than 99% of the global on-road vehicle fleet (IEA, 2009), and 94% of transportation fuels come from petroleum. Alternative fuels, including electricity for rail, presently represent about 5-6% of total transport energy use, 2% of which is biofuels (IEA, 2009). However, in a few countries, wider adoption has been driven by strong policies addressing energy security.

In Brazil, sugar cane-derived ethanol and some biodiesel supply about 50% of total transport fuel energy for LDVs (IEA, 2009). In Sweden, imported ethanol is being encouraged through taxation policy. In the United States, ethanol, derived from corn or imported from Brazil, is currently blended with gasoline up to 10% by volume in some regions, although it still accounts for only about 3% of total US transport energy use (USDOE, 2009).

Current national policy has mandated a tripling of renewable fuels by 2022, including a substantial amount of cellulosic ethanol. In addition, the state of California has enacted laws requiring 10% lower carbon fuels by 2020.

CNG is widely used in LDV fleets mainly in Pakistan, Argentina, Iran, Brazil and India (International Gas Union, 2009). Liquefied petroleum gas is also used in several countries while Sweden is encouraging the use of biomethane for vehicles (IEA Bioenergy, 2010). The ongoing shale gas boom is leading to renewed interest in CNG and LNG fuels for HDVs around the world.

Electricity makes a small contribution to the transport sector in many countries, mostly for rail. Incentives for electric passenger vehicles have been enacted in various countries, but the total number of electric passenger LDVs worldwide is only in the tens of thousands.

Hydrogen is used in oil refining, but the total number of demonstration hydrogen-powered vehicles worldwide is perhaps 1,000. Commercial introduction at the level of tens of thousands is planned for 2015.

*While many of these alternative fuel pathways offer potential societal benefits in terms of reduced emissions or a more diverse primary energy supply, the best choice going forward is unclear.* Much of the public discourse has been framed as winner-take-all debates among advocates for particular 'silver bullet' fuel or vehicle technologies. Policy proposals and media coverage suffer from a 'fuel du jour' syndrome, waves of short-lived enthusiasm for one technology after another. Given the rapidly changing technology and policy landscape, consensus is lacking about which option or options to pursue, and when and where to pursue them. In this section, we review the current, near-term (2020) and long-term (2035-2050) projections for technical performance and cost of different fuel/vehicle pathways.

### **Technical Options for Future Vehicles**

Several recent studies have assessed the performance, technical status and cost of different vehicle types (Bandivadekar et al., 2008; CONCAWE, 2007; IEA, 2009; Kromer & Heywood, 2007; Plotkin & Singh, 2009).

### **More Efficient Internal Combustion Engine Vehicles**

These studies suggest there is still considerable scope improving the efficiency of ICEVs. In many cases, the extra first cost of higher efficiency vehicles will pay for itself in fuel savings over the vehicle lifetime. Improved efficiency of gasoline ICEVs and hybridized drivetrains could significantly reduce GHG emissions and oil use while alternative vehicle and fuel technologies are developed. Current ICEV technologies could utilize biofuels with relatively minor changes. This suggests that the first policy measure in reducing carbon emissions and oil

use should be rapidly implementing vehicle efficiency standards. This is ongoing around the world, including the United States where a new law essentially doubling fuel economy by 2025 was put in place in 2010 (USEPA 2010).

Consumer acceptance of high-efficiency drive trains and lighter cars will depend on a host of factors including vehicle performance and purchase price, fuel price and advancements in materials and safety.

Several promising new types of vehicles will be ready for initial deployment over the next few years. These include BEVs, which are starting to appear now as plug-in hybrids and full battery cars, and hydrogen fuel cell vehicles, which are slated for market introduction by about 2015.

### **Electric Vehicles**

There are many possible configurations for plug-in electric vehicles (PEVs) including pure battery cars and plug-in hybrids that rely partly on batteries and partly on engines using fuels such as gasoline or biofuels. PEVs offer significant long-term potential for environmental benefits and oil displacement. They also represent a radical departure from conventional vehicles in terms of efficiency (three to four times that of a conventional gasoline vehicle), range (currently about 150-200 km), utility, flexibility and the refuelling experience (home charging typically takes several hours).

Thus, consumer acceptance of battery vehicles is a key issue for their future success. Recent studies at UC Davis indicate that most drivers will charge at home at night (Axsen et al., 2011). This requires home chargers (which can be built as needed) as part of the larger electric power system. As many as 50% of US consumers may have access to plug in at home and even more if charging at work is an option. Driving and charging behaviour influence the potential benefits of PEVs.

Costs and performance of batteries are a key technical issue for adoption of electric vehicles. Although the costs are coming down and performance is improving, the technology is still expensive for use in passenger vehicles. Automakers are making major commitments to plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs), and models are entering the market. For PHEVs, there is a trade-off between vehicle cost, which is higher for larger battery models, and the fraction of kilometres run on electricity. The high cost of batteries may encourage use of small-battery PHEVs even beyond early markets. Figure 3 shows the projected costs of batteries over time according to a recent study by the US Department of Energy and the US Environmental Protection Agency. Costs of \$200-300/kWh are desirable for battery cars to compete economically, a cost that is perhaps 5-10 years in the future.

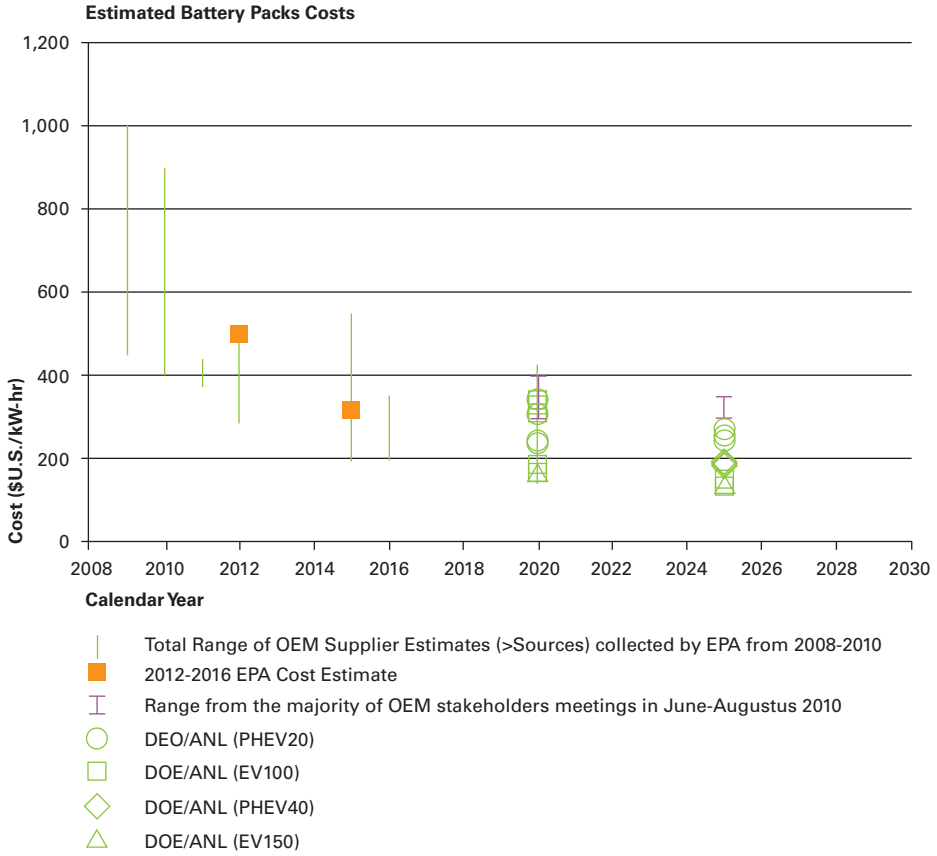


Figure 3. Projections for battery costs over time.

### Hydrogen and Fuel Cell Vehicles

Hydrogen and fuel cell vehicle technologies are progressing rapidly and could be commercially ready by about 2015, according to recent statements by automakers and independent assessments (NRC, 2008). Figure 4 shows 2015 technical goals for fuel cell vehicle technologies set by the US Department of Energy. Hydrogen fuel cell vehicles offer high efficiency, good performance, a greater-than-500 km range and a short refuelling time of only a few minutes. Larger vehicles could be powered by fuel cells, and the consumer could use FCVs much like today's gasoline vehicles. Many major automakers have committed to introducing fuel cell vehicles, seeing them as a necessary component of an electric drive future. Our assessments suggest that fuel cell vehicle technology is about as mature as BEV technology, and commercial-ready fuel cell vehicles will lag electric vehicles by only a few years, not by several decades. Most automakers see roles for both battery and fuel cell technologies in a future electrified LDV fleet.

	Today	2015 Goals
In-use durability (hr)	2,000-4,000	5,000
Vehicle range (miles/tank)	280-400	300
Fuel economy (mi/kg H <sub>2</sub> )	72	60
Fuel cell efficiency	53-58%	60%
Fuel cell system cost (\$/kW)	51	30
H <sub>2</sub> storage cost (\$/kWh)	15-23	10-15 (NRC) 2-4 (USDOE)

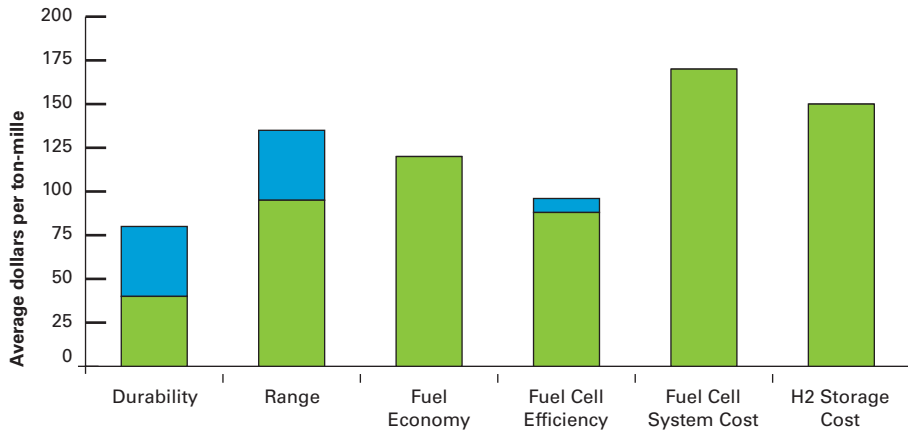


Figure 4. Technical status of hydrogen fuel cell vehicles as compared with 2015 USDOE goals. Source: adapted from Ogden, Yang, Cunningham, et al. (2011).

Remaining technical issues are fuel cell system cost and durability and hydrogen storage cost.

It appears that hydrogen fuel cell vehicles could play a major role in the future light-duty vehicle market beyond 2025, but realizing this will require strong stakeholder coordination, policy and consistent support during an initial transition period (Greene, Leiby, & Bowman, 2007; NRC, 2008).

### 3. Fuel Economy and Vehicle Cost Comparison

Figures 5 and 6 compare the relative fuel economy of different vehicle types and the projected incremental prices compared with a gasoline ICEV.

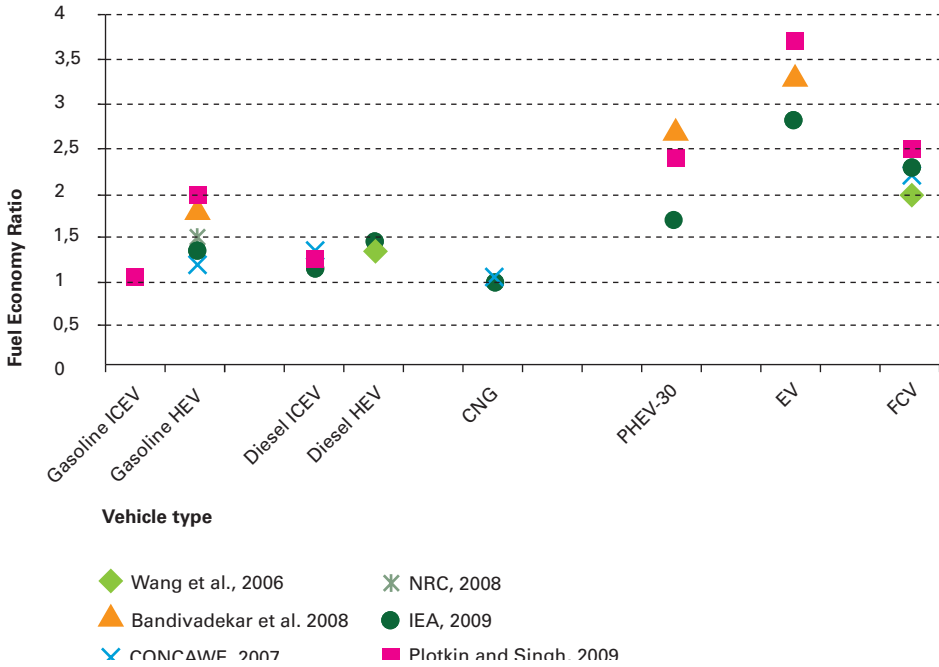


Figure 5. Relative fuel economies of future alternative drive chain LDVs compared with advanced spark ignition, gasoline-fuelled, internal-combustion engine vehicles, based on several recent studies. Source: Sims et al. (2011).

Some interesting trends are apparent. The more electrified the vehicle, the higher the fuel economy and the higher the first cost. Pure battery EVs have a particularly high first cost, but also the highest fuel economy, and often the lowest running costs. There is a trade-off between a higher first cost for an efficient vehicle and lower fuel costs for running the car.

#### Technical Options for Future Transportation Fuels

We now turn to assessing the technical prospects for introducing new fuels, focussing on biofuels, electricity, hydrogen, natural gas and unconventional oil.

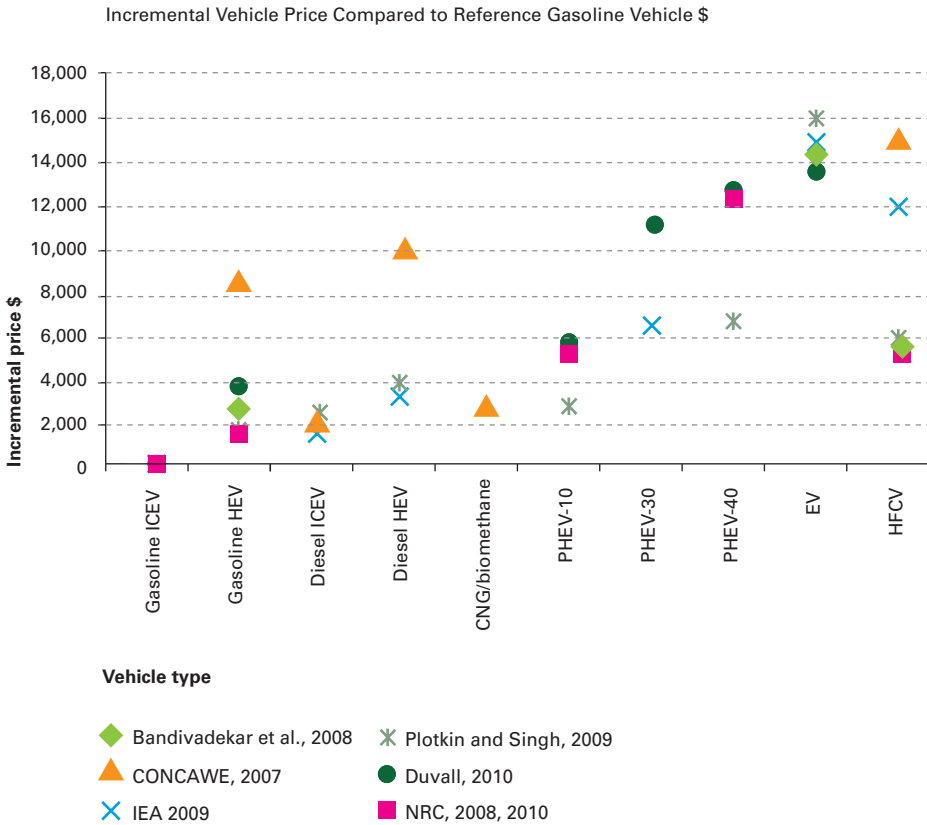


Figure 6. Relative incremental retail price for future mid-sized alternative drive LDV compared with advanced gasoline, spark ignition, internal combustion engine vehicles as the reference price (= \$0). Examples of liquid biofuel production pathways. Source: Sims et al. (2011).

Notes: The reference gasoline ICEV had a price range of USD (2005) 21,000-24,000 as quoted in the various studies. Bandivadekar et al. (2008) gave projections for 2035. NRC (2008) assumed mature technologies with cost reductions due to experience learning and mass production post-2025. CONCAWE (2007) was for 2010 technologies; IEA (2009) and Plotkin and Singh (2009) were for 2030 technology projections. The pure battery EVs in these studies had an assumed shorter range (typically 320 km) compared with the reference gasoline car because of imposed battery weight and cost limits. PHEV -10, -30 and -40 imply the range in miles on electricity only. Biofuels can be used in all gasoline and diesel vehicles.

**Biofuels**

There are many potential resources and conversion pathways for producing biofuels Today’s ‘first-generation’ biofuels are made primarily from food crops such as corn or sugar cane that are used to produce ethanol from sugars/starch or biodiesel from vegetable oil (Figure 7).

Future generations of biofuels will be made from cellulosic materials as well, including agricultural and forestry wastes and dedicated energy crops (grasses or woody plants). Using waste products limits the input requirements because these inputs were already being used to produce the primary crop (food, fibre or forest products); growing crops specifically for use as a transportation fuel feedstock requires more inputs. Conversion of sugar or cellulose-based biomass to biofuels requires processing and separating the materials to yield sugars that can be fermented. Next-generation fuel production could also involve thermo-chemical processes (e.g. gasification or pyrolysis of cellulosic materials).

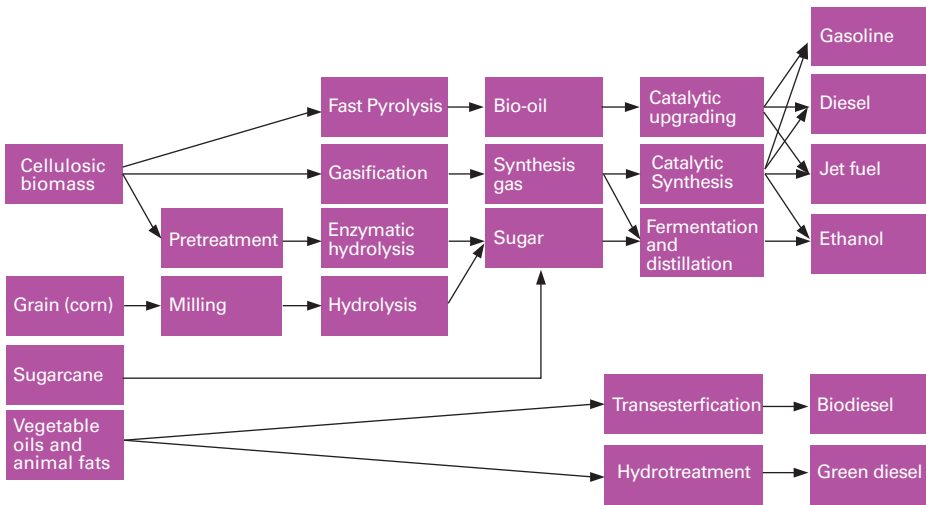


Figure 7. Examples of liquid biofuels production pathways. Liquid biofuels are already being produced from sugar/starch crops and oil plants/animal fats with first-generation technologies. Second-generation technologies will produce ethanol and diesel from cellulosic biomass. Source: Parker et al. (2011).

Biofuels can make significant contributions to a long-term sustainable transportation energy supply, although ultimately land use constraints will limit the total amount of biofuel that can be produced at competitive costs. The International Energy Agency (IEA) estimates that by 2050 up to 32 EJ of biofuels could be employed, contributing perhaps 27% globally to transportation fuel supply (IEA, 2011a). UC Davis research on the US supply potential of biofuels shows that advanced biofuels from waste, residues and energy crops grown on marginal land could provide between 2 and 16% of transportation energy in the United States in the next decade. (These biomass sources would avoid potential negative impacts of energy crops grown on agricultural land.) An additional 5% could come from conventional corn and soy-based biofuels. In total, we estimate

that it would be possible to meet 6.5-22% of US transportation fuel demand (15-45 billion gallons gasoline equivalent per year) with biofuels costing \$3-4 per gallon gasoline equivalent (gge). Biofuel costs would increase sharply above this level of demand because of biomass supply constraints. This result depends on advancements in conversion technologies, the development of reliable feedstock supply chains and the participation of potential biomass suppliers.

Biofuels can be blended with gasoline or diesel and used in existing vehicles, which eases their introduction into the transportation system. Advanced liquid biofuels require few vehicle changes, and some biofuels (so called drop-in biofuels) can be compatible with existing petroleum infrastructure. Liquid biofuels have an advantage over other petroleum alternatives (hydrogen and electricity) in serving sectors such as aviation and freight that require easily transportable, energy-dense fuels.

The costs and benefits of biofuels vary greatly, depending on the specific pathway taken. With current (or 'first generation') biofuels production technology based on ethanol from sugar or starch, biomethane and biodiesel, the lowest cost biofuels do not provide major environmental benefits. Some represent marginal improvements over petroleum while others are actually worse than petroleum fuels in terms of environmental impacts.

Advanced biofuels now under development (cellulosic ethanol or diesel from biowastes, bio-oils from algae) could provide significant environmental benefits. The first commercial-scale biorefineries are expected to produce large quantities of advanced biofuels by 2015. If these technologies prove to be viable, rapid expansion could take place in the United States to meet the 2022 requirements of the Renewable Fuel Standard. Advanced biofuels are expected to have small GHG footprints, but face some of the same indirect land-use change challenges as conventional biofuels if cultivating their feedstocks displaces food crops.

Biofuels raise a host of sustainability questions (GHG emissions, land use, water use) and macroeconomic issues (competition for land used in agriculture). Balancing sustainability with increasing biofuel production requires the consideration of many factors. There is ongoing effort by policymakers to incorporate sustainability metrics into policies encouraging the use of biofuels. However, capturing all these factors within a policy and regulatory framework will be challenging.

### **Electricity**

Unlike most other alternative fuels, electricity is already in widespread use by consumers for a variety of purposes, so much of this infrastructure already exists and can be used to provide electricity to vehicles as well. As a result, building

infrastructure for providing fuel to electric vehicles is largely focused on the point of refuelling – the vehicle charger.

It is expected that most drivers of PEVs will recharge primarily at home, so much of this recharging infrastructure will be concentrated there (Aksen et al., 2011). However, some level of public access to charging away from the home is probably needed to overcome the range limitations of pure BEVs, though the appropriate balance between private and public charging equipment will depend on the mix of BEVs and PHEVs, and the needs and preferences of their drivers. There is some evidence that public recharging stations may be needed to reassure drivers (*i.e.* to ease 'range anxiety') without being used very often. Aside from that concern, public charging will need to be ubiquitous if electricity is to displace most petroleum fuel usage because many drivers do not have access to overnight off-street parking.

Even with significant penetration of BEVs and PHEVs in the next few decades, electricity demand for recharging these vehicles will make only a minor contribution to total electricity demands. If PEV adoption is concentrated in certain regions, this could require upgrades to distribution infrastructure, but there may not be a need for additional generating capacity in the near term. Over the long term as PEV demands grow and affect the overall timing of electricity demands, this could induce changes in the mix of generation capacity that would be used to meet all demands. Demands for electric vehicles could be part of a future grid that incorporates intermittent renewables.

Although electric battery cars have zero tailpipe emissions, the well-to-wheel environmental benefits of PEVs depend on the type of electricity supply. Electricity offers a huge low-carbon resource base and large potential benefits in terms of reducing GHG emissions and air pollutants and displacing oil. With the current average US grid mix, there is relatively little GHG benefit for PEVs compared with gasoline hybrids. To realize potential GHG benefits of PEVs, it is necessary to substantially decarbonize the electricity supply over time by incorporating renewables and fossil electricity with carbon capture and sequestration (CCS). Decarbonizing electricity is a technical challenge for the electric vehicle pathway.

### **Hydrogen**

Hydrogen and fuel cell vehicle technologies are progressing rapidly and could be commercially ready by about 2015. Hydrogen will require a new fuelling infrastructure, and infrastructure build-out is currently the rate limiting factor for introducing hydrogen vehicles.

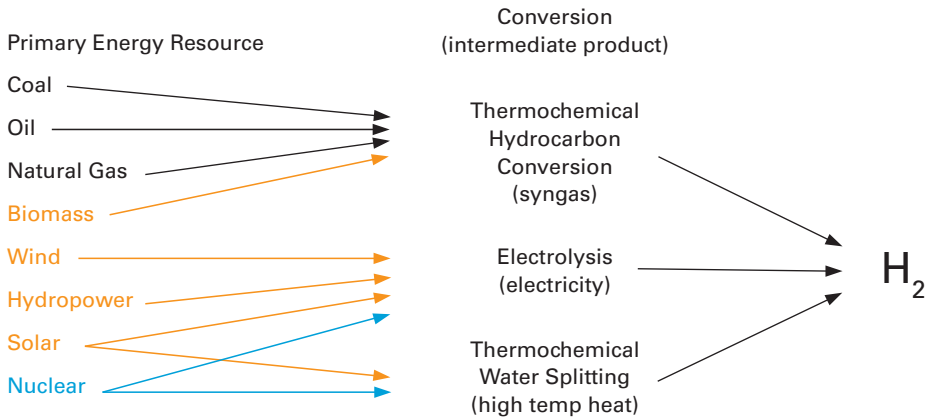


Figure 8. Different pathways for hydrogen production. Source: Ogden, Yang, Cunningham, et al. (2011).

Like electricity, hydrogen is an energy carrier that can be produced from a variety of primary energy resources (see Figure 8), although some pathways are superior to others in terms of cost, environmental impacts, efficiency and technological maturity.

Significant amounts of hydrogen are produced today for industrial and refinery purposes, most commonly from steam reforming of natural gas. Hydrogen production from fossil sources is a commercially mature technology. If we used all the hydrogen made for industry today, this could fuel 150 million vehicles or about 20% of the world's cars. The large scale of the industrial hydrogen enterprise gives confidence that hydrogen could be produced in the future at high volumes for vehicles.

In the near to medium term, fossil fuels (primarily natural gas) are likely to continue to be the least expensive and most energy-efficient resources from which to produce hydrogen. Conversion of these resources still emits some carbon into the atmosphere, although the emissions per kilometre are 30-50% lower with fuel cell cars using hydrogen made from natural gas than with comparable gasoline or diesel cars.

However, future hydrogen production technologies could virtually eliminate GHG emissions. For large central plants producing hydrogen from natural gas or coal, it is technically feasible to capture the  $CO_2$  and permanently sequester it in deep geological formations, although the widespread use of sequestration technology poses important challenges and will not happen on a wide scale until 2020 at the earliest. Production of hydrogen from renewable biomass is a promising midterm option (post 2020) with very low net carbon emissions. In the longer term, vast carbon-free renewable resources such as wind and solar energy

	Hydrogen	Electricity	Biofuels
<b>Fuel consumption (assumed vehicle fuel economy)</b>	5 billion kg H <sub>2</sub> /yr 0.6 EJ/yr (60 kg H <sub>2</sub> /mi)	90 billion kWh/yr 0.33 EJ/yr (300 Wh/mi)	12 billion gge/yr 1.4 EJ/yr (25 mi/gge)
<b>Primary resources required (EJ/yr)</b>	To supply all hydrogen from natural gas would require about 0.8 EJ/yr, about 3% of total natural gas use in the United States today	In the near term (2020), there will be a growing use of renewable electricity. Future grid scenarios imply a mix of low-carbon sources by 2050	Corn (about 30% of 2008 crop) + Forest wastes, 0.4 EJ/yr (24 million tons of estimated 61 million tons available) + Ag. residues, 0.5 EJ/yr (33 million tons of estimated 238 million tons available) + Municipal solid waste, 0.4 EJ/yr (29.5 million tons of estimated 135 million tons available)
<b>Fuel production plants (number of plants, average size [bbl oil equiv/day or GJ/day])</b>	24 central biomass H <sub>2</sub> plants (30-200 tonnes H <sub>2</sub> /day); most H <sub>2</sub> production via 1-2 tonne/day on-site natural gas reformers at refuelling station	28 GW at 35% capacity factor = nighttime electricity from 28 1,000-MW coal or nuclear plants or 10,000 3-MW wind turbines (~ total US installed wind capacity today) (28 GW < 5% of US electricity generation capacity)	150 corn ethanol plants 76 cellulosic bio-refineries 16 biodiesel plants
<b>Fuel distribution network (type, extent in miles, compatibility with existing system)</b>	9,000 miles hydrogen pipeline in urban areas; most production on-site	Use electricity transmission and distribution system. May need 'smart grid' upgrades	Additional 7,000 rail tank cars; rail receiving yards at 25% of fuel terminals
<b>Vehicle refuelling or recharging interface (number of stations)</b>	18,000 stations total: 14,000 on-site SMR, 4,000 pipeline stations	Home recharging + fast-charge stations on interstates	None if cellulosic biofuels are 'drop-in'; 20,000 E85 stations if all ethanol
<b>Cost breakdown for infrastructure capital investment</b>	\$38 billion total: \$4 billion biomass plants, \$9 billion pipelines, \$21 billion on-site SMRs, \$4 billion pipeline stations	\$16-42 billion total: \$800-2,100 per vehicle for in-home chargers	\$50-70 billion; more than 80% of investment is for bio-refineries, rest is for biofuel delivery system

Table 1. Infrastructure investments needed to support 10% of US light duty vehicles (20 million vehicles) fuelled with hydrogen, electricity or biofuels.

might be harnessed for hydrogen production via electrolysis of water. Although this technology is still improving, high costs for electrolyzers and renewable electricity (in part because of the low capacity factors of intermittent renewable sources) suggest that renewable electrolytic hydrogen will likely cost more than hydrogen from fossil resources with CCS or biomass gasification.

Once hydrogen is produced, there are several ways to deliver it to vehicles. It can be produced regionally in large plants and can be distributed by truck or gas pipeline; or it can be produced on-site at refuelling stations (or even homes) from natural gas or electricity. No one hydrogen supply pathway is preferred in all situations, and like electricity, it is likely that diverse primary sources will be used to make hydrogen in different regions.

Because there are many options for hydrogen production and delivery, creating such an infrastructure is a complex design problem. The challenge is not so much producing low-cost hydrogen at large scale as it is distributing hydrogen to many dispersed users at low cost, especially during the early stages of the transition.

The early stages of hydrogen infrastructure development pose special problems. Consumers will not buy the first hydrogen cars unless they can refuel them conveniently and travel to key destinations, and fuel providers will not build an early network of stations unless there are cars to use them. Major questions include how many stations to build, what type of stations to build and where to locate them. Key concerns are cost, fuel accessibility, customer convenience, the quality of the refuelling experience, network reliability and technology choice.

Early infrastructure 'cluster' strategies that co-locate vehicles and stations in so-called lighthouse cities (early market regions) could allow good fuel access for consumers even with a sparse, relatively low-cost early fuelling network (Ogden & Nicholas, 2011). Although hydrogen will be more costly than gasoline initially, costs will become competitive on a cents-per-mile basis as demand grows and the system scales up.

In the near term, most hydrogen will probably come from natural gas. Many very low-carbon supply pathways are available for long-term future hydrogen supply, including renewable hydrogen and fossil hydrogen with CCS. In the long term, low-carbon hydrogen could cost \$3-4/gge, competing with gasoline at \$2-3/gallon on a cents-per-mile basis.

Once demand for hydrogen increases beyond a few percent of the fleet, it should be possible to deliver hydrogen at a cost competitive with gasoline (on a cents-per-kilometre basis).

### **Natural Gas**

As noted in a recent MIT report, *The Future of Natural Gas*, (MIT 2011), there are abundant supplies of natural gas in the world, and many which could be developed and produced at relatively low cost.' In the United States, the development of low-cost and abundant unconventional natural gas resources, particularly shale gas, has led to a rapid increase in supply and drop in price. Technical progress has expanded low-cost gas supply. However, extraction of shale gas via fracturing is under scrutiny and is being increasingly regulated, because of potential environmental impacts.

The use of natural gas in transportation has been growing worldwide. In addition to CNG use in passenger vehicles, CNG and liquefied natural gas (LNG) are finding use in long-haul trucks and marine applications. Like hydrogen, CNG requires also coordination of stakeholders to build the refuelling network. An alternative to direct use of natural gas is using it as a feedstock to make liquid fuels (gas to liquids GTL), electricity or hydrogen for vehicles.

Key questions for policymakers are 'how much will environmental regulations add to costs for shale gas and oil development' and 'will natural gas be a long-term solution or a bridge fuel in a carbon-constrained world?' Although natural gas is the lowest carbon fossil fuel, at some point lower carbon alternatives will be needed, fossil sources with CCS or renewables.

### **Unconventional Oil**

There are a variety of options for unconventional sources of oil that could provide a ready substitute for conventional crudes. An estimate of the size of these resources and costs are shown in Figure 9. The amounts of unconventional oil are huge, but costs are higher than today's sources (although not higher than today's prices). One of the main issues is the environmental footprint of unconventional oil, which will be a higher carbon alternative than conventional oil. It will be hard for these technologies to play a major role if strict cuts in carbon emissions hold (IEA, 2010).

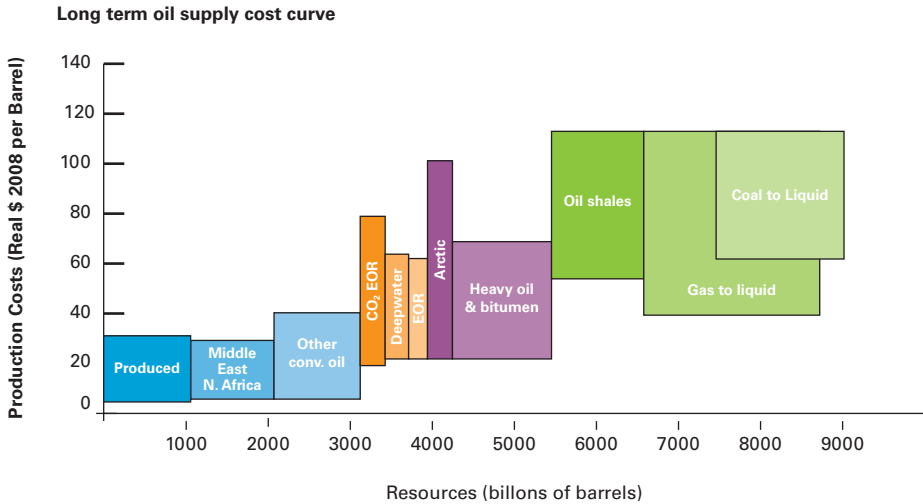


Figure 9. Long-term oil supply curve. Source: IEA World Energy Outlook (2008).

#### 4. Technology Status and Timing for Fuel Infrastructure: US Case Study

Widespread adoption of new fuels means that extensive new fuel production and delivery infrastructures will be required. It is technically feasible to build new fuel infrastructures for biofuels, electricity, hydrogen or natural gas. Each faces infrastructure challenges that differ among fuels and conversion pathways. We illustrate this through a case study of the United States.

For biofuels, the main infrastructure issue is developing advanced biorefineries that can produce biofuels at large scale with competitive costs and low net carbon emissions. New biomass delivery systems will be needed to collect biomass and bring it to biorefineries, but the technologies for biomass harvesting and transport are well known. Liquid biofuels are relatively easy to store and transport, and require few vehicle changes to implement. Some so-called drop-in biofuels may be at least partly compatible with the existing petroleum delivery and refuelling infrastructure. This would be a significant advantage in terms of logistics, if new infrastructure is not required.

Electricity is already widely available to consumers, and it is unlikely that BEVs will have a major impact on the grid for several decades. (A large number of PEVs will need to be driven in a region before power plants are operated differently or new ones are required.) The main near-term infrastructure needs are new in-home chargers plus some public fast chargers to facilitate

longer-distance travel. (Availability of secure charging sites at home or work will impact ultimate market penetration of EVs.) In the longer term, integration of charging demands (via smart grid concepts) will need to occur as part of the larger evolving electric power system, and a low-carbon electricity supply will be needed.

Hydrogen requires infrastructure changes throughout the supply chain: new hydrogen production and delivery systems and a network of refuelling stations. Successful introduction will require close coordination of vehicle and infrastructure deployments in carefully chosen geographic areas or lighthouse cities to finesse the 'chicken or egg' problem. The largest near-term infrastructure issue is more logistical than technical: finding strategies for low-cost build-out until hydrogen demand is large enough to exploit economies of scale. Before 2025, hydrogen fuel will likely be produced from natural gas via distributed production at refuelling stations, or, where available, from excess industrial or refinery hydrogen. Beyond 2025, central production plants with pipeline delivery will become economically viable in urban areas and regionally. For the long term, low-cost, low-carbon hydrogen production technology will be needed.

As an example of the infrastructure investments needed to support introduction of new vehicles, the table below sketches the infrastructure that would be needed to support about 10% of US light-duty vehicles (20 million vehicles) using hydrogen, electricity or biofuels (Ogden, Yang, Fan and Parker 2011). This is only one of many possible supply scenarios. Even at this relatively modest level of alternative vehicle market penetration, which might be reached by 2025-2035, tens of billions of dollars would be needed to build new infrastructure. For hydrogen, investments would occur primarily in production and delivery; for biofuels, biorefineries are the major capital cost; and for electricity, in-home chargers make up the majority of the infrastructure cost. Building a larger-scale infrastructure (serving 50% of US vehicles) would cost at least five times as much. To put these large numbers in perspective, the total expenditure for oil and gas refining and delivery infrastructure in North America is projected to be about \$300-400 billion between 2007 and 2030 or about \$15-20 billion per year.

Studies of hydrogen and electricity charging infrastructure requirements in Europe give roughly similar estimates to those in the United States. This is not surprising as the technologies and feedstock base is comparable. However, it may be more likely that biofuels will be imported into Europe than for the United States.

## 5. Environmental Aspects of Alternative Fuels

The environmental impacts of different alternative fuels have been analysed in many studies. Figure 10 shows a graph based on a recent IPCC report (Sims et al., 2011) that summarizes the GHG emissions associated with different fuel/vehicle pathways. Several trends are apparent.

- The higher energy efficiency of diesel and hybrid ICEVs means lower well-to-wheels GHG emissions than conventional ICEVs, even on petroleum derived fuels.
- Electric drive vehicles (battery vehicles and hydrogen fuel cells) have higher efficiency, but need decarbonized electricity or hydrogen from low carbon sources to achieve zero or near-zero well-to-wheels emissions (Yamg and McCarthy 2009).
- There is considerable uncertainty about the GHG emissions associated with biofuels depending on indirect land-use considerations.
- Electric drive vehicles (hydrogen fuel cell or electric battery) run on renewable or low carbon fuels can approach zero well-to-wheels GHG emissions.

Other externalities associated with transportation fuels are air quality effects on human health, water and materials use (Delucchi, 2011; Ogden, Williams, & Larson, 2004; Sun, Ogden & Delucchi, 2010).

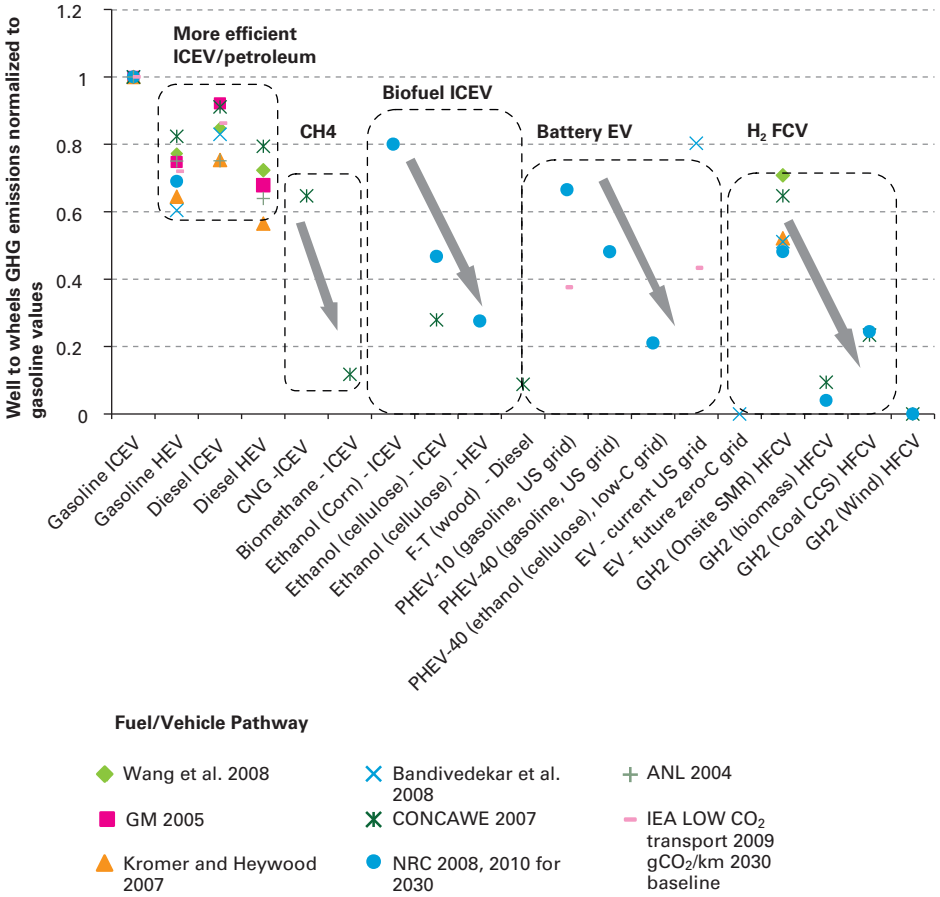


Figure 10. Well-to-wheels GHG emissions per kilometre travelled from various studies of alternative light duty fuel/vehicle pathways, *normalized* to the GHG emissions value of a gasoline ICEV but excluding land use change impacts. The diagonal arrow indicates the well-to-wheels emissions impact of moving from fossil to lower carbon primary supplies, and/or adopting higher vehicle efficiency.

Notes: WTW GHG emissions per km for the gasoline ICEV reference vehicle (“Gasoline ICEV” = 1 on the y-axis) were normalized to the average emissions taken from the gasoline ICEV in each study that ranged from 170-394 gCO<sub>2</sub>/km. For all hydrogen pathways, hydrogen is stored on-board the vehicle as a compressed gas (GH2). SMR, steam methane reformer.

## 6. Will Consumers Adopt New Technologies?

Understanding consumer behaviour is important for market introduction of alternative-fuel vehicles and infrastructure, and to realize maximum benefits from these technologies.

For BEVs, it is critically important to understand the trade-offs among battery size, vehicle cost and consumer travel and recharging behaviour. UC Davis' studies of vehicle recharging behaviour showed that more new vehicle buyers may be well set up for vehicle recharging than estimated in previous analyses (about half have access to charging when parked at home) and that the success of EVs in meeting energy and emission goals depends on users' recharging and driving behaviour as much as or more than on vehicle design.

For hydrogen, early station placement is an important factor influencing refuelling convenience and consumer acceptance. Consumers will not buy hydrogen cars unless they can refuel them. We found that strategic colocation of early hydrogen vehicles and stations in clusters can greatly improve fuel accessibility for early consumers while reducing initial infrastructure costs. Initially a sparse network of fewer than 1% of gasoline stations may be enough to assure fuel availability (Ogden & Nicholas, 2011).

Similar considerations would hold for dedicated natural gas vehicles, although they are less severe because natural gas is widely distributed to consumers in many parts of the world.

For biofuels a flex-fuel vehicle strategy is attractive, marketing cars that are capable of running on any mix of gasoline and ethanol or for diesel vehicles on mixes of biodiesel and petroleum derived diesel fuels.

## 7. Do We Need Fundamental Scientific Breakthroughs to Implement Alternative Fuels?

It is sometimes suggested that game-changing, fundamental scientific discoveries are needed before we even start down a path of implementing alternative fuels and vehicles. Is it prudent to wait for a breakthrough before getting started? Probably not, for several reasons. We already have the technical capability to build well performing zero or near zero emission vehicles and produce low or zero carbon fuels. Technologies such as electric and hydrogen cars and biofuels are ready to make the next step along the innovation process (see Figure 15). Although continued incremental technical advances may be needed to realize the full potential of different pathways, the issue is more one of 'start-up costs',

scaling up manufacturing and infrastructure logistics, than a need for basic scientific breakthroughs. Second, the urgency of the climate change problem means that we need to implement lower carbon alternatives quickly. Given the long time frame for developing new technologies and getting them into the fleet, this means starting now with promising technologies rather than waiting for perfect ones. Of course, breakthroughs could make the whole enterprise of transition to alternative fuels easier, and basic R&D should be supported.

The major critical technical areas for improvement are listed below by fuel.

For biofuels, the main technical issue is developing large-scale biorefinery technologies that can convert widely available cellulosic feedstocks to low cost 'drop-in' liquid fuels, compatible with the existing petroleum infrastructure. Although there are promising approaches to this, the actual deployment of commercial scale biorefineries is still in early stages.

For electric vehicle pathways, the critical technology is the battery. Current batteries are still too costly by a factor of 2-4, and have a lifetime, perhaps 5-7 years, about half the lifetime of a typical passenger vehicle today. Projections for battery technology evolution are optimistic that these goals will be reached. To realize the full benefits of EVs and tap into huge wind and solar resources, it may be necessary to implement 'smart grid' technologies and develop lower-cost renewable electricity. Inventing new business models for battery ownership and electricity for transport may be required as well.

For hydrogen, the key vehicle technologies are the fuel cell, with respect to cost and durability, and the hydrogen storage system with respect to cost. Fuel cells are rapidly approaching their cost and performance goals. The other major technical issue is producing hydrogen from zero emission pathways at low cost and large scale. Options include H<sub>2</sub> from renewables (wind or solar electrolysis, biomass gasification), where the issue is primarily cost rather than technical feasibility or resources; nuclear hydrogen where issues are cost (electrolytic H<sub>2</sub>), technical feasibility (water splitting systems powered by nuclear heat), and the same waste, safety and proliferation issues as nuclear power; and fossil-derived hydrogen with CO<sub>2</sub> CCS, which offers nearly zero emissions, relatively low cost, assuming suitable CO<sub>2</sub> disposal sites are available nearby and that hydrogen is produced at large scale. Biomass hydrogen with CCS could even result in negative net carbon emissions. However, much remains unknown about the potential environmental impacts and feasibility of CO<sub>2</sub> sequestration.

### 8. Is There a Winner in the Contest for ‘Fuel of the Future’?

Figure 11 shows a sample comparison of three different fuels across multiple metrics: consumer acceptance, technology status, cost, infrastructure requirements, resource needs, environmental performance and transition issues (green is ‘challenge solved’, yellow ‘medium challenge’ and orange ‘difficult challenge’). This figure should be taken as illustrative only, because of the large uncertainties in evaluating the relative merits of different pathways. The intent is to show that comparing among pathways is a complex business where many factors must be considered. The key message is that there is no one definitive winner among alternative fuels. This speaks to the need for a portfolio approach, discussed in the next section.

	Hydrogen	Electricity	Biofuels
<b>Consumer acceptance</b>	Cost of H <sub>2</sub> FCVs; early fuel availability	Cost of EVs; recharge time & place/range	Veh. ~ gasoline/diesel; food/fuel/land issues
<b>Tech Status: Vehicle</b> <i>(critical Tech)</i>	FCVs demo; Commercial c.2015; <i>(Fuel cells/H<sub>2</sub> sto.)</i>	Pre-commercial PHEVs and EVs; <i>(batteries)</i>	Commercial vehicles similar to gasoline veh.
<b>Tech Status: Fuel</b> <i>(critical Tech)</i>	Large scale fossil H <sub>2</sub> commercial; <i>Low-C. H<sub>2</sub> production</i>	Elec.system exists, but need decarbonized grid. <i>Low-C. elec generation</i>	1 <sup>st</sup> gen biofuels from starch, sugar crops 2 <sup>nd</sup> gen. <i>biorefinery</i>
<b>Infrastructure</b>	New infrastructure needed (mature H <sub>2</sub> infrastructure \$1,400-2,000/car)	New in-home (cost \$1,000-2,000/car) and public chargers, upgrade T&D	EtOH partly compatible w/petroleum infra (“drop-in fuels” fully compatible)
<b>Economics (mature tech., full scale)</b>	H <sub>2</sub> FCV \$3,600-6,000 > gasoline ICEV; H <sub>2</sub> delivered \$3-4/gge	\$5,000 (PHEV) to \$15,000 (EV) > gasoline ICEV	Biorefineries are primary infra. cost; Biofuel for 10-20% demand < \$3-4/gge
<b>Resources</b>	Diverse resources for H <sub>2</sub> production, huge low-carbon resource base	Diverse resources for electricity production, huge low-carbon resource base	Limits on providing enough low cost biofuels for all transportation
<b>Environmental impacts/oil use</b>	H <sub>2</sub> Pathway dependent many low-impact options	Elec. Pathway dependent many low impact options	Biofuel Pathway dependent
<b>Transitions (time, cost to breakeven)</b>	Requires stakeholder coordination, policy 10-20 yr (\$10s-100sB)	Veh. adoption determines transition time 10-20 yr (\$10s-100sB)	Biorefinery build-out determines transition time. RFS 2022 \$100sB

Figure 11. Comparison of alternative fuels across multiple dimensions. No one fuel wins on all measures. (Green is “challenge solved”, White “medium challenge” and Orange “difficult challenge”). Source: Ogden and Anderson (2011).

## 9. A Portfolio Approach Towards Sustainable Transportation

We have made a case that there is no single obvious 'winner' among alternative fuel pathways for the title of 'car of the future'. Alternative fuels are just one part of a strategy that also incorporates high efficiency and reduced travel demand to reach goals for low-carbon transport. How can we use the multiple technologies together to meet goals for deep cuts in carbon? Here we describe scenarios for a low-carbon transportation future, based on several influential recent reports: the European Commission Roadmap and White Paper on Transportation, the International Energy Agency's Blue Map scenarios and other views of low carbon futures.

An important insight is that you cannot achieve environmental and energy security goals with any one approach in isolation. A portfolio that combines improved efficiency, reduced travel and decarbonized fuels gives the best chance of success. Synergy, not competition among fuels, is needed at least for a while.

## 10. IEA Scenarios

The IEA has developed a range of scenarios for the world's future energy system that could sharply reduce GHG emissions, potentially stabilizing the atmospheric CO<sub>2</sub> concentration at 450 ppm, a level that is thought to avoid some of the worst impacts of climate change. Figure 12 shows the evolution of the energy system over time under different technology and policy scenarios. In the 'Baseline' case, emissions continue to grow to 2050, accompanied by a rapid rise in CO<sub>2</sub> concentrations in the atmosphere. By contrast, the 'Blue Map' scenario, which was developed to meet goals for stabilizing the atmospheric CO<sub>2</sub> concentration at 450 ppm, has much lower emissions and does meet the goal for 450 ppm. Each sector of the energy system shows reductions in GHG emissions to meet the goal. Transportation is a key part of the solution, with major GHG accomplished reductions by 2050.

Figure 13 provides more details on the future global fuel mix for transportation. In the 'Baseline' case, transportation related GHG emissions double by 2050. The Baseline case is a continuation of current trends, with total energy use growing rapidly. Only moderate efficiency improvements are made and most of the transport sector fuelled by fossil-derived liquid fuels, with gasoline, diesel, GTL and CTL dominating, with only a minor role for CNG and biofuels and essentially no electric drive. The 'Blue Map' case, which represents a stabilization path at 450 ppm, the Blue Map scenario high efficiency, renewable biofuels, electricity and hydrogen all play major roles. The 2050 GHG emissions (Figure 12) are about 50% less than those in 2007. Conventional gasoline and diesel-powered LDVs are largely replaced by a portfolio of vehicle drive-trains (IEA, 2010).

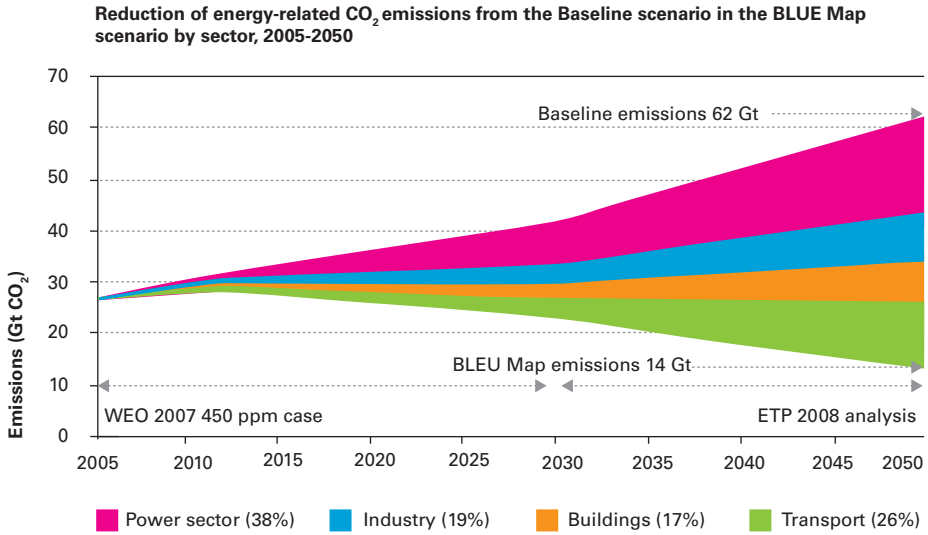


Figure 12. GHG emissions reductions from different sectors of the energy system. Source: IEA (2008).

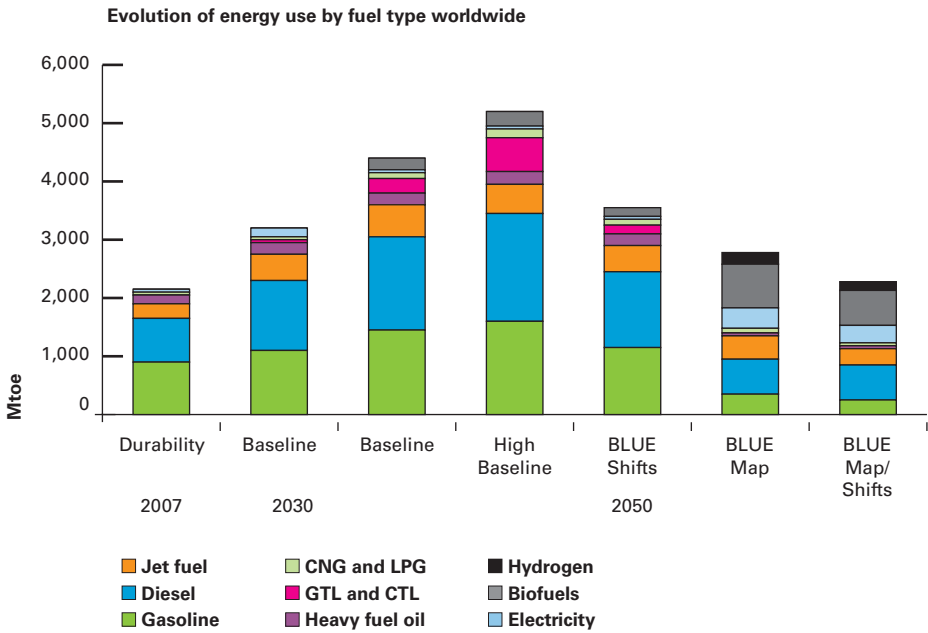


Figure 13. Evolution of energy use worldwide by fuel type. Source: IEA (2010).

Figure 14 illustrates the Blue Map vision of the LDV sector, where electric drive trains and low carbon fuels rapidly gain market share. With carbon constraints, the future light duty sector is made up of a very efficient ICEV fleet running on biofuels and some petroleum fuels, plus about 50% electric and hydrogen cars. The Blue Map scenario also invokes a 30% reduction in vehicle miles travelled.

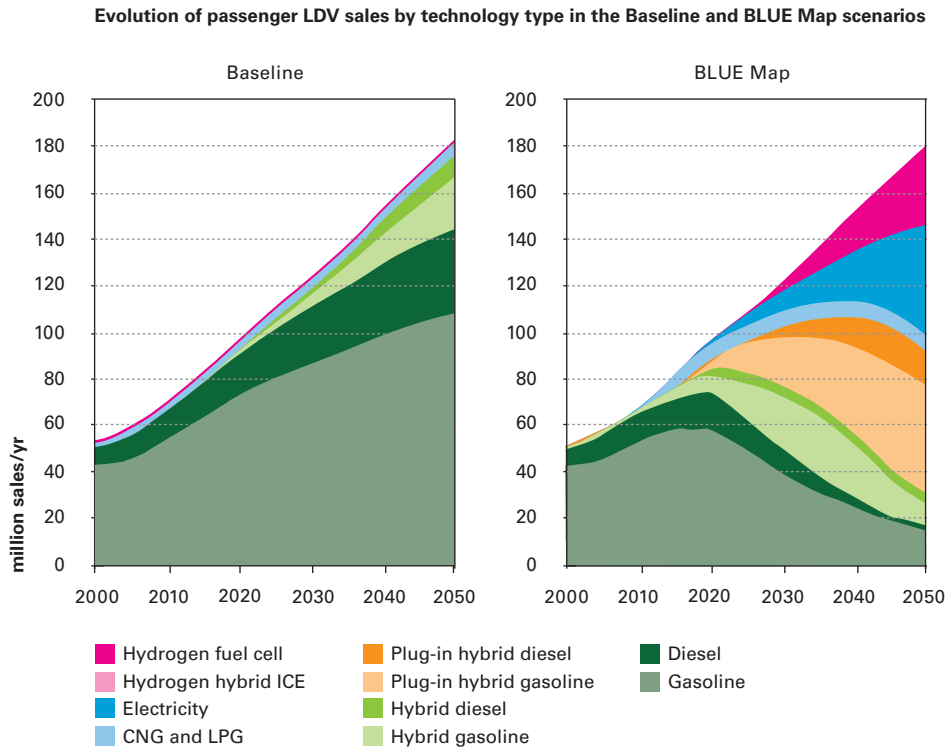


Figure 14. Scenarios for sales of new LDVs to 2050 by technology type. Source: IEA (2010).

### 11. European Commission White Paper: Transportation Roadmap

Another recent comprehensive study by the European Commission analysed trends and transportation futures for the European Union (European Commission, 2011). One of the main findings was that “Growing out of oil will not be possible relying on a single technological solution. It requires a new concept of mobility, supported by a cluster of new technologies as well as more sustainable behaviour”.

Similar to the three-pronged approach suggested in this chapter, the EU study found that ‘technological innovation can achieve a faster and cheaper transition to a more efficient and sustainable European transport system by acting on three main factors:

- Vehicles’ efficiency through new engines, materials and design;
- Cleaner energy use through new fuels and propulsion systems;
- Better use of network and safer and more secure operations through information and communication systems.

Finally, they noted, ‘The synergies with other sustainability objectives such as the reduction of oil dependence, the competitiveness of Europe’s automotive industry as well as health benefits, especially improved air quality in cities, make a compelling case for the EU to step up its efforts to accelerate the development and early deployment of clean vehicles’.

## **12. Can We Meet Long-Term Goals with Technology Changes Only?**

The transport scenarios presented above rely on a portfolio approach where highly efficient vehicles and low carbon fuels dominate by 2050. They imply a technology revolution, but they also postulate significant changes in driving patterns and even city design to reduce travel demand. Clearly, it might be difficult to change people’s energy habits, so the question naturally arises whether we could achieve deep GHG emissions cuts and a diverse secure energy supply in the transport sector even without invoking changes in behaviour or compromises in performance? The answer is a qualified yes, that technology could do it all, but only if most key technologies meet or exceed their stretch goals. However, even if it is technically feasible to pursue this path, ruling out the possibility of behavioural change commits us to a more unforgiving and expensive transition going forward. This is true for several reasons. First, the lower the demand, the less supply has to be built. Reducing demand makes the whole system more feasible and less expensive. If travel demand is lowered via behavioural change, it gives technology more ‘wiggle room’. Rather than having to meet all technology goals perfectly, a technology can have partial success if travel demand is lower (Leighty, Ogden, & Yang, 2012; McCollum & Yang, 2009).

## **13. Won’t We Have to Pick Winners Eventually?**

In a sustainable transportation system c. 2050, there will probably be a diverse mix of efficient vehicles and low carbon fuels. But not all the possible options in Figure 1 will succeed. Given the uncertainties and risks, it is not possible today to select the winners and losers, although we can find guidance by sketching

some of the potential costs and benefits. In the long term, the market will decide on winners, which technologies are widely implemented. Adopting a portfolio approach for the next 10-20 years could give us more flexibility, by avoiding early lock-in.

## 14. Alternative Fuel Transitions

*It is likely that putting our energy system on a climate ‘stabilization path’ will require a huge scale-up in alternative fuels and vehicles by 2050, especially use of renewable liquid fuels and electric drive trains.* Alternative fuels each face different transition barriers and costs, but share some common concerns.

### Timing for Alternative Fuel Transitions

Transitions in the transportation sector take a long time, for several reasons (Figure 15).

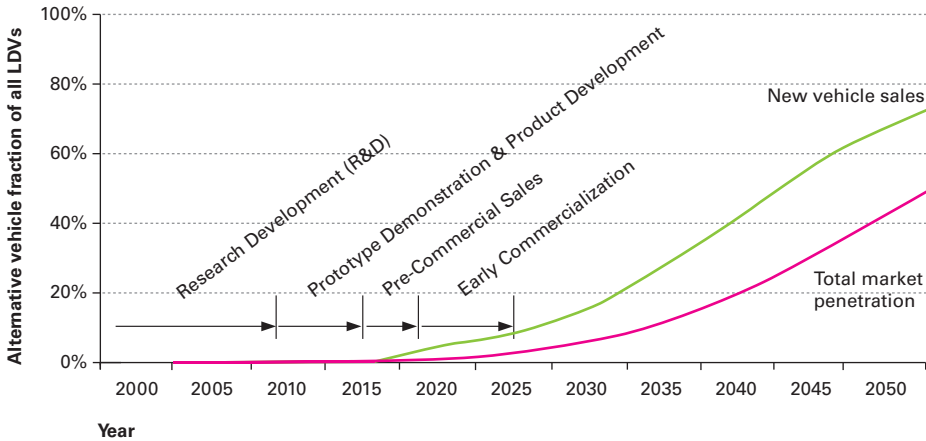


Figure 15. The steps needed to commercialize a new vehicle technology add up to a long time horizon. An alternative vehicle technology for which research and development began in 2000 might not reach 50% market penetration or hope to capture 75% of new vehicle sales until 2050. Source: Cunningham et al. (2008).

First, passenger vehicles have a relatively long lifetime (15 years average in the United States). Even if a new technology were to rapidly capture 100% of new vehicle sales, it would take a minimum of 15 years for the vehicle stock to turn over. In practice, adoption of new vehicle technologies occurs much more slowly; it can take 25-60 years for an innovation to be used in 35% of the on-road fleet.

For example, research into gasoline HEVs in the 1970s and 1980s led to a decision to commercialize in 1993, with the first vehicle becoming available for sale in 1997. HEVs still represent only about 3% of new car sales nationally in the United States, 5% in California and fewer than 0.5% of the worldwide fleet. This slow turnover rate is also true for relatively modest technology changes such as the adoption of automatic transmissions or fuel injection. The time frame for new technologies relying on electric batteries, fuel cells, or advanced biofuels could be even longer since they all need further RD&D investment before they can be commercialized.

Second, changing the fuel supply infrastructure will require both time and a significant amount of capital, especially if this means switching on a massive scale from liquid fuels to gaseous fuels or electricity. Historically, major changes in transport systems such as building canals and railroads, paving highways, and adopting gasoline cars have taken many decades to complete. Transitions will require developing new supply chains using renewable or other low-carbon sources and replacing existing fossil fuel and electricity plants. Such paradigm shifts will require close coordination among fuel suppliers, vehicle manufacturers, and policymakers.

Each fuel/vehicle pathway faces its own transition challenges, which can vary with region and can slow market penetration (Figure 16). These include infrastructure compatibility, consumer acceptance (based on, *e.g.* limited range or long recharging times for batteries and limited initial infrastructure for hydrogen fuel cell vehicles), cost, availability of primary resources for fuel production, GHG emissions and other environmental and sustainability issues (such as air pollutant emissions and water, land and materials use).

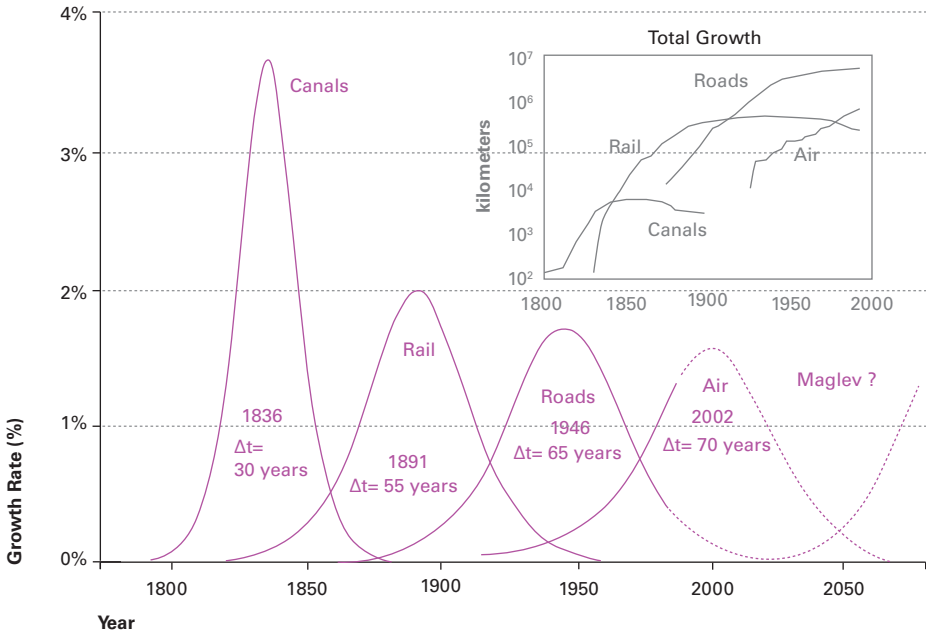


Figure 16. It takes 30-70 years to fully implement new infrastructures, judging by historical data on the time it has taken for major US transportation infrastructures to reach their peak market penetration. Source: Ausubel, Marchetti, and Meyer (1998).

**Transition Costs and Risks**

Implementing new types of vehicles and fuels will require stakeholders (automakers, fuel suppliers, consumers, policymakers) to coordinate in new ways, take risks, make major investments on evolving technologies and undergo a relatively long period before payback. A series of recent studies have estimated the transition costs to bring new vehicle and fuel pathways to cost competitiveness with existing fuels (IEA, 2010; NRC, 2008, 2010 Ogden, Yang and Parker 2011).

In most cases, the economics are likely to be difficult during a 10-20 year transition period of scaling up infrastructure and vehicle manufacturing. Investments on the order of tens to hundreds of billions of dollars may be needed to bring new technologies (e.g. plug-in hybrid or hydrogen fuel cell cars) to competitiveness with incumbent technologies (gasoline and diesel ICEVs).

Ramping up use of alternative fuelled vehicles has significant start-up costs, and it can take time to buydown the cost of vehicles and scale up fuel infrastructure.

However, alternative fuelled vehicles ultimately save on fuel costs because of their high energy efficiency. Once the savings on fuel costs counterbalance the extra vehicle first cost, we have reached 'breakeven'. From the point of view of the whole economy, at breakeven the alternative fuel is just as good as the incumbent it replaced. If alternative fuel vehicle costs continue to decline with learning and scale, eventually it becomes cheaper to own and operate the alternative fuelled vehicle, an economic benefit. If externalities like GHG emissions and air pollution health damages are figured in, alternative fuels break even even sooner (Sun et al., 2010). Generally it takes 10-20 years of development and several million vehicles for alternative pathways to reach 'breakeven' with conventionally fuelled vehicle technologies. The total subsidy to get to breakeven is perhaps tens to hundreds of billions of dollars, spent over one to two decades. For electric and hydrogen fuel cell vehicles, about 80% of the transition cost is for buying down the cost of vehicles. Infrastructure is perhaps 20% of the transition cost. For biofuels, the fuel supply, particularly the biorefinery, is the major expense. The IEA has estimated economy wide investments for different energy sectors to 2050 to achieve the Blue Map scenario. The long-term savings from improved energy efficiency and new primary sources outweighs the capital investments for transition (IEA, 2011b).

### **15. How Do Transition Costs Compare with the Cost of 'Business as Usual'**

The preceding section has focused on the costs of making a transition to alternative fuels and vehicles, but we should note that continuing a petroleum-based fuel supply also has significant costs. Oil supply investment costs are growing rapidly, especially for exploration and production, with oil companies drilling deeper wells in more remote areas. Much of the oil capacity that will be needed in 2030 has not been built yet and will require development of new oil fields and investments in refineries that can deal with heavier crudes, oil sands, and gas to liquids. The IEA's *World Energy Outlook 2008* has estimated that oil supply infrastructure development between 2007 and 2030 will cost about \$6.3 trillion globally for a new supply capacity of about 50 million barrels of oil per day (enough to fuel a fleet of about 1.3 billion cars, assuming an average fuel economy of 25 mpg and a vehicle driven 15,000 miles per year). In North America alone, the oil infrastructure costs for that period are estimated to be about \$1 trillion, or an average of \$45 billion per year.

How would the global capital outlay compare for alternative fuels versus oil? The IEA estimates that about \$1.3 trillion would be needed worldwide for oil refineries and fuel transport, the remaining \$5 trillion for exploration and production (drilling oil wells). The investment for oil refineries and transport is then about \$1,000 per vehicle served (assuming 1.3 billion vehicles in 2035).

Counting exploration and production, total oil supply investment costs would be about \$5,000 per vehicle.

By contrast, the capital cost for biofuels in the United States would be about \$100-360 billion to build biorefineries and biofuel transport capacity to fuel about 30-60 million cars, or \$1,600-10,000 per vehicle served (assuming a 25-mpg vehicle that travels 15,000 miles per year). The biofuels analogy to oil exploration and production is developing land for biofuel production. However, these costs are likely to be very small compared with drilling oil wells, especially if low-carbon residues are employed (if the land is already developed for another purpose). And even for energy crops, land costs are treated more as rents or operating costs than capital costs.

For hydrogen or electricity, 80% of the transition costs are associated with the vehicle, with infrastructure accounting for only 20% of the total. The US National Research Council has estimated that infrastructure capital costs would be \$1,000-2,000 per car for PHEVs (including only the in-garage charger but not electricity transmission or generation or primary resources to make electricity). For hydrogen, infrastructure capital costs are estimated to be \$1,400-2,000 per car, including hydrogen production, delivery and refuelling equipment, but not the capital costs for the development of primary resources to make hydrogen – for example, natural gas wells, biomass resources, or wind farms.

The average annual transition cost to bring HFCVs or PHEVs to cost competitiveness is about \$4-8 billion per year over a 10- to 15-year period, and roughly 20% of this for infrastructure (or \$0.8-1.6 billion per year). The cumulative infrastructure transition cost is roughly \$8-12 billion, compared with projected capital expenditures in North America of perhaps \$100-150 billion for oil refineries and fuel transport, and an additional \$600-800 billion for exploration and production between 2007 and 2030. (This does not count oil investments that might be made abroad to serve North American markets). We could launch an alternative fuel infrastructure for much less than we are planning to spend on oil, and at a comparable investment cost per vehicle served.

## 16. Transition Insights

The time required for fuel and vehicle transitions is long. Although electric vehicles and biofuels are beginning to enter the market (and hydrogen fuel cell vehicles could enter by about 2015), it will take several decades for any alternative fuel pathway to make a major difference in GHG emissions or oil use because of the time required for market penetration, vehicle stock turnover and fuel supply development.

The transitions in vehicle fleets and energy supply systems necessary to reach low-carbon scenarios for 2050 must begin soon and progress rapidly, with rates of market penetration and change near feasible limits. To reach major market penetrations by 2050, new vehicles and fuels need support during early commercialization, as manufacturing and fuel supply systems are scaled up.

Making a transition to a low-carbon transportation system is a complex undertaking with multiple actors: consumers, energy suppliers, vehicle manufacturers and policy makers. Consumer behaviour will have a strong influence on which types of vehicles are adopted and what type of infrastructure is needed. Some fuels, notably hydrogen, will require close stakeholder coordination to introduce fuels and vehicles together in particular locations. And most decarbonized fuels will require development of new primary supply chains that could interact with other sectors of the economy (electricity, food, land use). One of the key challenges for policymakers is mitigating the stakeholder risks inherent in introducing new technologies.

## 17. Conclusions

A revolution in transportation technology will be needed to meet societal goals. The good news is that it appears to be technically feasible to cut transportation-related GHG emissions by at least 50-80% by 2050. Further, this is more a matter of logistics and marketing than the need for fundamental scientific breakthroughs, although these would be helpful in reaching true zero emissions.

We have found that there is no single transportation fuel or vehicle of the future. Just a few years ago the policy discussion about alternative fuels was framed around finding a single 'silver bullet' replacement for petroleum. In light of recent studies, we now believe that the future is unlikely to be a winner-take-all competition among biofuels, electricity, hydrogen, natural gas and petroleum. Instead, the path towards sustainable transportation will be paved by a long series of actions taken together across many fronts over the next decades to improve vehicle efficiency and reduce travel demand while developing new types of vehicles and building new fuel systems tapping into low-carbon primary supplies. By 2050, we will probably see a diverse mix of low-carbon fuels and efficient vehicles in different transportation sectors and regions.

A portfolio approach is essential if we want to achieve deep cuts in transportation GHG emissions and oil use by 2050. The long-term performance and cost projections for key technologies such as electric batteries, fuel cells, and advanced biofuels are promising but still uncertain and it will take at least a decade to bring these technologies to scale. If we down-select too soon, we run the risk of

cutting needed options. This suggests that we need to nurture a range of options over the next decade or so with strong, consistent policy to improve our overall chance of long-term success. A successful portfolio strategy will require a new approach to alternative fuel policy, one that recognizes the uncertainties and long time horizon for change.

The goal is to nurture a broad set of the most promising efficient, low carbon technologies and get these to the point where they could compete in the market. This does not mean that all the options in Figure 2 will succeed. For the long term, the market and consumers will decide which fuels and vehicles dominate.

What should policymakers and industry do now? Despite the uncertainties, there are clearly measures that could be taken now with a high degree of confidence to reduce transportation-related GHG emissions and oil use. These include increasing the efficiency of ICEVs (including hybridizing drivetrains) and bringing lower-carbon biofuels into use. In parallel, we need a strong program of support to nurture emerging electric drive transportation technologies (batteries and fuel cells) so that they can be commercialized soon enough to bring deep cuts by 2050. And we need ongoing science to assess the impacts of choices with respect to GHG emissions, oil use, and water, land, air and materials. None of these necessary steps are likely without strong, but flexible policies.

Investments needed to launch new clean vehicles and fuels are much less than money flows in the current energy system, but are still an order of magnitude larger than typical R&D expenditures. Industry is risk averse. Regulations do not cover the whole fuel pathway. One of the big questions is how policy might help industry traverse the 'valley of death' to bring needed innovations to large-scale use? Do we need a new type of institution to fund development of a portfolio of solutions? As a next step, we propose city scale 'networked demonstrations' of pre-commercial technologies to test the entire system and encourage investment (e.g. thousands of electric vehicles and 50 public chargers in a city; or thousands of hydrogen fuel cell vehicles and a network of 20 stations). Working through a series of niche markets for technologies such as battery or fuel cells has succeeded in other technological realms, but this approach may not be fast enough to meet goals for GHG reduction. Counting the economic cost of externalities such as health impacts may be the key to making alternative fuels competitive sooner (Ogden et al., 2004; Sun et al., 2011).

Fortunately, it appears that staying in the game to commercialize multiple fuel/vehicle options would have a relatively low cost compared with the money flows in the current transportation fuel system, although it is more expensive than traditional government spending on research and is risky for individual industries. It will be challenging to craft policies that can support a range of new

technologies and are flexible enough not to pick winners. At the same time, we will need measures of success for different options over time, and the ability to stage public support in a timely way. Once the technologies are successful, savings on fuel costs will more than pay for the cost of building new infrastructures and support will not be needed. The net impact on the economy will be positive, even without counting externalities. How long should policymakers continue betting on a diverse set of options when some may not succeed? It is hard to answer this question definitively, but it is vital to note that the costs of bringing new technologies to competitiveness is still at least an order of magnitude lower than the costs of continuing with conventional fuel supply.

We are moving into a creative new era for the transportation energy system. As we did 100 years ago at the dawn of the automobile and oil age, we are rethinking our energy system's design and structure; new fuels and vehicles are a critical piece of the picture. This analysis and most others are reaching towards the future from the perspective of our current system. But ultimately the shape of our transportation system may be quite different as we design within the constraints of not just energy and climate but also land, water, air, and materials. Technology and policy are evolving rapidly, with decision-makers facing a dynamic future playing field. Perhaps the greatest need now is for strong and consistent policies, and roadmaps and strategies showing how stakeholders can coordinate to take feasible steps towards a sustainable transportation future. The ongoing challenge is putting the pieces together into realistic visions that can inspire action.

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# Information and Communications Technology (ICT) Unleashed

# 04

Peter Sweatman

**We are in a transformational period where the mobility of people, and goods, benefits from rapid technological innovation, and also from information that leads to better decision making, on a level not possible just a few years ago. The motorist is guided to her destination, and avoids traffic snarls. The urban dweller can move seamlessly from a parking facility to rapid transit. The long distance truck driver can plan a route based on time and fuel efficiency. The use of these beneficial technologies in transport is currently ad hoc in nature, and the benefits are marginal relative to the daily grind of our massive legacy transport systems. The systematic use of these, and many other technologies, will lead the transformation of mobility.**

With strong policy support, future intelligent transport systems (ITS) will overcome barriers to innovation and enable consumers to choose sustainable mobility. ITS impacts industries, public entities and consumers. The use of sensors, data, information systems and communications to advance mobility constitutes a public-private enterprise known as ITS.

Mobility relies very broadly on the actions of the public and private sectors and is subject to scrutiny for its impact on society (both positive and negative), on the environment (negative) and on the economy (both positive and negative). Sustainable mobility will require order-of-magnitude improvements. This will call for actions, and the decisions leading to those actions, to be linked specifically to outcomes. Comprehensive use of information and communication creates these essential links. If the enterprises providing this network of intelligent transport do their job wisely, users and decision makers will change their behaviour dramatically, in ways we cannot always foresee.

Information and communications technology (ICT) is one of the strongest forces for sustainable mobility, because it impacts the demands we place on transport as well as the efficiency with which we meet those demands. On the demand side, technology encourages our citizens and organizations to access services remotely, including remote learning, teleworking and telecommuting, and to

interact socially without physical, face-to-face presence. On the supply side, our need for mobility, both individually and industrially, will continue, and will even increase in certain aspects. Mobility will continue to enrich and advance our societies and economies; it will also be made more available to all sections of society – those who are older, poorer and more vulnerable. Global mobility will also increase with rapid advancements in motorization in the developing world.

For a given level of mobility, ICT makes motorized transport more efficient. Passenger car and commercial truck transport currently benefit from ITS solutions, which improve safety and traffic flow within routes and across corridors; these solutions include user charging methods with varying degrees of specificity. New connected vehicle systems (vehicle-to-vehicle [V2V] and vehicle-to-infrastructure [V2I]) offer order-of-magnitude improvements in safety, traffic efficiency, fuel efficiency of vehicles and carbon emissions. Eco-driving assistance potentially allows all drivers to drive as efficiently as the most efficient driver. Such systems also allow drivers to avoid routes, and trips, which are inefficient by virtue of traffic speed and density, infrastructure or topography. From the driver's perspective, technology demonstrates and benchmarks efficiency, and makes it a competitive virtue.

ITS also reaches deep inside vehicles so that they can predict and adapt their performance. Vehicles with hybrid powertrains can maximize the use of electric power and minimize the use of internal combustion engines, depending on their zone of operation (urban-suburban-rural) and the topography of the route. Intelligent systems can periodically take over the driving of large, heavy commercial vehicles to minimize energy use subject to terrain, or in highly congested traffic. In these same trucks, losses in the transmission of energy can also be managed actively when in long-distance cruise mode.

Long-established transport industries must change and are actively reinventing themselves. The vehicles produced and marketed globally by the automotive industry are undergoing a rapid rate of technological change driven by evolving needs and beliefs in society. Users are demanding connectivity, new personal services and 'green' performance values, as well as safety, fuel efficiency and reduced environmental impact. Electrified vehicles represent a new threshold, not only for automakers but also for newly associated industries such as electrical storage and distribution, renewable energy and recharging. The advent of ICT, both on vehicle platforms and on consumer electronics devices, changes the nature of the industry: new capacities and performance levels are enabled in vehicles and the highway infrastructure via software rather than through physical improvements.

Significant challenges exist in the technological advancement of highway and city infrastructures because it is increasingly difficult to fund the maintenance,

much less the construction, of these important public assets. Nevertheless, there is a great need to enable new capabilities to attract and accelerate economic development, manage traffic, improve emergency services, reward citizens with overdue improvements in essential services and monitor the health of networks. The deployment of intelligent systems in highway and city infrastructures is generally at a low base because they compete with the fundamentals of civil construction and maintenance.

All of these changes, transforming the ‘intelligence’ of the transportation system, involve additional players, new data and information resources and new transportation services. The transition from an automotive industry to a broader set of transport enterprises is one of the major challenges facing our economies. Those enterprises centre on the automotive industry and its suppliers, but expand to include the ITS, the ICT, freight and transit industries and infrastructure managers at the state, regional and local levels. These enterprises are among the largest investors in R&D and are drawing on a broader field of expertise, including engineering, urban planning, behavioural science, emergency medicine, business, public administration and policy and community services.

The goal of sustainable mobility will require order-of-magnitude changes in the impacts of the entire transportation enterprise. Technology will play a large role in focusing on clean, efficient and smart movement of passengers and freight, effective use of infrastructure and networking of information. In addition, there will be a completely new capability for the ‘systems’ virtues of providing alternatives, pricing services efficiently, operating in adaptive and predictive modes and monitoring impacts. Alongside these direct and indirect benefits of technology, there will need to be major changes in the volume of demands made by users. New intelligent transport enterprises will empower the accessibility of individual users and have far-reaching effects on the decision making and behaviour of transport users.

## **1. Viewpoint of Transport, ITS, ICT and Sustainable Mobility**

A collection of perspectives from different global regions is likely to encounter variations in terminology, and even differing views on definitions. It is difficult to operate in the vast realm of transport, and transport research, without adopting a certain viewpoint. The vast majority of personal vehicle trips in the United States employ automobiles of advanced design, operated extensively by a diverse driving population, utilizing a deteriorating and overcrowded highway system. The use of sensors, data and information systems (as deployed by the ITS industry) to improve the safety and efficiency of the highway system

is underway but has not reached its full potential. Commercial freight vehicles share an extensive infrastructure with personal vehicles and have a disproportionate influence on severe crashes, infrastructure wear, consumption of fossil fuels and greenhouse gas (GHG) emissions. Availability and use of urban public transit is limited. This complex and largely ad hoc transportation system, upon which society relies and invests in heavily, leads to human harm, and it contains inefficiencies, inequalities, represents poor economic choices and imposes a vast environmental footprint. One's exposure to, and perception of, this complex landscape will clearly influence an exposition of the influence of ITS and ICT on sustainable mobility.

Transportation is a highly practical and operational field, as opposed to abstract or theoretical. *It is a public-private enterprise that provides accessibility to goods and services, as well as social connection.* The automotive sector, producing cars, trucks, buses and two-wheelers, is an important part of transportation. So are road and bridge infrastructure, and stand-alone public transport systems such as rail, subway and bus rapid transit. Today we think of transportation as broader than these traditional sectors because we found that they could no longer proceed and develop independently, and because we needed better management and better ways to pay for transportation investments. We now have traffic management, dynamic messaging, tolling, dynamic pricing, managed lanes, new mobility hubs in big cities and bike rental schemes. Motorists have embraced navigation systems, telematics and concierge services; crash avoidance systems and aspects of driving are becoming automated.

The traditional sectors of transportation are being bound together, and eventually transformed, by ICT and ITS. ICT is invading transportation through the consumer electronics devices that are carried into vehicles of all modes, and through the management and payment services being adopted by vehicle manufacturers and road managers alike. ITS was born in transportation, either through more intelligent functioning of roads for safety and traffic flow or through driver assistance systems in vehicles. ITS is developing rapidly to support connectivity of the vehicles and infrastructure and will need to be capable of supporting the introduction of autonomous vehicles in concert with manually controlled vehicles. We are seeing a revolution in the achievable goals of ITS through rapid technological progress, coupled with deeper understanding of the needs of users.

Although the term transportation has an operational connotation, the term mobility is less specific and often refers to a prized aspect of civilized society. Mobility may be construed as a demand, a need, and sometimes as a right, to move from A to B. Transportation is on the supply side, and summons the combined efforts of enterprises, both private and public, in providing mobility. But to be more precise, the real need is accessibility, and so transportation

should provide not only mobility, but also connectivity and proximity. That is, we may be able to act and interact remotely, or find what we need close by, and therefore circumvent the need for trips.

*Sustainable mobility* speaks to a future transportation system that meets societal needs for accessibility while the public health issue of motor vehicle injuries is solved, environmental impacts are dramatically reduced, dependence on non-renewable energy is removed, the economy is fully supported and public costs can be met. Incremental reductions in the negative impacts of our current transportation system will not be sufficient: future transportation needs to change in terms of what it delivers, and how it delivers. Innovation is needed not only in technology but also in the behaviour of users and enterprises involved in transportation.

Although there may be differences in interpretation between the themes of *sustainable mobility* and *sustainable transportation*, further discussion is not warranted in the context of the current chapter. Suffice it to say that discussion of sustainable transportation in the US context would usually include elaboration of a range of alternative energy sources and specific reference to reducing dependence on foreign oil.

Having provided information on my viewpoint, and ventured certain essential definitions and distinctions from a distinctly US perspective, I shall henceforth use the European term *transport* in place of the American term transportation. However, my discussion will retain a US flavour.

## **2. Sustainable Mobility Is in Dynamic Competition with Other Policy Aims**

Policy makers have a major challenge in promoting sustainable mobility, while taking care of competing aims for the transport system. There are many substantial barriers to large scale innovation: technological, institutional, financial, political and economic. Transport safety is a pre-eminent consideration in the United States, and generally represents the 'high bar' for the introduction of significant changes in transport. It is important to recognize that major US ITS programmes have the primary goal of safety. In particular, the ability to avoid crashes is a prerequisite for the light-weighting and downsizing of vehicles that will be needed for sustainability.

We should not create the impression that transport is a single system, nor that future transport could be designed in a single optimal manner. Sustainability is a necessary, but not sufficient, condition for *sustainable mobility*.

In order to protect against shutdowns caused by emergencies and major disruptions, we need the system to be highly responsive and sufficiently redundant as to provide options when links are severed. Transport ultimately needs to be *resilient* – able to flourish under multiple forms of internal and external threat (Page, 2010). This is an emerging consideration of some significance, and we may find that sustainability is subsumed by resilience – that sustainability is one of several attributes of mobility, which will protect its prized status in society.

As we innovate on a large scale, as we must, we will need transport to be resilient to well-intended actions, even such as innovation, as well as random events. Important weapons in the resilience toolbox include diversity, adaptive capacity and anticipation (Page, 2010). Although intelligent systems are essential to the development of all these attributes in our transport systems, innovation will not always be aligned solely to sustainable mobility.

In transport, we are accustomed to the gradual introduction of improvements. From a policy perspective, interventions are usually based on the assessment of the problem and post-evaluation of the results. However, the scale of change required means that major innovations will need to be introduced without this rigorous, but expensive, time-consuming process. Therein lies a policy challenge that will need to be addressed. The ability to transparently monitor the effects of such innovations will be critical and will, of course, be enabled by the intelligent systems we seek to introduce.

Continuous improvement needs to be very widely supported by the private and public entities that design, deploy and operate our transport system. We also need to remain active in changing our complex transport system over a protracted period of time, while maintaining a degree of mobility similar to that which we currently enjoy, for both persons and freight. This requires very significant movement in the way individuals and corporations use transport, in the engineering and technological elements we employ and eventually in true systems performance and in the transition from fossil-based energy to renewable energy.

It is difficult to imagine how such significant and protracted changes could occur without being driven by strong consumer engagement with a much improved transport product. Intelligent systems will provide the vehicle for this engagement, leading to the development of more responsive and satisfying transport services. Policy makers will need to be highly attuned to the needs and desires of consumers, empowering consumers in the interests of sustainable mobility while dealing with competing needs for resilient transport systems.

### 3. The Evolution of ITS, with ICT, as a Force for Sustainable Mobility

ITS has evolved over the past twenty years or more, and has been influenced by ICT, to the extent that we are able to envisage the intelligent transport enterprises of the future. These enterprises will positively impact every element of sustainable mobility and the transition to achieve sustainable mobility.

ITS was developed within the transport sector, but has been influenced by the broader field of ICT throughout its history. We may recall visions of an intelligent vehicle-highway system, a smarter means of traffic control or better informing drivers of traffic conditions. All of these visions were facilitated by developments outside the transport sector. The availability of global positioning systems (GPS) is a prime example. We now have vehicles that are rich in their abilities to sense, connect and compute, assisting drivers to make decisions more easily – or to make better decisions – and to avoid the errors that may lead to crash risks.

Although ITS has usually been associated with safety, it has also been deployed to improve traffic efficiency and has been employed for important service functions such as toll collection. The utility of ITS for managing the credentials and fitness of heavy vehicles operating on the road system has long been recognized.

Generally speaking, the deployment of ITS in vehicles has been much faster than deployment in our highway and city infrastructures. On the infrastructure side, ITS has remained in the sphere of transportation research and development and has not received large scale, mainstream deployment.

Meanwhile, smartphones have rapidly invaded US consumer culture, and represent a marketplace phenomenon with great potential for transport. Automotive manufacturers rapidly changed from a position of protecting the integrity of original equipment manufacturers' (OEMs) systems to embracing connectivity for personal devices within vehicles. With the coming generation, it appears that personal communication devices are more popular than cars. Automakers are moving rapidly to provide in-vehicle systems and interfaces that allow the use of such devices without additional safety risks of driver distraction. This process has been assisted by the USDOT's<sup>1</sup> release of guidelines for the design and installation of such devices in vehicles.

These complex interactions between government, industry and consumers hold important lessons for sustainable mobility. The strong desire of consumers for connectivity has driven rapid change in automotive systems. At the same time, safety concerns have accelerated innovation in driver interfaces, including voice

1 [United States Department Of Transportation.](#)

commands. Policy makers have largely played an enabling role for consumer-driven changes.

### **Government and Industry Roles in the Development of ITS**

ITS has proven to require a partnership between industry and government. Yet it is not clear how that partnership should be convened and developed and who should take the lead. The strong regulatory flavour of federal departments of transportation has not been conducive to collaborative action with the automotive industry, with some notable exceptions. For example, the USDOT's development of a safety-critical connected vehicle platform, in conjunction with global vehicle manufacturers, has been instrumental in bringing forth credible technology for broad-scale crash avoidance. This technology is currently undergoing model deployment in cars, trucks and buses in Ann Arbor, Michigan.

The required ITS partnership between industry and government is also complicated by the diverse industry sectors and levels of government that need to be involved. At the federal level, there is an active partnership between the USDOT and the automotive industry for automotive safety, and particularly for the deployment of connected vehicles. The relationship is less collaborative for the improvement of fuel efficiency and the reduction of emissions, while USDOE<sup>2</sup> R&D in renewable energy vehicles is highly collaborative. At the state level, there are strong partnerships between state DOTs, highway construction companies and the owners and operators of toll facilities and managed lanes. Partnerships are also arising between state DOTs and automakers, to increase the operational and maintenance efficiency of state-owned highway networks, using the rich data streams now available in vehicles.

The US government-led sphere of ITS research, which is primarily focused on safety through crash avoidance, includes active engagement with automakers, suppliers and research institutes. Analogous efforts in Europe tend to have broader objectives that include safety, traffic efficiency and reduced environmental impact. In all cases, policy makers are in active partnership with industry and seek model deployments that provide critical information about consumer behaviour and reactions to innovation.

### **Current Growth in the ITS Industry**

Sustained growth in a beneficial ITS industry will be essential to policy-making for sustainable mobility. Aside from advanced safety systems in vehicles, the current US practice of ITS is mainly in traffic management and traveller information. The current market for ITS products and services is substantial and growing. For example, the US ITS market is estimated at \$52 billion (Keeling & Mooney, 2011),

<sup>2</sup> [United States Department of Energy.](#)

comparable in market size with the motion picture industry. Yet the deployment of ITS is not considered to be 'mainstream,' and only a small percentage of the US highway network currently benefits from ITS. At the same time, ITS is growing more rapidly in the automotive sector. Examples include the highly popular navigation systems and growing demand for active safety systems such as lane departure warning applications.

Considering the entire scope of the transportation industry, ITS is currently having a significant influence upon safety and a growing influence on mobility. Automotive applications of ITS are proving popular, even though current applications lack the connectivity needed to create overwhelming, rather than worthwhile, benefits. The introduction of personal devices in vehicles is still in its infancy with regard to reliable system-wide benefits. Many important questions are yet to be answered. For example, how do users perceive the accuracy of real-time traffic information and to what extent are they prepared to make reasonably significant decisions such as redirecting to another route?

ITS is currently on the threshold of a widespread crash avoidance capability, opening the way to many other developments in sustainable mobility. With the advent of extensive vehicle connectivity, and much improved reliability of information delivery, our focus should turn to the strength and richness of transactions with the users who will ultimately drive sustainable mobility.

### **ITS Systems and Services Influencing User Behaviour**

The consumers of transport products and services will play a decisive role in the sustainability of future mobility. ITS systems and services are providing the information, including pricing signals, required to make decisions that determine whether trips are made, what transport modes are used, which routes are used, whether parking is available and what additional services may be needed.

The ability of ITS applications to play a major role in sustainable mobility may be expressed in two important characteristics brought to light in this discussion:

- The reliability of the technology in delivering accurate information in a way that is immediately understood by the user and
- The strength of the transaction enabled with the user in influencing decision processes, behaviour and the subsequent impacts on sustainability.

It is instructive to consider these characteristics as they apply to various ITS applications currently in the marketplace. Let us consider two examples of advanced automotive safety applications. The electronic stability systems commonplace in today's cars are highly reliable and are extremely effective in reducing single-vehicle crashes. However, these devices clearly have limited scope in solving the problems of today's transportation system.

The emerging technology of lane-departure warning systems are reliable (although they do not work under all conditions) and also have greater scope in influencing system behaviour because they interact more frequently with drivers and influence overall driving behaviour beyond specific safety risks (e.g. they cause drivers to use their turn indicators more often).

If we now consider applications that may be enabled on personal devices, we will see that there is a very different mix of the reliability of the service and its potential scope in influencing the user. Smartphone applications may have unreliable wireless or internet connections but could potentially influence many aspects of transportation decision making and operation.

In order to fully influence user behaviour, ITS systems need to be both sufficiently reliable and capable of significant transactions with users. With good reason, vehicle-based safety ITS has concentrated on reliability and accuracy. Generally, this high level of system accuracy is apparent to the user: for example, it is clear to the driver when he/she departs from the traffic lane. In contrast, traffic information on a personal device may or may not be accurate, and may not always be available. And it may be difficult for the user to determine the accuracy of the information or to overcome even infrequent dissonances when the information is clearly wrong. When credible information is available and is used, the impact on the efficiency of a trip, or the pleasure experienced, could be significant.

In order to have a major influence on sustainable mobility, ITS systems need to develop and maintain a high degree of transactional strength with users. That is, information will be accepted and acted upon with a high frequency and will provide a range of options and additional services. To achieve this, ITS systems need sufficient reliability and accuracy, and this needs to be apparent to users. Independent means of confirming the credibility of ITS systems will be required by users, and also by manufacturers and suppliers of such systems. Policy-makers will need to provide a larger resource for independent assessment of ITS systems, going well beyond the current focus on safety.

#### **4. ITS Empowering the Consumers of Transport Services**

As we evolve from being purchasers and users of transport products to being consumers of transport services, we will interact more frequently with a range of transport enterprises. These interactions will enable more specific targeting of services, will provide greater value and will lower the cost of mobility. The ITS systems that provide the conduit for these interactions will enable a broad range of transactions between users and multiple enterprises. These enterprises may

be public or private and may reside within, or outside, the traditional sphere of transport.

Let us consider some interesting current examples of enriched user transactions and the specific qualities they represent. (1) Xerox has researched and developed LA Express Park, which allows users to reliably find and pay for parking spaces in the City of Los Angeles, saving time and avoiding wasteful circling on city streets. (2) Overnight parking for long-distance truckers, too often a premium in the US Midwest, may be planned and booked in advance using several systems, including ParkingCarma, being deployed by the Michigan Department of Transportation in the I94 corridor. These applications exhibit several qualities needed for interactive ITS systems of the future:

- Effectively combining the ITS business culture (specifically for the transportation sector) and the ICT business culture (incorporating extensively amortized consumer communication platforms and devices);
- Involving multiple private and public enterprises, including companies new to the transport sector;
- Taking specific care of reliability, so that applications are reliable enough: if the long-distance trucker is informed that there is one available space out of 300 at a privately operated Jackson, Michigan truck stop, that space better be available when she arrives fatigued and out of driving hours;
- Combining elements of advanced technology (sensing and automation) with communication between multiple entities, for a much richer set of benefits: our trucker may be monitoring parking availability at several sites and enter into an assisted decision process that improves safety as well as productivity;
- Creating ITS data that may be used to expand current businesses or create new businesses: our trucker may require services, perhaps the need to replace a hard drive on her laptop;
- ITS data begin to provide a predictive capability: this customer may consistently require certain services and have predictable travel patterns; and
- The ITS transaction involves variable payment for services, heralding the transportation services industry of the future.

Most of these transformational features are included in the traffic data service provider Inrix. This growing enterprise uses 'probe' data from vehicles (including freight trucks) all over the United States, as they go about their business, plus data from subscribers to a smartphone application. Traffic information is provided to subscribers, both as real time information on routes of immediate interest and as traffic predictions up to 12 h ahead. Users can not only receive information about incidents causing non-recurring congestion, but can also report information. The company will also provide real time advice on the current best route to a destination and share the user's arrival time with others. Although such data may be embedded in various OEM traffic information products,

a prime mode of delivery of traffic services is the smartphone. Further, the Inrix Traffic Scorecard produces year-by-year indices of traffic delay and trip times on routes and corridors in major cities across the country. Among other things, this information influences business decisions concerning location of facilities, eventually influencing local economies.

Most significantly, emerging ITS applications are transactions connecting end users, service providers and other entities, private and public. *These commercial transactions* rely on data from widely distributed, highly leveraged, low-cost sources and could not exist without connectivity, sometimes using multiple paths. These ITS transactions have a heightened ability to influence the behaviour of individuals and companies because the data have a commercial value and, therefore, impact decision-making at increasingly higher levels, with greater spans of influence. Such services and transactions are already impacting policy-makers by providing network management data at a lower cost, as well as desirable consumer services that were not feasible without ITS.

## 5. Policy Creating Technological Innovation: The US Connected Vehicle Platform

It is not often that the government develops a communication platform that may be used by the automotive industry and entrepreneurs, potentially to develop myriad applications of value to consumers. The over-riding importance of motor vehicle safety led the US Department of Transportation to develop a connected vehicle platform that would support a comprehensive set of crash avoidance applications.

Benefiting from rapid advances in sensing and communication technologies, and from knowledge of human response to advanced safety systems, the connected vehicle platform is currently being tested on a significant scale. For the purposes of collision avoidance, the USDOT-sponsored Safety Pilot Model Deployment is currently deploying almost 3,000 vehicles (cars, trucks and buses) in the City of Ann Arbor, Michigan. These vehicles are equipped with a connected vehicle platform for V2V and V2I communication, along with a set of driver advisory applications aimed at avoiding the most severe types of crashes. This platform emphasizes reliability in communication, using dedicated short-range communication, and interacts frequently with the driver. This interaction is very soundly based, using robust data monitoring the actions of other vehicles, and the status of traffic features in the immediate vicinity. Such traffic features include signalized intersections and curves in the roadway.

This *connected vehicle platform*, although designed for crash avoidance, is a precursor for sustainable mobility and is being used for further transport

objectives, additional to safety. Additional uses currently include ecodriving applications, monitoring of infrastructure condition and winter weather operations. Transactions involve not only drivers, but also city and highway managers and motor carriers. In the case of ecodriving applications that have competitive elements, transactions extend to other family members and other company drivers.

In the future, as applications on the connected vehicle platform come to involve an increasing degree of automation, research will continue to address reliability because the technology will have more layers. But there will also be an increasing amount of research into the effectiveness of the transactions being carried out. We need to better understand a two-way decision and action process that more deeply and powerfully influences not only the way people drive, but also how far they need to drive, and perhaps whether they choose to drive at all.

By removing safety as a necessary barrier to innovation, this programme has a profound influence on policy-making for sustainable mobility.

## **6. The Influence of Innovative: Data-Driven Management in Cities**

Cities need to manage services for the benefit of their citizens, institutions and employers. Great difficulties in funding the construction and maintenance of city infrastructure have led to an increased use of data in decision making. Energy and transportation are key service sectors, which cities strive to manage under increasingly challenging economic circumstances. The generation, transmission and distribution of energy, and the way it is used and conserved, are critical economic, environmental and societal issues. Intelligent systems are used to manage demand for electricity through dynamic pricing and using remote modulation of appliances in homes. Cities manage public transit systems, fare payment, tolls, traffic management systems and parking facilities. The management task must deal with large perturbations, including events, incidents and attacks.

Through these activities, cities deal with a wide range of transactions that are as important to the city as they are to the user, and most of which involve payment for services. There is an emphasis on making payment as simple as possible for the user, while increasingly using pricing signals to modulate and manage demand. The systems used for these transactions need to be highly reliable and secure. The data generated by these transactions may be mined to help develop improved systems and services, to reduce costs and to improve efficiency. According to one of the latest reports from ITS America (Keeling & Mooney, 2011), on ITS market conditions:

‘Many cities are sitting on potential treasure troves of data, such as, from individual tickets, journeys and usage of public transport, to data in road charging or toll schemes. Transportation providers and agencies have a vast amount of information and data at their disposal from across their entire transport network. This represents a valuable opportunity to gain greater insight into the network, make better and more informed decisions, take appropriate action and help improve the quality of the transport services.’

Whether the issue is energy, transportation or water, cities will lead the way in creating richer and more meaningful transactions with users. Because these transactions involve payment for services, there is a stronger potential for changing the behaviour of users. For example, higher prices for parking in the central city encourage consideration of public transportation, and not just for a single journey. The implications for future ITS systems and applications are clear: crafting transactions with more profound effects on user behaviour, payment for services including dynamic pricing, a clear requirement for high reliability and guaranteed security of personal and institutional information. And the data created allow tracking of managers’ objectives and help in the design of more profound systems. Opening up the data to further rounds of entrepreneurship will expand the range of services and transactions available to the users.

Most of these useful ITS characteristics are evident in managed lanes currently being constructed on the Washington DC Beltway. The transaction controlling entry to the express lanes involves several decisions because it includes free entry to multiple-occupancy vehicles or dynamic pricing, depending on traffic levels on the tolled lanes. Users must sign up for an E-ZPass, or an E-ZPass Flex if they intend to exercise the high-occupancy option. Reliable new technology is needed to detect whether vehicles have three or more occupants. This new service is being marketed on the basis of trip *predictability* (‘designed to provide a predictable trip’). Data collection will be extensive, given the need to charge for different segments of the trip, and will support a complex public-private partnership between the state agency and two private companies. The political environment surrounding such projects ensures that security and privacy of data are paramount.

The power of open transport data in cities is well illustrated by the case of New York City taxis. In 2007, they were required to fit GPS devices and provide the data to the city. Smartphone applications now use this data to help users understand where to hail cabs, and at what time of day. The applications also help commuters avoid certain intersections. The City of New York has also used the data to support important decisions such as the pedestrianization of Broadway. This opening up of city transportation data occurred at a time of unprecedented political attention to the introduction of more mobility options and perceived competition with the

city's ability to accommodate cars. Nevertheless, during this period, there was a decline in car trips and an increase in the use of public transit. Around this time, New York City also introduced traffic signal pre-emption for transit buses, and this was associated with a significant increase in transit ridership.

These experiences cast the consumer more broadly as a citizen in a political environment and illustrate how the technology has been hardened with respect to reliability, security and privacy. The transactions employed have clear benefits for users, and the value of accumulated, publicly available data is fully recognized. Thus the use of this data to track the impacts of city decisions is also illustrated effectively.

## **7. The Important Contribution of New Mobility**

New mobility inspires us to rethink the entire purpose of the transport system, and to consider the interaction of transport and urban form. One of the central principles of new mobility is that the real goal is accessibility: providing access to our needs for participation in the economy, services, experiences, supplies and goods. Mobility is not the only way to create such access: we can bring or consider things in closer proximity, or we can use remote access. Trips may be eliminated altogether when connective networks are used for working remotely, shopping online, visiting a doctor online or being educated online. Cities are being ranked according to an accessibility index developed jointly by the Universities of Michigan and Maryland. The metropolitan accessibility index takes into account work and non-work opportunities and the cost of travel. This index is designed to inform policy decisions on transport projects and land use.

The University of Michigan's Sustainable Mobility, Accessibility, Research and Transformation (SMART) programme (Zielinski, 2010) operates in numerous large cities worldwide to identify natural hubs where a full range of transportation modes and services may connect, in support of seamless multi-modal trips. Communication technologies are used for gathering information across the system, way-finding and multi-service fare payment. This programme vastly expands the range of transport-related industries and enterprises to include real estate, tourism, logistics, retail, energy and utilities and entrepreneurial ventures. It also provides leadership in connecting urban planners, city engineers and leaders, business leaders and innovators, entrepreneurs and community leaders.

For reasons of safety, we are beginning to see a small degree of automation in vehicle control, based on improved sensors deployed in every vehicle. Connected vehicle technology will help drivers to operate much more efficiently, and with much less risk, and will increase automation. This breakthrough will

permit vehicles to operate with much less energy, by avoiding highly wasteful stops, accelerations, travel speeds and rapid speed adjustments relative to other vehicles in traffic. In aggregate, connected vehicles will much reduce traffic congestion and tend to eliminate such unseemly events. Ultimate efficiency and safety will belong to vehicles that drive themselves. In the event that such vehicles operate in a driverless mode, reduced vehicle downtime may produce higher mileage, albeit in a highly efficient operating mode.

Technology also promotes efficient mobility by encouraging the use of alternative modes of transport. Consumers are attracted to public transport by technology that creates a new experience in scheduling and fare payment. Information technology also enables seamless multi-modal trips that may combine not only 'conventional' modes such as personal car and transit, but also new business offerings such as fractional vehicle ownership, car-sharing services and ride sharing. In this world of new mobility, journeys may begin with an automobile but will routinely continue and end with other modes, including new business modes. The traveller will additionally benefit from new connective hubs accessed, experiences enjoyed and chores accomplished in the course of their trip.

Similarly, technology broadly impacts the efficiency of the freight movements underpinning our economies. Important ICT platforms and applications are abundant in supply chain management, border security, cargo tracking, interactive warehousing, port operations, intermodal transfers, dispatch and highway operations. Once the truck is in the road, technology plays an increasingly important role in carrier safety, vehicle and load compliance, credentialing, route selection and driver coaching. Technology will also enable large and heavy commercial vehicles to keep goods moving, with much reduced energy inefficiency, through measures such as managed lanes, truck-only lanes and platooning.

Finally, technology addresses the rate at which alternative and renewable energy sources are introduced into the transport system. To increase the diversity of energy sources for vehicular transport, we need to deal with the geographic dispersion of sources and incomplete distribution networks; this requires route planning and real time communication for refuelling. For example, commercial trucks operating on natural gas need careful planning of refuelling stops. The most effective use of electric cars, avoiding 'range anxiety' for consumers, will call for continuous communication for 'refuelling' en route, at stops and at destinations, within acceptable trip time parameters. Such communication with the electric utility is also needed for overnight charging at home at the lowest cost. Communication technology will be essential to the creation of sufficiently large pools of electric vehicle customers, along with sufficient flexibility and responsiveness in individual charging events, so that prices for renewable electricity could be competitive with the price of electricity from conventional sources.

New mobility is synonymous with sustainable mobility, and expansion of these programmes will directly improve sustainability, and will directly create economic opportunities and employment. New mobility also challenges ITS to create linkages to non-transport networks so that individual trips may be evaluated through a much broader set of considerations that speak to the real purpose of the trip, rather than reaching a specific destination. This vastly expands the scope of ITS transactions. It is also apparent that ITS data will be instrumental in evaluating the accessibility of cities. For example, integration of New York's taxi GPS data into an accessibility index would provide more robust and defensible long-term planning of controversial innovations such as bike lanes and pedestrian plazas.

New mobility demonstrates that public policy goals for sustainability can be actively supported by entrepreneurship. The ability to engage, and please, consumers is a key element of the policy toolkit for sustainable mobility. Open data policies are a powerful way of assisting such beneficial entrepreneurship.

## 8. ITS Transactions to Enable the Deployment of Clean Vehicles

Policy-makers everywhere are interested in accelerating the deployment of renewable energy in transport. ITS controls the rate at which the most promising types of alternative, renewable energy sources are introduced into the transport system. As a prime example, electrified vehicles using renewable energy require ITS connectivity in order to achieve mainstream status in the transport system. The connected vehicle platform is virtually essential to the wider introduction of full electric vehicles: those vehicles that rely entirely on their battery for their available driving range.

From an environmental perspective, there are some important differences between full electric vehicles and hybrids such as plug-in hybrid electric vehicles (PHEVs). PHEVs offer notable advances in fuel efficiency over conventional vehicles with internal combustion (IC) engines, but the gap is narrowed by the on-going introduction of innovations in IC engines. Full electric vehicles offer some reduction in GHG emissions when the electricity is generated from a conventional mix of coal, gas, nuclear and so on. However, GHG emissions attributable to full electric vehicles disappear when renewable sources such as wind and solar provide the electricity used to power the vehicle. *The use of electricity from renewables in full electric vehicles is the real game changer from the perspectives of climate change, energy security and air pollution. This will be impossible without the connectivity provided by ITS.*

Full electric vehicles and PHEVs share a dependence on further battery development and both require a ubiquitous, reliable and convenient external charging

network. Full electric vehicles are subject to consumer concerns about 'range anxiety'. Owners of full electric vehicles are likely to expect charging on demand, faster charging, battery swapping services, vehicle-to-grid intelligence and related services. Owners of full electric vehicles are more likely to adopt ITS applications such as route guidance, ecodriving applications, crash avoidance applications and parking management. All of these applications relieve anxiety related to running out of battery power and reduced personal safety in vehicles, which are much smaller and lighter than conventional vehicles that have proven extremely versatile and robust in operation.

There is a further economic imperative for electric vehicles to be connected. The price premium of electricity from renewables such as solar and wind can be overcome if electric vehicles can be aggregated and presented to the grid as a balanced load. Under this scenario, renewables will effectively become cheaper because no reserve will be required for controlling the load. The aggregation of electric vehicles as a controllable, affordable, renewable-friendly load, the use of applications for energy efficiency, the communication of energy-related data to consumers and real time communication for access to charging stations are essential to the mainstream use of electric vehicles.

A connected vehicle system will support the four key drivers in the success of full electric vehicles: trip reliability, range maximization, crash avoidance and affordable environmental neutrality. This ITS transaction with users takes on new and interesting dimensions. The connected electrified transportation system needs to provide consumers with stress free mobility, much reduced personal driving effort and unprecedented safety. At the same time, the energy used needs to be affordable, readily available as a 'fuel', free from harmful emissions and renewable. Automakers, along with certain new partners, need to be willing to receive data from their customer's vehicle, operate the required applications on an open-source transportation communication platform and communicate advice and instructions back to the vehicle.

A common, multi-purpose, open-source platform for transport system communications needs to be established. This platform, and developed applications, needs to be operated for the benefit of the automotive customer, with customers able to select applications for use with their own vehicle data. Customers need to be able to choose additional functionality, on the same platform, provided by ITS companies, fleet management companies, car-sharing companies and parking management companies.

The demands on ITS systems include all of the attributes we have already discussed, but now extend to ITS being a potential show-stopper. We also see significant new elements of the ITS transaction. The user owns and controls

his/her data and opts in to the services provided; this is a significant shift from current telematic systems offered by automakers, where the customer and their data are closely held by the automaker. The transaction also creates significant new classes of enterprise, such as the electric vehicle aggregator, the independent operator of the connected vehicle platform and the 'electric fuel' operator.

### **9. The Strength of the ITS Transaction**

It is important for policy-makers to consider how to empower the consumer. The ITS transaction is a critical part of the transformational potential of ITS, and its evolution thus far provides important lessons for policy-makers. The perspective of the individual consumer therefore deserves further consideration, based on the ITS examples provided above.

Again, the discussion begins with safety. Safety applications come from a trusted source, such as an automaker or public transportation agency; they need to be unobtrusive and avoid false positives in order to retain credibility. The user may choose to confer total dependence and trust on an application or set of applications.

Commercial transactions must be secure, and often apply to new services that were previously difficult to offer or charge for; pricing may be variable depending on the current status of the transportation system. These services may provide real time information or predictive information. It may be possible to opt in to receive privileged information, but the user then needs to agree to provide further data. It may even be possible to control your own data and obtain custom information based on that data.

The user's perception of value is a critical factor. The transaction may provide specific value in lowering the user's costs, but the value proposition may be relatively complex. The user may be willing to make an anonymous contribution to larger datasets for the common good. Reforms and capital projects may be supported by pooled data, and such data may sway political support and lend itself to long-term planning and execution of transportation projects. The user may be able to benchmark his/her behaviour or performance against others. The user may also be able to define certain personal values, in a manner visible to others.

The perspective of the private company is also important to the transformational potential of the ITS transaction. Applications may assist companies to better manage their businesses or lower costs, or enable the offering of new services.

The transaction may enable payment for services, which were hitherto considered infeasible or non-commercial. It may be possible to significantly improve quality management processes, including those affecting safety of employees and the general public. It may be possible to mine data that companies accumulate in the course of business. This may allow a company to provide a customer with data that help them understand their product in a larger context. Data may also be necessary in navigating and sustaining multi-partner transport enterprises. Cooperation in transactions may also support public relations efforts projecting good citizenship.

Sustainable transportation requires innovative behaviour on the part of individuals, groups and enterprises, both public and private. The ITS transaction, the act that brings about the delivery of a beneficial ITS technology, has unique power in creating innovative behaviour. The design of the ITS transaction has the opportunity to appeal to the motivations and objectives of private users and companies alike. We have seen that ITS transactions are already diverse and often ingenious. It is difficult to even imagine what the future may bring with comprehensive attention to open anonymous data, control over personal data and independent assessment of ITS transactions.

## **10. The Direct and Indirect Contributions of ITS to Sustainable Mobility**

The goal of sustainable mobility entails change on a large scale, enabled by major innovations. Such changes, whether technological, behavioural, industrial, institutional or political, need to be accompanied by an open, publicly available flow of data that speak to the performance of the system. This is not the way things are usually done in transport. In this respect, ITS is a pre-eminent innovation and change-agent for sustainable mobility.

By removing safety as a necessary barrier to change, ITS open up new fields of opportunity. In doing so, it creates versatile platforms that equally serve traffic efficiency, energy efficiency and emissions reduction and extend the useful life of infrastructure. The connected vehicle platform offers unprecedented potential for innovation in the operational performance of all passenger and freight vehicles. This platform removes motor vehicle safety as a public health issue and supports the orchestrated and uninterrupted movement of vehicles.

Change will be driven primarily by the consumers of transport services. These consumers are the sought-after customers of an expanding set of transport enterprises, including an automotive industry in transition. The behaviour of transport consumers, including their beliefs, decisions, actions, responses and performance in certain roles, will have a defining influence on sustainability.

Along with technological advances and policy decisions, consumer behaviour will determine our progress towards sustainability.

New intelligent transport enterprises will empower the accessibility of individual users and have far-reaching effects on the decision making and behaviour of transport users. With the advent of extensive vehicle connectivity, and much improved reliability of information delivery, our focus should turn to the potential of the transactions with the users who will ultimately drive sustainable mobility. ITS systems need to develop and maintain a high degree of transactional strength with users. That is, information will be accepted and acted upon with a high frequency and will provide a range of options and additional services.

Emerging ITS applications are transactions connecting end users, service providers and other entities, private and public. These ITS transactions have a heightened ability to influence the behaviour of individuals and companies because they involve data that have a commercial value and therefore impact decision making at increasingly higher levels, with greater spans of influence. Transactions begin to occur in the larger context of the city or region, and the value of accumulated, publicly available data is fully recognized. Recognizing that accessibility is the true goal of consumers; new mobility reaches out to connect with a much broader range of sectors and partners within the city or region.

Vehicles operating with renewable energy represent a major technological innovation for sustainability. ITS is indispensable to the wide deployment of electric vehicles, and the transactions involved are the most powerful that we have discussed. A common, multi-purpose, open-source platform for electric vehicle communications needs to be established. This platform needs to be operated for the benefit of the consumer, with consumers able to select applications for use with their own vehicle data. Consumers need to be able to choose additional functionality, on the same platform, provided by ITS companies, fleet management companies, car-sharing companies and parking management companies. Users own and control their data and opt in to the services provided.

## **11. Policy-Making to Enhance the Direct Contribution of ITS to Sustainable Mobility**

US government policy for ITS has been successful in the deployment of advanced safety systems in vehicles, in the development of the connected vehicle platform for crash avoidance and in ensuring the versatility of that platform for applications with broader potential for sustainability. Policy-making has also assisted the inclusion of communication and information systems in vehicles, helping to avoid

the problems of driver distraction. Related advances in ITS system architecture, standards, security and privacy have supported the development of the new ITS systems. Many of these policy suites have concentrated on the technical aspects of ITS, on safety and the protection of users. This needs to continue.

There is now a much larger role for policy-making to enable transactions that empower transport consumers. Attention should turn to the creation of platforms for transport data collection, processing and dissemination. Transactions require open access to anonymous data, as well as the ability for consumers to control their own data and derive benefit should they so choose. Policy-makers should continue to encourage the introduction of new technologies for assisting, and supplanting, drivers. Guidance on the coexistence of human and robotic vehicle control will be needed. The choreography of different classes of vehicle – cars, buses, trucks, two-wheelers and three-wheelers – in cities will require policy guidance. Guidelines for granting priority to certain classes of vehicle will be required.

Although aspects of this larger policy role specific to ITS may be foreseen reasonably readily, policy-makers need to do much more to plan for the ITS platforms of the future. How else can we create, for the first time, the venue for the 'systems' virtues of providing alternatives, operating in adaptive and predictive modes, and monitoring impacts during periods of potentially disruptive innovation? These future platforms need to accommodate communication, information, data and payment. Independent authority will be needed to ensure that access is provided to private and public entities, that consumers have control over their data, and that ITS platforms operate in a stable and reliable manner. Independent assessment of the reliability of ITS technologies is also needed.

The development of connected vehicles has suffered from an inability to coordinate the provision of the required technology, in vehicles and in the infrastructure. Independent authority is needed to ensure that fully interoperable technology is deployed in vehicles of all classes, in the infrastructure of streets and highways, and in the traffic and data systems used in our cities.

The availability of data is a pervasive issue with great future potential. Protection of the rights of individuals to control their own ITS data, and consequent freedom to receive customized information, would encourage greater utility of ITS transactions. Open access to public sector pooled ITS data, while maintaining the privacy of individuals, should be facilitated. Companies benefiting from ITS standards and platforms developed with government support should be required to provide open data, consistent with their need to conduct confidential business.

Policy-makers need to move from a position of back-room support for ITS to a position of convening the future ITS.

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# A Behavioural Perspective on Voluntary Reduction of Private Car Use

# 05

Tommy Gärling and Margareta Friman

## A caveat

**The following statements about private car use appear to be similar to facts about addiction (Sellman, 2010):**

- **Increases with easy access to cars,**
- **Cannot be restrained to essential use,**
- **The goal is a trip,**
- **Leads to bodily changes (weight increases, reduced fitness),**
- **Problem is denied and others (society) blamed,**
- **Successful treatment is effortful and takes time,**
- **Relapses unless values change (selling the car).**

**Is voluntary reduction of private car use really feasible?**

A continuing increase in private car use causes several serious threats to human environments (Goodwin, 1996; Greene & Wegener, 1997; van Wee, 2007). One threat is global warming in part owing to gasoline-powered cars' emissions of carbon dioxide. Another threat is depletion of natural resources in part resulting from cars' fuel consumption and material needs. In urban areas, car traffic is a threat to livable environments owing to air pollution, noise, congestion, traffic accidents and traffic structures infringing on land use as well as demolishing aesthetic qualities and cultural values. Because of these various well-documented threats, reducing the negative consequences of private car use is on the political agenda in many countries.

Some transport policy measures aim at reducing car use in urban areas. Other measures (*e.g.* increasing capacity of road infrastructure, reducing vehicle emissions by clean car technology or fuels) do not require a car-use reduction. According to a general assessment (Hensher, 1998), a policy mixture is needed that combines investments in technological and infrastructure changes with travel demand management (TDM) targeting both reduction in car use and changes with respect to when and where car users drive, particularly on major commuter arteries during peak hours and in city centres. TDM is 'a general term for strategies and programmes that encourage more efficient use of transport resources (road and parking space, vehicle capacity, funding, energy, etc.)' (Litman, 2003,

p. 245). In keeping with this definition, TDM measures have been said to encompass any initiative with the objective of reducing the negative impact of car use (Taylor & Ampt, 2003). A list of TDM measures are given in Table 1. A new classification of TDM measures going beyond the commonly used push-pull distinction (Vlek & Michon, 1992) is presented in Loukopoulos (2007). A distinction is there made between TDM measures that are ‘forced upon’ private car users (e.g. road closures, car-free zones) and TDM measures making car users voluntarily change travel behaviour (e.g. pricing, information campaigns). It has been argued that voluntary-change measures are preferable in a democratic society. It is also the measures that car users prefer (Eriksson, Garvill, & Nordlund, 2006; Steg & Schuitema, 2007) and that may be more politically feasible (Gärling & Schuitema, 2007). Yet, if people’s voluntarily acting in their own interest causes threats to citizens’ well-being, a democratic society needs to (and does) implement ‘mutually-agreed upon’ coercive measures (Hardin, 1968; Ostrom, 1990). Current car use is such a threat to now living people as well as even more to future generations. At some point unless voluntary measures work, politicians therefore need to implement coercive measures to a larger extent than they already do.

In this chapter, we will focus on voluntary change measures from the perspective of behavioural science. In the next section, we raise a question that a fair amount of behavioural research has addressed: Does having environment-protection attitudes and values make car users reduce car use? Our answer is yes, but not to any larger extent. It is still necessary to implement transport policy measures aiming at reducing car use. A second question we address is therefore how car users respond to such transport policy measures. Lastly, we ask whether transport policy measures are effective if they are voluntary.

## 1. Does Having Environment-Protection Attitudes and Values Make Car Users Reduce Car Use?

In social psychology, attitude is a central construct defined as a positive versus negative evaluation of a target (referred to as the attitude object), which may be an object, fact, opinion or behaviour (Eagly & Chaiken, 1993).<sup>1</sup> Already in the 1970s, Fishbein and Ajzen (1975) (see also Fishbein & Ajzen, 2010) proposed an extremely influential theory of attitudinal determinants of behaviour referred to

1 Fransson and Gärling (1999) define environmental concern as a positive attitude towards protection of the environment. Schultz (2001) and Stern (1992, 2000) make a distinction between egocentric environmental concern (protection of environmental threats to own health), social-altruistic environmental concern (protection of environmental threats to all human beings) and biospheric environmental concern (protection of environmental threats to the ecosystem). As shown by, among others, Hansla, Gamble, Juliusson, and Gärling, (2008) and Hansla, Gärling, and Biel (2012), these differences in environmental concern are in different ways related to the self-enhancement versus self-transcendence value dimension described below.

as the Theory of Reasoned Action (TRA). In this theory, intention to perform a behaviour is related to the joint influence of the attitude towards performing the behaviour and a subjective norm towards performing the behaviour. Attitude and subjective norm are both defined as beliefs; in the former case, beliefs about the degree to which the consequences are positive or negative and in the latter case, beliefs about the degree to which important referents (parents, spouse, friends, society) approve or disapprove performance of the behaviour. The evaluations of the consequences of the behaviour that determine the attitude may be influenced by different factors, own previous experience, knowledge of others' experience or personal, social or societal values. An intention to switch from unsustainable to sustainable travel behaviour may be because of environment-protection values that both make environmental consequences salient and determine how positive or negative these are evaluated. Another possibility is that important referents are believed to approve switching from unsustainable to sustainable travel behaviour and thus exerting an influence through the subjective norm.

In cross-cultural research in more than 50 countries, Schwartz (1992, 1994) measured groups of people's value priorities. On the basis of the results, an invariant value structure was constructed. As Figure 1 shows, the structure is a circumplex with similarity among the values varying across the circle periphery. The values also vary along two orthogonal dimensions, self-transcendence versus self-enhancement and openness to change versus closeness to change. Empirical studies have found differences between individuals in environment-protection attitudes and values (*e.g.* Schultz & Zelezny, 1999) that are related to the degree of self-transcendence (harmony or unity with others, world and nature) over self-enhancement (feeling good about oneself and maintaining self-esteem). A measure of differences among individuals along the self-enhancement versus self-transcendence dimension has furthermore in several studies been found to correlate with self-reported pro-environmental behaviours (see meta-analysis of 57 independent samples reported in Bamberg & Möser, 2007). Some of this research demonstrates a correlation with reduction of car use (Gärling, Gillholm, & Gärling, 1998; Nordlund & Garvill, 2002, 2003).

Car use has both individual and societal consequences (Garvill, 1999). Car users prioritizing self-enhancement values tend to emphasize positive individual consequences such as comfort, time savings and flexibility, whereas car users prioritizing self-transcendence values tend to emphasize negative societal consequences including car use's threats to human environments. Yet, as in many other similar cases, commonly referred to as social dilemmas (*e.g.* Gärling, Biel, & Gustafsson, 2002; Vlek, 2007), car users have a general tendency to place higher weight on personal than societal consequences. Personal consequences are directly felt; societal consequences are postponed and since they depend on many others' car use, the responsibility individuals ascribe to themselves

for them is diluted. External social pressure (*e.g.* regulations, information campaigns) or internalized social norms (*e.g.* felt moral responsibility; see Biel & Thøgersen, 2007; Thøgersen, 2006, for different conceptualizations of subjective norm) are therefore important factors in attempts at influencing car use.

In TRA, there is no acknowledgement of the existence of impediments to performing a behaviour (implementing an intention) such as situational constraints or lack of financial and other resources. Ajzen (1991) therefore proposed an extended theory referred to as the Theory of Planned Behaviour (TPB). In this theory, perceived behavioural control is an additional determinant of intention. If control over the behaviour is perceived to be complete, TPB does not differ from TRA. TPB highlights the relation between intention and behaviour: The correspondence between intention and behaviour will increase with the degree to which perceived behavioural control accurately matches actual control. Gärling and Fujii (2002) proposed and found evidence for a modified TPB. As shown in Figure 2, reflecting a desirability or optimism bias (Bar-Hillel & Budescu, 1995), attitude is posited to causally influence perceived behavioural control such that the more desirable a behaviour is, the more one perceives to have control over the behaviour. Since actual control is not affected, the consequence is a larger discrepancy between perceived and actual control. The discrepancy is further exaggerated since high perceived behavioural control reduces the felt need to plan, that is, to acquire knowledge of how to implement the intention. On the other hand, a low perceived behavioural control increases planning such that the discrepancy between perceived and actual control decreases. In this way, the modified TPB provides an explanation of why forced planning (mental or actual practice) has such large positive effects on the correspondence between intention and behaviour (Gollwitzer & Sheeran, 2006).

The correspondence between attitude (or intention) and behaviour has been extensively researched since the 1950s (see, *e.g.* meta-analyses by Conner & Armitage, 1998; Sheppard, Hartwick, & Warshaw, 1988). The initial belief was that the correspondence would be perfect ('one should expect that people do what they say that they would do'). After this belief had been refuted by early studies, for a time the reverse was believed ('what people say they would do cannot be trusted'). The truth is that the correspondence is not perfect but generally strong. Also, the reasons why it is not perfect have been identified. Applied to travel behaviour, Fujii and Gärling (2003) discussed two types of errors: People do not do what they intend to do (false positives) or people do what they not intend to do (false negatives). False positives are examples of influence of situational factors: A rainy morning may change an intention to walk or bike to work and instead use the car. False negatives are exemplified by habits: An intention to walk to work may be overridden by a developed habit to use the car for the work commute. Both false

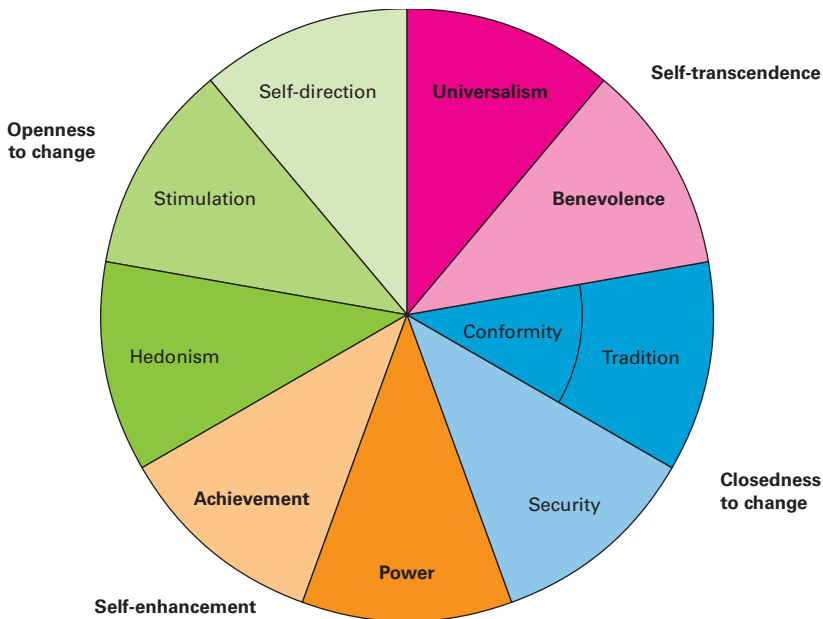


Figure 1. The circumplex structure of value priorities (Adapted from Schwartz, 1992, 1994).

negatives and false positives are counteracted by strong intentions, which in turn are influenced by attitude, subjective norm and perceived behavioural control. In another extension of TRA referred to as the Theory of Interpersonal Behaviour (Triandis, 1977), a complementary relationship is proposed between intention and habit such that when a habitual behaviour is developing, the influence of intention becomes proportionally weaker, and the reverse. A habit may, however, not develop only because a behaviour is repeated. Its repetition also needs to result in reduced pre-choice information processing<sup>2</sup> (Gärling, Fujii, & Boe, 2001; Verplanken, Aarts, van Knippenberg, & van Knippenberg, 1994; Verplanken, Aarts, & van Knippenberg, 1997). A new situation usually brings out a process of searching and evaluating available information to reduce uncertainty about what to choose (or how to behave). If the choice or behaviour has a positive outcome, the probability that it will be repeated increases. After having been repeated a number of times, the need to search and evaluate information may become reduced. The reduced need is because the relevant information is embedded in

<sup>2</sup> Ajzen (2002) argues that a behaviour may be repeated because one has a stable positive attitude towards the behaviour and therefore has an intention to perform the behaviour. It cannot thus be inferred from observing a repeated behaviour that it is a habit unless also demonstrating that pre-choice information processing is reduced.

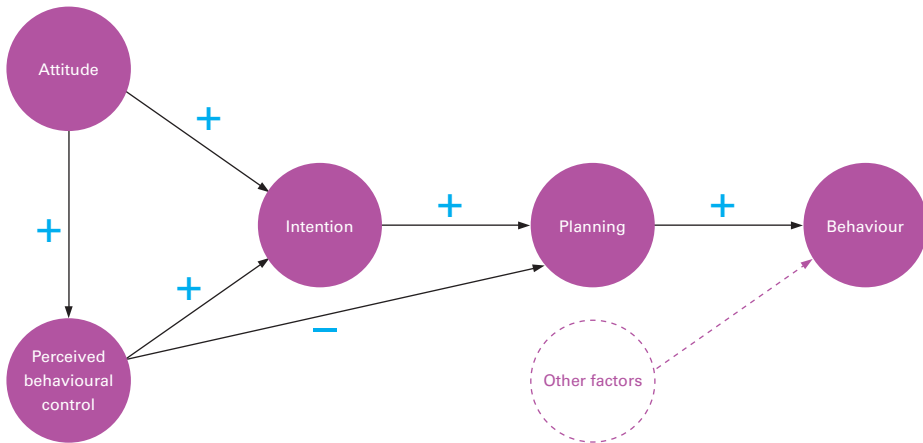


Figure 2. Mediators of the Attitudinal Determinant of Behaviour (Gärling & Fujii, 2002).

a behavioural script retrievable from memory. If a choice is required, it is said to be script-based. The development of script-based choice is facilitated if the circumstances are not changed. For instance, always using the car for the work commute may develop into a script-based choice such that information about alternatives are not searched and evaluated. But the habit of using the car may also generalize to other trips, eventually resulting in a generalized car-use script (Fujii & Gärling, 2007). Breaking a car-use habit is possible by forcing car users to process information about alternative modes (Fujii & Kitamura, 2003; Fujii, Gärling, & Kitamura, 2001; Garvill, Marell, & Nordlund, 2003; Thøgersen, 2009; Thøgersen & Møller, 2008). Yet, a new habit of using alternative modes may not develop if it does not lead to a positive outcome.

*Summary.* Environment-protection attitudes and values are related to a dominance of self-transcendent value priorities (harmony or unity with others, the world and nature) over self-enhancement value priorities (feeling good about oneself and maintaining self-esteem). This difference in value priorities is weakly related to pro-environmental behaviours including choices to reduce private car use. Prioritizing self-transcendent values over self-enhancement values makes people place a higher weight on societal consequence (threats to human environments) over personal consequences (comfort, time savings and flexibility). Whether and how value priorities may be changed and what the consequences would be for pro-environmental behaviours have not been investigated. This is an issue for future research. Other factors than environment-protection attitudes and values still seem to have important influences on private car-use reduction. These factors include social norms, situational constraints and habits.

## 2. How and Why Do Car Users Respond to Transport Policy Measures Aimed at Changing Their Car Use?

The potential effectiveness of different transport policy measures implemented with the aim to reduce or change car use depends on how car users (and sometimes also others) respond to them. Theoretical accounts have been given in the past, exemplified by economic demand theory (Ubbels & Verhoef, 2007), micro-economic choice theory entailing the assumption of utility maximisation (McFadden, 2001) or the proposition of behaviouristic psychology before the 1950s of that behaviour is controlled by hedonic feedback (Dwyer, Leeming, Cobern, Porter, & Jackson, 1993). All these accounts have in common that they fail to recognize that private car use primarily results from people's needs, desires and obligations to participate in various out-of-home activities (*e.g.* work/school, shopping, exercising or visiting friends/relatives) (Axhausen & Gärling, 1992; Gärling, Kwan, & Golledge, 1994; Jones, Dix, Clarke, & Heggie, 1983; Root & Recker, 1983), and that, therefore, car-use reduction must be broadly viewed as changes that may potentially have consequences for car users' satisfaction with their everyday life. In this section, we propose an alternative theoretical framework grounded in self-regulation theories in cognitive and social psychology (Carver & Scheier, 1998). The theoretical framework (Gärling, Eek, et al., 2002) lays out a new approach for how to understand the multi-faceted nature of car users' responses to various transport policy measures. It is to some extent implemented in current methods for voluntary travel behaviour changes that will be discussed in the next section.

The theoretical framework is illustrated in Figure 3. The various travel alternatives people face consist of bundles of objective attributes that describe trip chains (purposes, travel modes, destinations, departure/arrival times, travel times and monetary costs). Individuals' choices of travel alternatives are partly determined by these bundles of attributes. Another determinant is the goals that individuals set. Such goals form a hierarchy from the concrete (programmes) to the abstract levels (principles). The goals are nested reference values in negative feedback loops that regulate ongoing behaviour or changes in behaviour. The feedback consists of acquired information that is used to regulate behaviour to attain goals. If a discrepancy between the present state and the goal arises, some action is carried out with the aim of minimising the discrepancy. After implementing, for instance, a road pricing scheme, a car-use reduction goal may be set if individuals experience an increased monetary travel cost (Loukopoulos, Gärling, & Vilhelmson, 2005). On the other hand, if various other changes are encountered, such as decreased travel times by car (due to less congestion) or decreased living costs (*e.g.* children moving out, income increases), a car-use reduction goal may not be set. In effect, there exists no direct relationship between increasing the monetary costs of private car use and individuals' setting of a car-use reduction goal. A similar line of reasoning would apply to changes in choices of destinations, departure times and routes.

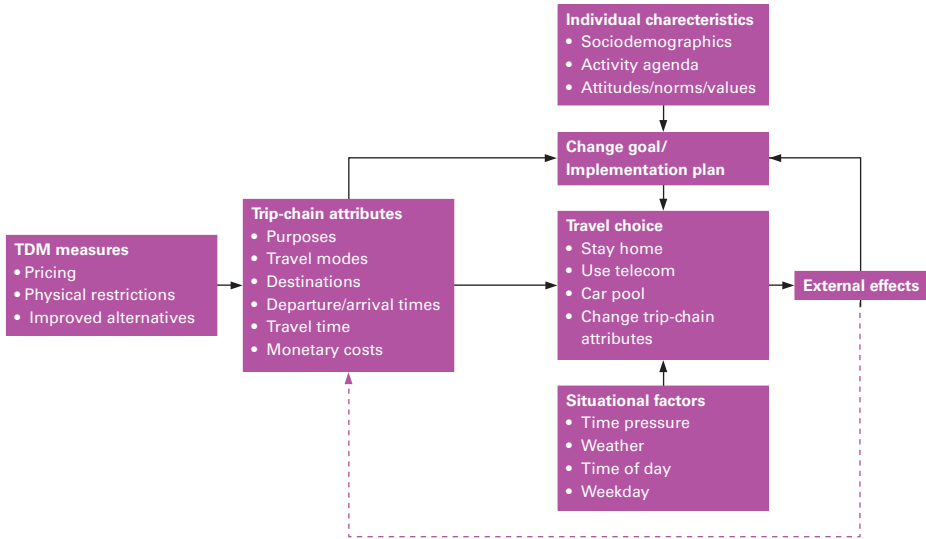


Figure 3. The Theoretical Framework (Adapted from Gärling et al., 2002b).

A broad range of needs, desires, attitudes, norms and values influence the goals that individuals set and which they strive to attain (Austin & Vancouver, 1996). A parallel has been drawn to TRA and TPB by equating goal with (goal) intention (Gollwitzer, 1993). And as already noted, as in TRA and TPB, intention is influenced by attitudes, (subjective) norm and value, including also environment-protection attitudes and values. Goals are assumed to have the two primary attributes content and intensity (Locke & Latham, 1990, 2006). Goal content in turn has four separate parts: difficulty, specificity, complexity and conflict. Difficulty is related to the degree of impediments to obtain the goal, specificity to whether or not the goal is easy or difficult to evaluate, complexity to the number of different evaluation dimensions and conflict to the degree to which the achievement of one goal inhibits achievement of another goal. The second primary attribute, intensity, is related to commitment, perception of goal importance and the processes engaged by goal attainment. Previous research on goal setting and attainment (e.g. Lee, Locke, & Latham, 1989) has shown that specific, more difficult goals may increase the likelihood that they are attained. Degree of commitment to the goal, degree of knowledge and skill, and immediacy and clarity of feedback about goal progress are moderating factors.

After having set a car-use reduction goal, individuals form a plan for how to achieve the goal and make commitments to execute the formed plan. In social psychology, this process is referred to as the formation of implementation

intentions (Gärling & Fujii, 2002; Gollwitzer, 1993). The plan that is formed consists of predetermined choices that are contingent on specified conditions (Hayes-Roth & Hayes-Roth, 1979). In making plans for how to reduce their car use, individuals may consider a wide range of alternatives such as staying at home, suppressing trips and activities or using electronic communications instead of driving, or they may car pool or change the effective choice set of travel alternatives including purposes, destinations, modes or departure times. Eventually, they may also consider longer-term strategic changes, such as, for instance, moving to another residence, change work place or work hours.

It is hypothesized that individuals seek and select options that lead to the attainment of the goal they have set, although it is not assumed that this process necessarily lead to an optimal choice among all available options. Consistent with the notion of bounded rationality (Gigerenzer, 2008; Simon, 1982), it is instead assumed that options are chosen that are satisfactory but not necessarily the best available. Experimental laboratory-based research (Payne, Bettman, & Johnson, 1993) has shown that people in an optimal way invest as much effort that is required to make a sufficiently accurate decision. Yet, they may still not attain an optimal outcome because of cognitive bottlenecks (Kahneman, 2011). This is an important difference to microeconomic utility-maximisation theories, assuming that people invariably invest maximal effort leading to an optimal (utility-maximizing) outcome. In the theoretical framework, how much effort people invest depends on properties of the set goal (*e.g.* if it is specific or non-specific).

A second important difference to utility-maximisation theories is that individuals' choices are made sequentially over time. This implies that a change-process is prolonged and thus fails to instantaneously result in a positive outcome. Furthermore, both benefits (effectiveness) and costs of the chosen alternatives are evaluated. If such evaluations after a moderately costly change seem to indicate that there is still a discrepancy between the outcome and the goal, more costly changes may be chosen. Even though it has been shown that people make optimal accuracy-effort trade-offs in laboratory experiments (Payne, Bettman, & Johnson, 1988), we do not know whether they do in real life when making complex travel choices. Actually, much speak for that people fail to make optimal accuracy-effort trade-offs when they make complex travel decisions. It is well documented that habitual car use and other daily habits and routines cause choice inertia (Fujii & Gärling, 2007; Verplanken et al., 1994, 1997), and research has also demonstrated that a status quo bias exists such that the current state is overvalued (*e.g.* Samuelson & Zeckhausen, 1988) making changes less attractive. Particularly if a car-use reduction goal is non-specific, evaluations of whether or not a change-alternative is effective may possibly be biased towards confirming the expectation that it is not (Einhorn & Hogarth, 1978; Klayman & Ha, 1987). Furthermore, previous research has demonstrated that an immediate and clear

feedback is essential (Brehmer, 1995). A system for changing current car use that does not provide such feedback is likely to fail. It is also possible that a goal is reduced or given up if the costs increase too much.

On the basis of the theoretical framework, the existence of a hierarchy of car-use change alternatives that vary in effectiveness and costs has been proposed (Gärling, Gärling, & Loukopoulos, 2002). In Table 2, three distinctly different categories of potential change options are specified together with the costs associated with each. It is further assumed that an inverse relationship exists between effectiveness and psychological costs for these change alternatives. In the following, a description is given of each alternative.

A first stage involves making car use more efficient by chaining car trips, car pooling or choosing closer destinations. The costs are an increased need to plan ahead. The resulting change in car use may, however, not be sufficient to achieve the car-use reduction goal that is set.

In a second stage, trips may also be suppressed in order to achieve a larger reduction in car use. In addition to increased planning, trip suppression implies changes in activities but perhaps merely suppression of some isolated (*e.g.* shopping) trips. With regard to activity change, leisure activities seem to be the next most likely to be removed from the activity agenda or substituted by in-home activities, whereas more consequential changes, for instance, in work hours are the least likely.

If the car-use reduction goal is still not attained, other travel modes than the car are chosen. For instance, since work activities cannot easily be suppressed, public transport may be chosen for the work commute. The costs associated with switching mode include additional planning and increased time pressure. Thus, in order to alleviate the effects of a potentially harmful increased time pressure (Gärling, Gillholm, & Montgomery, 1999; Novaco & Gonzales, 2009), suppression of some minor leisure activities and shopping trips may also be made.

It should be noted that Table 2 describes only a possible way of how sequential choices of change alternatives are made. Survey results suggest that the hypothesized hierarchy may vary with trip purpose and household as well as individual characteristics (Gärling, Gärling, & Johansson, 2000; Loukopoulos, Jakobsson, Gärling, Schneider, & Fujii, 2004). Furthermore, it may not always be the case that costs vary inversely with effectiveness; transport policy measures may be applied, or other changes (*e.g.* residential relocation) may occur, that either singly or in combination facilitates less costly changes that are effective.

TDM measure	Examples
Physical change measures	<ul style="list-style-type: none"> <li>- improving public transport</li> <li>- improving infrastructure for walking and cycling</li> <li>- park and ride schemes</li> <li>- land use planning to increase accessibility</li> </ul>
Legal policies	<ul style="list-style-type: none"> <li>- prohibiting car traffic in city centres</li> <li>- parking control</li> <li>- decreasing speed limits</li> </ul>
Economic policies	<ul style="list-style-type: none"> <li>- taxation of cars and fuel</li> <li>- road or congestion pricing</li> <li>- kilometre charging</li> <li>- decreasing costs for public transport</li> </ul>
Information and education measures	<ul style="list-style-type: none"> <li>- individualized marketing</li> <li>- public information campaigns</li> <li>- social modeling</li> </ul>

Table 1. Travel Demand Management (TDM) Measures (Adapted from Steg, 2003).

*Summary.* In the preceding section, we reviewed three major social-psychological theories primarily accounting for attitudinal determinants of travel behaviour and changes in travel behaviour. In this section, we have described an alternative theoretical framework grounded in self-regulation theories. It subsumes elements of the attitude theories. As has been noted, it constitutes an extension of economic demand theory, microeconomic utility-maximisation theory and behaviouristic psychology's hedonic feedback principle.

In order to understand how transport policy measures affect car-use reduction, the theoretical framework posits that two processes need to be examined further. The first is how the measures affect the size and type of car-use reduction goals that are set by different individuals. The second is the degree to which the measures facilitate or prevent that set car-use goals are attained. These questions should be answered in advance of implementing any transport policy measure, preferably by empirical studies. In the next section, we review such studies.

Change alternatives	Possible costs
More efficient car use - Trip chaining - Car pooling - Choosing closer destinations	Additional planning
More efficient car use - Trip suppression	Additional planning Activity suppression
More efficient car use - Trip suppression - Mode switching	Additional planning Activity suppression Increased time pressure

Table 2. Three Categories of Change Alternatives and Their Associated Costs (adapted from Gärling, A. Gärling, and Loukopoulos, 2002).

### 3. Are Voluntary Changes in Car Use Effective?

Voluntary travel behaviour (VTBC) measures have been proposed as being an attractive democratic and effective method for making private car users reduce their car use. A definition given by Ampt (2004) is ‘...change that occurs, when individuals make choices for personal reward without a top-down mechanism, regulation of any sort or a feeling of external compulsion’. VTBC measures have been applied widely in the form of, or as part of, sometimes extensive programmes. In the beginning, the programmes were small-scale engaging only hundreds of households. In Australia, it started with two early trials of *TravelBlending* in Sydney and Adelaide (Rose & Ampt, 2001). An early implementation of the *IndiMark* programme took place in Perth, Australia (Brög, Erl, Ker, Ryle, & Wall, 2009). Another implementation was launched in Brisbane (Marinelli & Roth, 2002) as part of ‘TravelSmart’, a broader programme to preserve the environment and increase quality of life. Implementations have then been growing in number, engaging increasingly larger number of households. Most of the state capital cities in Australia have significant programmes running, broadly aimed at the implementation of more sustainable travel behaviour and transport systems. Several large-scale implementations of *IndiMark* have been made in Australia, Austria and Germany targeting thousands of households (Ker, 2003). In the UK, ‘personalized travel planning’ programmes have been implemented (Cairns et al., 2008), and in Japan ‘travel feedback’ (TFB) programmes (Taniguchi, Suzuki, & Fujii, 2007). A general conclusion from both meta-analyses (Bamberg & Möser, 2007; Fujii & Taniguchi, 2006) and narrative reviews of evaluation studies (Jones & Sloman, 2006; Richter, Friman, & Gärling, 2010, 2011; Redman, Friman, Gärling, & Hartig, 2012) is that these different programmes succeed in reducing private car use. One may still question this conclusion since evaluations of many of the large-scale programmes have lacked adequate controls (Fujii, Bamberg, Friman, & Gärling, 2009; Stopher, Clifford, Swann, & Zhang, 2009), whereas

adequately controlled evaluations have been small-scale targeting selected samples. In the remaining part of this section, we present and discuss the techniques that are the effective ingredients of VTBC measures.

VTBC programmes differ in where and how they are implemented (see Table 3). Implementation may be made in residential areas targeting all trips or in work places or schools targeting only commute trips. Techniques used as part of VTBC measures differ in whether they (1) include motivational support (changes in attitude, subjective norm) to set a goal (intention) to change travel, (2) request that plans are formed for how to change travel (implementation intention) and (3) provide customized information facilitating plan execution (negative feedback controlling goal progress). For instance, both IndiMark (Brög et al., 2009) and TravelBlending (Rose & Ampt, 2003) provide customized feedback information. In addition, TravelBlending provides motivational support without, however, directly requesting goals to be set. Only Japanese TFB programmes (Fujii & Taniguchi, 2005) have requested that goals are set and that plans are formed. VTBC measures also differ in the procedure they follow. IndiMark involves two or three contacts to conduct a travel survey as well as measuring intentions to change travel, to provide customized information and to provide further customized information if necessary. TravelBlending involves four contacts, with the purpose to motivate a travel change, to conduct a travel survey, to provide customized comments and to provide additional customized comments. A single contact is entailed by less elaborated programmes (Taniguchi et al., 2007).

Bamberg, Fujii, Friman, and Gärling (2011) noted that the techniques used by VTBC measures are key to an understanding of why they work. In principle, techniques entail *communication* to participating car users. As Figure 4 shows, the targets of such communications are determinants of car-use changes as identified in the preceding sections.

As was illustrated in Figure 1, the process of car-use change starts with the setting of a change goal (car use reduction and/or increase in public transport use), followed by the formation of a plan for achieving the set goal, and lastly obtaining and processing of feedback about goal progress. Setting a change goal is equivalent to forming an intention (Ajzen, 1991; Fishbein & Ajzen, 1975; Gärling & Fujii, 2002) that is influenced by anticipated positive consequences of changing current travel behaviour or avoiding negative consequences of not changing current travel behaviour (attitude); social pressure and felt obligation (subjective norm) to travel more in line with self-relevant standards and perceived feasibility of attaining the goal, primarily the perception of feasible travel alternatives (perceived behavioural control). Following goal setting and the formation of a plan, plan execution is regulated by negative feedback.

Location	Technique	Procedure
Residential area (all trips) Workplace (commutes) School (commutes)	Motivational support Customized information Request for goal setting Request for plan formation	Single stage Multistage (travel diary survey, feedback)

Table 3. VTBC Programs Differ in Where and How They Are Implemented (Gärling & Fujii, 2009).

Techniques that provide feed-forward information target goal setting, either directly or indirectly by influencing its determinants (attitude, subjective norm and perceived behavioural control) through motivational support. Taniguchi et al. (2007) showed that public-transport use increased by 76% for TFB programmes in Japan that directly requested goal setting compared with 25% with no request of goal setting. Independent evidence for the need for motivational support inducing a positive attitude is not available since this was provided for almost all TFB programmes (26 out of 31). Most of them (24) used environmental damages as arguments for change, but also health (15) and the availability of specific public transport resources (9) were used to motivate changes. Providing feedback may likewise be conceived of as motivational support. It is, however, often unclear what kind of feedback should be given and how it works. For instance, some people may set a goal to lose weight (walking and cycling providing more exercise than driving) and consider feedback on weight loss to be essential. Other participants set goals to reduce car use because they cannot any longer afford using their cars as much as before. They would presumably be motivated by feedback on how much money they save.

A plan (e.g. how to use the bus instead of the car for work trips) needs to be formed to attain the set car-use reduction goal. Fujii and Taniguchi (2006) conclude in their review of Japanese TFB programmes that requesting a plan to be formed has a strong effect on travel behaviour changes. Such programmes yielded the largest reduction in CO<sub>2</sub> emissions (35%), the largest reduction in car use (25%) and the largest increase in public transport use (100%). In a meta-analysis of the results of 14 TFB programmes (Taniguchi et al., 2007), it was shown that car-use reductions were more strongly achieved in 11 programmes, which requested participants to form a plan for how to change their travel behaviour. In seven of the 14 programmes, participants were also asked to set a change goal before forming a plan by stating the percentage by which they would reduce their car use and increase their public-transport use, respectively. The average car-use reduction for the goal-setting programmes was 20% compared with 10% for the programmes with no goal setting. Yet, the results are inconclusive because at least four of the latter programmes also featured a request to form a plan.

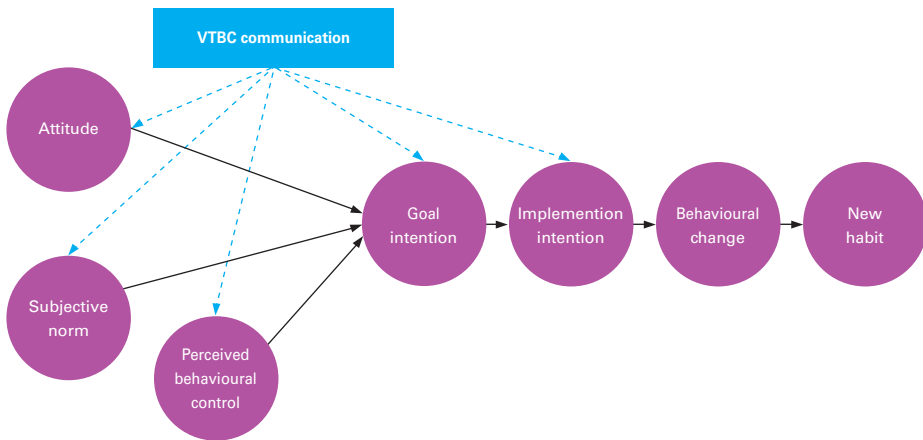


Figure 4. The Targets of Communication in Voluntary Travel Behaviour Change (VTBC) Programmes.

It has been proposed that customized information about alternative travel modes facilitates the formation of a plan to change travel. Consistent with this, Brög and Schädler (1999) found that in an implementation of IndiMark in Germany, an increase in public transport use from 53% to 64% was observed for those who had been informed about public transport alternatives but no change for those who had not been informed. It may still be possible to inform people about public-transport alternatives through non-customized information if the information attracts sufficient attention, for instance, in times of increasing gasoline prices. However, drawing on parallels to customer-oriented marketing, Brög (2000) argued against this by noting that, instead of being flooded by useless information, people should receive only the information they need. Brög and Schädler (1999) reported a study where an Austrian public-transport operator sent out standardized information packages. Another group took part in the IndiMark programme that uses customized information packages. A control group received no information. The results showed that the public transport shares in the group with standardized information was the same as in the control group, while in the IndiMark group the public transport shares were 17% larger.

Providing customized information is not invariably used. Taniguchi and Fujii (2007) reported a TFB programme providing non-customized information on how to use bus services. Additionally, participants were asked to form a plan for how to use these services. This programme resulted in a strong increase in the frequency of bus use. Yet, customized feed-forward information, for instance an individually designed map for public transport, may have had an even stronger impact.

Because customized information minimizes the cognitive costs of processing the information, it should be more effective in facilitating a behavioural change. But it may not be necessary in case participants are requested to form a plan (Fujii & Taniguchi, 2006). A programme using the latter technique is perhaps successful because it forces participants to consider travel alternatives and acquire the needed information themselves. Thus, while forming a plan, participants invest the cognitive costs they would not choose to do if they were not requested to form a plan. In a field experiment by Fujii and Taniguchi (2005), the effectiveness of a TFB programme that requested participants to form plans (the planning group) was compared with a TFB programme that only provided customized information (the advice group). The results showed that the planning group reduced the number of days of car use more than the advice group.

*Summary.* Available evidence suggests that the techniques of motivational support and requests to set goals of changing travel behaviour, requests to form plans for how to change travel behaviour and providing customized information of how to make changes are effective ingredients in VTBC programmes. It is still the case that too few systematic comparisons have been made at a large scale, allowing the relative cost-effectiveness of each technique to be determined. Yet, this may not be the appropriate approach since evidence suggests that the techniques jointly affect the different components of the process of voluntarily changing travel. Evaluating techniques that according to theoretical analyses are optimally combined appears to be more needed.

#### 4. Remarks

It has been argued (Figure 4) that VTBC measures embedded in large-scale programmes aim at changing targeted private car users' knowledge, attitudes and values such that their car use is reduced or changed. *Since the measures use techniques to influence car users, is it justified to refer to them as 'voluntary'?* A parallel may be drawn to the current discussion of libertarian paternalism (Thaler & Sunstein, 2008): 'Nudging' people in a certain desirable direction may still count as a voluntary change. Although people are invited (and perhaps urged) to participate but still have freedom to do so (and to quit at any later point in time), does this not qualify the measure as voluntary? Taylor (2007) claimed that 30-40% of Australian households offered to participate in VTBC programmes at least consider participating. It was also found that participants had more positive environment-protection attitudes than non-participants. Seethaler and Rose (2005) furthermore demonstrated that Australian households who already use public transport are more likely to participate. A related question asks whether those who participate and change their car use differ from those who participate and fail to change? Fujii and Taniguchi (2006) reported results from Japan

indicating that an implemented neighbourhood TFB programme was more effective in promoting public transport in new residents than in old residents. It was believed that the former were less likely to have developed habitual car use and would therefore more easily change. In a similar vein, Ampt (2004) found that in Australia individuals and households are more likely to change their travel after having encountered significant changes in their lives such as a new job, the birth of a new child, or moving house.

VTBC measures are sometimes applied in conjunction with transport policy measures that change travel alternatives. *Do concurrent changes in travel alternatives make VTBC measures more effective and the reverse?* Even though walking and biking are popular sustainable alternatives to car use (Olsson, Gärling, Ettema, Friman, & Fujii, 2012), these slow modes are restricted to some user groups, short trips and good weather conditions. Public transport should therefore generally be considered to be the most important sustainable alternative. Only providing economic incentives do not seem to be sufficient: Previous research has failed to show lasting effects of a free monthly public-transport ticket offered to frequent car users (Fujii & Kitamura, 2003; Thøgersen & Møller, 2008). In a field experiment in Denmark, Thøgersen (2009) furthermore failed to find that economic incentives (as motivational support) work better if combined with VTBC measures. Likewise, Brög and Schädler (1999) compared the effects of free public-transport tickets in an IndiMark programme and the distribution of free public-transport tickets in a German city without any other treatment (e.g. information or motivation). Before-after comparisons revealed no differences in modal shift. Jakobsson, Fujii, and Gärling (2002) showed that increased costs reduced car use only if combined with requests to make plans for how to switch to other modes or suppress travel.

In contrast, available evidence shows that effectiveness of VTBC programmes may increase if accompanied by improvements of the quality of public transport (see Redman et al., 2012, for review). Reliability, frequency, travel time and fare level (Hensher, Stopher, & Bullock, 2003), comfort and cleanliness (Swanson, Ampt, & Jones, 1997) as well as security (Smith & Clarke, 2000) are important determinants of positive evaluations of quality of public transport services. Friman, Edvardsson, and Gärling (1998, 2001) and Friman and Gärling (2001) furthermore emphasized the importance of understandable and easily available information. Findings from Auckland, New Zealand, showed that good quality public transport is an important condition for the effectiveness of VTBC measures (Taylor, 2007). Ker (2003) analyzed large-scale implementations of IndiMark in six German cities, which were accompanied by improvements to public transport services, ranging from minor increases in service level to extension of a subway line to the target area. Increases in public transport use were observed compared with control groups.

Evidence thus seems to suggest that in the individual planning phase of VTBC programmes, providing attractive travel alternatives is the most effective. This is understandable since participants are already motivated by having set a change goal, thus they have moved to the planning phase. *Would in this stage attending to alternatives that are satisfactory increase positive attitudes to these alternatives?* This is in contrast to solely providing economic incentives – when these are discontinued behaviour tends to revert back (Dwyer et al., 1993). If the attitude becomes positive, the behaviour is instead likely to be repeated and a habit eventually developed.

*Is voluntary setting of car-use reduction goals really essential?* Fujii et al. (2001) showed that a forced change (a temporary freeway closure) led to that car users switched to public transport that for some of them lasted after the freeway opened again. It is important to note that these car users did not switch voluntarily. A possible explanation for switching was claimed to be that the car users' previous over-estimates of travel time with public transport were corrected. Pedersen, Friman and Kristensson (2011a, 2011b) likewise demonstrated that anticipated dissatisfaction with using public transport changed to satisfaction after car users (voluntarily) started to use public transport.

## 5. Implications for Transport Policy

The fact that voluntary change from unsustainable to sustainable travel apparently occur should not be taken to imply that transport policy measures aiming at car-use reduction are not needed. Theoretical and empirical evidence in fact suggests that voluntary changes are unlikely unless (1) car users form an intention to change, for instance, owing to increasing car-use costs or that they are persuaded to feel responsible for contributing to the protection of the environment, (2) acceptable alternatives are available and (3) society and important others approve change (or disapprove non-change). Although an intention to change (based on a positive attitude) is necessary, it is thus not sufficient. A broadband mix of transport policy measures is called for. These measures are in place. What seems to be lacking is the insight that no single measure is a quick fix. For instance, developing green cars and fuels has too little impact if car use continues to increase. Besides, similar to planning the environment such that accessibility increases, these are long-term measures that in the short term have to be complemented by other measures. Car-use charges do not work unless acceptable alternatives are available and the public perceives they are justified. It does not mean that they should not be pursued. Prohibition of car use can only be used to a limited extent since alternatives are not available. It may still in the end be argued that in a democratic society, no measure will work unless car users are motivated to change. Influencing car users through different information techniques therefore has a central role.

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# Wishful Thinking in Transport Policy

# 06

Arie Bleijenberg

- **This essay advocates a realistic vision on how to achieve sustainable mobility. The focus lies on more than halving CO<sub>2</sub> from European transport, while these emissions are now still growing.**
- **Wishful thinking needs to be ended about both reducing mobility growth and a modal shift away from the road. Such changes can be achieved only by policies that restrict road transport – limited road capacity, transport pricing and lower speed limits – and hardly by stimulating alternatives for the road.**
- **Between two-thirds and three-quarters of the required reduction in CO<sub>2</sub> emissions from transport can be achieved by clean technology: very energy-efficient vehicles in combination with low-carbon energy. Most technologies are waiting on the shelves to get on the road, and new innovations will emerge. However, this will happen only if the knobs of already applied policy instruments are turned much tighter.**
- **The policy measures used to achieve low-carbon transport should not favour specific technologies – for example, electric vehicles or bio fuels – but need to be technology neutral. The incentives should be on reducing CO<sub>2</sub> emissions regardless of the specific technology.**
- **Between one-quarter and one-third of the required reduction in CO<sub>2</sub> emissions can be achieved by making transport policies more economic sound. Combating congestion is not the right compass for transport policy, and wishful thinking about this needs to be ended also. Instead, the economic focus should shift to improving accessibility, being the combination of nearness and speed.**

## 1. Public Transport and Urban Planning

In the 1970s, public concern arose about the degradation of our environment. Evidence strengthened that our health, buildings and forests were negatively affected by acid rain, noise, black soot, the destruction of the ozone layer and other forms of pollution. Also the conviction grew, that the increasing concentration of greenhouse gases (GHG) in the atmosphere will lead to dangerous changes in the global climate. It became urgent to reduce our ecological footprint. From the start it was evident that mobility was one of the main causes of the environmental problems. Industry, agriculture and energy use for buildings

are other major sources of pollution. Now, 40 years later, substantial progress has been made in reducing air, water and soil pollution. However, some persistent environmental problems are still not tackled. Climate change is one of these persistent challenges we face, and reducing CO<sub>2</sub> emissions from transport appears to be the hardest to achieve.

The core of the green answer to reduce the environmental impact of mobility was to reduce car and truck use, or at least reduce its strong growth. It was – and still is – advocated that drastic changes in our mobility patterns are unavoidable. Public money was spent on improved bus services, high-speed rail lines, light rail connections, passenger terminals, multi-modal freight hubs, dedicated freight rail lines, P + R facilities and so on. This was intended to counteract the rapid increase in market share of road transport, which accelerated from the 1960s. These policy measures were, of course, in the interest of railway companies, who used the environmental concerns as an argument to increase their subsidies. Green politics supported this vision, and it took a few decades before environmentalists began to oppose to some new railway lines, especially for high speeds.

In addition to support for alternative transport modes, better urban planning should shorten travel distances and reduce car dependency. Wrongly planned new towns were blamed for increased commuting distances, car traffic and the resulting congestion. Walking and cycling were seen as alternatives for the car.

It is evident that the above incompletely summarized approach to achieve sustainable mobility has not been successful. The market share of cars and trucks continued to grow, as is convincingly shown in the Figures 1 and 2.

And despite the use of more energy efficient cars, vans and trucks, the total CO<sub>2</sub> emissions from European transport increased by 30% in the period 1990-2005. Finally, statistics reveal that urban planning did not succeed in stopping the growth in travel distances. For decades, the average trip distance has grown by somewhere around 1% per year.<sup>1</sup> Each year we travel further to work, for leisure, shopping and visiting friends and relatives. And each year the production of our consumer goods requires more truck kilometres due to logistical changes. Do not blame the urban planners for this increase in trip distances, because people and firms decide themselves where they locate their activities, although within the boundaries drawn by planning authorities.

In retrospect, the policy papers from the 1970s and 1980s advocating the above summarized vision of sustainable mobility showed to be mainly wishful thinking.

1 Aviation is wrongly not included in most mobility statistics, and its inclusion would reveal a higher growth in average trip distance.

The business as usual projections, on the other hand, turned out to be rather accurate. One illustration of wishful thinking is the former aim of the European Union to keep the modal split in freight transport at its 1990 level. This can only be labelled as a political illusion, with the knowledge of the real world developments as shown in Figure 2. Nice to tell to voters, but entirely incredible from the outset.

So, the sketched vision of sustainable mobility needs a rethinking in the light of reality. The following parts of this essay develop a new vision on sustainable mobility, acknowledging – instead of neglecting – the main driving forces behind transport and mobility.

## 2. Speed

Some argue that the attempts to change the modal split and to reduce transport demand have not been fierce enough. And they have a point. However, I am convinced that ‘more of the same’ will not result in sustainable mobility, for this approach does not take account of speed as one of the fundamental driving forces behind mobility.<sup>2</sup>

The history of transport can be described as an ongoing decline in the ‘friction of distance’. Faster transport is the most important key in this development, especially for passenger travel.<sup>3</sup> Until the industrial revolution, travel speeds were low and had not increased much for ages: walking around 5 km/h, horses and boats between 8 and 15 km/h. The associated mobility volumes stayed small. Then, within a century between 1830 and 1910, the main modern transport technologies were developed: steam railway, car, truck, diesel ships, electric train and airplane. These new technologies made higher transport speeds possible.

2 The dominant role of speed in the development of mobility is discussed at length in ‘The attractiveness of car use’ (Bleijenberg, 2012).

3 The ‘friction of distance’ comprises the time, costs and discomfort of covering a certain distance. For passengers, the travel time is dominant in the long run. For freight, the concept of ‘generalized costs’ is adequate, comprising direct costs of transport, transshipment, storage, risks and interest losses (e.g. owing to transport time). This essay does not discuss the drivers behind freight transport at length. However, the central point that reducing the ‘friction of distance’ is a major driver behind both transport growth and mode choice is valid for both passengers and freight. For freight, the removal of trade barriers is a second major cause of growth.

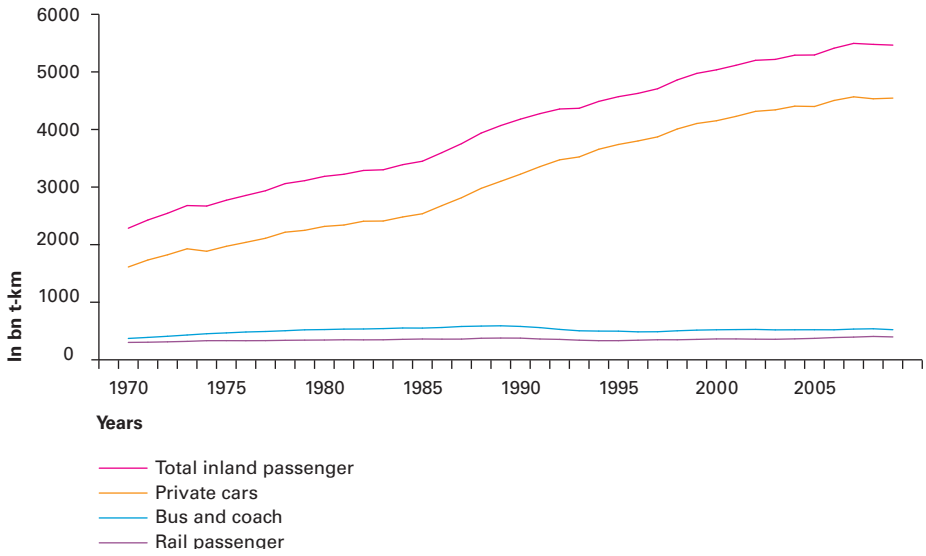


Figure 1. Historic development of EU27 passenger transport, 1970 - 2009 (in billion t-km). The car dominates 40 years of growth in passenger mobility (CEPS, forthcoming, based on ITF/OECD data).

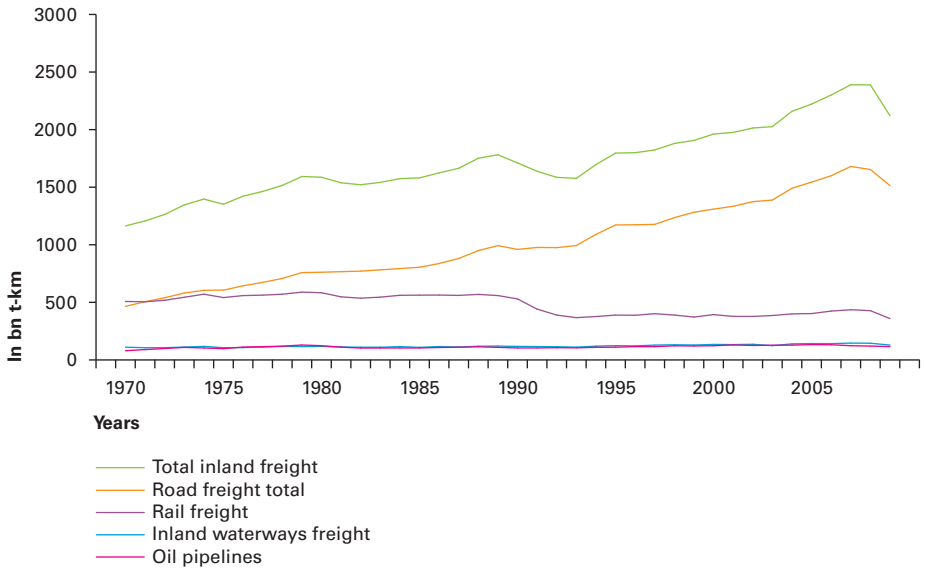


Figure 2. Historic development of EU27 freight transport, 1970 - 2009 (in billion t-km). Trucks dominate 40 years of growth in freight transport (CEPS, forthcoming, based on ITF/OECD data).

Now, the average speed of both the car and the conventional train lies around 45 km/h, and aviation is even faster with an average door-to-door speed of roughly 250 km/h.<sup>4</sup> These higher speeds made it possible to cover greater distances in the same time frame and are at the root of the strong mobility growth in Europe since 1850.<sup>5</sup> Of course, it is not only the available technology, but also its affordability and the socio-cultural acceptance of the new transport modes, which made faster and further transport a reality.

Speed is not only the main driving force behind mobility growth, but has also a decisive impact on the transport mode used. Historic developments reveal a shift to ever faster transport modes. Until 1850, horse carriages were dominant, after that the railways became the dominant transport mode for many decades and from 1930 the car has the largest market share. Now aviation outstrips the car in its growth rate.

The door-to-door speed of public transport (PT) relative to that of the car determines to a large extent the market share of busses, metros and trains. If PT offers the same travel time as the car, roughly half of the people will choose PT. However, it is difficult and costly for PT to offer a fast door-to-door service. Data for the Netherlands show that for 88% of all car trips, PT takes more than twice the travel time of the car.<sup>6</sup> And for only 0.01% of the trips PT is faster. This explains why the aggregate share of PT is limited to around 10% in most countries. Of course, in large cities, where the speed of the car is low, the share of PT is much higher than the national average and can be as high as 50%. These large and dense cities offer the best opportunities for mass transit.

From the presented analysis of speed as a main driving force behind mobility growth and the resulting dominance of the car, the conclusion follows that the green vision on sustainable mobility can only be achieved if the average speed of road transport is reduced. Shorter travel distances, more walking, cycling and PT, can become reality if the attractiveness of the car is diminished. And increased generalized costs for road freight will curb current trends towards longer transport distances and more complex supply chains, with each ton being lifted more often. Policies aimed at stimulating alternatives for cars and trucks will generate additional mobility and will not cause a substantial environmental gain if road transport is not restricted.

4 For rail and air transport, the travel time to and from stations and airports is included (Verkeer en Waterstaat, 2002).

5 Empirical evidence shows that the average time spent travelling is rather constant at around 1.1 hour per day. For an overview, see Bleijenberg (2012). Starting from the thesis of constant travel time, mobility growth can only be the result of population growth and increased travel speed.

6 *Mobiliteitsbalans 2010* (KiM, 2010).

In theory, it is easy to reduce the attractiveness of road transport. This can be achieved through insufficient road capacity, setting and enforcing tight speed limits and by making fast modes more expensive. However, exactly these effective policy measures are opposite mainstream transport policy. Combating congestion is priority one in most Western European countries and expanding motorway networks is a high priority in Eastern Europe. Furthermore, making cars, trucks and aviation pay their full costs is perceived as political suicide, with only few exceptions.

So, the choice is to either accept current mobility trends or to have the political courage to take effective, but unpopular, measures. Politicians and interest groups have frequently tried to ignore this dilemma by creating illusions about changing mobility patterns without taking harsh measures. In many cases, the bill for wishful thinking went to the tax payer. However, illusions can be politically attractive, but they do not change the real world.

### 3. Policies for Clean Technology

Attempts to change mobility patterns did not bring sustainable mobility much closer. Have other policies been successful in reducing pollution from transport?

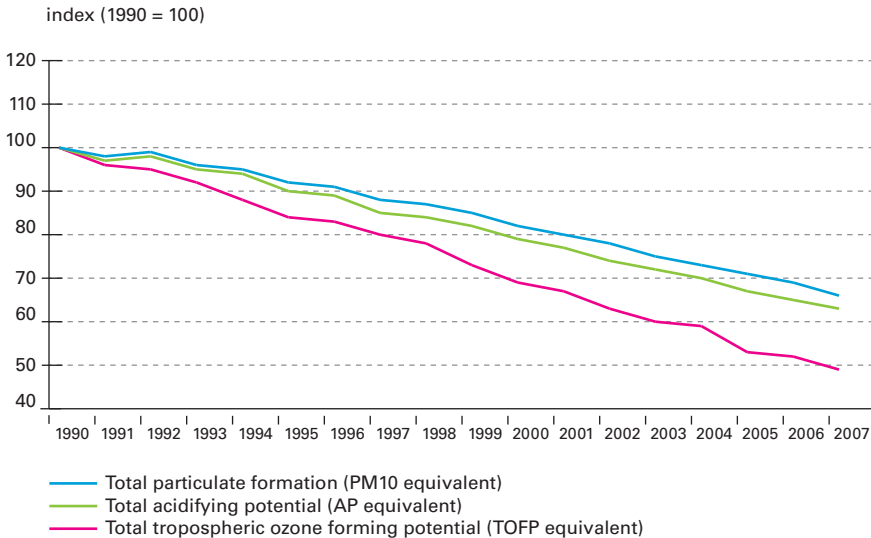


Figure 3. Strong reduction in air pollution from European transport, despite the growth in transport volume (European Commission, 2011).

A big success has been the introduction and subsequent tightening of environmental standards for vehicles, the so-called Euro standards. In the late 1980s, Europe introduced vehicle emission standards, despite fierce opposition from the car industry. In the 20 years since, the maximum acceptable pollution levels have been decreased by 95% for particulates and by 85% for the classical air pollutants. The positive effects of these European emission standards are convincingly shown in Figure 3.

The total emissions of particulates and nitrogen oxides from European road transport are strongly decreased since 1990, despite the growth in transport volume in the same period. Technological improvements of engines, fuels, vehicles and exhaust gas treatment made this environmental gain happen. Crucial for these improvements were the political agreements on the standards which forced the car and truck industries into these innovations.

This historic success in reducing air pollution shows the way to achieve a strong reduction in the GHG emissions from transport. Many studies conclude that energy efficient vehicles combined with low-carbon fuels have the potential to more than halve the CO<sub>2</sub> emissions per vehicle kilometre before 2050, mainly using existing technology.<sup>7</sup> New innovations will make further reductions possible.

However, these technical improvements will only be realized if strict policy measures are taken. Just like the Euro standards forced down air pollution from vehicles, a subsequent tightening of standards for energy efficiency and the CO<sub>2</sub> content of energy carriers will be successful in combating climate change. Additional to European policy, it is crucial that member states create fiscal incentives to stimulate the use of very efficient vehicles and low carbon energy. Copying best practices from other member states will do the job.<sup>8</sup> This brings the key to the required drastic reduction in GHG from transport in the hands of policy makers. Furthermore, the policy instruments to be used are well known and already applied in the European Union, several Member States and in other world regions.<sup>9</sup> So, the political challenge is to tighten the knobs, despite opposition from some involved industries.

7 Many studies support this conclusion. *E.g. Transport, energy and CO<sub>2</sub> – Moving towards sustainability* (IEA, 2009), *50 by 50 report – Global fuel economy initiative* (IEA et al., 2009), *EU Transport GHG: Routes to 2050?* (Skinner et al., 2010), *Support for the revision of Regulation (EC) – No 443/2009 on CO<sub>2</sub> emissions from cars* (Smokers et al., 2011). The variety in foreseen technological solutions will not be discussed in this essay.

8 Best practices of national policies are reviewed in *Member states in top gear – Opportunities for national policies to reduce GHG emissions in transport* (van Essen et al., 2012).

9 An extensive overview of national and international policy instruments to reduce CO<sub>2</sub> from transport is presented in the recent book *Cars and carbon – Automobiles and European climate policy in a global context* (Zachariadis, 2012).

Three policy instruments have proven to be effective and form together the core of the required policy package for low-carbon mobility:

- *Setting and tightening European standards* for the energy efficiency of vehicles and the carbon content of the fuels and electricity used. The combination of standards should address the well-to-wheel emissions of the vehicles, including the GHG emissions from refineries, power plants and the production of bio mass.
- *Fiscal and financial incentives* to stimulate the purchase of energy efficient cars and low-carbon fuels. National governments can differentiate the rates of existing taxes to stimulate low-carbon transport. Many governments already successfully use vehicle taxes, sales taxes, fuel taxes and company car taxation for this purpose.
- *Fuel taxes* also generate a strong incentive to buy fuel-efficient vehicles. A 10% increase in fuel price will result after some years in a 3-4% better efficiency of the vehicles.<sup>10</sup> Increasing fuel taxes is also needed for fiscal and economic reasons. Otherwise the promoted shift to very energy-efficient vehicles would reduce tax revenues and increase the underpayment of road users for the infrastructure costs.

So, already widely applied policy instruments need to be used more strongly to get the existing clean technology on the road and to achieve a drastic reduction in the global warming impact of mobility. Yes, we can!

Crucial for achieving these results is that the policies are technology neutral. Incentives need to reduce CO<sub>2</sub> emissions, no matter by which technology. Policy support for specific technologies – be it electric, hydrogen, gas or bio fuels – need to be avoided, and existing support measures should be phased out. It is widely accepted that governments are not good at ‘picking the winners’. It is a challenge for politicians to resist lobbies for specific technologies, because they can score better in the media by, for example, driving an electric car and by granting subsidies to bio fuels, than by tightening standards. Instead of promoting specific technologies, governments should only create strong incentives to reduce CO<sub>2</sub>, while the winning technologies will result from innovations by the involved industries together with preferences of the buyers. Technological improvements should be mainly market driven and not subsidy driven. This approach will lead to the cheapest and fastest way to achieve the required CO<sub>2</sub> reduction, and is generally supported by involved industries.

Another justified wish from the car industry is to have a predictable timeframe for tightening the standards, giving them certainty and enough time for their R&D investments. Thirdly, neither the standards nor the fiscal and financial

<sup>10</sup> Conclusion from a meta-study by the Netherlands Environmental Assessment Agency (PBL) and CE Delft (Geilenkirchen et al., 2010). The total fuel saving of a 10% increase in fuel price is for the long run even estimated at 6-8%, because car ownership and mileage will also diminish somewhat.

incentives should have discontinuities or steps. This avoids that industries have to focus – and waste – their efforts on these steps, because the size of the incentives changes there abruptly. The European Union should make a Directive to achieve this, thus ending the wide variety in existing national discontinuities.

Not only for economic and environmental, but also for political reasons it is important to design the policy instruments along the three lines of technology: neutrality, predictability and continuity.<sup>11</sup> Doing so avoids unnecessary opposition from the involved industries, thus increasing the acceptability of tighter standards.

#### 4. Economy, Accessibility and Congestion

If clean technology contributes most to low-carbon transport, does this imply that current transport policies in Europe are on the right sustainable track? No, they are partly uneconomic and follow frequently a wrong compass.<sup>12</sup> To a large extent mobility policy chases the illusion of congestion free urban areas. This aim conflicts with a second fundamental mechanism in mobility – additional to the thrive for speed: good accessible locations attract new economic activities. This mechanism is, in fact, the economic rationale behind most infrastructure projects. However, these new industries, offices, houses, shops, theatres and so on attract new traffic, creating new congestion. This closes the circle. Many historic examples illustrate this mechanism. Ancient and medieval cities were often built at the crossroads of waterways and trails. And after railway stations were built just outside many cities in the decades around 1900, the further urban growth concentrated in the vicinity of the stations. Now the stations are in the heart of many cities, with high-rise buildings surrounding it. A third more recent illustration is that building ring roads around the larger cities in the 1960s, spurred urbanization at the outskirts, and these ring roads now belong to the most congested highways. Of course, this process of spatial adaptation to new infrastructure takes several years or even a few decades, but the outcome is inevitable. New infrastructure improves the accessibility of specific locations, making these locations attractive for new economic activities and urban development, which generates extra traffic, thus creating congestion. An indirect demonstration of this mechanism is the fact that there are no large cities in the world without congested roads. The absence of congestion might instead indicate that the urban economy is in bad shape.

<sup>11</sup> The optimal design of policy instruments to achieve low-carbon transport is thoroughly discussed in a European Task Force on Transport and Climate Change with participants from the car, oil and transport industries, from environmental NGOs and from European and national government agencies. See the report for more information: *The pathway to low carbon transport in the EU – From possibility to reality* (CEPS, 2012).

<sup>12</sup> See for an overview of national policies related to transport and climate change: *Member states in top gear – Opportunities for national policies to reduce GHG emissions in transport* (van Essen et al., 2012).

Policies of many countries to reduce congestion are based on the false assumption that increasing travel speed is the key to strengthen the urban economy. This wrong starting point leads to an overemphasis on road building. The correct starting point is that the large economic benefits of urbanization are the result of good accessibility.<sup>13</sup> And because accessibility is the time it takes to reach other activities, accessibility can be achieved by the combination of both nearness and speed. This is a crucial insight for transport policy, which is unfortunately overlooked quite often.

The economic value of proximity is in fact the driving force behind the urbanization process, which is a worldwide continuing trend for many ages. People and firms cluster together in cities, because they profit from the nearness of other firms and people.<sup>14</sup>

So, both urbanization and higher travel speeds can increase the accessibility, and thus the associated economic benefits. However, cities with a high density generate much traffic in a small area, which is impossible to cope without congestion. The economic value of nearness in these cases is higher than the economic costs of congestion. Starting from the proper notion of accessibility, it is clear that cities have a better accessibility than rural areas and compact cities better than a scattered built environment, despite a certain level of congestion.

Making large and high-density cities accessible – a condition for economic prosperity – requires mass transit, be it in public or private hands. Only mass transit can handle large flows of travellers at reasonable speeds in a crowded city. Because the speed of the car is rather low in urban areas, it is easier for mass transit to offer a competitive travel time. And because of the large volume of passengers in dense urban areas, mass transit can be economic viable. A comparison of the largest cities in the United States reveals that mass transit is more effective in reducing congestion costs than road building.<sup>15</sup> Moreover, car-city, Los Angeles, even has the highest congestion costs per inhabitant of all big US cities.

13 See Bleijenberg (2012) for a more extensive review of the links between economy, accessibility, urbanization and mobility.

14 A large market for consumer goods generates economies of scale in production and distribution, resulting in lower prices. A large demand also generates a higher quality and variety of services, such as theatres, leisure and shopping centres, while a large labour market allows for specialization and a better match between firms and employees. Another important benefit of a greater concentration of population is that knowledge and new ideas spread more easily. These and similar benefits of proximity are often summarized as agglomeration economies.

15 *Smart congestion relief – Comprehensive analyses of traffic congestion costs and congestion reduction benefits* (Litman, 2012).

Urban and transport policies in combination should strike the right balance between creating economic value by higher densities and by faster transport. Combating congestion is the wrong compass for transport policy. Two standard economic tools offer a better compass. The first is the use of socio-economic cost-benefit analysis (CBA) for expanding infrastructure networks. This is common practice in several countries and at the European Union level as well. The aim of CBA is to distinguish between profitable and unprofitable investments. The second economic tool is setting prices for transport, which correspond with the social costs. This needs to be done by governments, for there are no markets for infrastructure use, traffic safety and pollution. Setting economic prices will imply that user charges for cars will become higher, while fixed taxes can be reduced in several countries. User charges for trucks and vans need to be more than doubled, for they are currently underpaying for the costs they impose on society, mainly for infrastructure and traffic accidents. These charges will lead to higher load factors and to more efficient logistics. And last but not least, congestion pricing creates economic benefits by improving the accessibility of city centres.

It is estimated that the economic best combination of urban and transport policies will reduce CO<sub>2</sub> emissions from transport with somewhere in the magnitude of 10-20%. Compact cities with good mass transit, economic infrastructure building and transport pricing all contribute to this environmental gain. Although this is an important contribution to low-carbon mobility, it is modest in comparison with the potential CO<sub>2</sub> reduction achieved by fuel efficiency and low-carbon energy. This latter contribution is estimated at around 50-75%.

## 5. Images and Interests

Two surprising conclusions follow from the above summarized attempts to achieve sustainable mobility. Current transport policies are to some extent uneconomic. An economic approach would not only yield economic benefits, but in addition reduce the environmental impact of transport. Why is this win-win policy not followed?

Secondly, the most promising way to reduce CO<sub>2</sub> from transport – clean technology – is not the favourite approach of many green politicians and environmentalists. Why not?

This last section of this essay searches for some answers on these intriguing questions.

The economic approach of transport policy seems to be supported only by independent academics and by environmentalists. Mainstream transport policy focuses instead on infrastructure building, combating congestion and subsidizing public transport, believing that the first two are best for the economy and PT is needed for social and environmental reasons. This is widely seen as effective, however, contested in this essay. To summarize, common beliefs somewhat overdone: all new infrastructure is good for the economy, congestion is a sign of inadequate infrastructure capacity, freight transport should grow with the same rate as the economy, transport demand is price insensitive and finally, road users are the cash cow of finance ministers.<sup>16</sup> Most people – thus most voters – probably have similar images of mobility as their basic belief. And these popular images set the frame for policy makers. If most people believe that building more roads will solve congestion, politicians will follow this approach. Who is going to tell that congestion is inevitable in large urban areas? Who is going to tell that road users should pay more, because this is justified by the costs of infrastructure, traffic accidents and pollution?

However, the sketched mainstream image of mobility is largely incorrect. Therefore, these popular misconceptions of mobility need rectification, thus creating the scope for policy makers to move towards an economic sound transport policy. Just one illustration: in the 1990s, the Dutch Transport Minister was asked to take a stand in the at that time hot debate about the total costs of transport. The staff of the Ministry replied that they did not have an opinion on this issue. Do not be surprised that if you do not correct the false image that road users are a cash cow, that you will not get support for any form of pricing policy, as successive Dutch governments experienced in the last 20 years.

So, correcting popular images, and creating a more realistic view on mobility, is crucial for realizing a more economic transport policy. Doing so, it is important to realize that existing images are in the interest of powerful industries, such as construction, oil, car, railway and transport companies. It is their business to keep the transport system running. Furthermore, it would sure help if the media would employ more independent research journalists, who can critically distinguish between the general interest and special interests. Now the mass media recycle to a large extent information presented by the PR staff of companies and ministries.<sup>17</sup>

<sup>16</sup> Many publications correct these common misconceptions. To mention just a few: *Getting the prices right* (Kageson, 1993), *Roads and economy – State-of-the-art report* (Bleijenberg, 1996), *Efficient transport for Europe – Policies for internalization of external costs* (OECD/ECMT, 1998), *Entkopplung von Wirtschaftswachstum und Verkehr – Beispiel Regionale Wirtschaftsförderung* (Petschow et al., 2008), *Price sensitivity of European road freight transport* (de Jong et al., 2010), *Cart or horse: Transport and economic growth* (Leunig, 2011).

<sup>17</sup> In 2009, there were six times more professional PR people employed in the United States than news editors and reporters. In 1980, this ratio was only two (*Economist*, 2011). See for an uncovering description of current mass media *Flat Earth news* by Nick Davies (2009), journalist at the Guardian for 30 years.

The next question is why many environmentalists do not embrace clean technology as the main route towards sustainable mobility. As stated above, many greens support the more economic approach of mobility. This would lead to somewhat lesser mobility growth and together with building compact cities to better opportunities for walking, cycling and mass transit. This outcome is in line with the green vision on sustainable mobility. However, it is unlikely that the effective but unpopular policy measures required in this green vision will be taken, partly because of existing misconceptions about the economic impact of such measures. It looks as if many greens are more interested in achieving a shift to other transport modes or reducing mobility growth, than in reducing pollution itself. The western way of living is frequently seen as root cause of the environmental problems, and thus there is a need to change the consumer society. This wish, however, does not correspond with a vision on sustainable mobility mainly based on clean technology, which leaves mobility patterns largely unchanged. The following saying might apply to the approach pursued by many environmentalists: the perfect is the enemy of the good. Most likely, people prefer to drive a very energy-efficient car using low – or no – carbon energy, over not driving their car at all. So, policies to force clean technology into the transport system are both effective in reducing GHG and have a better chance to become publicly and politically accepted.

Finally, a third question: why are the advocated and promising policy measures for clean technology not high on the political agenda? Part of the answer is that clean technology is not backed by a strong industry lobby. However, there are a few exceptions. The power industry sees a new market in electric vehicles, gas companies see opportunities in natural and biogas as transport fuel and, thirdly, suppliers to the car industry see a chance in innovative technologies to make cars much more fuel efficient. But the large industries behind the transport services have an interest in continuing business as usual.

A second reason that standards and fiscal incentives are not high on the agenda is their limited appeal for the mass media. It is hard to get media attention for these rather dull and somewhat technocratic policy measures. On the contrary, it is achievable to get front page and prime time coverage for the opening of a new road or railway and for the latest model electric vehicle. So, the current intertwine between mass media and politics does not favour such rather invisible policy measures to achieve low-carbon transport. Images are in media and politics apparently more important than the effectiveness of measures.

This summary of images and interests influencing transport policy shows that a successful transition to sustainable mobility requires different kinds of efforts. Although the low-carbon technologies, as well as the policy instruments to get these applied, are largely available, the public acceptance of much stricter standards and strong fiscal incentives remains a delicate issue.

Creating a shared vision of the required pathway – instead of the current confusing and opposing positions – is an important step forward. This essay is intended to contribute to the development of a new and shared vision on sustainable mobility. Strengthening the evidence base – as opposed to wishful thinking – is needed to achieve this, in combination with a stronger focus on the general interest, instead of lobbies from vested interests.<sup>18</sup> Politicians need to institutionalize the general interest in, for example, independent research institutes and advisory councils and in legal procedures. Wrong images surrounding transport and mobility need to be actively corrected in and by the mass media, thus creating the acceptability of effective and economic sound policies in the public opinion.

It is clear that this agenda for sustainable mobility has a much wider relevance and reinforces the public case in general. Achieving sustainable mobility is just one of the issues requiring evidence-based policy and a stronger focus on the general interest in our societies.

<sup>18</sup> Economic growth will be hurt if special interest groups accumulate too much power, concludes Mancur Olson (1982) in his book *The rise and decline of nations*.

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# Shifting Gear: Beyond Classical Mobility Policies and Urban Planning

# 07

Maarten Hajer, Anco Hoen and Hiddo Huitzing

**Mobility is the elixir of modern society. Man has been a travelling species for longer, of course. The quest not only for food, power and wealth, but also for ideas has inspired people to travel for ages. But during the modern era, we have perfected the mobility system. We now have a global economy that is not only functionally highly integrated, but celebrates this interconnectivity as well. This cultural celebration of the sheer endless opportunities is symbolized by the intercontinental holidays of middle class families. Sending images and story lines from faraway places and bringing insights and paraphernalia have become an indicator of social success. Less discussed but increasingly significant: Modern society thrives on the fuels, food and other resources (from rare earth to phosphates) that we extract or grow at faraway places and ship between different continents.**

This era of 'hypermobility' has long been known to be unsustainable. The metabolic dimension, the flows of resources and environmental effects, from oil drilling to CO<sub>2</sub> to spillage of phosphates into the seas, are the flip side of our progress and are something we now urgently have got to come to grips with. The knowledge of 'limits' dates back to the 1960s but is now finally giving way to knowledge that focuses on potentials, on transformations and on transition. Interesting is what this shift in emphasis could also mean for the debate on (car) mobility. After all, it was in the 1960 that the initial idea of allowing as many people into the world of car mobility (a car for everyone) started to arouse feelings of discomfort, something Phillip Larkin describes so well in his bleak 1972 poem 'Going, Going' (Larkin, 1972). The new post-war generations grew to maturity holding 'post-material' values (Abramson & Inglehart, 1995) and eloquently stated to raise question about the price of progress and growth.

While the occasional faraway holiday is a symbolic marker of success, it is the everyday reality of 'auto mobility', which has become the comfortable basis of Western day-to-day life.<sup>1</sup> This article focuses on this cornerstone of the system: the car. Cars are no longer a luxury belonging to the middle classes but are within reach of nearly everybody. What is more, the car can no longer be regarded as an individual technological artefact but has evolved into a 'large technological system' (Summerton, 1994) that has been perfected to include multilane motorways with giant petrol stations, parking houses in the inner cities, out of town shopping malls and also much of our urban fabric and form, from the cul-de-sac to the very idea of a suburban life styles as a blend between city and country living. This large technological system also comprises a powerful 'car industrial complex', that is crucial component of the economy, for instance, in terms of jobs, knowhow and innovation.

Car-based mobility is our default option, well embedded into our routines. It is our 'normalcy'. It is a cultural cornerstone that we cannot simply remove. Organizing mobility on a sustainable footing is a tremendous challenge. But it is one that, somehow, needs to be met. The 'small' agenda is one of direct environmental impacts, of health-related effects, of noise, particles and spatial impacts. There we at least know where to find solutions. The 'big' agenda is that of climate change and natural resources. Here many options to drastically reduce greenhouse gas emissions from transport have been identified. But strategic decision makers stare the scientific facts and predictions in the face like a rabbit looks at the headlights of a car approaching. There is a scientific consensus that achieving the 2°C target is *technically* feasible, for rich countries this would require a stunning effort to reduce emissions with a factor 5 (Rogner et al., 2007). Unfortunately, little progress towards the ultimate goal has been made over the last 15 years. In fact, current policy scenarios predict that the share of transport (which of course is more than merely cars) in greenhouse gas emissions may rise from the current 25 to 50% in the year 2050 (European Commission, 2011a). Hence we simply have to rethink the mobility strategies in a fundamental sense.

Hence the question is not if this legitimizes government intervention but *what sort of intervention* can be envisaged in the first place that may be promising to bring this transition about. Here serious 'out-of-the-box' thinking is required, or, in this context perhaps appropriate, 'gearbox' thinking, as we need to urgently shift gears.

1 This chapter focuses on the context of the developed world. It is obvious that the car is not within reach of everyone outside the rich countries. The predictions of a growing middle class in the developing world, reaching a stunning 3 billion in 2050, would logically imply a pervasive shift in the degree of car ownership elsewhere, with great environmental and spatial consequences. Such issues are beyond the scope of this paper.

As experts we need to provide the thinking that may be drawn upon in a new policy making. Yet we have to reconsider the sort of advice we give, as well as the very way in which we relate to the mobility field. The traditional approach would be to turn to governments, seek to persuade them with studies that assess which technical measures are potentially effective. Governments would then have to adopt and enforce these measures through legislation, emission standards and pricing measures. The reality of policy making and politics is that vested interests and lack of imagination stand in the way of even applying those measures that scientists have reason to believe to be powerful policy instruments, road pricing being one of the most well known.

The combination of a well-developed large technological system and a strong cultural adherence to the social and cultural practices of car mobility reality is a lethal cocktail. We cannot possibly come up with an alternative, let alone a blueprint. What we aim to do in this chapter is create a perspective that may help to find new strategies that go beyond the results of the thinking of the last 15 years. We start by briefly describing the problem at hand, and the technical solutions that have been identified to meet the challenge of a sustainable mobility.

## 1. The Problem at Hand

The transport sector is a major contributor to greenhouse gas emissions. Approximately 25% of global and European CO<sub>2</sub> emissions are transport related, and this share will increase. The bulk of the emissions are caused by road transportation and passenger car transport in particular (see Figure 1). In order to meet long-term climate goals, the European Commission has announced that the transport sector should limit its CO<sub>2</sub> emissions to 60% of 1990 levels (European Commission, 2011b). This is a serious challenge, certainly if we consider that in a scenario without policy change passenger transport activity would increase by 51% between 2005 and 2050 while freight transport activity would go up by 82% (EC, 2011a). Consequently, without additional climate policy, the share of CO<sub>2</sub> emissions from transport would continue to increase to 38% of total CO<sub>2</sub> emissions by 2030 and to almost 50% by 2050 (EC, 2011a).

There are three core elements to the 'solution':

- use alternative (non-fossil) energy carriers;
- use alternative fuel vehicles (AFVs) and
- travel less kilometres.

There is a clear distinction between these three elements regarding their emission reduction potential. This is illustrated by Figure 2. The combined potential of alternative fuels and AFVs is far greater than the potential of less travel.

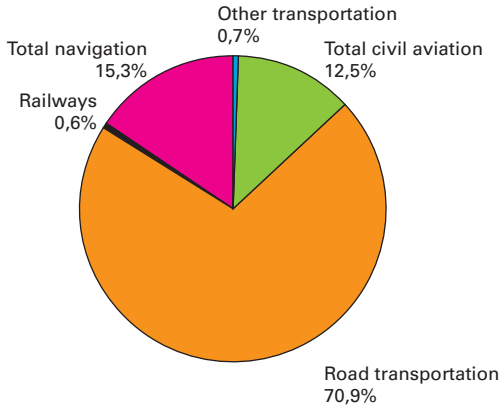


Figure 1. Share by mode in total transport CO<sub>2</sub> emissions, including international bunkers. EU-27 (2007).

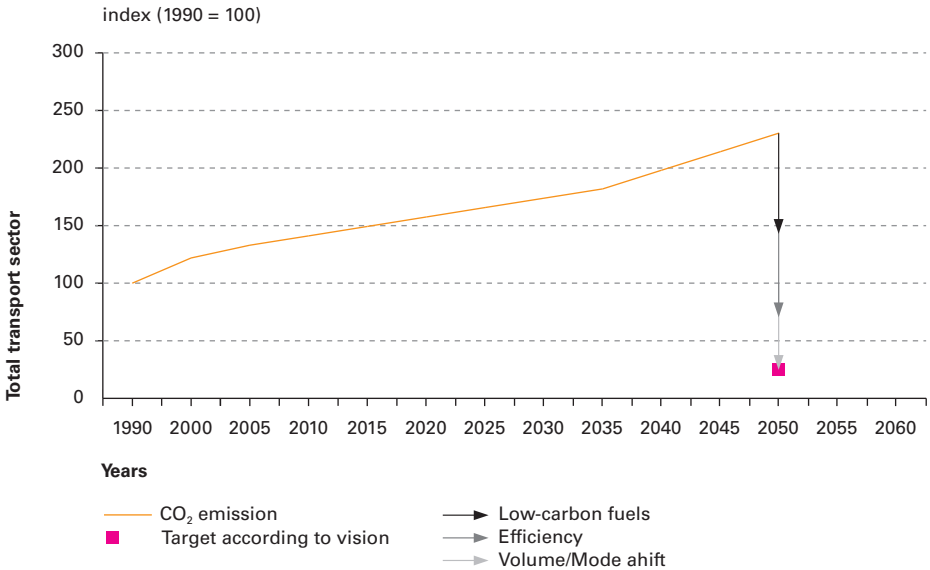


Figure 2. Route towards a low-carbon transport system in the EU in 2050. Feasible CO<sub>2</sub> emission reduction for transport. Schematic representation of potentially feasible emission reduction for the transport sector, by 2050.

Roughly 80% must come from a combination of CO<sub>2</sub> neutral fuels (electricity, hydrogen and biofuels) and vehicle technology (battery electric vehicles and fuel cell vehicles). There is a clear distinction between passenger car transport and

other modes such as heavy duty freight transport, shipping and aviation in this respect. Freight transport (road, rail, air and navigation) and civil aviation will be dependent on biofuels for large CO<sub>2</sub> emission reductions since alternative (electric or hydrogen) propulsion is not technically feasible. For passenger car transport (and light duty freight transport) electric and hydrogen propulsion is a viable option. If hydrogen and electricity are produced with wind or solar energy, this group, which is responsible for approximately 50% of transport CO<sub>2</sub> emissions, can emit up to 95% less CO<sub>2</sub> (Hoen, Geurs, de Wilde, Hanschke, & Uytterlinde, 2009).

Reducing travel demand or changing travel behaviour can attribute approximately a 20% emission reduction, mostly through road pricing and increased logistic efficiency in freight transport. The additional effect of spatial planning is limited at this point, not the least because in the developed world 70% of the building stock of 2050 is already there (Hoen et al., 2009, Hajer, 2011).

In the next two sections, we will look at some popular measures that aim to increase the use of AFVs and reduce the demand for mobility (amount of kilometres driven). The focus is on passenger transport and mostly on car-based travel. We will assess whether these measures can be effective from a technological point of view and at the same time from an energetic society perspective. We will illustrate that for effective policy making, there is often not only the need to look at technical potential or model-based scenarios but also at societal response to the challenges of sustainable mobility. The extent to which society accepts policies should be included in policy assessment, and this need becomes more pronounced if we take into considerations that modern society is made up of articulate, autonomous citizens and innovative companies. Many want change and are ready to take action. On the other hand, there are also citizens who are sceptical of the need for change. This scepticism often focuses not so much on the need for change itself, but stems from a lack of trust in government initiatives that aim for this change, and the idea that such initiatives will constrain their actions. Here lies the challenge of governments, which is to combine two societal developments:

- The need to attune our natural resource use to the earth's carrying capacity, here in particular the need to curb CO<sub>2</sub> emissions. This is a major challenge that we are faced with for the coming decades.
- The emergence of what we call the 'energetic society' (Hajer, 2011): A society of articulate citizens and firms, with an unprecedented reaction speed, both in terms of capacity to obstruct and in terms of learning ability and creativity.

In the next section, we will start of with a review of some possible measures to reduce demand for transport, or in other words drive less kilometres. In Section 4, we look at measures that aim to increase the use of clean vehicles using clean fuels.

## 2. 'Drive Less'

We find many examples of measures in literature that have the potential to reduce the number of kilometres that people and companies drive. To name a few, road pricing or congestion charging, improving public transport, telecommuting and teleconferencing, spatial planning to shorten travel distances, Park and Ride facilities to limit car traffic in cities and logistic efficiency in freight transport. With such a wide variety of options, it might be considered surprising that the emission reduction potential in Figure 2 is assessed to be limited.

We will elaborate a little on this by looking at the historical development of transport. It would be fair to say that in the past 200 years, mobility has 'exploded' (Mom & Filaski, 2008). The average distance that a person travels per day has increased with 1-4% each year (van Lint & Marchau, 2011). Apart from the increased travel distance, the population size has also increased dramatically. All in all the combined personal mobility of a growing population is roughly 80 times higher than it was in 1800. To put it differently, the mobility explosion is the result of much more people travelling many more kilometres over the past 200 years. What could be the reason for this massive increase in mobility?

The most important reason is that technological innovations in mobility have made it possible to travel much, much faster. Horse and carriage (the main mode of transportation around 1800) reached average speeds of 7 km/hour. Current car travel reaches average speeds of 70-100 km/hour and aviation surpasses that with ease with speeds of up to 900 km/hour. While travel speeds increased travel times remained fairly constant at roughly 1.1 hours per person per day (Zahavi & Talvitie, 1980; Schafer & Victor, 2000). According to Marchetti (1994), the 'law' of constant travel time has held for centuries and even applies to inmates who kill time by walking an hour on the prison grounds. We put law in parenthesis because there is also evidence that travel times are not constant. Harms (2008), for example, shows that for the Dutch case, people currently travel longer and more often than 30 years before. Interestingly, we do not find indications in literature that travel times decrease owing to higher travel speeds.

Apart from constant travel time, there is evidence that people tend to spend roughly the same percentage (15%) of their income on travel (Schafer & Victor, 2000). As a consequence, since faster travel is more expensive, with increasing income over time, people spend more money (in absolute terms) on travel, choose faster modes of travel and thus travel longer distances.

This tells us that there seems to be a 'natural tendency' of people to travel and that as long as we increase infrastructure capacity and invent technologies to increase travel speeds, it will be difficult to reduce the demand for travel.

Moreover, this natural tendency is reinforced by the elements of transport policy that aim to increase accessibility and decrease travel times. Such policies are aimed to facilitate travel, which instead of reducing the number of kilometres travelled, gives an incentive to travel more.

It should be noted here that there are differences between the different modes of travel. A kilometre driven by train is from a perspective of CO<sub>2</sub> emission reduction on average better than a kilometre driven by car. So if transport policies are successful in shifting travel demand to more energy efficient or CO<sub>2</sub> intensive modes travel demand policies may be effective from an environmental viewpoint. We should also note, however, that car travel is by far the preferred mode of transport. In the Netherlands, the number of passenger kilometres driven with cars is approximately six times as high as the number travelled by train. Train travel can accommodate only a limited part of a reduction in car travel. Moreover, the substitution between modes is limited. New public transport links generally attract new travellers instead of car travellers (Hilbers, van de Coevering, & van Hoorn, 2009). Reviewing what we have shown so far might lead one to argue that emission reduction technology (clean fuels and vehicles) cannot be only about changing the modal split but should also focus on CO<sub>2</sub> neutral transport. To see if this could be true, and whether the mechanisms described above indeed occur, we will review some successful or promising and some counterproductive measures to reduce kilometres driven.

## **Successful Measures**

### *Road pricing and Congestion Charging*

Use-related charges have been on the policy agenda for several decades. Singapore was the first to implement the Electronic Road Pricing (ERP) system in 1998. In London, Stockholm and Milan, similar schemes were introduced in 2003, 2007 and 2008, respectively. The main reasons for introducing these use-related charges are to improve accessibility in heavily congested urban area and to improve air quality. Li and Hensher (2012) give an overview of the effects of the congestion charging schemes (CCS) in the aforementioned cities (see Table 1).

The reduction in car traffic amounts to 15-20% in all four cities. The use of public transport increased substantially. Results for air quality are less clear. For London, no consistent evidence of improved air quality resulting from the CCS was found (Kelly et al., 2011). For Stockholm and Milan, positive effects on air quality are reported (Börjesson, Eliasson, Hugosson, & Brundell-Freij, 2012; Rotaris, Danielis, Marcucci, & Massiani, 2010).

The congestion charging in London presents a watershed in policy action in the UK (Banister, 2008). Although it has been successful in decreasing car use and

increasing public transport use (with little negative spin-off outside the charging area), it was very difficult to get it implemented. Before implementation, 40% of the people were in favour of the measure and 40% were against the measure, illustrating that substantial political commitment was needed to follow through. Interestingly public opinion has shifted since the implementation to 55% being in favour. Increases in public support have also been observed in Norway.

Impact of the projects	Congestion charging schemes			
	London	Stockholm	Milan	Singapore
Reduction in traffic (vehicles with four or more wheels) entering the zone during charging hours	18%	Trial: 22% after permanent implementation: 18%	14,2% (23% during the morning peak hours)	40-45% ) Area licensing scheme). 15% (electronic road pricing) 70%
Reduction in cars entering the zone during charging hours	33%	Not available	Not available	70%
Change in traffic beyond charging hours	Observed peak traffic after the charging hours in the first year, normalised in the coming years.	Observed peak traffic after the charging hours in the first year, normalised in the coming years.	Observed peak traffic after the charging hours	+23%
Change in traffic round the charging zone	-5%	+10%	-3,6%	Not available
Change traffic in the inner road	+4%	+5%	Not available	Not available
Increase in speed in the inner road	30% (From 14 km/h to 18 km/h)	30-50% (33% in the morning peak)	4%	20%
Change in speed in the inner road	Not available	Not available	Not available	-20%
Increase in bus speed inside the charging area	6%	Not available	7,8% Attributed to charging zone in combination with bus lanes.	Not available
Increase in the use of public transport	Above 7% totally, 37% in bus passengers entering the zone	9%	6,2% Totally, 9,2% in metro passengers	21%

Table 1. Some effects of CCS in London, Stockholm, Milan and Singapore. Source: Modified from Li and Hensher (2012).

### *Mobility Budget*

A measure that seems to become more and more popular among Dutch companies is the so-called mobility budgets for employees with a company car. The traditional finance model for company car is to give the employee a tank card for which (s)he could essentially buy a 'limitless' amount of fuel. A mobility budget on the other hand gives an employee a fixed amount of money each month. The employee is free to decide how to spend this budget. Her or she may also decide to work at home if the schedule allows it or use public transport instead of the car.

This is an interesting approach since it creates an incentive for the car driver to 'earn money' by thinking creatively about his or her mobility behaviour. If by the end of the month, the employee has not fully used his or her budget the remainder can be spent on other things.

Pilots show that companies can set the mobility budgets below the average monthly costs of the traditional system so that they too save money.

### **Counter Effective Measures**

#### *Free Public Transport*

Public transport is often viewed as the environmentally friendly counterpart of car traffic. It has been put forward regularly by local governments as a means of improving accessibility and livability (better air quality, lower noise levels) of cities. Research on free public transport and also adding new public transport services, however, shows it hardly results in people transferring from car use to public transport (Hilbers et al., 2009). It rather results in people who used to walk, bike or not travel at all to make use of public transport. Moreover, people who already used public transport tend to travel more often and greater distances. In the end, the net effect on accessibility and air quality might well be negative since only few less car kilometres are driven while additional kilometres are driven by bus, tram and metro.

This illustrates that good policy intentions of which citizens may benefit may result in the opposite outcome. In this specific case, it is probably the result of people finding the path of least resistance. For many individuals, the benefits of easy travel outweigh the benefits becoming healthier by cycling or walking and living in an environmentally friendlier city.

#### *Financial Compensation for Commuters*

Another example of pricing policy that leads to adverse effects is the 'commuter compensation'. This is a compensation for people who use their private car for the commute (or business trips for their employer in general) paid by the national government. The compensation amounts to 19 euro cents per kilometre

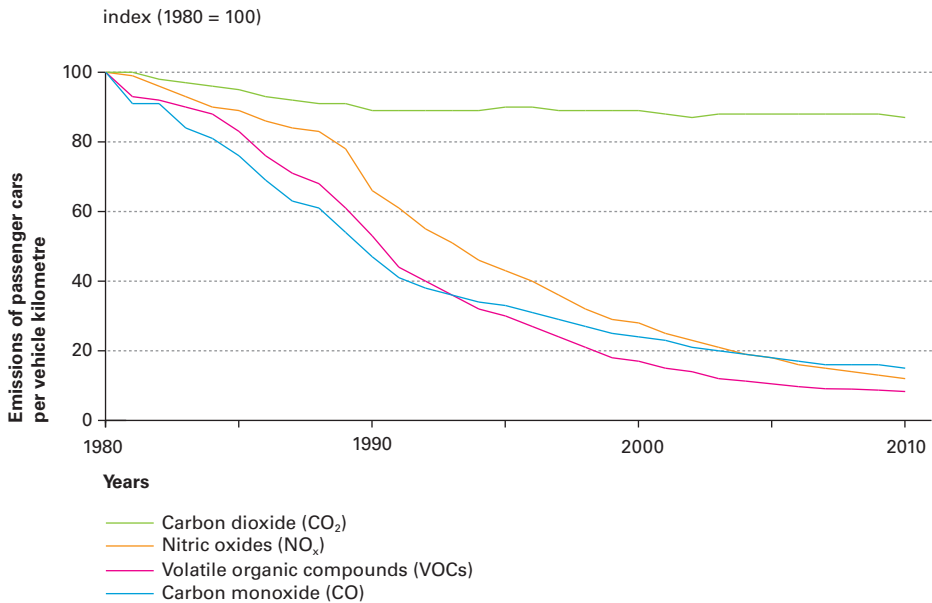


Figure 3. Trend in emission of CO<sub>2</sub> and air pollutants in The Netherlands. Source: CBS, Registration of emissions.

in the Netherlands. The measure creates an incentive to either work farther away from home or live farther away from work. In effect, the total amount of kilometre's driven increases by this measure, which in turn leads to more congestion, casualties and emissions. It is interesting to note that in April of 2012, an interest group announced that the commute compensation should be increased owing to rising oil prices. From the perspective of more sustainable mobility, this would be the exact opposite of good pricing policy. In fact in the so-called Green Tax Battle several Dutch experts argued that abolishment of the commute compensation would be a very efficient way to reduce CO<sub>2</sub> emission on the short-to-medium term (Stichting Natuur en Milieu, 2011).

### 3. Clean Vehicles and Fuels

#### Successful Measures

##### *Emission Limits for Passenger Cars*

Passenger cars have a very substantial part in the road towards sustainability. They contribute significantly to air pollution and greenhouse gas emissions. It is technically feasible to make (near) zero-emission passenger cars, provided new

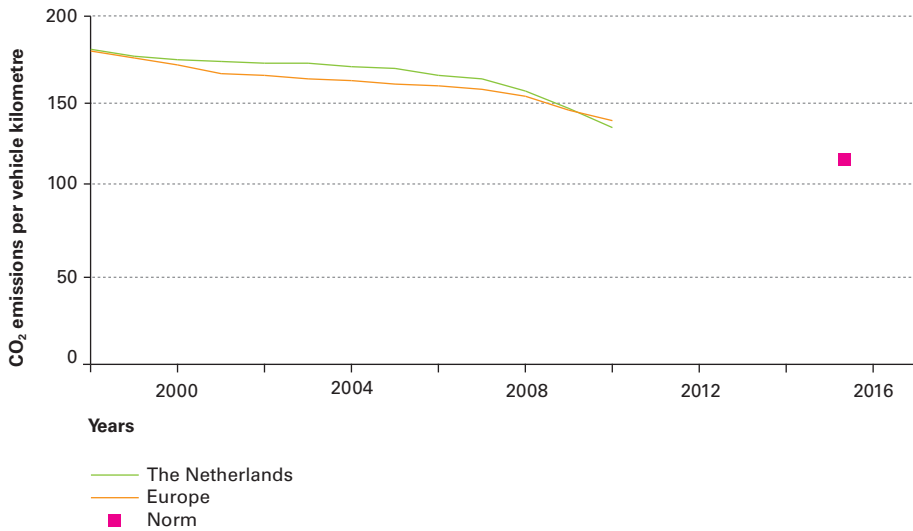


Figure 4. CO<sub>2</sub> emission of new cars in Europe and the Netherlands. Source: RDW, T&E.

vehicle technology emerges and renewable energy carriers will be available. Interestingly for air pollution there has been a long track record of policies that have achieved just that.

Cross-boundary air pollution was a hot topic from the 1980s throughout the beginning of this millennium. For the transport sector, it resulted in EU legislation for road vehicles, the so-called Euro norms. Around the year 1990, it started with Euro 1 and currently only Euro 5 vehicles are allowed to be newly sold. Euro 6 limit values have also been agreed upon and will come into force around 2014. These Euro norms have been very successful (see Figure 3). Total emission of NO<sub>x</sub>, VOC and PM (particulates) of cars has dropped with more than 70% between 1990 and 2010, while mobility has increased with roughly 50%. The Euro norms initially confronted car buyers with additional costs (roughly €500-1,000 in current prices) mostly coming from the catalytic converter that filtered exhaust emissions but to the surprise of many the costs of the converter quickly came down and is now below €100.

We will not go into the details of why the Euro norms have been so successful and what made car manufacturers willing to adhere to the regulations set by the EU. We can say that it is probable that the sense of urgency about air pollution

and the associated environmental problems of acid rain was high at the time (Hajer, 2005). This might very well have created the willingness to pay for the additional costs. Although records show that car manufacturers initially objected to the emission limits in the end, they conceded to the EU regulations, perhaps in part to avoid reputational damage. Whatever the reasons have been, the fact is that these policies were very effective.

However, the successes for air pollution do not hold for CO<sub>2</sub> emissions (by far the dominant greenhouse gas emitted by the transport sector). Figure 3 shows that CO<sub>2</sub> emission levels hardly dropped in the same period that the Euro norms came into force even though energy efficiency has been on the policy agenda for more than 15 years. Until 2010, the approach was different from that of air pollution. It started with a series of voluntary agreements with the European, Japanese and Korean car manufacturers to reduce the CO<sub>2</sub> emissions of passenger cars with 25% between 1995 and 2008 to a level of 140 g of CO<sub>2</sub> per kilometre driven. Although the CO<sub>2</sub> emissions dropped slightly as can be seen in Figure 4, the European Commission felt that the progress was too slow. Important to note is that Figure 4 shows emission levels according to the ECE test-cycle. This means that CO<sub>2</sub> emission is measured on the basis of a stylized drive cycle with limited acceleration that is not comparable with real-world driving. Moreover, electric appliances and air conditioning are turned off during the test. This means that the progress shown in Figure 4 is smaller if real-world CO<sub>2</sub> emissions are regarded.

The lack of progress resulted in new negotiations between car manufacturers and the EC, which ultimately resulted in legislation. A norm (or limit value) for CO<sub>2</sub> emissions was set with substantial financial penalties for those who would not meet the target. The new legislation was finalized in 2010. It is interesting to see that around the year 2008 (when negotiations started), the CO<sub>2</sub> emission per kilometre dropped sharply implying that the strict approach was a lot more successful than the voluntary agreements. The drop in CO<sub>2</sub> emissions is probably also the result of the economic and financial crises and increased oil prices, that in turn led (at least in the Netherlands) to an increased interest in smaller more energy-efficient cars.

One might conclude from the above that emission limits for cars is a very successful measure and that the EC should continue on this path to ultimately induce the transition to zero-emission vehicles. Simply tightening the emission limit further and further would ultimately require that car manufacturers refrain from building cars with an internal combustion engine and shift production to battery electric and hydrogen cars, but such a 'top-down' policy approach is likely too simple to actually work.

First, we should consider that the current emission limit of 130 g CO<sub>2</sub>/km is technically achievable without significantly altering size, comfort and performance levels of cars. A reduction of up to 95 g/km would even be feasible in this respect (Smokers, Fraga, & Verbeek, 2011). Further reductions, however, require advanced vehicle technology that will change the way car users are able to fulfill their mobility needs. Advanced vehicle technology such as plug-in hybrid, battery electric and fuel cell are required, which cannot be operated in the same fashion as conventional vehicles. Particularly battery electric vehicles and fuel cell vehicles currently have limitations with regard to range, fuel time and fuel availability (Hoen & Koetse, 2012). Van Meerkerk, van den Brink, and Geilenkirchen (2011) show, for example, that due to the current features of electric cars, only 5% of households would be able to substitute their conventional car with an electric car without having to alter their current mobility behaviour. Hoen and Koetse (2012) show that the average Dutch car owner has a strong negative preference particularly for electric and hydrogen cars.

Second, the additional costs that are associated with a shift to zero-emission vehicles are substantial and not comparable with the additional costs that were associated with the catalytic converter. Even with significant improvements to battery technology, electric cars are expected to be roughly €15,000-20,000 more expensive than a conventional car (Nijland, Hoen, Zondag, & Snellen, 2012). In the coming years, additional costs may be three times as high.

With the elaboration above, we want to make clear that AFV adoption cannot simply be enforced by setting stricter emission limits. There are strong indications that society may be hesitant and that there will be a need to 'engage' the general public. Hoen and Koetse (2012) show that car users who drive a limited number of kilometres a year are most likely to adopt an AFV in the coming years. Although technically this should be attributed to the limited range of these vehicle types and better performance on range will increase preferences, it also means that policies to promote electric vehicles aimed at this group will stand a better chance of succeeding than policies aimed at those who drive more. This illustrates the importance for policymakers to identify the individuals who are likely to energize the transition.

#### *Purchase Tax Incentives*

A Dutch example of pricing policy that has led to an increase of the share of fuel-efficient cars is the CO<sub>2</sub> purchase tax differentiation (Kieboom, Geilenkirchen, & van Meerkerk, 2010). It entails lower purchase price taxes for cars that emit less CO<sub>2</sub> and additional purchase tax for larger energy inefficient cars. Several other countries have adopted similar tax schemes (Denmark, Germany). In the Netherlands, a tax incentive is also in place for company car drivers.

It is interesting to see that the sales of small energy-efficient cars have increased substantially over the last years (Kieboom et al., 2010). The same holds for company cars (Ecorys, 2011). The average CO<sub>2</sub> emission of passenger cars is below the EU average and in 2011 was in fact close to the 130 g/km goal that is set for the year 2015. Car commercials on television actively promote the policy by stressing the tax exemptions for private and company cars, which some may consider surprising since car manufacturers usually make higher profits on larger cars.

#### 4. The Need for an Alternative Approach

The account of policies based on typical technical measures such as taxation or CO<sub>2</sub> norms will not be sufficient to reach the goal of a carbon neutral mobility. Not only are the measures falling short in effects, but the expected political 'fall out' is such that politicians often already lose faith before the measures are put forward.

At some point, we will need to address established social practices of mobility more directly. This realization is not new, of course. Others have argued along similar lines that the traditional approach to transport planning generally focuses on economic arguments of rationality that fail to explain why the outcomes of policy measures hardly ever match up with expectations. Banister (2008) states *'...there always seems to be a reason for not changing and maintaining the status quo. However good public transport is, there will always be a reason for still using the car.'* The current car system seems remarkably stable and unchanging since it is reproduced through an extensive economic, social and technological network of vested interests, agents and flows (Dennis & Urry, 2009).

Some 'hard core' traditionalists may argue that it is 'technically feasible' to reach the desired outcomes purely by technological means. But their insistence fails to take politics into account. Surely, 'we have got the technology' but there is just no consensus on using it. We calculate that we can stay within the 2°C target for an estimated 1-2% of GDP annually (PBL Netherlands Environmental Assessment Agency, 2009a). But the political leadership cannot come to an agreement nevertheless. In the field of mobility, we see this being repeated. It is unlikely that in current circumstances, clean fuels and low carbon vehicles alone can deliver on the 2° goal. But can we step out of current habits and defaults? Reducing kilometres driven directly affects travel behaviour since it involves either changing the mode of transport (from car to public transport) or substituting trips altogether (through teleworking or Internet shopping).

Of course, changing mobility habits has been discussed as well. How do we get a person who is currently commuting by car, to change modes and go by train instead? While the lock-in in countries such as Australia or the US is massive,

European countries often still have the size, scales and density that would allow a social alternative. Moreover, most likely people know that public transport is safer, less polluting and less susceptible to congestion.

### *Transport Policy Facilitates Travel*

There are two fundamental principles to transport planning that have proven to be remarkably robust over a long period: (1) travel is derived demand and (2) people minimize their generalized cost of travel (Banister, 2008). This basically entails that all travel has purpose and hence economic value and that increased travel speeds reduce total costs of the system ('time is money'). Ex-ante (cost-benefit) policy evaluations often show that reduced travel time makes out a significant part of the overall benefits of an infrastructure project. This paradigm thus leads to the rationale that more travel needs more infrastructures, which explains the explosive mobility growth that we mentioned in Section 3. We need not explain that this paradigm is not compatible with the paradigm of sustainable mobility. We might argue that they are each other's exact opposites.

### *The Car as a Discourse*

Even if the built environment is conducive to a more sustainable form of mobility, we see that this alternative fails to materialize. In Western European city regions, the densities, connectivity's and spatial lay out of work, recreation and living are such that a much more benign mode of transport could be envisaged. What is more, these countries do have the planning capacities to help bring about such changes. For countries such as Denmark, the Netherlands, Belgium or Norway, they do not have a national car industry that puts undue pressure on the governments. Yet still, even in countries with such a great advantage change is slow in coming.

It is often underestimated how power is also embedded in discourse: in a particular way of seeing, underpinned by a more or less stable set of concepts, ideas and classifications (Hajer, 1995). The dominant discourse promotes and privileges car travel and reinforces the bias in the system (in terms of passenger kilometres per year car travel is almost four times higher in the Netherlands than public transport (Hilbers et al., 2009)). Cars and suburban life styles are a core component of advertizing and commercials. The car is accepted as the dominant and most desirable means of transport. Even in Dutch research, we hardly find future scenarios with no or even much reduced car travel. Most scenarios, even those with stringent climate goals incorporated in them, predict that car travel is dominant even in the long term. Sure, the car gives individual flexibility, comfort and convenience (Dennis & Urry, 2009) and is viewed by many as a tool that provides a great sense of freedom. A view that is constantly reinforced in advertisements and through policy privileges. But this default also stands in the way of finding out if there are viable alternatives that could link way of moving to cultural icons that could become new 'life style carriers'.

Thinking ‘in the box’ is trying to figure out how to organize the political dilemma surrounding measures that, some way or another, limit our freedom of car movement. Road pricing, increased parking fees, fuel levies – we can all name the policy measures that politicians fear owing to the lack of public support. Arguing that these measures are necessary, since there is a climate problem and that therefore CO<sub>2</sub> emissions need to be reduced, is insufficient. Here it is important to differentiate the smaller group of active skeptics of a ‘after the car’ discourse (Dennis & Urry, 2009) from the large contingent of people who do not actively choose against a more sustainable approach, but that simply live on default.

At this point, we must rethink the role of scientific expertise as well. After all, as experts we are co-producers of existing realities. By and large, experts are comfortable with a role of what Wildavsky (1979) called ‘speaking truth to power’, preferably using analytical techniques to arrive at ‘(cost) optimal’ solutions. It is the type of relationship between science and politics that political scientist van Gunsteren (1994) described as learning via ‘analysis and instruction’. Yet this approach is increasingly ill suited for our contemporary world. Our world is changing at a rapid pace (think of technological developments of cultural preferences) and the commanding power of the political centre is waning (Hajer, 2009). Interestingly, Van Gunsteren also coined a second type of learning, which he described as ‘variation and selection’. This is interesting as it hints at ways to break out of habit, default and discourse. It suggests that there is a future in the experiment, the temporal. Furthermore, it suggests that incremental policy change via experiment may have one big advantage over large-scale change: It allows people to readjust their values based on actual experience of an alternative. Hajer describes his favourite example thereof in the PBL essay *The Energetic Society*, discussing the work of the Commissioner of the New York City Transport Department, Janette Sadik-Khan (Hajer, 2011, pp. 36-37):

‘When Janette Sadik-Khan took office in 2007, she was confronted with a city that was short of money, but that urgently needed to improve the quality of its surroundings and come up with a new transport strategy. In addition, she was faced with a city that was, and still is, famous for the long drawn-out legal proceedings used by residents to effectively oppose all kinds of changes.

Janette Sadik-Khan took a new approach: (1) let the city experience what is possible in terms of quality improvements; (2) implement plans quickly, if necessary on a temporary basis; and (3) measure change, analyze data and communicate the results.

To improve the quality of the local environment small, temporary swimming pools were placed in various areas of the city in the summer months, when the city swelters. The most high-profile decision, however, was to transform Broadway, one of the main roads in Manhattan, into a series of squares between Times Square and Union Square. The transformation took

place literally overnight, by placing planter boxes in the middle of Broadway and painting green traffic-free areas on the road. This initially controversial 'reclaim the street' project is now incredibly popular. Sales on Times Square increased by 71%, there were 63% fewer injuries to car drivers and passengers, 35% fewer injuries to pedestrians, 80% fewer pedestrians walking in the road, taxi journeys to the north of the district went 17% faster and so on (New York City DOT, 2010a; New York City DOT, 2010b)'.



Courtesy of NYC DOT.

The point of the example is that Sadik-Khan worked with (1) experiment, (2) *ex durante* evaluation, (3) public relations and (4) experience as precondition for value change. She achieved pedestrianization that would never have worked through the old techniques. She created a *space of experience* that made it possible for citizens to visit and explore an alternative and think about the new preferences and possibilities that came with it. She used statistics to monitor the result and shared this with the public. She started cheap and quick, and only moved to more permanence and heavy investment after she had won the stakeholder and the general public.

A change in public acceptability will not happen overnight and the dominant discourse requires that policy measures aiming at more sustainable mobility will likely have to be eased in gently. Nevertheless, the New York case shows an alternative way to move about; it is thinking out of the box.

Facing the dilemma of moving towards sustainable mobility could benefit from thinking about the origin of preferences, public acceptability and behaviour and much less about the traditional (technocratic) transport planning solutions that focus on technology and technological acceptance, reduced travel times and improved accessibility. Moreover, we must realize that traditional transport planning has resulted in a situation where stressing the benefits of car use is the dominant discourse. A change in both of these key elements will facilitate a road to more sustainable mobility. In the next section, we will argue that there are six key steps or requirements to mobilize the Energetic Society that can help overcome the dilemmas pointed out in this section.

## 5. Exploit the Energetic Society

The need for an alternative approach towards sustainable mobility tells us that we need to look at mobility in 2050 from different perspectives. We need to look at more than just the physical and technical dimension of less movement and AFVs. We have established earlier that to achieve the goals, we need to drive less and change to alternative fuels and vehicles. But how to achieve this transition remains the question. The transition cannot be made by government alone, although the government does play a substantial role.

The government alone can define the goals, by taking a clear position for sustainability, by making sure that the 'polluter pays' by, for example, a carbon tax, and by taking away financial incentives that work in the opposite direction. Government can also influence mobility behaviour in the long term by working on an infrastructure of sustainable transport, from high speed rail connections, low or zero-emission river and marine freight transport to neighbourhoods

who combine working, living and recreation, thus reducing mobility needs. And government can influence mobility behaviour by creating rules and regulations that are favourable for sustainable transport. Still, all that is not enough to achieve the sustainable mobility goals for 2050. We need to leave the shelter of the silo and think socially, connecting measures to what we know from history and policy to aspirations about the future.

Historically, strong environmental regulation has always been accompanied by broader social movement. What is more, although the famous works of Donald Worster<sup>2</sup> and Samuel P. Hays<sup>3</sup> might have shown that those movements together produced a sea of change in their times, those contributing did so for very different reasons. The wilderness protection and the launch of the National Parks in the United States were the result of a coalition of German educated foresters, Washington-based policymakers, a newly urbanized population rediscovering the natural environment they had left a generation ago, and a political leadership ready to capture all the energies. The big surge of environmental awareness of the 1960 and 1970s came from a coalition comprising concerned biologists, such as Rachel Carson<sup>4</sup>, local movements struggling with pollution sites, and a newly educated generation that discovered and prioritized ‘post-material’ values from the comfortable position of having grown up in families where parents had devoted their lives to beefing up the material quality of their family life.

We think that the climate change strategies of today demand a search for kindred spirits that can together create the often unlikely coalitions that then could bring about real social change. In other words, an effective climate strategy requires more than outlining a policy of effective goal achievement – it also must tap into social and cultural forces that can help make it work.

First, we need to give more thought to the importance of *framing*. Although it is arguably always the individuals that act, we know that they change their choices because of collective action frames. Big achievements in environmental politics can be explained because of broader cultural alliances, that is what the history of environmental politics reveals. Interestingly, these forces were mobilized through a shared way of seeing. ‘Wilderness protection’ was something many Americans positively related to, around 1900; it laid the foundation for the broad coalition of the conservation movement, composed of very different groups. ‘Industrial pollution’ was a mismatch with the aspirations of a new post-material generation in the 1960s.

2 Compare Nature's economy: A History of Ecological Ideas (1977).

3 Compare Conservation and the Gospel of Efficiency: The Progressive Conservation Movement 1890-1920 (1959).

4 Compare Silent Spring (1962).

The question now is whether 'climate change' has the maximum potential to mobilize social energy in the early 21st century. The current frame of '80%' reduction, 'cap-and-trade', a 'threat of apocalypse' and 'coordinated' policy efforts might facilitate an agreement among states, but is not going to help make this into a broad cultural force.

We think that a clean and fair economy based on energy that is in endless supply is the irresistible master frame. As Nordhaus and Shellenberger (2008) remind us, Martin Luther King did not say 'I have a nightmare'; he said 'I have a dream' and created a movement. Some decades ago, we used leaded petrol poisoning our very own children; we threw bottles in the bin harming garbage collectors and wasting resources. Our cars gulped down petrol in the way of children drinking lemonade. Looking back, and based on what we know today, it is pathetic. We may have a tendency to romanticize the past, but not one containing leaded petrol, scattered remnants of broken bottles or thirsty cars. In that vein, it might help to show how pathetic a continued reliance on fossils, polluting oil and dirty coal actually is.

Innovation in itself is a no go. It is a technocratic wish. Yet, coupled to the findings of climate change and 'peak oil', it forms into something. This is a frame that speaks of a move from the 'age of polluting fossils' to the 'age of autonomy, based on endless renewables'. Key words in that alternative discourse would be innovation, smart solutions, global justice, accountability and autonomy.

*Smart solutions.* Young people like iPods, not clumsy cassette players with big batteries (that quickly run out anyway). It is this generation that will have to be brought on board. They like efficient vehicles. Petrol is not going to become cheaper. All money spent on petrol cannot be used for other purposes.

*Global justice.* Renewables quickly create the potential for developing countries to take care of their own demands, through solar cells (photovoltaic [PV]), mobile networks and the like. Western commitments should, in that vein, perhaps be more about sharing patents and technology and less about money.

*Autonomy.* All people in the West like to think of themselves as autonomous choice making individuals. Renewables create autonomy for developing countries. Renewables enhance the autonomy from geopolitically unstable regions.

*Endless supply.* Some sources of energy are unlimited; we only have to find the ways to harvest them. What a dream, what a mental shift. Tap into that resource by directing innovation to harvesting the endless resources of renewables. What a focused target for our 'knowledge economy', that is, our universities and firms.

The social power of this discourse can be seen already. Local initiatives spring up everywhere. Solar energy PV schemes are tremendously popular, urban agriculture is 'cool'. Mobility is still very much a state thing. But it is a deeply cultural domain. Is it foreseeable that the trendy elitism is moving into driving hybrid, electric scooters, classy electric bikes?

*Shifting gear.* We need to shift gear. If we need to change the default in mobility, there clearly is a major role for the state. The role of the state is, first and foremost, one of setting long-term goals and making fully clear that these are no longer open to discussion. Only states can make futures more predictable and thus help create the environment that is conducive to making long term investments in a greening of the economy.

The prime task of the state is to set clear limits and clear goals. The state should create a level playing field, both in space and time, providing the certainties and opportunities that are needed to unleash a creative competition.<sup>5</sup> The government has to be a stable, trustworthy institution to give businesses and civil society a base for innovations. Citizens have no problems with a government that names the issues. They do have a problem with a government that appears not to care about the difficulties they come across in their daily lives. The business community, also aware of the challenges, needs clarity about the government's objectives and expectations. The same goes for finance, banks and private funds make risk assessments before investing, and in doing so require a future that is as predictable as possible. A future where investing in sustainable innovation is attractive. The problem for business is not so much over-ambitious government, but the perception of an unpredictable government. And as far as sustainability is concerned, predictability has not been a strong point in recent years. In the developed world, the 'green growth' frame has the potential to guide, bind and inspire and form a basis for the new discourse.

Second, *setting the defaults right* is a very powerful idea. All forms of organization come with a bias, as the American political scientist Schattschneider observed in the early 1960s (Schattschneider, 1960). Later that decade Bachrach and Baratz (1962) famously elaborated the idea that much power is embedded in 'non-decisions'. These ideas are now very relevant to the climate debate. *Our society's default is based on the consumption of fossil fuels.* In ordinary life we take one 'non-decision' after another, perpetuating the non-cool, climate-harming lifestyles. States can change defaults. Set the rules that make it attractive to conserve energy and to turn to renewables. One clear marker could be to define

5 This is the position also argued for by Anthony Giddens in his *Politics of Climate Change*. It is a call for what he calls an *enabling state* (Giddens, 2009).

new 'priority rules'. These new priority rules might be based on the trias energetica (Lysen, 1996): Highest priority should be given to energy saving, followed by the use of renewables; only then followed by 'cleaned' fossils. Combine this with explicit commitments to CO<sub>2</sub> reduction targets.

This requires using judicial and institutional means. Mobility budgets, CO<sub>2</sub> targets for regions? Or perhaps, closer to the initiative of Janet Sadik-Khan, experiments on a local level with adjustments of the rules of the game. For instance, we know that the limit to cycling is a distance from home to work of around 8 kilometres. Within that many people would consider it, beyond that hardly anybody does. What would be the effect of a radical prioritization of low carbon traffic during the morning rush hour? Slow clean traffic having a priority to combustion engine-driven vehicles? Copenhagen is getting close with its wide bike lanes. City governments have the power to undertake this experiment.

Third, *dynamic regulation*. Make sure you keep the dynamics going, through a system of *dynamic regulation* via which only the top 10 or top 20 vehicles are entitled for a tax reduction, thus stimulating innovation. The core of such a system is that government rewards those that embrace innovation and penalizes laggards. Compare the Japanese Toprunner programme where the best performing (in energy efficiency) is taken as a 'benchmark' for the industry requirements.

Fourth, *financial instruments*. We know that one reason for the faulty default towards fuels comes directly from the fact that fuel prices do not cover all costs. So far, we have been unable to internalize environmental costs. States can support the development of the autonomous society by correcting this bias of the industrial age. Make fossil fuels expensive: The single biggest stimulus is putting a high price on CO<sub>2</sub> emissions. The effectiveness of financial instruments is conventional wisdom. Nothing new, but they are to be an essential part of the mix. By pricing detrimental environmental effects, polluting products and activities become more expensive. This encourages citizens and companies to choose environmental friendly alternatives. Such pricing in addition stimulates innovation. For sustainable mobility to take hold a carbon tax, or another form of carbon emissions pricing, encouraging the use of AFVs and alternatives to travel is an important component.

Fifth, stimulate citizens to *share*; sharing cars give consumers access to a pool of resources, enabling them to choose the perfect vehicle for each and every occasion, a sports car for dates, a utility vehicle for holidays, a small car for errands and a classic car for a wedding (Chase, 2011), while saving them the costs of owning, maintaining and parking a car. Sharing cars may also remove some of the inhibitions identified towards alternative fuelled vehicles (Hoen & Koetse, 2012).

Sixth, use learning through ‘variation and selection’: Here it is crucial to decentralize goal achievement. This can be done setting national targets and provide the incentives to compete, allowing, indeed encouraging, creativity in goal achievement. This is to be accompanied by a new, much upgraded organization of monitoring and feedback.

The value of feedback is what Fung (2004) has theorized to be ‘accountable autonomy’. Set targets, monitor progress, show differences in performance. A subsequent key role for the state is basic policy evaluation: Explain why some are ahead and others lag behind. Put a premium on improvements. Yet there is also a flip side: Punish misuse of the rules that are meant to prevent climate change from getting out of hand. Of course, there will always be loopholes; the thing is to fix them quickly.

Monitoring and learning are closely connected (Sabel, 1994). Moreover monitoring especially is an instrument through which the government could demonstrate its support of transparent collaborations between citizens and business. Free access to information can open up the door to new forms of collaboration between the private and the public sectors (Fung, Graham, & Weil, 2007). At the societal level, there are significant benefits, partly because new innovative services can be developed that the government is unable to deliver itself (van den Broek, Huijboom, van der Plas, Kotterink, & Hofman, 2011). This could be a way to develop the ‘clearly targeted personal information, including social pressure, awareness raising, demonstration, persuasion and individual marketing’ that is crucial to the acceptability sustainable mobility according to Banister (2008).

An advanced version of monitoring and feedback is the ‘test, learn and adapt methodology’ of randomized controlled trials (RCTs). Long a prerogative of medicine, the method is also now used in international development and business to identify which policy or sales method is the most effective. Effectively with the use of RCT policies can be evaluated and adapted while they are being implemented, which sharpens the feedback loop (Haynes, Service, Goldacre, & Torgerson, 2012).

## 6. Concluding Remarks

Sustainable mobility is a very ambitious vision of the future. It is one that has to inspire change in a physical environment that is not very conducive to this ideal. Over the last 70 years, we have created an extensive urban environment that is largely based on endless supplies of fossil fuels. It has become a large technological system that comes with many default options that we will need to change in order to achieve a sustainable future. This large technological system is not merely a physical entity. It comprises life styles, industry, commerce.

Interestingly, we see a return to urban values at the same time. Economists are rediscovering the value of the dense inner cities (Glaeser, 2011); cities are now the major centres of new jobs, and demographically people move back into more dense urban environments. Partly this is an effect of the crisis. Urban living is less costly than suburban living combined with urban jobs. Partly it is a true value change.

At the crossroads of value change, physical and social technology, with the aid of regulation, pricing and information, we may shift gear and release new social energy. The key is that the mobility modus is determined by more than just the need to go from *a* to *b*. The reasons alternative transport modes can be competitive or attractive are that they combine low emissions with additional goals. Societal goals such as livability in cities, citizens' concerns with health and well-being, personal goals such as an experience, a sense of identity, autonomy or business goals such as a corporate identity, cost reductions or maintaining competitiveness. And, also, the current recession helps the starting trend of sharing expensive consumer products such as cars.

PBL calculations show that the EU goals for sustainable mobility are theoretically achievable by 2050 (PBL Netherlands Environmental Assessment Agency, 2009b). However, policy towards sustainable mobility has an only chance of success if it builds up to a new discourse, which is co-produced across all levels and among governments, individuals and businesses. Participation is no longer to take place in the formulation of government policy; it now becomes an involvement in active social engagement.

We are not saying that small steps and local initiatives are the solution, just that without them there will be no solution. Here we should not forget that some of the new associative governance formations, such as the C40 cities<sup>6</sup> collaborating on climate change, are not without power. The C40 represent 8% of the global population and agreements in such association can therefore really make an impact, for instance, by kick-starting innovation using the power of public procurement.

Government at all levels can shift gear in the right direction and support successful initiatives, thus promoting incremental change in the right direction. Of course, while the strategy will remain, the tactics may change. Policy must be adaptive and co-created to some extent, so that it can respond flexibly to changing circumstances or new insights.

Practically, the devolution of policy making towards regions and municipalities and the use of markets and individuals to deliver services and innovations need to be matched by monitoring and feedback tools of the information society as mechanisms to identify and nurture successful innovations and prevent straying in the wrong direction. This can be done by government through evaluations and RCTs (Haynes et al., 2012) and by citizens, by comparing the performance of cities and businesses on a sustainability scale.

If environmental history teaches us anything, it is that major shifts were always the result of a combination of factors, including changing cultural preferences, new knowledge and often facilitated by experiences of actual crisis. The trick this time round is to try and get the change going without the latter one. Here experts may help, not only by pointing at the need for change, but much more by identifying the viable alternatives. The combustion engine car is unsustainable and does not fit into the ideal of a clean future for 2050.

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# Business as Unusual

# 08

**Views from Industry: Toyota, Port of Rotterdam and Maersk**  
**Miranda Schreurs and Folmer de Haan**

**In this chapter a European perspective on sustainable transport is considered although some global dimensions are touched upon as well. In the chapters of this book authors explored different aspects of sustainable mobility in an essayistic manner: its definition, trends, technical developments, behavioural aspects and governance issues. In this chapter we try to bring all this, together with the European policy comparing research that was commissioned on the occasion of this book, in relation with industry developments. We do so by presenting the results of interviews with three key businesses in the sector. This chapter starts with a short and basic introduction of the industry sectors discussed at the interviews and continues with some relevant policy developments. Then we discuss what the interviews delivered and we finalize this chapter with some concluding remarks.**

## **1. Introduction into the Interviewed Sectors**

The transport sector has a large impact on global carbon dioxide (CO<sub>2</sub>) emissions, accounting for roughly one-quarter of European and 23% of global CO<sub>2</sub> emissions. It is the second largest emitter after the power and energy sector. The two largest contributors to greenhouse gas emissions in the transport sector are road and international maritime, with international aviation coming in third. In this chapter, we focus on the largest two emitting sectors: road which is by far the biggest source of transport-related emissions, and international maritime which is experiencing major growth rates.

The automobile's invention in the latter part of the 19th century and the implementation of production-line manufacturing beginning in the first decades of the 20th century made the delivery of large numbers of affordable cars possible. The automobile has transformed life and economies and added many benefits, but has also led to an ever denser network of roads and highways. As of 2010, there were an estimated one billion cars globally, a doubling over 1986 when there were 500 million cars. This means that today there is essentially one car for

every seven people in the world although the distribution of the vehicles remains unbalanced. In the United States, the ratio of cars to people stands at 1:1.3. France, Japan and the United Kingdom were at about 1:1.7. In China, the ratio is 1:17.2 and in India 1:56.3.<sup>1</sup> As an increasingly large global middle class emerges, there has been an explosion of ownership of automobiles. This has led to major road congestion, a problem that is exacerbated by peak travel, as discussed by Todd Litman and illustrated in Figure 1, Chapter 2.

Similarly, international shipping has exploded. Due to its comparatively lower costs, shipping accounts for about 90% of world trade and there are over 50,000 merchant ships internationally.<sup>2,3</sup> European companies own about 41% of the world's total shipping fleet but competition from other regions is intense.<sup>4</sup>

Global emissions from transport grew by 45% from 1990 to 2007, with emissions from road transport being the largest in terms of volume, and emissions from shipping and aviation showing the highest growth rates. This growth is expected to continue with an expected growth of 40% from 2007 to 2030, unless business-as-usual-developments can be changed. Emissions from international shipping accounted for approximately 3% of total global CO<sub>2</sub> emissions in 2007, meaning that if shipping were ranked as a country, it would be the fifth or sixth largest emitter in the world.<sup>5</sup>

In the case of Europe, emissions from the transport sector are increasing whereas in other sectors they have been decreasing. Emissions have increased by about 36% in the two decades since 1990.<sup>6</sup> This trend has, however, been broken in relation to road transport CO<sub>2</sub> emissions in France, Germany, and Japan where between 1995 and 2007 there was a stabilization or in the case of Germany, a drop in transport related CO<sub>2</sub> emissions.<sup>7</sup>

In many OECD countries, passenger road travel has the largest share of carbon dioxide emissions within road transport (estimated at 74% in the United States, 69% in Germany, and 71% in the United Kingdom). In contrast, trucks are

1 John Susanis, "World Vehicle Population Tops 1 Billion Units"; WardsAuto, <[http://wardsauto.com/ar/world\\_vehicle\\_population\\_110815](http://wardsauto.com/ar/world_vehicle_population_110815)>, 15 August 2011.

2 International Chamber of Shipping, "Shipping and World Trade"; <[www.marisec.org/shippingfacts/worldtrade/](http://www.marisec.org/shippingfacts/worldtrade/)>. Retrieved on 20 August 2012.

3 See also the second paragraph of Todd Lidman's chapter in this book.

4 Commission of the European Union, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Strategic Goals and Recommendations for the EU's Maritime Transport Policy Until 2018, Brussels, 21.1.2009, COM(2009) 8 final.

5 OECD/International Transport Forum, "Reducing Transport Greenhouse Gas Emissions: Trends & Data, 2010"; OECD/ITF, 2010.

6 European Commission, Reducing Emissions from Transport, <[www.internationaltransportforum.org/Pub/pdf/10GHGTrends.pdf](http://ec.europa.eu/clima/policies/transport/index_en.htm)> <[http://ec.europa.eu/clima/policies/transport/index\\_en.htm](http://ec.europa.eu/clima/policies/transport/index_en.htm)>.

7 OECD/International Transport Forum, Reducing Transport Greenhouse Gas Emissions: Trends & Data, 2010, OECD/ITF, 2010.

responsible for approximately 27% of emissions in the United States, 31% in Germany and 29% in the United Kingdom.

There is, however, considerable difference among countries in the share of transport-related CO<sub>2</sub> emissions from different transport modes. For example, in the Netherlands international maritime transport is responsible for 53% of domestic CO<sub>2</sub> emissions, whereas in Spain it is 18%, and in Germany and the United States only 5%.<sup>8</sup> An interesting comparison of the modal split of freight volume in the different EU countries is given below.<sup>9</sup>

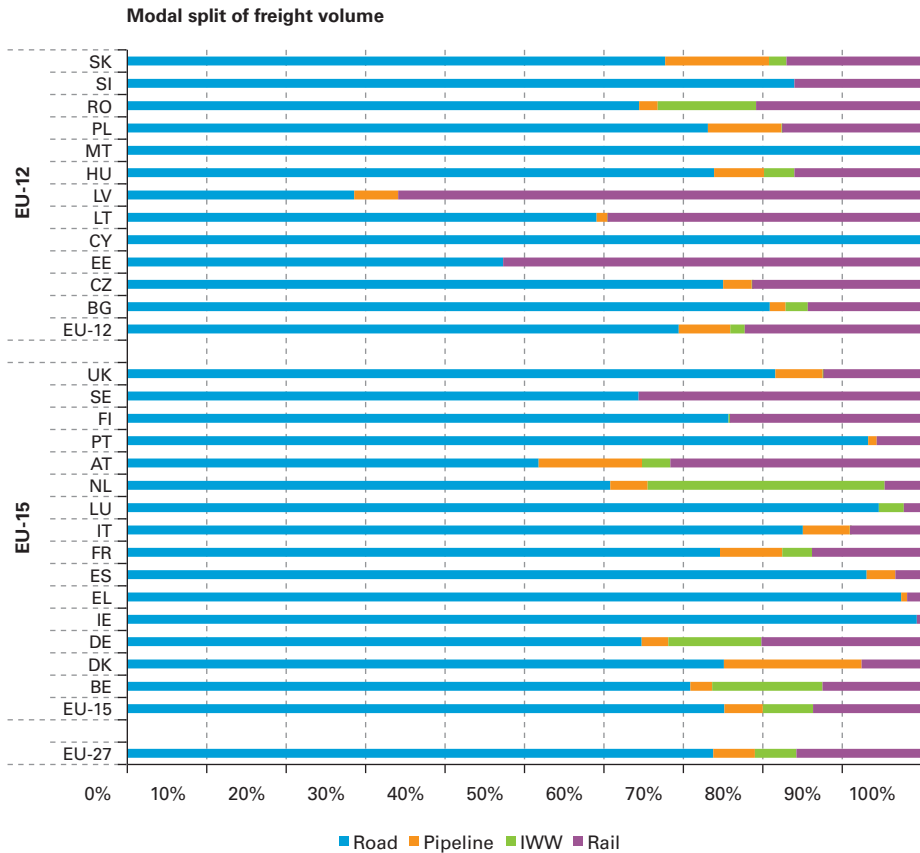


Figure 1. Modal split of freight volume (shares in tone-kilometers in 2009) (Note: Transport volumes are allocated by origin of transport company. Source: DG MOVE Pocketbook (EC, 2011c).

8 OECD/International Transport Forum, Reducing Transport Greenhouse Gas Emissions: Trends & Data, 2010, OECD/ITF, 2010.

9 Drawn from the study commissioned on the occasion of this book and the conference: Member States in Top Gear, CE Delft, 2012.

## 2. Policy Developments

Achieving the kinds of CO<sub>2</sub> emission reductions necessary to keep global average temperatures from increasing above the 2°C, as has been called for by global leaders on the basis of warnings from the Intergovernmental Panel on Climate Change, will require major emission reductions in all sectors. The European Union has set a goal of cutting its emissions by 80-95% of 1990 levels by 2050. The European Commission estimates that this means a minimum of a 60% reduction of emissions from the transport sector over the same time period. Given the growth of emissions from this sector, this challenge will be major. An interim goal that has been proposed by the Commission is a reduction of greenhouse gas emissions from the transport sector by 20% below their 2008 levels by 2030. This is, however, too little, too late as it means an 8% increase in emissions above 1990 levels. Furthermore, this will mean that huge cuts will be necessary from 2030 onwards if a 2050 target of a 60% cut is to be achieved.<sup>10</sup>

The level of emission reductions being called for will require major changes in the transportation sector, both within Europe and globally. In the European context, the Commission has produced a series of transportation strategies. Two important ones are the 2009 Maritime Transport communication, and the European Commission's 2011 Transport White Paper: A Roadmap to a Single European Transport System. While the Maritime Transport communication focuses on cost efficiency and long-term competitiveness the White paper on transport aims at fostering clean, safe and efficient travel throughout Europe. It is to be sustainable, integrative, user-friendly, and technology-led and to support economic progress, competitive growth, and efficient use of resources.

The White Paper has several relatively ambitious goals although in some instances it is questionable how the various goals listed are to be achieved simultaneously. Several key areas for infrastructure development, modal integration and shift, efficiency improvements, and new technologies are discussed. These include the highly ambitious target of achieving a 60% reduction in carbon dioxide emissions by 2050 relative to 1990 levels while increasing transport and supporting mobility. It is argued that this will require greater coordination across Europe, also in terms of infrastructure investment decisions. According to the White Paper, this means establishing new transport patterns which can carry larger volumes of freight and greater numbers of travelers through modal combinations. Greater attention to demand side reduction should also be encouraged.

<sup>10</sup> European Commission, White Paper: Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System, Brussels, 28.3.2011, COM(2011) 144 final.

The Commission notes the need for improved energy efficiency, the optimization of the performance of multimodal logistic chains, and more effective use of transport and infrastructure through improved traffic management and information systems. In addition, it is argued that efficiency improvements can be stimulated by the use of advanced logistic and market measures for an integrated European rail system (including the removal of restrictions on cabotage, abolition of barriers to short sea shipping, and undistorted pricing).<sup>11</sup> In other words, the transformation will be complex and difficult. There is no silver bullet.

In sum, what we can see is that the transport sector needs to move away from the unsustainable trajectory it is currently on. If business as usual continues, then the environmental and societal footprint of the transport sector will only become more problematic than they already are. As Joan Ogden sketches in Chapter 3, technical advancements will be needed on at least three fronts: improved energy efficiency, reduced travel demand and adoption of low carbon fuels. This kind of transition is unlikely without strong coordination at the European level, a comprehensive policy framework with a guiding vision, and the participation of industry and society alike.

### 3. Views from Industry

The Commission's strategy is unlikely to be successful without a close, but transparent relationship with industrial actors. Particularly important will be the role played by first movers that link ecological considerations closely with their business models. With this in mind, we approached three major players in the transport sector that have taken some important first steps to improve their sustainability record and environmental performance, and asked them what has motivated them to focus more on sustainability in their business models. We also asked them to look ahead and consider what the major sustainability challenges will be in the coming decades and what can be done to address them.

The first interview was with Toyota, Europe, located in Brussels where we talked to Didier Leroy, CEO.<sup>12</sup> The second was with the Port of Rotterdam Authority where we spoke to Hans Smits, CEO.<sup>13</sup> And, finally, we interviewed Maersk, a Global Fortune 500 company, in the fields of shipping, container, and transport activities. Here we spoke with Mr. Kornerup-Bang, Lead Advisor, Environment

<sup>11</sup> In this book a chapter written by Peter Sweatman is dedicated to the Information and Communications Technology, Chapter 4.

<sup>12</sup> Interview was conducted by Folmer de Haan and Miranda Schreurs at the Tokyo Europe headquarters in Brussels, Belgium on 7 June 2012.

<sup>13</sup> Interview was conducted by Folmer de Haan and Michiel Ooms at the Rotterdam Port Authority on 6 July 2012.

and Climate Change at A.P.M. Muller Maersk.<sup>14</sup> These interviews touch on the diversity of the mobility industry, covering business-to-business as well as business-to-consumer perspectives. The interviews also point to the different views and concerns of companies that are primarily concerned with a single transport modality (e.g. the automobile or shipping) and those with more regional and global perspectives where different modalities come together in a worldwide value chain. The Port of Rotterdam is such a hot spot.

The following draws from these interviews as well as from material available from these companies and other third party sources. It reflects on aspects of the visions seen in the Commission's White Paper as well as on views from industry players themselves on how their industries are likely to change and how they see the future.

What one sees from these interviews is a transport sector where some progress has been made to improve sustainability, but substantial challenges remain. These challenges also present opportunities to these industries to become more efficient, develop new technologies and processes, and remain competitive players in an increasingly global context. Each of our interviewees stressed not only the difficulties ahead, but also the opportunities they see for developing new winning strategies and competitive advantages.

What we also see in the interviews, is that the European and global dimensions of sustainable transport must take a central role. Lack of strong coordination at the European level means there is considerable inefficiency in the transport sector and it is an area where much progress is needed. Lack of adequate global environmental and sustainability standards means that the playing field is not level. Nevertheless, despite these challenges all three interviewees pointed to a business case from moving ahead of competitors on sustainability issues. They stressed also the importance of bottom-up business-to-business initiatives. This goes for worldwide transport chains, according to Maersk, as well as for local spots according to the Port of Rotterdam. While high-level coordination and legislation is needed (with international coordination on climate mitigation efforts, for example) a parallel bottom-up thinking and action is of increasing importance.

#### **4. The Automobile Industry**

The European automobile industry is relatively large, employing two million people directly and supporting an additional ten million jobs in associated

<sup>14</sup> Interview was conducted by Folmer de Haan and Michiel de Vries at the Copenhagen headquarters of A.P.M. Muller and Maersk, in Copenhagen, Denmark on 6 August 2012.

industries, including the metals, plastics, chemicals, textiles, electric and electronic systems. Exports are valued at about 70 billion Euro annually. The European Automobile Association has over 250 plants in 18 EU countries.<sup>15</sup> The automobile industry is, therefore, a central industry for Europe.

The industry is, at the same time, one that contributes to many of the sustainability problems facing Europe. How the industry develops, the kinds of technologies it invests in, and the lobbying activities it engages in with national governments and at the European level will substantially influence whether the Commission's goals for transforming the sector can be achieved. Also important will be the competition that exists between automobile manufacturers as they struggle to hold on to or increase their share of the market. This, of course, means reacting both to consumer demands and the regulatory requirements facing the industry. Below, we look at the activities of one player in the automobile market that is changing the technology. We questioned why, how and what could be learned from this case.

## 5. Toyota Europe

Toyota was a first mover in the development of the hybrid automobile, for which it has won many accolades. Originally viewed with skepticism, Toyota began research on hybrid technologies already in the mid-1960. As late as 1997, hybrid technology was still not taken seriously by many automobile manufacturers. Toyota, however, saw a niche and moved into it. The hybrid technology fits into the existing fossil fuel based infrastructure of the modern highway, but reduces reliance on fossil fuels by also making use of a battery-run power system. The large-scale reductions in carbon dioxide and other harmful air pollutants achieved, relative to comparable models, have made the hybrid automobile increasingly popular. This was a technological bet that played out well for the company. Toyota has been one of the dominant companies in the hybrid market for years now.

Still, the hybrid market today represents only a small percentage of automobiles sold. Globally, hybrids account for about 1% of total automobile sales. In Japan and California the statistics are stronger, with hybrids accounting for over 5% of recent car sales. In the US the overall share is at around 3%, but in Europe below 1%.<sup>16</sup> In Europe, the diesel engine has been a strong competitor to the hybrid.

<sup>15</sup> European Automobile Manufacturers Association, *European Automobile Industry Report, 09/10*. Available at: <[www.acea.be/images/uploads/files/20090519\\_ACEA\\_Industry\\_Report09FULL.pdf](http://www.acea.be/images/uploads/files/20090519_ACEA_Industry_Report09FULL.pdf)>. Accessed 27 August 2012.

<sup>16</sup> The International Council on Clean Transportation, *ICCT Hybrid Vehicle Handout*, <[www.unep.org/transport/gfei/autotool/approaches/technology/ICCT\\_hybrid\\_handout.pdf](http://www.unep.org/transport/gfei/autotool/approaches/technology/ICCT_hybrid_handout.pdf)>.

One of the barriers for the hybrid automobile has been its relatively higher cost. Joan Ogden shows in Chapter 3 that in the range from less to more electrified vehicles there is a good tradeoff between lower fuel costs and higher first costs. Battery pack costs are expected to fall considerably in the coming two decades. According to some industry watchers, within the next years, plug-in hybrid electric vehicles with a battery of 10-15 KWh will become less expensive than the internal combustion engine vehicle, making good prospects for the further development of this technology.<sup>17</sup> Others, however, place their bets on diesel technologies.

Toyota Europe's CEO, Didier LeRoy, does not know what the future will hold but sees sustainability as a key issue. The industry, he concedes, needs to think about emissions, resources, and the health of the planet. Which low carbon technology will be the winning technology of the future is still unclear. Will it be hydrogen fuel cells, electric mobility, or alternative fuels? Because of this lack of clarity, technologies with the least lock-in, but still rendering possible large emission reductions, seem to be the best bet for the coming years.

Future market developments will need to be closely integrated with infrastructure development, and this is one of the challenges for industry players. Currently, the transport infrastructure is designed for automobiles and trucks that are powered by fossil fuels. A transition to hydrogen fuel cells or electric mobility will require large-scale investments in new infrastructures. Joan Ogden illustrates in her chapter in Euros that this will take time and money and until the technological future is more certain, LeRoy sees a need for more flexibility in technology. In the case of fuel cells, for example, several sticking points remain. These are infrastructural (in the case of fuel cell packs, for example, there is no system in place for easily replacing them when travelling long distances), technological challenges with the development of hydrogen, and cost factors. Biofuels also may play some role, but LeRoy does not see them as a priority.

Toyota is responding to this situation by building on its existing expertise but expanding upon it with new hybrid combinations. The plug-in hybrid takes automobile technology one step closer in the direction of full electric mobility, while remaining tied to the hybrid battery-fossil fuel engine combination. Toyota's LeRoy is convinced that the plug-in hybrid is the best technology for the coming years. It might be a kind of transition technology. The technology allows for full electric mobility within urban areas, but still makes use of the hybrid battery-fossil fuel dual system for long distance travel.

<sup>17</sup> Global Hybrid Car Market Expected to Grow at a Rate of 18.92 Percent in the Next 3 Years, Reportstack.com, 24 July 2012, <<http://finance.yahoo.com/news/global-hybrid-car-market-expected-143000032.html>>.

When asked if this model can succeed without sufficient incentives from local communities and urban administrations in the development of an electric plug-in infrastructure, LeRoy responded that the company does not believe that the technology will succeed unless the customer can easily find it. It cannot require having to drive around the city looking for a place to plug-in. This is why the car has been designed to also run as a traditional hybrid when the electric battery runs low. Other incentives put in place to encourage the use of electric vehicles, such as in-city parking spaces reserved for electric vehicles, can also be decisive in crowded urban settings.

When a longer time horizon is taken, *e.g.* 15-20 years, LeRoy personally bets on a major component of urban transport being electric with long distance travel depending on fuel cells, although not everyone in the industry see it this way. One future scenario might be trucks that make use of 100% fuel cell based technology, or urban transport that is fully electric, and plug-in hybrid technologies for other distances.

Still, these kinds of models will require the development of new infrastructures. For example, there would need to be fuel cell stations every 200 kilometres or so to allow for fuel cell battery replacement by trucks.

A further challenge LeRoy sees in regard to promoting sustainability is the lack of clear agreement on a long-term European vision. There are different national strategies and investment priorities (thus, whereas Germany is making a strong push on developing fuel cells, the United Kingdom is working on hydrogen technologies). Some industries have strong lobbies and are able to protect their technologies in this way.

## 6. The Shipping Industry

Shipping is widely viewed as among the most sustainable forms of transport for goods. Nevertheless, the shipping industry and especially related infrastructure, such as ports, still have considerable potential left for improving their sustainability.

A system of global regulation subjects ships to uniform, but still insufficiently developed pollution and environmental standards. The International Maritime Organization regulates ships and shipping through a series of conventions. Yet, the conventions do not adequately address many sustainability issues. Much needs to be done to improve the performance of the industry through greater attention to standards regarding the efficiency of ships and logistic chains, tighter air pollution controls, better coordination of container transport, stricter monitoring and enforcement, and new infrastructure development.

According to the WWF and other environmental activists, sub-standard ships and shipping practices are contributing to wide-scale marine pollution and damage. Problems include the release of oil and chemicals through both accidental spills and operational discharges, transfer of alien species through ballast water, release of biocides from toxic chemicals used in antifouling paints, dumping of garbage and sewage, air pollution (sulphur dioxide, nitrogen oxides, and carbon dioxides), physical damage to marine ecosystems, noise and wave damage, and negative impacts on marine mammals and whales. The WWF also argues that international law is not doing what is needed to protect the world's oceans and seas. The setting of international standards, the environmental group argues, is "reactive, slow, and based on industry-driven compromises"<sup>18</sup>

One set of players that has some influence on the shipping industry's performance, while being a source of considerable pollution itself, are Europe's many port authorities. Europe has a large number of ports, including Rotterdam (NL), Antwerp (BE), Hamburg (DE), Bremen/Bremerhaven (DE), Valencia (ES), Felixstowe (UK), Gioia Tauro (IT), Algeciras (ES), Zeebrugge (BE), Marsaxlokk (MT), Le Havre (FR), and Barcolone (ES). The Port of Rotterdam is one of the world's busiest container ports and most important harbours. It is one of the central hubs of deep-sea and inland water transport and is by far the largest port in Europe. It is therefore interesting to look at in terms of what it is doing to advance sustainability.

## 7. The Port of Rotterdam and the Rotterdam Port Authority

The Port of Rotterdam is one of the world's largest and continues to grow. In terms of goods that move through the port, there was a 150% growth in volume between 1990 and 2010, from approximately 288 million metric tons to 430 million metric tons and a total annual added value of 22 billion Euro.<sup>19</sup> To accommodate growing demand on the port, it has expanded into the sea with the building of a Maasvlakte, reclaimed land in the North Sea near Hoek van Holland. A further extension, Maasvlakte 2, started in 2010.

Access to transport links is important for global industrial players, like the petrochemicals industry that is centered in Antwerp, near to Rotterdam. The fact that Rotterdam is a transport hub that can link European goods transport to global markets is part of what makes the port attractive for investors and

<sup>18</sup> WWF, Sub-standard ships and poor shipping practices are leading to massive marine pollution and damage, <[http://wwf.panda.org/about\\_our\\_earth/blue\\_planet/problems/shipping/](http://wwf.panda.org/about_our_earth/blue_planet/problems/shipping/)>. Accessed on 27 August 2012.

<sup>19</sup> Port of Rotterdam, Throughput: Time Series, <[www.portofrotterdam.com/en/Port/port-statistics/Documents/throughput\\_time\\_series.pdf](http://www.portofrotterdam.com/en/Port/port-statistics/Documents/throughput_time_series.pdf)>.

industries. As Mr. Hans Smits, CEO Port of Rotterdam, noted, industrial concentration is a visible trend making near-to-port locations attractive for industries. Due to its location and scale, Rotterdam has many comparative advantages in this regard. All of this means that the challenges to sustainability are manifold, including competing uses of land, air and water quality, waste production and management, and noise. This also means that becoming a “sustainable” leader in Europe will require much continued progress at cutting dependence on highly polluting fuels and improving fuel and resource efficiency. At the same time, as a contraction point, the port can acquire even in times of economic crisis. Acquisition and the subsequent allocation policy, for example, is an important instrument working towards more sustainability.

## 8. The Port of Rotterdam Authority

The Port of Rotterdam Authority with approximately 1,200 employees is responsible for connecting different modalities. It can be thought of as a node in transport chains and in this way can influence both macro and micro economic development. Beyond this, it is a major organization involved in spatial planning decisions. It deals, for example, with governments at the local level for matters pertaining to onshore power supply and with national and European governments in relation to the emissions trading system. In some areas, it also functions at a global level, such as in relation to the International Maritime Organization’s Environmental Ship Index and the development of the European commission’s transport infrastructure TEN-T.

The Port Authority has produced a Vision 2030, which sees the harbour as the leading European hub for global and intra-European cargo and the global hub for containers, fuel and energy. It is also envisioned as an integrated “sustainable petrochemical” and energy complex together with Antwerp.

Some of the challenges mentioned are the creation of an efficient logistics chain in a European network. Mr. Smits anticipates, based on research, that technical innovations will account for 25% of improvements and sustainability performance for the remaining 75%.

The port is also part of the Rotterdam Climate Initiative, which has set a target to cut in half carbon dioxide emissions in 2025 compared to 1990. CO<sub>2</sub> emissions in 2010 were about 30 million tonnes, compared with 24 million tonnes in 1990 so the challenge is a major one. Within the Climate Initiative, the Port of Rotterdam Authority is working on greening its own transportation fleet, and switching over to greater use of biofuels. Still, in its sustainability planning, the authority anticipates that reliance on fossil fuels will still be high and biofuels will play

only a small role. Liquid natural gas (LNG), however, is gaining importance rapidly, both as a shipped and handled raw material and as a fuel for inland and near shore shipping. This is strongly influenced by developments in the international gas markets.

The Port Authority's sustainability plans focus on three areas: its own management, the use of land, and transport. Various measures are being taken to promote sustainability. In the transport area, for example, onshore power has been introduced. Where such power stations are available ships are now required under law to use them. Potential remains, however, as not all ships can make use of the electric stations.

The port authority has set itself the goal of being a leader within Europe, but admits that there are lessons that could be learned from elsewhere. Whereas Los Angeles Long Beach makes it possible for deep-sea container vessels to load and unload using electricity supplied from dockside and incoming road transport runs on liquid natural gas rather than diesel or oil, these are still areas that must be worked on in the Port of Rotterdam.

A consortium of European harbors (Le Havre, Bremen, Hamburg, Antwerp, Rotterdam, and Amsterdam) has initiated a European Ship Index, as part of a global effort to reduce greenhouse gas emissions and air pollution tied to ships and ports.<sup>20</sup> The goal here is to document the strategies and actions being taken by ships and to create an index that can then be used globally. The index measures a ship's emissions based on its levels of nitrogen oxide, sulphur oxide, particulate matter, and greenhouse gases. Ships surpassing the International Maritime Organization (IMO) pollution standards are rewarded with a 5% reduction in harbor fees. The voluntary program is intended as an incentive to promote change.

The Port of Rotterdam Authority makes use of both public and private legal instruments in managing port activities and trying to influence sustainability. In fact, being able to rely on both public law as well as private law gives the Port Authority considerable governance power. This puts it in a unique position and means it has a large set of instruments available: varying from allocation policies, to covenants, new infrastructure, and many more. Modal shifts – getting more goods off the roads and onto ships for transport in land – can do more for emissions reductions than many other measures. Through the issuing of contracts, the port authority can try to influence modal shifts through working with container terminals. For example, a limit can be set on the percentage of containers that can be transported by road. The rest must go by rail or inland waterway.

<sup>20</sup> Port of Rotterdam, Port of Rotterdam Authority Uses Environmental Ship Index, <[www.portofrotterdam.com/en/Brochures/ESI-EN.pdf](http://www.portofrotterdam.com/en/Brochures/ESI-EN.pdf)>.

The port authority sees much potential in addressing inefficiencies in the logistics chain, an area “which must be vastly improved”. Much can be done, for example, in consolidating consignments to reduce the volume of transport movements. Improvements can be made in the infrastructure by adding container transfer points and inland terminals. The “extended gate” concept that would move containers directly from the ship to an inland location, such as Duisburg, where customs clearance would then take place could also reduce harbor congestion and pollution.

When the picture is extended to Europe, “talk about room for improvement! Efficiency? Progress? There are plans for ten main corridors which we wholeheartedly support. But they are all being treated as separate projects. Imagine if the entire network could be planned and managed by a single organization. What a quantum leap that would be.”

Inland shipping accounts for approximately 7% of goods transport in Europe. It is often viewed as more environmentally sound when compared to goods transport by road. Yet, high emission levels of sulphur dioxide, nitrogen oxides, particulates, and carbon dioxide from inland ship engines threatens the environmental lead shipping has. As replacement of ship engines can only be a long-term strategy, fuel switching is considered critical. The establishment of a liquid natural gas network linking the Netherlands and Germany for inland barges and short-sea vessels is also being launched. This is seen as part of a strategy to develop a northern European LNG infrastructure network to make it possible for ships to switch from more polluting bunker fuels to natural gas.

## 9. Maersk

The A.P. Møller-Mærsk Group is involved in many industries, including logistics, upstream oil, and oil drilling. It is a Global Fortune 500 company with over 117,000 employees.<sup>21</sup>

Maersk Line is one of the companies within this conglomerate. It is a container shipping company employing 25,000 people in 125 countries. With over 600 vessels, it is the world’s largest shipping company with a global market share of 15%. It plays an integral role in the supply chains of thousands of companies around the world.

<sup>21</sup> CNN Money, Fortune 500, 154. A.P. Møller Mærsk Group, <<http://money.cnn.com/magazines/fortune/global500/2012/snapshots/11152.html>>.

Shipping has grown enormously in the last 50 years reflecting the huge expansion in international trade in manufactured goods, which has exploded from around 95 billion US dollars to roughly 12 trillion US dollars today. Ocean transport accounts for about 90% of this global trade. Containerization has been an instrumental factor in this rapid growth. While the rise in global trade has brought with it many improvements in the quality of life, it has also had substantial environmental consequences, in terms of greenhouse gas emissions, the use of natural resources and environmental pollution. Even though ocean shipping has the smallest environmental footprint of the various transportation modes, the industry as a whole has a major impact on greenhouse gas emissions and the environment.<sup>22</sup>

A system of global regulations subjects ships to uniform, but still insufficiently developed pollution and environmental standards. The International Maritime Organization regulates ships and shipping through a series of conventions. Approximately one-third of the world's seaborne trade is for the shipment of oil and petroleum products. As a result, oil spills are one of the hazards associated with the shipping industry. This has resulted in numerous conventions dealing with oil pollution, responsibility and liability for oil pollution, oil pollution response, and other related matters.

In addition, there are conventions on the control of harmful anti-fouling systems ("a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms"), on preparedness, response and cooperation in relation to pollution incidents by hazardous and noxious substances, and on the prevention of pollution from ships (MARPOL).

Still, much could be done to improve the performance of the industry through greater attention to standards regarding the efficiency of ships and logistic chains, tighter air pollution controls, better coordination of container transport, stricter monitoring and enforcement, and new infrastructure.

Maersk Line's sustainability policies are, in part, pushed by the historical values of a family-built firm, but also by consumer demands in relation to sustainability and the growing pressures on global material resources. Interestingly, Mr. Kornerup-Bang sees some disconnect between what happens in the international climate negotiations where at the national level countries may be reactive and resist a global climate agreement, and the action of specific firms and industries that may be more proactive.

<sup>22</sup> Maersk Line, Sustainability Progress Report 2011: Route 2, <[www.maerskline.com/globalfile/?path=/pdf/Sustainability\\_report](http://www.maerskline.com/globalfile/?path=/pdf/Sustainability_report)>; see also, Maersk Line, About Us, <[www.maerskline.com/link/?page=brochure&path=/about\\_us/environment](http://www.maerskline.com/link/?page=brochure&path=/about_us/environment)>.

In the case of the Copenhagen Climate negotiations, for example, he suggested there could be a reactive stance at the national level, but still considerable interest in improving sustainability performance and energy efficiency by specific firms and industries.

Kornerup-Bang sees the drive for sustainability largely as a bottom-up phenomena, but this does not mean there is not a role for international climate negotiations or the setting of international regulatory standards. There is a need, for example, for global agreements on shipping regulations under the International Maritime Organizations. Otherwise, there will be free riders. From a commercial point of view, it is also important that there are regulations. In the marine transport sector, there is still much work to be done to convince players at the political level of the advantages to be gained from greener shipping. The company is thus supportive of a global agreement on shipping, rather than a unilateral European agreement. When a European agreement on shipping emissions nevertheless is pursued, the company argues, it must be designed in such a way that it can eventually be replaced by a global agreement. The company is somewhat skeptical as to whether market based instruments can work for the shipping industry as a whole. A major global issue is the need for better enforcement mechanisms as this will also level the playing field. Without adequate enforcement this will not happen. Transparency on sustainability performance is also crucial. It enables businesses the choice for a specific 'low carbon carrier'.

What is lacking is sufficient discussion on what the optimal transportation system as a whole could look like – when one looks at the entire value chain. When there are globalized chains, it is important to be smart about where abatement efforts are focused. A mode by mode approach is insufficient when major cutbacks in emissions need to be realized.

Both technical and non-technical advancements are needed. One of the major ways in which efficiency improvements have been achieved to date, for example, is working on minimizing empty container capacity. If trade flows become unbalanced, with more exports than imports to a global region, there will be empty capacity. Shipping lines are always looking to optimize shipments and in that way avoid empty capacity. This is crucial to high energy efficiency per container. Other steps being taken include fuel switching.

Too strong a focus on technical solutions risks searching for improvements within the existing system, and that is definitely not enough. By taking a system-wide view, it is possible to ask what is the optimum transportation system and based on this a vision regarding the appropriate technical measures will surface. There are many small improvements that contribute toward sustainability, but

they are not game changing. Developments on the system level can potentially be game changing. For Maersk, triple A vessels are next generation developments in which both operational and technical developments can lead to sustainability improvements. Furthermore, there are potentials with biofuels. Fuel diversification can have a major impact.

Regarding the ability of large scale and more local scale policy action, Mr. Kornerup-Bang argues that at the international level agreements are needed. Otherwise it will not be possible to address carbon dioxide emissions effectively. At the same time, much can be achieved at the port level. Here there are steps that can be taken to improve collaboration and incentivize efficiency. Customers must also collaborate. Thus, Maersk operates in Rotterdam with the most modern equipment. In less highly efficient ports, such as in Nigeria and Ghana, where ports are clogged by many smaller, less efficient ships, the company is introducing special ships called WAFMAX that reduce cargo footprints by up to 30% due to their higher cargo capacities and fuel efficiency. On board cranes eliminate the need for use of port cranes. Of course, there is also a business interest at play here as Maersk sees this as a way of solidifying its position as a market leader in the region.

Maersk Line is also a founding member of the Sustainable Shipping Initiative (SSI), which is hosted by Forum for the Future and WWF, and is an industry-NGO collaboration to improve the environmental performance of the shipping industry. The SSI issued a report, *The Case for Action*, which looks forward to the opportunities and challenges facing the shipping industry in the context of shifting patterns of trade and global and economic power as well as rising fuel costs and changing customer demands.<sup>23</sup> Based on this the SSI launched a *Vision for 2040* in November 2011. The focus is on finding new technologies to increase efficiency, diversify energy sources, and reduce “radically” greenhouse gas emissions; making container ships more easily recyclable and using fewer hazardous material, and producing a “standard of standards” to drive sustainability performance improvements.

This suggests a multi-pronged strategy that focuses on sustainability at the global and local level where ports and customers are brought into the process.

<sup>23</sup> Sustainable Shipping Initiative, *The Case for Action*, <[www.forumforthefuture.org/sites/default/files/project/downloads/ssifullreport.pdf](http://www.forumforthefuture.org/sites/default/files/project/downloads/ssifullreport.pdf)>.

## 10. Summary

Road transport illustrates the challenges that exist in shifting the still fossil fuel-dominant automobile sector in a more sustainable direction. Long-term technological and system uncertainties make investment decisions difficult. In the meantime, while avoiding technology lock-in, steps can be taken to reduce the heavy dependency on fossil fuels. Moving urban transport in the direction of electric mobility may be one important step towards a larger system transformation. As long as public perceptions about the ease of using new technologies can be addressed, some possibilities appear to exist with new technologies, such as the plug-in hybrid Toyota has developed. These findings support the arguments made by Joan Ogden and Tommy Gärling in this volume: transition technologies will be needed until longer-term infrastructure choices can be made.

The Rotterdam Port Authority sits at the intersection of government and industry. As is the case with other major ports of similar size and activity, it has a large direct and an even larger indirect ability to influence societal and ecological footprints. The Rotterdam Port Authority combines an interesting mix of both public and private law in its toolbox of instruments. This toolbox can be used to encourage, and when necessary, implore changes towards sustainability in the shipping and related industries. There are interesting lessons to be learned here with broader applicability beyond the region and the transport modes that connect at the port.

The international maritime shipping industry is illustrative of how globalization has brought new dimensions to goods transport. Although shipping has a much smaller ecological footprint than other transportation modes for carrying the same volume of goods similar distances, the scale of the industry means that major improvements are needed if emissions and resource waste problems are to be addressed. As Maersk Line points out, there is still major room for improvement in system-wide efficiency levels. Individual companies can take some measures to improve their own efficiency, but larger system level changes that strengthen transparency, result in better enforcement of standards, and address the entire value chain's performance are needed.

## 11. Concluding remarks

The interviews presented in this chapter support many of the observations made by the authors of other chapters in this book. Clearly, more than incremental changes to existing transportation structures, technologies, and behaviours will be needed if the sustainability issues facing the planet – a growing population, resource scarcities, space limitations, climate change, biodiversity loss,

and pollution – are to be adequately addressed. System transformations will be necessary.

The task must be a global one. Difficulties in achieving global agreements, however, suggest the need for innovations that can already put system transformations in motion today.

There will be need for top-down coordination in order to improve efficiency across transport modes. Some legislation will be necessary to stimulate changes, but also greater emphasis must be placed on enforcement of existing standards. Unless the playing field is leveled, the costs will fall too unevenly on some actors and front-runners may be discouraged from acting. Transparency is also a must. The best performers can benefit from greater transparency regarding their sustainability performance. Good performers should be rewarded. Polluters should be pressured to clean up their act.

The flexibility necessary for bottom-up innovation must also be provided. In fact, bottom-up initiatives are increasingly overtaking government actions. Industry front-runners are finding ways to successfully link sustainability improvements to their business models. They are both responding to what is required of them and are taking their own initiatives for change.

In their chapter on shifting modes of governance, Maarten Haajer, Anco Hoen and Hiddo Huitzing make a case for finding ways to encourage and support the 'energetic society'. Our interviews support this conclusion. There are many companies and industries willing to do more. There is also still much room for improvement.

# Column

Bas Haring

I was asked, as a philosopher, to take some distant perspective on the topic of sustainable mobility and hopefully to come up with a few new insights, “open minded” questions, or creative ideas. Philosophers have a bunch of tricks to achieve such added value. A first one is to look at the major concepts that are used in the field at hand: are definitions clear? Are they shared amongst the majority? What happens if these definitions are stretched a little bit, or shrunken or moved? Secondly, philosophers take a critical look at research questions, may help to reformulate them, and can sometimes even come up with new, original ones. And thirdly, philosophers typically have the ability to penetrate to the core of matters. What is really going on? And which are the hidden, secret essentials? Given my arsenal of tricks I am, at first glance, rather impotent. Definitions used are clear, well-established and even scrutinized in an, I would say, philosophical manner. “What is actually mobility?” would be a typical first question for a philosopher to raise. “And does mobility matter?” But these questions are already receiving serious attention. Even in this book. And it becomes clear immediately that mobility itself is not of utter importance. Mobility isn’t fun. What matters are the things you gain access to via this “damned” mobility. This is all very well known and there is consensus about what really matters.

A special branch of philosophers, the ethicists, who deal with the question of right and wrong won’t be of help either in this field of sustainable mobility. It is clear what is right and wrong here. Cars that run on fossil fuels are wrong. Individuals like their cars, but add up the individuals and evil arises in the form of carbon dioxide emissions and consequential climate change. So we all agree and there’s nothing to do here for a philosopher.

Permit me two brief reflections though, on the two solutions you all agree on: (i) less cars (or less car-kilometers); and (ii) different cars (especially cars with a different energy source). Less cars seems so logical, but for many it will be truly painful. Cars are not “just another invention.” Cars are like the fulfillment of Icarus’ dream: they can’t fly but they can more or less glide over the motorways. A dream that is available for almost everyone, and only since a couple of decades. And now we have to leave this dream. So soon and even voluntarily. This is maybe too difficult for too many people.

A different propulsion seems logical too: electric cars, cars on biofuel or hydrogen. But here is a major problem as well: next to oil (and its derivatives) there is no other substance that releases so much energy so easily. And the stuff is almost free. Available at vast quantities at a walking distance from the surface of the earth. Do we really expect future governments to leave this treasure in the ground? Even if the benefits are theirs, and the losses are for everyone? There is just too much oil, and it's too terrific stuff.

Back to the consensus and just leaving you with two comments. I sometimes compare philosophers with Martians who, from their remote planet and with powerful binoculars, scrutinize the earth and especially mankind. From such a perspective I have a rather peculiar view. I see a bunch of scientists and experts, intelligent people who take their thinking seriously and who more or less agree on what should be done. But they are not listened at. Especially not by those who count: decision makers. Is that why they congregate on conferences where they bathe themselves in a comfort zone within a kind of sustainable church, contemplating how to evangelise their shared beliefs? How can this be possible? I am not into politics but it seems to me that scientists and experts typically work in the interest of some ultimate everyone. Everyone existing now and everyone from the future. Whereas decision makers, and especially politicians, represent the interests of a selection of currently existing individuals. These interests are clearly not the same.

Maybe the scientists and experts should shift their attention a little bit. Maybe they should start to think small instead of big. Their point of reference is naturally The Hague, Brussels or Washington. But if big doesn't work, maybe small does. And many small solutions eventually form a big one. A Dutch bank – a kind of "green" bank – made a recent TV-commercial entitled "Small, the new big": Not a commercial for themselves, but a commercial for an alternative way. This bank attempts to mobilize individuals (in a different fashion than meant in this book), convinced that lots of small changes can crank each other up via informal social contacts and will cause a large change. I find this inspiring.

But there is another lesson in this initiative. A lesson for those who think to know what should happen. Go make commercials! And show them on TV or YouTube. Why focus on The Hague, Brussels and Washington? With that you acknowledge their power. Instead you can acknowledge the power of truth and proclaim it. Or lobby. In the same vicious way as your competitors: the ones who don't think in the interest of the ultimate everyman, but in the interest of every man for himself. Lobbying is dirty and expensive, but if you all agree on what should happen, what use is there for further talking?

Maybe the governments should think a little smaller too. They always wait for the larger governments: "We cannot do this alone." And nothing happens. Or they are afraid of losing some competitive advantage. But come on, what are the risks? How large will those losses really be? And wouldn't it be highly competitive to excel at something where no one else does? Also the larger ones should dare to think smaller and sometimes just do what they can. In some humble attempt.



# Authors



## Introduction

### Bert van Wee

Bert van Wee is Professor of Transport Policy and head of the section Transport and Logistics at Delft University of Technology, Faculty Technology, Policy and Management. His main interests are long-term developments in transport, large infrastructure projects, accessibility, the environment, safety and policy analyses.



## Chapter 1

### Phil Goodwin

Phil Goodwin is Emeritus Professor of Transport Policy at University College London and at the University of the West of England. He was formerly head of the Transport Studies Unit at Oxford University and UCL, a Non-Executive Director of the port of Dover, a local government official at the GLC. He was also an advisor on various technical and policy issues to the UK government, various foreign national and local government bodies, the EC, and the transport industries. He has published books, single chapters, journal articles and reports on travel demand analysis, transport policy and forecasting.

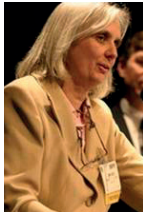


## Chapter 2

### Todd Litman

Todd Litman is founder and Executive Director of the Victoria Transport Policy Institute, an independent research organization dedicated to developing innovative solutions to transport problems. His work helps to expand the range of impacts and options considered in transportation decision-making, improve evaluation methods, and render specialized technical concepts accessible to a larger audience. He has worked on numerous studies that evaluate transportation costs, benefits and innovations and, in addition, his research is applied internationally in transport planning and policy analysis. He has also worked as a research and planning consultant for a diverse range of clients, including

government agencies, professional organizations, developers and non-government organizations. His career has taken him to more than two dozen countries on every continent except for Antarctica.



### Chapter 3

#### Joan Ogden

Joan Ogden is Professor of Environmental Science and Policy at the University of California, Davis and Co-Director of the Sustainable Transportation Energy Pathways (STEPS) Program at the Institute of Transportation Studies (ITS-Davis). Her primary research interest is technical and economic assessment of new energy technologies, especially in the areas of alternative fuels, fuel cells, renewable energy and energy conservation. She has written extensively on energy topics, especially a series of technical and economic assessments of hydrogen and fuel cell systems. In addition, she has been an advisor to the US government on future energy technologies and strategies.



### Chapter 4

#### Peter Sweatman

Peter Sweatman is Director of The Transportation Research Institute at The University of Michigan. He is an international leader in the scientific field of heavy vehicle-infrastructure interaction. He has a strong interest in advanced safety transport systems. His current research interests include intelligent transportation systems (ITS) and vehicle electrification. He joined UMTRI after a successful career in transportation research and development in his native Australia – working in both the private and public sectors – and with extensive international experience. As a specialist in efficient motorized mobility (connected car systems, ITS solutions) and on alternate modes of transport (fractional car ownership, transit solutions) he demonstrates how ICT will help in navigating to sustainable mobility.



### Chapter 5

#### Tommy Gärling

Tommy Gärling is Emeritus Professor of Psychology. He is affiliated with the Department of Psychology and the Centre for Finance at University of Gothenburg, Göteborg, Sweden. He is also a member of the Service and Market-Oriented Transport Research Group (SAMOT) at Karlstad University, Sweden. His research interests

span topics in economic psychology, environmental psychology and transport psychology. He is author and co-author of nine edited books, eighty single chapters and more than two hundred articles published in scientific journals. He is a former President of the environmental psychology division of the International Association of Applied Psychology, an associate editor of the *Journal of Economic Psychology* and a member of the editorial boards of the *Journal of Environmental Psychology* and the *Transportation Journal*.



### Chapter 5 Margareta Friman

Margareta Friman is a Professor of Service Research and Director of the Service and Market-Oriented Transport Research Group (SAMOT) at Karlstad University, Sweden. Her research interests are primarily topics in consumer and transport psychology. She is both an author and co-author of forty papers in scientific journals and book chapters. She is a member of the editorial board of *Journal of Service Management*. She is also an elected member of the steering board committee for the International Association of Public Transport academic network and an expert member of the European Cooperation in Science and Technology in the transport and urban development domain.



### Chapter 6 Arie Bleijenberg

Arie Bleijenberg is Manager Infrastructure at the Dutch research organization TNO. Earlier he was Manager Mobility and Logistics at the same innovation institute. As former head of Strategy and Research Policy at the Dutch Transport Ministry, his focus was on strengthening the evidence base of policies. He started his career at CE Delft as a consultant and researcher in transport and environmental economics. Former additional functions include president of T&E, senior advisor on transport pricing at the OECD, chairman of a Dutch Task Force advising the Government on sustainable mobility and, until the end of 2012, chairman of a European Task Force on Transport and Climate Policy, whose final report is expected later this year.



### Chapter 7

#### Maarten Hajer

Maarten Hajer is a Dutch political scientist with degrees in urban and regional planning. He is currently Professor of Public Policy at the University of Amsterdam and Director of the PBL Netherlands Environmental Assessment Agency. In his publication *The Energetic Society* (2011) he claims that if governments, in order to create green growth, stick to top-down policies only they will miss the boat. What societies need, according to Maarten Hajer, is cooperation between governments and bottom-up initiatives and innovations by citizens and corporations. Hence, new partnerships and a new division of responsibilities are needed.



### Chapter 8

#### Miranda Schreurs

Miranda Schreurs is the Director of the Environmental Policy Research Centre and Professor of Comparative Politics at the Freie Universität Berlin. She is Chair for the European Environmental and Sustainable Development Advisory Councils (EEAC) and in preparation to this book she has interviewed three key corporate managers of car manufacturer Toyota, logistics company Maersk, and the Port of Rotterdam on their approach towards sustainable mobility.



### Chapter 8

#### Folmer de Haan

Folmer de Haan is coordinating advisor at the Council for environment and infrastructure and secretary of the Dutch Energy council. His main interest is on energy, industry and strategic policy issues. He was co-interviewer of the three key corporate managers.



## Column

### Bas Haring

Bas Haring is a Professor at the Leiden University and teaches Public Understanding of Science. He holds a degree from the University of Utrecht in Artificial Intelligence. He aims to make science more accessible for the general public, and to train scientists in doing the same at the Leiden University. He also writes science books of which his debut *Cheese and the Theory of Evolution* (2001) won the Golden Owl Award for children's literature and the Eureka! prize for popular scientific literature. Moreover, he presented the philosophical television program *Stof* that was broadcast by the RVU in the Netherlands and has a column in a national newspaper.



### About the Council for the Environment and Infrastructure

The Council for the Environment and Infrastructure (Raad voor de leefomgeving en infrastructuur, Rli) advises the Dutch government and Parliament on strategic issues that are concerned with overall living and working environment. The Council is independent, and offers solicited and unsolicited advice on long-term issues of strategic importance to the Netherlands.

#### **Council for the Environment and Infrastructure (Rli)**

Nieuwe Uitleg 1  
P.O. Box 20906  
2500 EX The Hague, The Netherlands  
info@rli.nl  
**www.rli.nl**



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EEAC stands for the European Environmental and Sustainable Development Advisory Councils. Advisory councils for the environment and sustainable development have been established in most European countries to provide independent and evidence-based advice to their national governments. The network was started in 1993. Today it includes 21 councils from 16 European countries.  
**www.eeac.eu**





