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Werner Rothengatter
Yoshitsugu Hayashi
Wolfgang Schade *Editors*

Transport Moving to Climate Intelligence

New Chances for Controlling Climate Impacts of Transport after the Economic Crisis

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Editors
Werner Rothengatter
Institute for Economic Policy Research
Karlsruhe Institute of Technology
Waldhornstrasse 27, 76131
Karlsruhe, Germany
rothengatter@kit.edu

Wolfgang Schade
Fraunhofer Institute for Systems
and Innovation Research (ISI)
Sustainability and Infrastructure Systems
Business Area Transportation Systems
Breslauer Strasse 48, 76139
Karlsruhe, Germany
w.schade@isi.fraunhofer.de

Yoshitsugu Hayashi
International Research Center for
Sustainable Transport and Cities
Graduate School of Environmental
Studies, Nagoya University
Nagoya 464-8603 C1-2(651)
Japan
yhayashi@genv.nagoya-u.ac.jp

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Contributors

David Banister
Transport Studies Unit, School of Geography and the Environment,
University of Oxford, South Parks Road, Oxford, UK
david.banister@ouce.ox.ac.uk

Yves Crozet
l'Université de Lyon et Laboratoire d'économie des Transports (LET),
Président de l'Observatoire Energie Environnement des Transports (OEET),
LET-ISH, 14, Avenue Berthelot, 69363 Lyon, France
yves.crozet@let.ish-lyon.cnrs.fr

Elizabeth Deakin
University of California Transportation Center, 228 Wurster Hall,
Berkeley, CA, USA
edeakin@berkey.edu

Stephan Hubertus Gay
European Commission, Joint Research Centre – Institute for Prospective
Technological Studies, Economics of Climate Change, Energy and Transport Unit,
Seville, Spain; Edificio Expo – c/Inca Garcilaso, 341092 Seville, Spain
Hubertus.GAY@ec.europa.eu

Karst Geurs
Department of Civil Engineering, Centre for Transport Studies,
University of Twente, Enschede, The Netherlands
k.t.geurs@utwente.nl

Akshima T. Ghate
Centre for Research on Sustainable Urban Development and Transport Systems,
The Energy and Resources Institute, Darbari Seth Block, IHC Complex,
Lodhi Road, New Delhi 110003, India
akshima@teri.res.in

Yoshitsugu Hayashi
International Research Center for Sustainable Transport and Cities,
Graduate School of Environmental Studies, Nagoya University,
Nagoya, Japan
yhayashi@genv.nagoya-u.ac.jp

Robin Hickman
Transport Studies Unit, School of Geography and the Environment,
University of Oxford, South Parks Road, Oxford, UK
robin.hickman@ouce.ox.ac.uk

Ali Huzayyin
Civil Engineering Department,
Faculty of Engineering, Cairo University, Cairo, Egypt
ali_huzayyin@yahoo.com

Patrick Jochem
Institute for Industrial Production (IIP), Karlsruhe Institute of Technology,
Kaiserstr. 12, 76131 Karlsruhe, Germany
jochem@kit.edu

Hirokazu Kato
Graduate School of Environmental Studies, Nagoya University,
Nagoya, Japan
kato@genv.nagoya-u.ac.jp

Reiner Koblo
KfW Entwicklungsbank (KfW Development Bank), L3c2 Sector Division Transport
and Communication Asia, Palmengarten 5-9, 60325 Frankfurt, Germany
reiner.koblo@kfw.de

Michael Krail
Fraunhofer Institute for Systems and Innovation Research (ISI),
Sustainability and Infrastructure Systems, Breslauer Strasse 48,
76139, Karlsruhe, Germany
m.krail@isi.fraunhofer.de

Guillaume Leduc
European Commission, Joint Research Centre – Institute for Prospective
Technological Studies, Economics of Climate Change, Energy and Transport Unit,
Seville, Spain; Edificio Expo – c/Inca Garcilaso, 341092 Seville, Spain, Guillaume
Guillaume.LEDUC@ec.europa.eu

Hector G. Lopez-Ruiz
Laboratory of Transport Economics (LET), LET-ISH,
14, Avenue Berthelot, 69363 Lyon, France
hector.lopez-ruiz@let.ish-lyon.cnrs.fr

Yuan Lu
Department of Architecture and Fine Art, Beijing Jiaotong University,
3# Shangyuan Cun, Haidian District, Beijing, China
luyuanup@gmail.com

Xianmin Mai
Graduate School of Environmental Studies, Nagoya University,
Nagoya, Japan
xianminmai@gmail.com

Carolyn McAndrews
Robert Wood Johnson Foundation Health and Society Scholar,
Department of Population Health Sciences, Wisconsin School of Medicine
and Public Health, 707 WARF, 610 Walnut Street, Madison, WI 53726, USA
cmcandrews@wisc.edu

Hans Nijland
Netherlands Environmental Assessment Agency, Bilthoven,
The Netherlands
hans.nijland@mnp.nl

Haixiao Pan
Department of Urban Planning, Tongji University,
1239 Siping Road, Shanghai 200092, China
hxpank@online.sh.cn

Charles Raux
LET (Laboratoire d'Economie des Transports), CNRS and University of Lyon,
ISH, 14 Avenue Berthelot, 69007, Lyon, France
charles.raux@let.ish-lyon.cnrs.fr

Werner Rothengatter
Institute for Economic Policy Research, Karlsruhe Institute of Technology,
Waldhornstrasse 27, 76131 Karlsruhe, Germany
rothengatter@kit.edu

Bas van Ruijven
Netherlands Environmental Assessment Agency, Bilthoven,
The Netherlands
b.j.vanruijven@chem.uu.nl

Burkhard Schade
European Commission, Joint Research Centre – Institute for Prospective
Technological Studies, Economics of Climate Change,
Energy and Transport Unit, Edificio Expo – c/Inca Garcilaso,
341092 Seville, Spain
Burkhard.SCHADE@ec.europa.eu

Wolfgang Schade
Fraunhofer Institute for Systems and Innovation Research (ISI),
Breslauer Strasse 48, 76139, Karlsruhe, Germany
w.schade@isi.fraunhofer.de

Lee Schipper
Global Metropolitan Studies, University of California, Berkeley, CA, USA
schipper@berkeley.edu

Sanjivi Sundar
The Energy and Resources Institute, Darbari Seth Block,
IHC Complex, Lodi Road, New Delhi, India
ssundar@teri.res.in

Motoyuki Suzuki
Central Environmental Council of Japan, University of Tokyo, Tokyo, Japan
suzuki@ouj.ac.jp

Louis S. Thompson
Thompson, Galenson and Associates, LLC, 14684 Stoneridge Drive,
Saratoga, CA, USA
lthompson@alum.mit.edu

Yang Tang
Department of Urban Planning, Tongji University,
1239 Siping Road, Shanghai 200092, China
tangier81@gmail.com

Tobias Wiesenthal
European Commission, Joint Research Centre – Institute for Prospective
Technological Studies, Economics of Climate Change, Energy and Transport Unit,
Seville, Spain;
Edificio Expo – c/Inca Garcilaso, 341092 Seville, Spain
Tobias.WIESENTHAL@ec.europa.eu

Jinyu Wu
Urban Design Section, Shanghai Fudan Urban Planning and Design Institute,
Shanghai No. 220 Handan Road, Shanghai 200433, China
wjy_tj@163.com

Yangfei Zhang
Department of Urban Planning, Tongji University,
1239 Siping Road, Shanghai 200092, China
wilma_zyf@hotmail.com

Part I
Climate Control: The Long-Term Challenge

Chapter 1
Climate Control: The Long-Term Challenge

Werner Rothengatter, Yoshitsugu Hayashi, and Wolfgang Schade

1.1 The Status of the Debate

The IPCC Assessment Reports represent the present state of knowledge of a wide majority of experts, which share the insight that a part of the observed global warming of the atmosphere since 1750 is man-made and can be influenced by human actions. The "hockey stick" paradigm gives a most impressive picture for the change of temperature on earth beginning with the industrial revolution. The Fourth Assessment Report (IPCC AR 2007) exhibits scenarios for the development of (economic) activities and the associated expected increase of global warming. These scenarios give a wide range of possible long-term developments and impacts as summarized in Table 1.1.

In the A1F1 scenario, which assumes high economic growth and increased globalization, the best estimate shows an increase in the world temperature of 4°C, while the maximum increase could be up to 6.4°C. This leads to an expected sea level rise of up to 59 cm. The further impacts of the temperature increase are distributed worldwide ("tipping points"), as there are melting of glaciers, floods, droughts under extreme weather conditions, or irreversible changes of ecosystems. The Stern Review (2006) has translated these impacts into an economic scale and results in the hypothesis that the future economic damages to mankind are of an enormous order of magnitude such that strict mitigation strategies will pay, in the economic sense: a dollar invested in mitigation will save future damages of about five dollars.

W. Rothengatter (✉)
Institute for Economic Policy Research, Karlsruhe Institute of Technology,
Waldhornstrasse 27, 76131 Karlsruhe, Germany
e-mail: rothengatter@kit.edu

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Table 1.1 Summary of results of SRES scenarios of the IPCC (*Source*: IPCC 2007)

Case	Temperature change (°C at 2090–2099 relative to 1980–1999)		Sea level rise (m at 2090–2099 relative to 1980–1999)
	Best estimate	Likely range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations	0.6	0.3–0.9	NA
B1 scenario	1.8	1.1–2.9	0.18–0.38
A1T scenario	2.4	1.4–3.8	0.20–0.45
B2 scenario	2.4	1.4–3.8	0.20–0.43
A1B scenario	2.8	1.7–4.4	0.21–0.48
A2 scenario	3.4	2.0–5.4	0.23–0.51
A1F1 scenario	4.0	2.4–6.4	0.26–0.59

1.2 The Role of Transport

Transport counted for 24% of the worldwide production of CO_2 in 2003. For the OECD countries, this share was even 29% (see ECMT 2007). Road transport was the major emission source with 18%/23% for World/OECD, while aviation was responsible for 2–3% of CO_2 emissions. In the developed world, the share of road traffic, aviation, and waterway transport is even higher. In particular, aviation has increased the CO_2 emissions dramatically in the past 15 years. Taking the period between 1991 and 2003, these emissions have grown by 87% in the European Union. Furthermore, it has to be considered that CO_2 emissions make only 50% of climate gases produced by the aviation sector. Other components are water vapor, contrails, or NO_x.

From this follows: The transport sector is a major source of the climate problem and will increase its relative contribution dramatically in the forthcoming decades. While OECD countries presently count for about 70% of transport-induced GHG, this percentage will drop in the next decades. The dynamically developing countries and the countries that are presently at the threshold to industrialization (China, India, Latin America, South Africa) will take the lead.

While other sectors in the developed world like the production or the energy supply industries are starting to bring down CO_2 emissions, the transport sector is still showing a substantial increase of CO_2 production. Road traffic is the major climate problem of the transport sector, followed by air and maritime transport.

1.3 Motivation for This Book and Contents[1]

Until now the relevance of the transport sector has not been recognized sufficiently, which reflects in a minor importance of transport policy for the mitigation activities supported under the Kyoto Protocol. The possibilities to reduce CO_2 emissions in the transport sector are often underestimated, using the arguments that this sector shows a high growth on the one hand and high marginal mitigation costs on the other hand.

Such arguments are usually based on static analyzes and do not consider the capability of the transport system to adjust to challenges. Chapter 2 of the book focuses on structural changes in the world economy which might be induced by the economic crisis 2007/2008 and help to restructure the transport sector with respect to technology, organization, and consumer behavior.

The industrialized countries have caused the climate problem in the past and contribute the major part of CO_2 production today. Therefore, they have high responsibility to clear the path to a sustainable transport development. Chapter 3 presents some well-developed ideas on how CO_2 emissions can be reduced dramatically in the transport sectors of the industrialized world.

In the future, the climate responsibility will shift gradually from the industrialized to the developing and transition countries. China is already at the top of the list of CO_2 producing countries. Therefore, Chapter 4 focuses on the particular problems of the developing world and the chances for this world to change from followers to leaders with respect to climate policy.

There are a variety of instruments, which are appropriate to create the right incentives: Engineers favor new technologies, legal practitioners prefer regulation, sociologist moral suasion, and economists pricing instruments. Chapter 5 will show that no instrument is capable to solve the problems alone, while a combination of tools should be preferred which is adjusted to the country situation.

It is easy to describe the necessary policy actions to reduce CO_2 emissions by 20% until 2020 or by 50% until 2050. But it is very hard to implement such policy action plans in the real world as long as there is not enough market pressure to guide technology and behavior into the sustainable trajectories. Chapter 6 therefore presents some essential policy conclusions for a phased approach toward the climate goals.

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[1]Most of the chapters of this book have been presented to the Symposiums on Transport and Climate Change held at Karlsruhe and Nagoya in February and November 2009. The Nagoya Symposium was held as a joint event for presenting research results of WCTRS SIG 11 and the Strategic Research Project S-6-5 on Transport for Low Carbon Asia, jointly funded by the Ministry of Environment and the Graduate School of Environmental Studies, Nagoya University.

References

ECMT (2007) Cutting transport CO_2 emissions. What progress? ECMT, Paris
IPCC (2007) Fourth Assessment Report of the IPCC, New York
Stern N (2006) The economics of climate change. Report to the Treasury, London

Part II
Economic Crisis: A Chance for Climate Friendly Innovations in the Transport Sector

Chapter 2
Economic Crisis and Consequences for the Transport Sector

Werner Rothengatter

2.1 Introduction

The World Economic Crisis started in the financial sector and then affected international trade, production, and finally employment. Countries with high international trade volume were hit most badly, as for instance, Japan or Germany. When it comes to analyzing the long-term impacts of the crisis on economic development and transport, very simple and highly sophisticated approaches have been presented as well. A most simple hypothesis is based on the expectation that the crisis will only interrupt the development trends, and some years later the trajectories of economic and transport development will bounce back to the old trend lines. Under such optimistic assumptions, the OECD has followed that the crisis might only cause a time delay of 5 years for the expected traffic development. Retrenchment scenarios construct a contrasting picture, which assumes a break of trends in the globalization process and a further decline of growth rates compared with the old trends. Putting both impacts together, the breakdown during the crisis and the reduced growth rates later lead to a very pessimistic vision for traffic development – while the chances of achieving environmental goals seem to improve. Most experts agree that the real development will lie somewhere in between the optimistic and pessimistic scenarios.

A return to the formerly expected economic growth profiles can hardly be expected under the old economic structures. In this paper we therefore construct a consistent economic environment for a positive development prospect, which is based on the assumption of particular technological and behavioral changes. We call it the "Schumpeter Scenario" in memory of Joseph A. Schumpeter who is the founder of the evolutionary economic theory (Schumpeter 1952). A crisis in his view gives the chance for a creative disruption of old structures in the economy and fosters innovation as well as technological change. This leads to the question as to

W. Rothengatter (✉)
Institute for Economic Policy Research, Karlsruhe Institute of Technology,
Waldhornstrasse 27, 76131 Karlsruhe, Germany
e-mail: rothengatter@kit.edu

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what the structural changes might be in the foreseeable future and whether we might even expect a new "Kondratieff cycle,"[1] which would give an additional push to technology development and its spatial distribution. We try to answer this question in terms of hypotheses for speculative future developments, which seem probable according to the view of futurologists. On this basis we derive the consequences for the development of particular economic sectors and finally conclude with the associated impacts for the development of mobility and freight transport.

Using the system dynamics model[2] ASTRA we are able to simulate economic and transport scenarios in quantitative terms for the EU27+2 countries, which constitute the major part of Europe. The Schumpeter Scenario needs a number of country-specific inputs and has been elaborated for the case of Germany only.

ASTRA includes a module on transport, which is closely linked to the economic modules (e.g., mobility with disposable income and freight transport with trade activity) such that the trajectories can be drawn for the expected traffic developments on an aggregate level. One characteristic result will be that the factors, which might constitute the next Kondratieff – such as rise of energy costs, necessary energy savings, and CO_2 reductions, light materials or a growing share of service economies – at the same time lead to a dampening of vehicle movements and transport intensity. In particular there seem to be many technological and organizational options for resource-saving (green) logistics. This can lead to the conclusion that if the economy will overcome the crisis through Schumpeter-type technological change this type of technological change will influence production technology and organization in a way that the development of transport can be decoupled from the development of GDP, in the long run. This would improve the chance that the transport sector can contribute more substantially to the reduction of CO_2 emissions in the future, even under a regime of economic growth and continuing globalization.

2.2 The World Economic Crisis: Not Only a Financial Bubble

2.2.1 Financial Turmoil and Globalization

The reasons for the world economic crisis of 2008 are manifold: low interest policy in the US, missing control on the speculative financial operations of banks and other financial institutions, epidemic diffusion of risk certificates of which only classified risk and return categories – evaluated by rating agencies – were known, but not the real values behind them. "Financial investment banking," "Financial Engineering" and "Financial Product Management" were highly paid businesses for banking specialists who constructed clusters of certificates, tailored to the needs of financial institutions with respect to duration, risk, and expected value of returns.

[1] Explained in Sect. 2.3.

[2] System Dynamics has been founded by Jay Forrester (1962) and is based on the feedback mechanisms between the variables of the system over time. The essential components are: cybernetics, decision theory, numerical simulation, and mental creativity.

As interest rates were kept low by the Federal Reserve, the house prices went up such that it seemed to be a safe business to invest in the housing market. This was the rationale for the subprime mortgage loans given to low-income house owners. These high-risk certificates were pooled with lower risk assets to form new products for financial trading. The instruments applied are (Li 2008):

- *MBS*: Mortgage back security, a certificate based on a mix of different mortgage loans.
- *CDO*: Collateralized debt obligations, these are constructed financial products with different maturity, risk, and expected returns, secured by collaterals.
- *CDS*: Credit default swaps, a sort of insurance for bad risk.

As a result huge amounts of anonymous credit certificates were traded without sufficient information on the real values behind for the trading parties and driven by the expectation of rising prices of valuable assets, which were assumed to be safe collaterals of the products. When house prices went down in 2007 and a crisis on the mortgage credit market in the US emerged, followed by problems of mortgage banks (Freddie Mac, Fannie Mae) in spring 2008, this was interpreted as a natural market correction in a particular sector. However, the trust in the financial institutions faded away at an unprecedented speed, and the bankruptcy of Lehman Brothers in September 2008 indicated that the financial turmoil was not local and was limited to the mortgage credit market rather than global and included private and state-owned banks. This was the starting point for worldwide policy actions to save "system relevant" financial institutions to prevent the financial system from collapsing (e.g., the spectacular rescue action for the AIG insurance company in the US).

The development of the financial markets went in parallel with the dynamic globalization of production and trade. Since the beginning of the new millennium the imbalances of the country foreign trade activities increased rapidly. While countries such as the US, UK, Italy, or Turkey showed increasing deficits in their foreign trade balances, other countries such as Japan, China, or Germany enjoyed a rapid upturn of net exports, which were interpreted as a signal of economic strength. Figure 2.1 shows this development for the case of Germany, which was

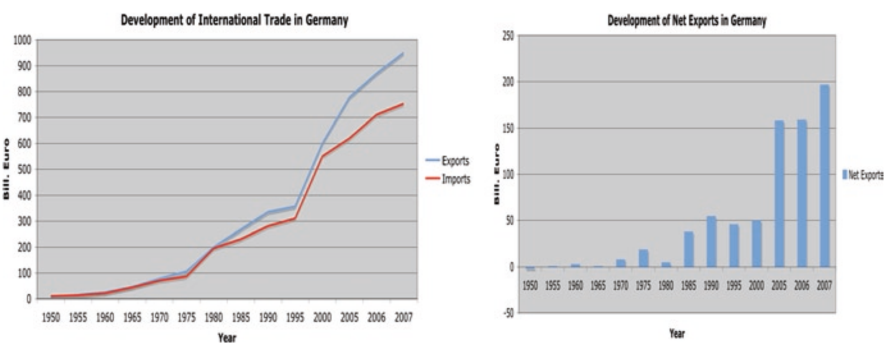

Fig. 2.1 Development of foreign trade in Germany until 2007 (*Source*: German Federal Statistical Office 2008)

the leading export country until 2009 (recently outpaced by China). It can be seen that the developments of trade imbalances seem to be closely correlated with the relaxed monetary policy in the US and the boom on the financial markets. A further disharmony can be observed for the development of fiscal budgets because low interest rates provided incentives to increase public deficits, in particular in Japan and in the US, and also in some European countries. There is still an ongoing debate among economists to which extent the trade and fiscal imbalances can be interpreted as a cause of the economic crisis following the financial turmoil. But it is widely agreed that they have caused heavy multiplier effects in the phase of the beginning slowdown of the economy. The sharp reaction of the world economy following the financial crisis supports the hypothesis that also the globalization process had been heated up by a trade bubble such that excessive expectations for global production and trade coincided with the bubble on the financial markets.

2.2.2 Impacts on the World Economy

The financial turbulences arrived at the real markets in fall 2008, induced by a rapid slowdown of foreign trade. Export turned down globally by more than 10% between summer 2008 and 2009, and this developed even worse for the export champions, Germany and Japan, which suffered from reductions of about 20%. The markets for some branches (steel production or chemical primary production) dropped at an order of magnitude of 40% and the exports of some transport related industries almost collapsed totally (up to minus 90% for heavy goods trucks). Speed and magnitude of the economic slowdown exceeded the downturn of the economies in the first phase of the world economic crisis in 1929.

The weakness of foreign trade led to a reduction of GDP in many countries except for China. Table 2.1 shows the expected GDP losses for 2009 in the EU, as OECD and EU Commission have estimated them in fall 2009. According to these figures all EU countries but three (Cyprus, Luxemburg, and Malta) have big difficulties with meeting the Maastricht criteria for public financial stability.

Most of the industrialized countries have responded to this development by the Keynesian Economic Policy, i.e., by stimulus packages to stop the downturn and to avoid the failures made after the crisis of 1929. While countries such as China and Korea spend the major part of the stimulus money for investment, research, and product development, the western industrialized countries are doing little to foster long-term investment in future technologies. This is partly caused by the rescuing activities for the financial system (China had no problem on this side) and partly due to the attempts of economic policy to stabilize trust in the economic development and support domestic consumption. One example is the scrapping program for old cars in Germany, the UK, and the US (in different forms) to foster the sales of new cars.

Table 2.1 Expected reduction of economic activity in 2009 (*Source*: EU-Commission 2009)

Country	Change of GDP	State deficit in % of GDP	Rate of unemployment in %
Belgium	−3.5	−4.5	8.5
Germany	−5.4	−3.9	8.6
Finland	−4.7	−0.8	8.9
France	−3.0	−6.6	9.6
Greece	−0.9	−5.1	9.1
Ireland	−9.0	−12.0	13.3
Italy	−4.4	−4.5	8.8
Luxemburg	−3.0	−1.5	5.9
Malta	−0.9	−3.6	7.1
Netherlands	−3.5	−3.4	3.9
Austria	−4.0	−4.2	6.0
Portugal	−3.7	−6.5	9.1
Slovak Rep.	−2.6	−4.7	12.0
Slovenia	−3.4	−5.5	6.6
Spain	−3.2	−8.6	17.3
Cyprus	+0.3	−1.9	4.7

The Keynesian policies had significant positive effects in the short run:

1. The economic downturn could be smoothened, i.e., the actual figures for 2009 look less dramatic than those exhibited in Table 2.1.
2. For 2010 most countries expect a modest positive growth rate again, followed by a higher growth rate in 2011, expectedly.
3. The impacts on the labor market are less severe because of "built-in stabilizers" such as employment guarantees, short-time work, and education programs.
4. The serious budget situation of some EU countries has improved (Baltic States, Hungary).

Nevertheless there remain high risks for the economic development in the medium run:

1. A consolidation of the state budgets will be necessary and the Central Banks will have to control money supply more strictly such that lower public expenditures and rising interest rates are probable.
2. After a brief upturn of investment due to refilling of inventories the overall investment activity might be lower than before the crisis because of more risk-averse behavior of the firms, affecting also the labor market. Firms, when planning to invest, tend to focus on countries with low wages and increasing demand (in particular, the BRIC countries).
3. The states seek to bring their industries into good positions after the crisis to gain a relative advantage in the phase of economic recovery. This increases the risk of protectionism, which is detrimental to world trade. In particular, China is presently showing such a mercantilist behavior.

4. The budget situations of some countries (e.g., Greece, Spain, Portugal, and Ireland) are still a cause of concern. Economic power of other countries will be absorbed to avoid bankruptcy of members of the European Currency Union.

In the long run, the next generation will have to pay for the increase of debt arising from the rescue and stimulus measures. As the share of long-term investment financed by stimulus packages is rather low in the EU the next generation will not enjoy major benefits from today's deficit spending policy. This might lead to growing shares of interest payments for old debt or to higher tax rates.

2.2.3 Short-Term Impacts on Transport and Logistics

While passenger transport is mainly driven by the disposable income of consumers, freight transport is in particular dependent on trade activity. Often GDP is used as an explaining variable for both, but its explanatory power is very limited. Fluctuations of trade are much higher than fluctuations of GDP as Fig. 2.2 shows. In phases of economic upturn the growth of trade can be double the growth of GDP, and this also holds for the negative direction. The present economic crisis demonstrates these relationships very clearly. Long-distance passenger transport went down proportionally to disposable income, i.e., around 5% in industrialized countries in 2009. Losses of air passenger transport are higher, because of reduced business travel, but not dramatically. While domestic freight transport has remained almost stable, international freight transport has been hit almost proportional to the losses in global trade (around 10% on the average and 20% in export oriented countries).

In the phase of the globalization bubble, beginning after the year 2002, also the transport intensity went up in the industrialized countries. This means that freight

Fig. 2.2 Development of world trade and global GDP (real) until 2007 (*Source*: Advisory Committee of the German Ministry of Economic Affairs 2008)

transport has not been in the focus of rationalization, because the relatively low transport prices induced miniaturization of spare parts and global distribution of the workflow, making use of wage cost differentials and improved proximity to the markets. Global supply chains with scheduled delivery patterns were developed to minimize inventory holding, at the cost of additional transport activity.

The economic crisis has lead to a dramatic reduction of international trade and freight transport. The firms have adjusted through short-term contracting and lean inventory holding to save costs in the short-run and foster flexibility in a phase of high uncertainty. The railways have lost more freight compared with road transport in the EU because of higher distances and dependency on bulk cargo consignments, which went down dramatically (steel, chemical basic products). Air freight transport lost about 13% world-wide in 2009 and even more than 20% in the export-oriented countries.

Also maritime transport is suffering from a drastic decline of international trade. Container transport, instead of growing at a rate of 8% and more, like in the phase of the globalization bubble, declined by around 10% (worldwide) and 20% (export champions). In May 2009 about 10% of the worldwide container ship capacity was unused.

The agents in production and transportation businesses seem to expect a change of the globalization trend to lower growth rates and have started to adjust to this by reducing capacity. In May 2009 the orders for 325 freight vessels, 47 tankers, and 78 container ships were cancelled (OECD 2009). The professionals in the business expect lower growth paired with higher fluctuations and try to reduce the sunk costs accordingly.

2.3 Scenarios of OECD/ITF for the Development After the Crisis

2.3.1 Economic Development

OECD/ITF (2009) have constructed several scenarios of the economic and transport development after the crisis:

- Trend development as it was forecasted before the crisis ("global economy").
- Fast return to the growth path, which was forecasted before the crisis ("bounce back").
- Sharp reduction of globalization and shift of production to regional clusters ("regional communities").
- Sharp reduction of globalization and economic growth ("retrenchment").

"Bounce Back" means in this context that the growth rates, which were predicted before the crisis, are reached again after 5 years. This is regarded as an optimistic perspective, while the regional communities and the retrenchment scenarios represent pessimistic cases (see Fig. 2.3).

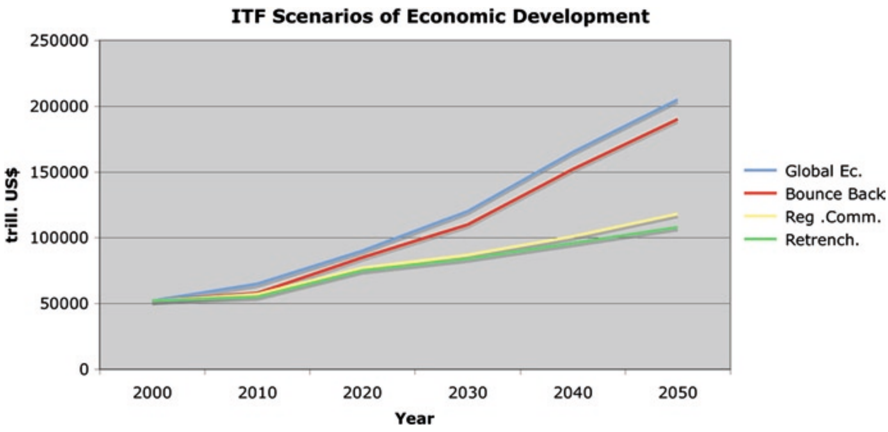

Fig. 2.3 Scenarios of the OECD/ITF study (2009)

As the most probable development might lie in between the extreme cases a further scenario was defined, called "adjustment" scenario, without a detailed specification of assumptions and the resulting development path.

2.3.2 Transport Development

The OECD/ITF study uses the IMO scenarios for the development of maritime transport, which have been derived from the scenarios of the IPCC assuming different climate mitigation policies, i.e., they are not related to the crisis and are skipped here. The study gives own predictions on the development global sales of road vehicles and of air passenger transport (Fig. 2.4). The gap between the trend and the adjustment scenario is up to the factor 1.7 until the year 2050, which underlines the high degree of uncertainty of all forecasts presented in these days.

The OECD/ITF study can be summarized as follows:

- A fast "bounce back" to the growth rates of transport as they have been predicted before the crisis seems not highly probable.
- The same holds for scenarios which assume a long-term weakness of the economy or an end of the globalization processes.
- The most probable development lies in between, but there is no specific description of assumptions and outcomes in quantitative terms. This reflects the high uncertainty of forecasts made in the present phase.

This gives the point of departure for the following own scenarios and simulations.

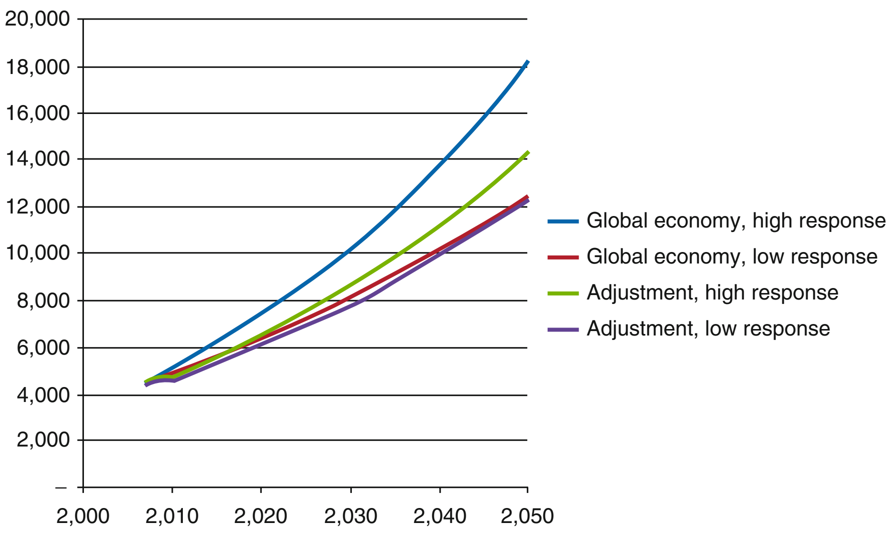

Fig. 2.4 Development of global air passenger transport according to OECD/ITF (2009)

2.4 Schumpeter Paradigm and Structural Change

2.4.1 The Schumpeter Paradigm

The world economic crisis has lead to serious doubts that the neoclassical economic theory, which was the main stream of economic theory before, is a productive approach to explain the economic dynamics (see Roubini et al. 1997). The basic assumptions of neoclassics are rational behavior of agents, perfect information, rational expectations, convex preferences and technologies as well as widely polypolistic markets. This is a world of no failure and no surprise, which leads to economic equilibria, which are pareto-optimal[3] at the same time. Keynes was one of the first prominent authors who attacked this abstract world, in particular the reasoning of neoclassic authors that their theory might not represent the short-term reality but would correctly describe the development path in the long run ("... in the long run we are all dead," Keynes 1923). The Keynesian theory takes up non-rational behavior of agents, in particular herd behavior on financial markets, which cause business cycles and sudden turbulences. But Keynesian theory gives little help for understanding the dynamics of growth and the structural changes associated with long-term development in a second-best environment. J.A. Schumpeter

[3] A single individual cannot improve on her economic position without making any other individual worse off.

(1952), the founder of the economic theory of evolution, closed this analytical gap. The heart of Schumpeter's theory is given by the following properties:

- Crises are not exceptional phenomena rather than periodically repeating episodes in a market economy.
- The agents are not perfectly informed and are not strictly rational. They follow routines, which they only change in the case of obvious failure.
- The dynamics of a market economy stem from intrinsic imperfections on one hand and the ability to adjust to changes of the environment quickly on the other hand.
- Agents change routines in or after a phase of crisis, not in a phase of prosperity. The propensity of entrepreneurs for innovation is maximal in such a phase.
- A crisis fosters structural change, which is necessary to guide the economy to a new phase of growth, stimulated by new products and new production processes.

The state can foster this process by investing in research and development, supporting the implementation of new technology (pilot applications) and by public investment in the necessary infrastructure.

2.4.2 Structural Change of the Economy

While it is highly probable that a severe economic crisis is followed by a substantial structural change it is impossible to predict the type of changes and their intensity with some degree of accuracy. Therefore the following considerations include speculative elements. They are based on two pillars: First, the observed reactions of the economy to rising energy prices and to expected climate change mitigation policies, and secondly, the ideas of futurologists as to the drivers of long-term societal and economic change.

While a decade ago the industrialists argued that environmental policy would jeopardize economic growth, today the environmental products make a good part of the production portfolio of big companies (e.g.: Siemens). The industry of highly industrialized countries has discovered that this is a market segment, in which they have – and are able to preserve – a technological advantage. This explains why parts of the industry were very much disappointed about the results of the Copenhagen Climate Conference (COP 15) and are putting pressure on the political side to come to international agreements. Furthermore, the last period of rising oil prices has shown – contrasting the opinion of neoclassical economists – that higher oil prices are not detrimental to economic growth as soon as the industry expects this development and has time to adjust. Energy-savings technology has developed a prosperous business. For instance, the Japanese and the European automobile industries were able to adjust within a short time range to the challenge set by the European Directive 2009/443 to reduce the average consumption of newly licensed cars to 120 g/km. As it seems highly probable that fossil energy will become more expensive in the long-term future and that climate policy will become more severe to achieve the reduction goals set, one can follow that all economic sectors, which contribute to energy saving and clean products, will have high chances to grow.

When it comes to speculative future economic trends the work of L. Nefiodow (2006) on the sixth Kondratieff deserves attention. W. Kondratieff (1926) had established the hypothesis that the economy shows long-term cyclical movements, where every upturn is initiated by new technologies. Schumpeter (1952) did a similar analysis and came like Kondratieff to the conclusion that the period of a long wave is 40–60 years. Starting with the industrial revolution (invention of the steam engine) they count four Kondratieff cycles until World War II. The fifth Kondratieff is linked basically to the information technology, which has been pushed by micro-electronics. In his analysis of the sixth Kondratieff, expected in the future, Nefiodow points out that some industries will play a dominating role. This may be (extending the list given by Nefiodow):

- Nano-technology
- Material compounds
- Robotics and Assistant Systems
- Energy technology
- Network clouds in information technology
- Health technology
- Knowledge economy

But there will not be any technology to play the role of the driver rather than a network of different industries. The same holds on the social side. Nefiodow expects that social networks develop, supported by the above technologies and that – after a long phase of individual egoism – the social networks will create new forms of life styles, preferences, and activity patterns.

These ideas can be translated into development prospects of economic sectors and change the composition of final demand and of inter-industrial flows in the input–output matrix. Both, the relative changes in the composition of final demand and of the input–output flows is what we call the structural change of the economy.

2.4.3 Structural Change of Freight Transport and Logistics

In this section we concentrate on freight transport and treat possible changes of consumer preferences only implicitly. This means that we assume that the changed world of production and trade meets the demand of consumers. On the side of production and trade the following changes are assumed:

- The trend towards lower shares of bulk cargo versus unitized and containerized goods will continue.
- The trend towards growing shares of services of GDP will continue.
- The trend towards smaller and lighter products (de-materialization of products) will continue, with an increasing share of electronics and communication technology.
- Energy-efficient products will be preferred, in particular in the automotive sector.
- The industry will plan the production of parts and subassemblies increasingly under consideration of logistic requirements.

This will lead to adjustments in the sector of freight transport and logistics and add to the structural changes, which will be induced by energy scarcity and the climate challenge. In particular, the following structural changes are expected:

- Further bundling of consignments and optimization of hubbing versus direct delivery.
- Increasing share of container shipping on inter-modal routes.
- Better loading factors for road and rail.
- Further increase of 4PL contracts and start of collaborative logistics (see Tavasszy et al. 2009).
- Stagnation of the trend towards fast JIT/JIS[4] processes and upcoming moving logistic platforms with fixed operation schedules at freight centers and slower transport operations on route. These platforms can be organized as open networks.

The state is assumed to support this development by the following measures:

- Substitution of quantitative capacity expansion by higher quality on the main corridors (focusing on reliability instead of operation speed).
- Introduction of infrastructure pricing for all transport networks with the result of higher costs of infrastructure use and higher reliability because of reduction of peak traffic demand.
- Stricter control of transport and social regulations.
- Successive internalization of external costs, in particular the costs of climate change.

It follows from these assumptions that two types of reactions can be expected: First of all the growth of transport volumes will be more modest or even tend to stagnate in industrialized countries, while the growth of tonkm will continue at lower rates compared with the forecasts made before the crisis. Secondly, the growth of vehicle km on roads might fall below the growth of GDP, which means a decoupling of freight transport movements from GDP. The chances of rail and inland waterways, and eventually also of coastal shipping, might increase such that the modal split changes in favor of environmentally more friendly transport modes. These expectations are qualitative in nature and have to be backed by quantitative analysis. This is the aim of the following chapter.

2.5 Simulations for Economic and Transport Development in the EU After the Crisis

2.5.1 The Scenarios

In a study of the German Ministry of Transport, Construction and Town Planning (Rothengatter et al. 2010), three scenarios have been constructed:

[4] 4PL: Forth Party Logistics (contracting logistic business out). JIT: Just in Time. JIS: Just in Sequence.

- A Status-Quo Scenario without the crisis.
- A base scenario with the crisis.
- A Schumpeter Scenario with structural adjustments after the crisis.

2.5.1.1 Status-Quo Scenario

The development of the economy and the freight transport demand is modeled under the assumption that there was no interruption of growth through the economic crisis. However, the scenario abstracts from the bubble development of globalization in the period 2002–2007 and substitutes this boom development by a continuous stable growth path based on the change of technology and demand (abstraction from exogenous influences such as the temporary booms of east–west trade after opening of the borders, the liberalization phase in the EU with dramatically dropping costs of road transport, and the financial crisis).

2.5.1.2 Base Scenario

The base scenario takes into account the temporary decline of the economy and of transport demand in the phase of crisis and assumes that globalization processes will be dampened substantially. With this regard this scenario is comparable to the "retrenchment" and "regional communities" scenarios of the OECE/ITF and can be characterized as a pessimistic view for the future development.

2.5.1.3 Schumpeter Scenario

If the world economy recovers and the globalization process is going on then structural changes are necessary. These are described by the assumptions in Sect. 2.4.3. The quantitative assumptions underlying the computation cannot be given in detail here. They can be found in the study prepared for the German MoT (Rothengatter et al. 2010), where the quantitative figures are described. They can be characterized as a modest move to new structures, but not as a radical change of economics and transportation, which could happen in a new Kondratieff cycle. Reason for sticking to a more conservative world of quantitative assumptions is that the simulation model, which is used for the quantitative computations, is calibrated on the development of the past decade 1995–2005. This implies that it would have been necessary to exchange calibrated equations in the model by speculative elements, which cannot be explained by observations of the past. The advantage of this approach is that the model is closer to reality in the first phase after the crisis while it indicates possible changes of structures for the future. These changes can develop more dramatic if actually a new Kondratieff cycle will occur, and they can be smaller if the technology and behavior are bouncing back to the old regimes before the crisis.

2.5.2 *The ASTRA Model*

The basic modules of the ASTRA model, developed by IWW, Karlsruhe, and TRT, Milan, are depicted in Fig. 2.5.

Detailed descriptions of ASTRA can be found in the Ph.D. theses of the developers W. Schade (2005) and M. Krail (2009).

ASTRA includes 29 European countries (EU27 + Norway and Switzerland) with their systems of national accounts and input–output tables (25 sectors). The model is based on the system dynamics philosophy, which means that it is composed of state and flow variables, which are inter-linked by dynamic (difference) equations. These equations are treated sequentially by numerical integration such that dynamic profiles for the variables are constructed, which not necessarily lead to a general equilibrium. The model is calibrated for the years 1995–2005. It produces ex post

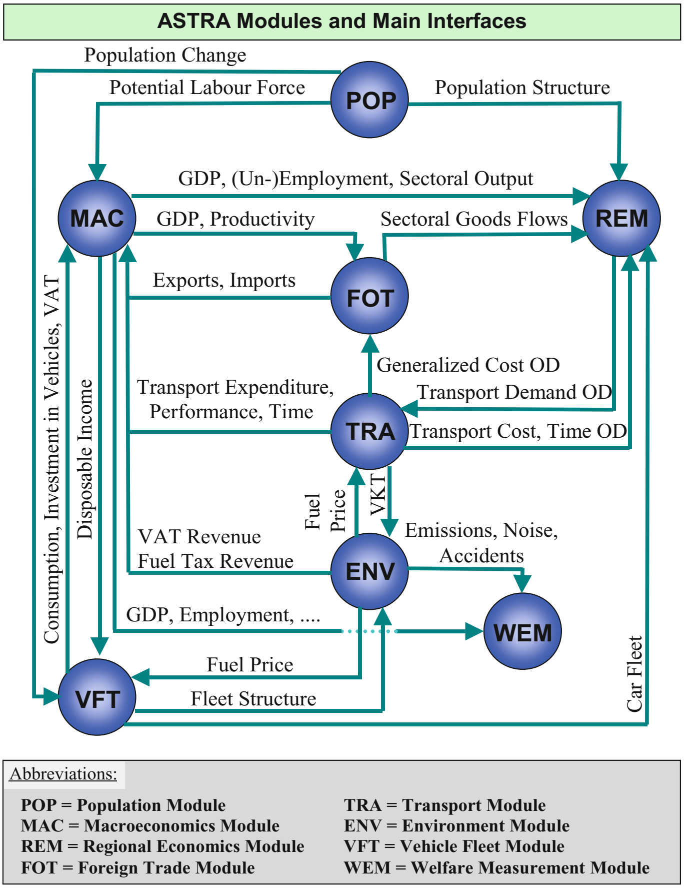

Fig. 2.5 Modules of the ASTRA system dynamics model

forecasts for the years 2006–2008, i.e., the results can be compared with the actual statistical data. Beginning with the year 2009 the model moves to the future sequentially in 3-month steps.

ASTRA is able to analyze and predict feedback mechanisms between the different modules, in particular the dynamic inter-dependencies between transport and the economy. It has been applied for European projects to simulate the long-term effects of transport investment programs, of technological change, of taxation and charging, or of regulations set by climate protection policy. With respect to transport the simulation capacity of the model is limited, such that it can only generate cluster results (e.g., freight transport by goods and distance classes) but no network figures. But it can be linked to a transport model (ASTRA) if detailed information on network flows is important.

2.5.3 Scenario Results

2.5.3.1 Macro-Economic Indicators

Figure 2.6 shows a comparison between the development in the base scenario and the Status-Quo Scenario. The latter defines the zero-line, which means the zero-line does not represent the status of variables before the crisis rather than the development of variables if the crisis would not have occurred.

The downward sloping time profiles for the variables (like GDP, consumption or exports, left picture) indicate that growth occurs, but it is significantly lower than it was expected without the crisis. GDP in the year 2030 is about 10% lower than in the status-quo case. The average growth rate of GDP is about 0.2% lower than it was

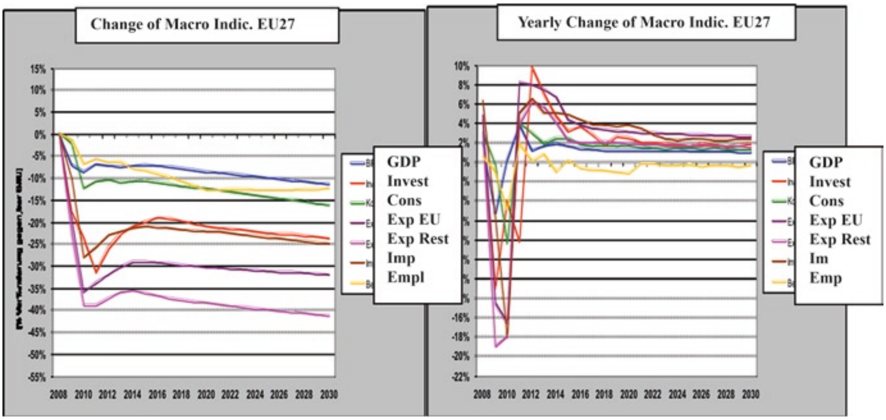

Fig. 2.6 Development of macro-economic variables in the base scenario compared with the Status-Quo Scenario (*Zero Line*, *left* figure); Growth rates of variables in the base scenario (*right* figure), EU 27+2 (*Source*: Rothengatter et al. 2010)

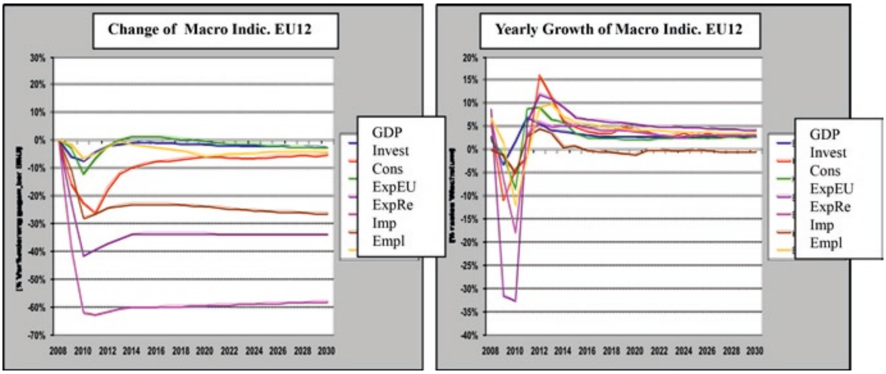

Fig. 2.7 Development of macro-economic variables in the base scenario compared with the Status-Quo Scenario (*Zero Line*, *left* figure); Growth rates of variables in the base scenario (*right* figure), EU 12 (*Source*: Rothengatter et al. 2010)

expected before the crisis (right picture). This can be regarded as the quantitative impact which has to be expected if the economy is not able to develop new structures after the crisis: Following the old routines will not bring sufficient new economic dynamics, expectedly.

It is interesting to compare the results for EU27 + 2 with the results for EU12 (the accession countries) (Fig. 2.7).

It can be seen on the left-hand picture that also the EU12 countries are hit dramatically by the crisis. But they show higher growth rates compared with EU15 + 2 (right picture) and are able to recover more quickly. This is indicated by the upward sloping curves for investment and exports and the stable position of GDP (on the zero line after a medium-term adjustment). This can be interpreted in terms of the OECD/ITF that the accession countries have a chance of a "bounce-back development," which leads them back to the previous growth path after a delay of about 5 years.

The Schumpeter Scenario has been elaborated only for the case of Germany. This is because preparing such a scenario for 29 countries would require high research inputs as the structural preconditions are different, in particular for the accession countries. Furthermore, recent input–output tables are not available for all countries such that the results for structural effects could be biased.

In the diagram the comparison scenarios (status-quo, left and base, right) define the zero line. The left diagram shows that in the first phase after the crisis all variables except for the investments develop at lower growth rates compared with the status-quo. The investment path is derived from the assumptions on the allocation of money from the stimulus packages of the state. After a time of restructuring, which the model predicts until the end of this decade, the economy recovers and the growth rates become even higher than in the case without a crisis. At the end of the time horizon, moving towards the year 2050, the profiles converge to the zero axis, i.e., the growth rates correspond to the originally expected development. Despite the higher growth rates the economy will not bounce back to the original growth

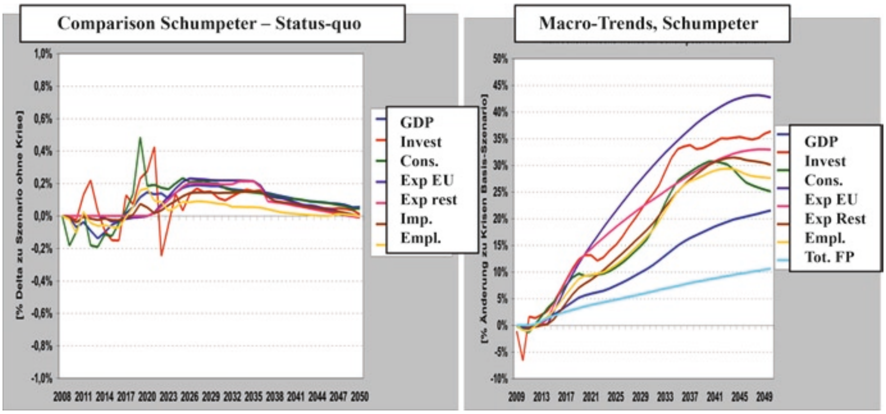

Fig. 2.8 Comparison of the development of macro-variables in the schumpeter scenario versus the Status-Quo Scenario (change of growth rates, *left* picture) and the Base Scenario (percent changes of variables, *right* picture); The case of Germany (*Source*: Rothengatter et al. 2010)

path, i.e., the GDP values of the Schumpeter Scenario are still lower than the GDP values of the Status-Quo Scenario in 2025 and in 2050. This means that the decline in the years 2008 and 2009 and the losses of growth in the phase of restructuring are so big that a "bouncing back" to the original growth path, i.e., the formerly predicted levels of variables in the future, is not possible.

The right-hand side diagram exhibits that the structural changes assumed in the Schumpeter Scenario will help to move the economy away from the pessimistic base scenario path. In the year 2025 the value of GDP is about 2% and in the year 2050 about 4% higher compared with the base scenario (Fig. 2.8).

2.5.3.2 Transport Indicators

Figure 2.9 summarizes the results for the transport variables. Freight transport in Germany will tend to grow in the future, which is shown by the upper three lines. The Status-Quo Scenario is depicted by the highest line, but this is no longer realistic after the crisis, as is underlined by the lines for the Schumpeter and the base Scenario. While the growth factor for the status-quo development is 1.5 (2025) and 2.1 (2050), it is reduced to about 1.3 (2025) or 1.8 (2050) in the scenarios considering the effects of the crisis. Although the GDP development is prosperous in the Schumpeter Scenario the growth of freight transport performance is modest, due to the assumptions on structural change.

A further impact shall be added in qualitative terms because the model results are less reliable in this area. The tonkm predicted in the Schumpeter Scenario can be transported with less vehicle km, because of the logistic effects listed in Sect. 2.3.3. Better bundling and loading of vehicles and the change of modal split lead to a significant reduction of the growth of road transport. While the forecasts

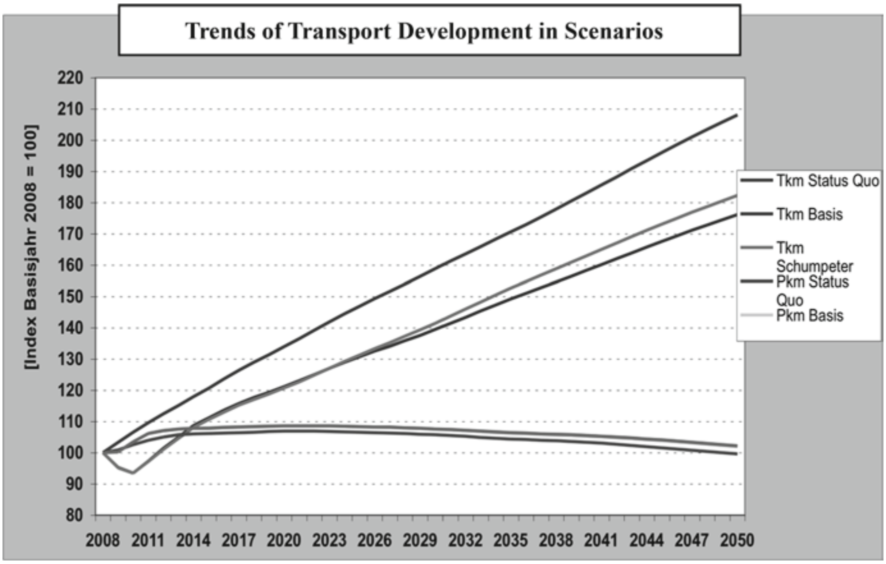

Fig. 2.9 Development of transport variables in different scenarios; Case of Germany (*Source*: Rothengatter et al. 2010)

for the German MoT predicted a growth of road freight transport in an order of magnitude of 84% between 2004 and 2025 this figure could be cut by half in a Schumpeter world – depending on the policy measures on the field of charging and regulating road transport. This would imply nevertheless that road transport will grow substantially despite restraining policy measures. It has to be kept in mind that Germany will be export-oriented in the future and the most frequented transit country of Europe. International transport is the main driver of freight transport, and the structure of goods and distances leaves only limited options for modal split – as a whole. But the growth could be limited to the growth rate of GDP from the present point of view, and further changes (e.g., energy prices, technology) in the long run (speculative futures) could cut the growth rates further.

Passenger transport is not very much affected by the crisis and might return soon to the original growth path. For Germany, passenger transport will most probably decline in the long run, as depicted by Fig. 2.9, because of the declining population, the changing age structure, and the limited increase of disposable income for the lower- and medium-income groups.

2.6 Conclusions

The economic crisis has hit the industrialized countries badly and had a big impact on freight transport, which collapsed temporarily in line with the trade activities. It can be expected that the economies will recover, but this recovery process presupposes that economic and transport structures change. This corresponds to the Schumpeter paradigm, which states that business cycles and fluctuations are natural phenomena in a market economy. A crisis gives the chance for a structural change, which is never possible in a phase of prosperity because routines only will be changed after the perception of failure. Against this background the construction of a "Schumpeter Scenario" has been tried in the paper to explore the possible development in the case of structural changes of the economy and of the transport sector.

It was shown that the change of the transport sector is consistent with a Schumpeter world, if transport operations are becoming more energy-efficient and environmentally friendly. A quantitative simulation shows that there is a high potential for creating such a world in the freight transport area, using the options of better bundling, loading, routing, and modal split. Vehicle operations on roads can be reduced substantially by such changes. The Schumpeter Scenario describes a possible change of trends in a consistent way. If the economy and the transport sector change to this trajectory it seems probable that additional market forces emerge, which foster the technological change towards even more sustainable production and transport. From this follows that the challenging environmental goals can be met in a world of economic growth, modestly continuing globalization and modest market conforming state interventions.

References

Advisory Committee of the German Ministry of Economic Affairs (2008) Yearly Report 2008 on the Economic Development, Berlin

Forrester JW (1962) Industrial dynamics. Pegasus, New York

Keynes JM (1923) A tract on monetary reform. Macmillan, London

Kondratieff ND (1926) Die langen Wellen der Konjunktur. (The long waves of economic dynamics). Archiv für Sozialwissenschaft und Sozialpolitik 56:573–609

Krail M (2009) System-based analysis of income distribution impacts on mobility behaviour, vol 28. Karlsruhe Papers in Economic Policy Research, Baden-Baden

Li D (2008) Subprime crisis, impacts and lessons. Presentation given to the colloqium of the faculty of business engineering and economics of the Universität Karlsruhe, November 2008

Nefiodow L (2006) Der Sechste Kondratieff. (The sixth Kondratieff). Rhein-Sieg-Verlag, Sankt Augustin

OECD/ITF (2009) Transport outlook 2009 – globalisation, crisis and transport, Discussion Paper No.: 2009-12 at the International Transport Forum. Preliminary Version May 2009. Leipzig

Rothengatter W, Liedtke G, Scholz A (2010) Verkehrsinfrastrukturpolitik zwischen Globalisierung, Konjunkturprogrammen und Wachstumserfordernissen.Teil 2: (Simulation von Strukturveränderungsszenarien zum Entwicklungspfad 2. Transport infrastructure policy facing globalisation, stimulus packages and requirements for economic growth. Part 2: simulation of structural change with scenarios for an alternative path of economic development). Study for the German Ministry of Transport, Construction and Town Planning, Karlsruhe

Roubini N, Alesina A, Cohen GD (1997) Political cycles and the macroeconomy. MIT Press, Cambridge

Schade W (2005) Strategic sustainability analysis: concept and application for the assessment of european transport policy. Nomos-Verlag, Baden-Baden

Schumpeter JA (1952) Theorie der wirtschaftlichen Entwicklung (Theory of economic development). Duncker&Humblot, Berlin

Tavasszy L, Wisetjindawat W, Liedtke G (2009) A comparative analysis of behavior-oriented commodity transport models. Presentation to annual meeting of the transportation research board, Washington, 20 Jan 2009, pp. 11–15

Chapter 3
Transport in the Past and Current Climate Policy Regime

Wolfgang Schade

3.1 Introduction

Although the Club of Rome has pointed to the risk of climate warming due to growing carbon emissions already in 1972 (Meadows 1972), the birth of global climate policy occurred two decades later at the Rio Earth Summit in 1992. At the Summit, the United Nations Framework Convention on Climate Change (UNFCCC) was agreed by more than 130 countries joining the negotiations. The Convention established a very first GHG reduction target, which was that GHG emissions in the year 2000 should be stabilized at the level of the year 1990. This should apply to the industrial world in particular. However, no separate GHG emission target was defined for the transport sector.

An important principle affecting the burden-sharing of GHG mitigation was already defined at that time. This *principle of common but differentiated responsibility* includes two fundamental elements: (1) the common responsibility of states for the protection of the environment at national, regional, and global levels and (2) the need to take into account the different circumstances, particularly each state's contribution to the climate change problem and its ability to prevent, reduce, and control the climate threat.

3.2 The Kyoto Protocol

On these grounds it took 5 years to develop the Kyoto Protocol. The Protocol was adopted in Kyoto, in December 1997 and entered into force in February 2005. While the UNFCCC *only encouraged* industrialized countries to stabilize GHG

W. Schade (✉)
Fraunhofer Institute for Systems and Innovation Research (ISI),
Breslauer Strasse 48, 76139, Karlsruhe, Germany
e mail: w.schade@isi.fraunhofer.de

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emissions, the Kyoto Protocol for the first time *committed* them to do so. Reduction targets were set for 37 industrialized countries and the European Union that agreed to reduce an average of 5% of their GHG emissions against 1990 levels over the 5-year period, 2008–2012.

However, the transport sector was not explicitly mentioned in the Kyoto Protocol, and the implementation of the protocol, e.g., in the EU by the EU Emissions Trading Scheme (EU-ETS) (European Commission 2003) focused on reductions by the largest GHG emitters in industry and energy conversion (some 10,000 plants) making up about 45% of total EU GHG emissions. Besides heavy and light rail transport propelled by electricity, the transport sector was excluded from these reduction efforts. In particular, air and maritime transport, that consume the so-called international bunker fuels and are the modes with the strongest growth projections, were not made subject to reduction efforts, as the Kyoto Protocol focused on emissions on national territory only.

The Kyoto Protocol established two further flexible market-based mechanisms, Clean Development Mechanism (CDM) and Joint Implementation (JI), allowing funding of GHG reductions not in national territory, but in other countries and receiving GHG reduction credits for these measures. Despite the fact that many opportunities to implement CDMs in the transport sector of developing countries exist, almost no projects were successful in becoming a CDM as the monitoring, verifying, and reporting (MVR) of transport measures was either too complex, or no rules could be agreed on, or the project scale was too small to generate sufficient GHG savings to fund the necessary investment.

Nevertheless, on a measure-by-measure basis, countries are taking domestic actions to reduce GHG emissions of transport and report them in the national GHG inventories submitted to the UNFCCC or the national reports submitted under the Kyoto Protocol. In such cases GHG savings often occur as a co-benefit of a measure, e.g., in the case of the so-called eco tax in Germany, which for transport fuels was implemented as a fuel tax escalator, increasing the fuel tax between 1999 and 2003 in equal steps in total by about 15 €ct/l and using the revenues to reduce the household payments to the pension funds. As a co-benefit, the measure reduced GHG emissions of transport by more than 2 Mt CO_2 eq. annually after 2003 (Bundesregierung 2009).

3.3 Bali Action Plan

Since the Kyoto Protocol only provided a reduction path until 2012, further agreements have to be developed for 2013 and beyond. This was the purpose of the Bali Action Plan agreed at the Conference of the Parties (COP13) in Bali (UNFCCC 2007), in which it was stated to set up two ad-hoc working groups, the working group on long-term cooperative action (AWG-LCA) that should develop a consistent long-term strategy for mitigation, adaptation, and financing and the working group on further commitments for Annex I parties under the Kyoto Protocol (AWG-KP) that should establish further reduction targets for the Annex I countries until 2017 or 2020. Both working groups should prepare an agreement to be adopted at the COP15 in Copenhagen in 2009. As we know now, this attempt failed and the outcome of COP15 was the so-called Copenhagen Accord (UNFCCC 2009) that again did not specify any commitments for the transport sector.

However, the Bali Action Plan introduced the concept of Nationally Appropriate Mitigation Actions (NAMA), which could provide a way forward to take transport measures, in particular in developing countries, to reduce GHG emissions as was proposed by several organizations after COP15 (CCAP 2010; Binsted et al. 2010).

3.4 Long-Term GHG Emission Targets

Despite the difficulties to agree on short-term strategies and GHG reduction targets, there seems to be consensus on long-term targets. The target to limit the global average temperature increase to 2°C is agreed in the Copenhagen Accord, i.e., at a global level. Further, the G8 in 2009 agreed to the target that until 2050 the global GHG emissions have to be reduced by 50% and for the industrialized countries the reduction should amount to at least 80% compared to 1990 (G8 2009). The European Commission had agreed to the same targets already in 2007 (European Commission 2007a).

Again, these targets do not specify any GHG reduction targets for transport, but they make it clear that transport must contribute to significant GHG reductions until 2050 and in the years to come, because in 2005 transport in the EU accounted for more than 23% of GHG emissions (European Commission 2007b). This share would already be larger than the remaining 20% of GHG emissions allowed in 2050, so that obviously transport must contribute to reductions in the developed countries. In developing countries the situation is more complex, as in these countries strong catching-up in motorization and transport demand is expected, making even a stabilization of transport emissions in the next decades a significant challenge (Sperling and Gordon 2009).

3.5 First Transport GHG Sectoral Target

In 2008 for the first time a sector GHG reduction target for transport was defined. This happened as part of a Communication of the European Commission and was not widely noticed. The so-called 20–20–20 targets also included some 10% targets. One of these targets referred to the non-ETS sectors, to which the transport sector belongs. Thus the EU transport sector should reduce 10% of GHG emissions of transport until 2020 compared with 2005 (European Commission 2008a).

Despite the fact that until a few years ago the common perception was that it would not be feasible to reduce GHG emissions of transport, it can already be observed that in a few developed countries the transport emissions declined in the years 2000–2007. Following the data reported to the UNFCC, and excluding bunker fuels, this decline amounted in Germany to −16% and in Japan to −7% (UNFCCC 2010).

Policy and scenario studies indicate that until 2020 (excluding bunker fuels) further reductions can be achieved in the German transport sector in the order of 45–55 Mt CO_2 eq. in 2020, which means a reduction of about 30% compared with 2005 (ÖI et al. 2008; UBA 2010).

Such analyses reveal that a target for transport of −10% until 2020 compared with 2005 could be formulated more ambitiously in the developed countries rather in the order of magnitude of −15% to −25%.

A few analyses also looked at long-term reduction scenarios that could provide indications for long-term GHG reduction targets for transport. It seems that for the developed world reduction targets of −60% to −80% until 2050 compared with 2005 seem to be feasible (PBL 2009; Schade et al. 2009).

3.6 GHG Targets for Bunker Fuel Emissions

The UNFCCC and the Kyoto Protocol cover GHG emissions on national territory (including the air space), but excluding international air and maritime transport. However, these segments are those already developing most dynamically today, each reaching a share of about 3% of global GHG emissions, which is, e.g., more than the UK emissions, and in a ranking of countries according to their GHG emission would mean the sixth or seventh position in the world.

Thus, it is obvious that these transport segments should not be neglected by climate policy. After failing to promote an international agreement for air transport, the European Commission developed a European proposal to include international air transport into the EU-ETS, which was put into force in 2008 (European Commission 2008b). It covers all air transport within the EU as well as flights with only the origin or the destination being within the EU. The cap of these flights is set to the average emissions of the period 2004–2006 at the level of airline operators. The trading system will commence in 2012 and the reductions of the cap in that year will amount to –3% and in 2013 and afterwards to –5%.

The International Civil Aviation Organization (ICAO) is proposing a sector approach for global aviation, which should be provided and agreed to at COP16 in 2010 (ICAO 2009). The approach consists of three elements: (1) between 2010 and 2050 average annual CO_2 efficiency per revenue tkm should increase by 1.5% (an alternative proposal was an increase of 2%); (2) stabilize the carbon emissions of air transport in 2020, and (3) reduce carbon emissions of air transport by –50% until 2050 compared to 2005.

The situation of maritime shipping is less advanced. The International Maritime Organization (IMO) published a study analyzing the GHG emissions of ships that revealed the significant share of GHG emissions of ships (3.3% of global GHG) and analyzed a number of measures to reduce these emissions (IMO 2009). These measures include setting standards for new ships (Energy Efficiency Design Index, EEDI), operational standards, and inclusion into ETS. In 2003 the EU requested the IMO to develop a global and concrete proposal, but so far no commitment is yet in place for shipping. Recently, the EU announced that they would take unilateral action on shipping if IMO and UNFCCC had not implemented actions by the end of 2011 (European Commission 2010).

3.7 Major Current Transport Measures

As sector targets have not been set or have been made operational only to a very limited extent, the importance of measures for GHG reduction of transport has been upgraded. Globally, a number of policy measures have been proposed or even implemented with a focus on GHG reductions.

The most prominent and effective one was the CO_2 emission standards for cars as, e.g., set by the EU (European Commission 2009). According to these European standards, the average CO_2 emission factor of new cars sold in the EU must be 130 g CO_2/km in 2015 and 95 g CO_2/km in 2020. A similar approach is currently being developed for light duty trucks. Studies indicate that this measure is the most effective of all measures to reduce GHG taken in the EU so far (Schade et al. 2010).

Similar approaches have been implemented, e.g., in the US (NHTS-CAFE standards, EPA CO_2 standards), Japan (top runner program), or China (fuel economy standards).

The US Corporate Average Fuel Economy standards (CAFE) date back to 1975. However, mainly in recent years the standards are becoming tougher. In 2006 the CAFE standards for light trucks were set to 23.5 mile per gallon (MPG) for model year 2010 and 23.9 MPG for 2011 (NHTS 2006). In 2009 the target value for model year 2011 was enforced to become 27.8 MPG (196 g CO_2/km), and a medium-term target of 35 MPG (156 g CO_2/km) for model year 2020 was announced. Also, the target values in 2011 were differentiated for passenger cars (31.2 MPG) and light trucks (25 MPG), achieving 2015 values of 35.7 MPG (cars) and 28.6 MPG (light trucks) (NHTS 2006). In 2010 joint targets from the NHTS (for fuel economy standards) and the US EPA (for CO_2 emission standards) were developed, which until 2016 foresee a combined car&truck standard of 32.7 MPG and a minimum standard of 34.7 MPG (US-EPA, DOT 2010).

Compared with the European standards, important communalities can be noted (e.g., standards refer to weighted new registrations of a manufacturer in a particular model year), but also two interesting differences can be observed: (1) for 2015 the passenger car standards in the EU are 130 g CO_2/km, while in the US they will be

156 g CO_2/km, although it must be remembered that the test cycle differs and auxiliaries (e.g., air conditioning) are treated differently. (2) the US have chosen the vehicle footprint (product of multiplying a vehicle's wheelbase by its track width) as the metric for vehicle-specific standards, while in the EU the vehicle mass (in kg) has been chosen as the metric after strong intervention by the car manufacturers' associations. Here it can be noted that the US has chosen the more appropriate metric, which does not rule out one of the very promising measures for efficiency gains, i.e., light-weight construction.

In China the first fuel economy standards for cars took effect in 2005 (phase 1) and were enforced in 2008 (phase 2). Contrary to the US and the EU, these standards defined a maximum fuel consumption for all cars (i.e., for all manufacturers), which is then differentiated by weight of the vehicle. As a consequence, the average fuel consumption of new cars in China in 2006 was 7.95 l/100 km and 7.87 l/100 km (183 g CO_2/km) in 2009, which is significantly above the European average for that year. Phase 3 was approved in 2009, which will take effect in 2012 and is expected to bring down the average fuel consumption of new cars in 2015 to 7 l/100 km (33.6 MPG), which would be less ambitious than the most recent US standards. It should be noted that in phase 3 the standard refers also to corporate average fuel consumption (CAFC) of each manufacturer, as in the EU and US (Oliver et al. 2009; Wagner et al. 2009; Wang et al. 2010).

In Japan, fuel efficiency standards have been in effect since 1985 as part of the Law Concerning the Rational Use of Energy. Japan is applying the top runner method, i.e., future targets are based on the most energy-efficient product that is available on the market today. The targets are differentiated by gross vehicle weight categories and are expressed as distance driven per liter of fuel (km/l). The targets address each manufacturer separately. For 2015 the fleet average fuel consumption of passenger cars should be 16.8 km/l (138-g CO_2/km), which is slightly less ambitious than the European targets for that year.

At the global level, it is also acknowledged that vehicle efficiency improvements are a feasible and most effective measure to reduce GHG from transport. The global fuel economy initiative "50-by-50" supported by four global organizations, FIA, IEA, ITF, and UNEP,[1] calls for a target of 50% fuel efficiency improvement of the average global fleet by 2050 compared to 2005, which requires the average new car to become 30% more fuel-efficient by 2020 and 50% more fuel-efficient by 2030, both compared to 2005 (FIA et al. 2009).

A second important measure should be highlighted without discussion in detail, namely, the shift to alternative low/no carbon fuels, either in the form of sustainable bio-fuels, where countries or regions have introduced bio-fuel targets, e.g., the 10% sustainable bio-fuels target by 2020 of the EU (European Commission 2008a), or electric mobility, either fueled by renewable electricity or by hydrogen fuel cells. Many countries and car manufacturers in the world are on the brink of bringing the first battery electric vehicles at affordable prices onto the market, in 2010/2011.

[1] FIA = Federation Internationale de l'Automobile, IEA = International Energy Agency, ITF = International Transport Forum, and UNEP = United Nations Environment Programme.

3.8 Conclusions

Recently, many studies revealed the large GHG reduction potentials of the transport sector. However, transport was neglected completely in the first 15 years of climate policy, as neither sectoral targets for transport were introduced nor climate policy measures included the transport sector.

The 10% reduction target of the EU for 2020 compared to 2005 was the first, which applied directly to the transport sector. The inclusion of air transport into the EU-ETS by 2012 will integrate one transport mode into the climate policy regime. It can be expected that the new EU Transport White Paper prepared by the European Commission for 2010/2011 will set further targets for transport.

Thus today the main approach to tap the GHG reduction potentials of transport is to implement single measures. The most widely applied method, as it is both cost-effective and effective to reduce GHGs, is to set efficiency standards for new vehicles. Other important measures are related to the introduction of biofuels or electric mobility.

An important aspect, in particular for the developed world, of setting sector GHG reduction targets of transport and fuel efficiency standards is that they both stimulate innovations and enable the creation of lead markets for low/no carbon transport technologies (Walz et al. 2007). Thus they contribute to maintaining/creating competitive industries in these countries, which can be seen as an important co-benefit of transport-related climate policy in the developed world.

In the developing world the situation differs. Transport measures will primarily be dedicated to improve accessibility and to reduce environmental impacts such as air pollution, noise, or accidents. Reductions of GHG of transport will be rather a co-benefit of such measures. However, with the introduction of NAMAs in the climate debate, an instrument suitable for developing countries emerges. These should be used to integrate classical transport policy objectives (accessibility, air pollution, etc.) with climate policy objectives to mitigate GHG of transport, despite the expected strong growth of motorized transport demand in these countries.

Conclusion: mitigating transport GHG in developed countries and international transport (air, maritime) will require sector reduction targets for transport. An order of magnitude of −15% to −25% until 2020 compared with 2005 seems to be reasonable. This will provide a clear signal to steer decision-making, technology development, and transport behavior towards low/no carbon transport. It should also be acknowledged at the end that climate policy and the security of energy supply are facing a high volatility of oil prices in the next decades and will go hand in hand.

References

Binsted A, Bongardt D, Dalkmann H, Wemaëre M (2010) What's next? The outcome of the climate conference in Copenhagen and its implications for the land transport sector. Bridging the gap

Bundesregierung (2009) Fifth National Report of the Government of the Federal Republic of Germany under the Kyoto Protocol to the UNFCCC, Berlin
CCAP – Center for Clean Air Policy (2010) Transportation NAMAs: a proposed framework, Washington
European Commission (2003) Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community. Official Journal of the EU
European Commission (2007a) Limiting global climate change to 2 degrees Celsius: the way ahead for 2020 and beyond. COM(2007)2, Brussels
European Commission (2007b) Energy and transport in figures 2007. Joint publication of EC DG TREN and EUROSTAT
European Commission (2008a) 20 20 by 2020 – Europe's climate change opportunity. COM(2008)30, Brussels
European Commission (2008b) Directive 2008/101/EC amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community. Off J EU
European Commission (2009) Regulation (EC) No 443/2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles. Off J EU
European Commission (2010) Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage. COM(2010)265, Brussels
FIA, IEA, ITF, UNEP (2009) Making Cars 50% More Fuel Efficient by 2050 Worldwide. Federation Internationale de l'Automobile, International Energy Agency, International Transport Forum, United Nations Environment Programme. http://www.fiafoundation.org/publications/Documents/50BY50_report.pdf
G8 (2009) Responsible leadership for a sustainable future. G8 summit declaration
ICAO – International Civil Aviation Organisation (2009) Aspirational goals and implementation options: a global sectoral approach for aviation. ICAO Working Paper HLM-ENV/09-WP/19
IMO – International Maritime Organization (2009) Prevention of air pollution from ships: second IMO GHG Study 2009. IMO MEPC 59/INF.10
Meadows D (1972) The limits to growth. Universe Books, New York
NHTS – National Highway Traffic Safety Administration (2006) Average fuel economy standards for light trucks: model years 2008–2011. Final Rule, US-DOT
ÖI, FZJ, DIW, ISI (2008) Politikszenarien für den Klimaschutz IV: Szenarien bis 2030. UBA climate change series 01/2008
Oliver H, Gallagher K, Tian D, Zhang J (2009) China's fuel economy standards for passenger vehicles: rationale, policy process and impacts. Energy Policy 37:4720–4729
PBL – Netherlands Environmental Assessment Agency (2009) Getting into the Right Lane for 2050, Bilthoven
Schade W, Jochem E, Barker T, Catenazzi G, Eichhammer W, Fleiter T, Held A, Helfrich N, Jakob M, Criqui P, Mima S, Quandt L, Peters A, Ragwitz M, Reiter U, Reitze F, Schelhaas M, Scrieciu S, Turton H (2009) ADAM 2-degree scenario for Europe – policies and impacts. Report D-M1.3 of ADAM project. Fraunhofer-ISI, Karlsruhe, Germany
Schade W, Krail M, Fiorello D, Helfrich N, Köhler J, Kraft M, Maurer H, Meijeren J, Newton S, Purwanto J, Schade B, Szimba E (2010) The iTREN-2030 Integrated Scenario until 2030. Report D5 of iTREN-2030 project. Fraunhofer-ISI, Karlsruhe, Germany
Sperling D, Gordon D (2009) Two billion cars – driving toward sustainability. Oxford University Press, New York
UBA – Federal Environmental Agency (2010) CO2-Emissionsminderung im Verkehr in Deutschland: mögliche Maßnahmen und ihre Minderungspotenziale. UBA texte series 05/2010
UNFCCC (2007) Bali Action Plan. Decision at COP 13 in Bali
UNFCCC (2009) Copenhagen Accord. Decision at COP15 in Copenhagen
UNFCCC (2010) UNFCCC GHG Data http://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php

US-EPA, DOT – US Environmental Protection Agency, Department of Transportation (2010) Light duty vehicle greenhouse gas emission standards and corporate average fuel economy standards. Final Rule

Wagner D, An F, Wang C (2009) Structure and impacts of fuel economy standards for passenger cars in China. Energy Policy 37:3803–3811

Walz R, Schade W, Doll C (2007) Interaction of EU Transportation Policy and Climate Policy. Intereconomics – Rev Eur Econ Policy 2(2):90–95, Kiel

Wang Z, Jin Y, Wang M, Wu W (2010) New fuel consumption standards for Chinese passenger vehicles and their effects on reductions of oil use and CO2 emissions of the Chinese passenger vehicle fleet. Energy Policy 38:5242–5250

Part III
Industrialized Countries: Experimental Protoyping

Chapter 4
Low-Carbon Transport in a Developed Megalopolis: The Case of London

David Banister and Robin Hickman

4.1 Introduction

A key environmental objective globally is to reduce the carbon intensity of the transport sector by 50% (1990–2050). In the European Union (EU) countries, this level must be even higher (80%) to allow for growth in the emerging economies. Over the last 12 years, even the more modest target of a 5.2% reduction in CO_2 emissions as set at Kyoto (1997) has proved difficult to achieve. Transport has made no contribution to this reduction as carbon emissions have continued to increase. The transport sector needs to be looking for a factor 12 reduction in carbon emissions by 2050 (NEAA 2009, p. 20). However, it is not just the final target that needs to be considered, as the pathways from the present to the future are equally important. Cumulative emissions over the period (1990–2050) means that countries and cities are already in serious 'deficit' as they are using up their 'carbon credits' in the hope that at the end of the 60-year period, substantial reductions will have taken place as the whole economy will be decarbonised (Fig. 4.2). Carbon budgets give one the means by which reductions can be phased in over a period of time, but even here the tendency is to look for slow initial actions (DECC 2009). The value of a tonne of carbon saved now is much greater than one saved later, and neither the targets nor the budgets confront emissions from aviation and shipping.

It is enormously difficult to see how the targets and the interim budgets can be achieved or even resolved within a multilateral debate, when there are so many priorities, perspectives and variables to be considered. This paper attempts to structure this debate within the context of London, where a 60% target reduction in CO_2 emissions has been set for transport (1990–2025), and recently confirmed by the Mayor's Draft Transport Strategy (October, 2009). A backcasting approach is used to determine the range of policy packages available to meet this target, given the

D. Banister (✉)
Transport Studies Unit, School of Geography and the Environment,
University of Oxford, South Parks Road, Oxford, UK
e-mail: david.banister@ouce.ox.ac.uk

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wide set of possible options that are being considered. This analysis is set against the background of two different images of the future for London, where one promotes the role of technological innovation more and the other places a greater emphasis on lifestyle changes. A transport and carbon simulation model has been developed (TC-SIM) to test the impacts of the different policy packages and the pathways that need to be followed. Two particular issues are discussed, one where effective actions can be taken to give 'quick hits' and the other covers the problems of including aviation in the analysis.

4.2 Study Approach

Backcasting is now seen as offering one means by which longer term futures can be visualised through setting challenging target reductions for carbon. These visions of the future are based on different views of how the future might develop (key drivers of change) and the different priorities given to economic growth, the environmental and other societal objectives. Within this framework, it is possible to explore the role that a wide range of policies can have, either individually or working together as a set of complementary measures (policy packages), in achieving the overall target-reduction levels. Pathways can be developed to establish the means to get from where you are to where you might want to be (backcasting), so that timelines of key decisions can be established. At all stages there is an extensive consultation process, where 'experts' are involved to comment on, and to make suggestions and changes to the proposals. This is important as it links the more theoretical and conceptual thinking to the reality of decision processes.

The TC-SIM model has been developed as a means to allow individuals to role play within the context of choices being made at the city or the regional level on carbon-reduction options. Part of this simulation includes the need to identify where key reductions can be made in the short term so that the 5 year budgets are not exceeded. Attention is now also being paid to the costs of alternative packages through multi-criteria analysis, where empirical weightings have been obtained to allocate priorities to particular options, and the costs associated with them estimated (Saxena 2009). Conventional economic appraisal methods and marginal abatement cost approaches seem to have limited potential, as many of the most effective carbon-reduction options for transport act to reduce and/or slow traffic down (urban planning, behavioural changes, ecological driving and slower speeds) and may have a high initial cost (e.g. the electric vehicles and plug in hybrid electric vehicle technologies). But this should not reduce the role that transport should have in making a major contribution to carbon-reduction targets – see www.vibat.org.

The backcasting method seeks to develop policy pathways in an agreed future direction to achieve clearly defined carbon-reduction targets (e.g. 60% between 1990 and 2025), through developing images of the future that represent 'desirable solutions', and then to cast back to determine the different pathways from the future to the present – it is a trend-breaking methodology (Fig. 4.1).

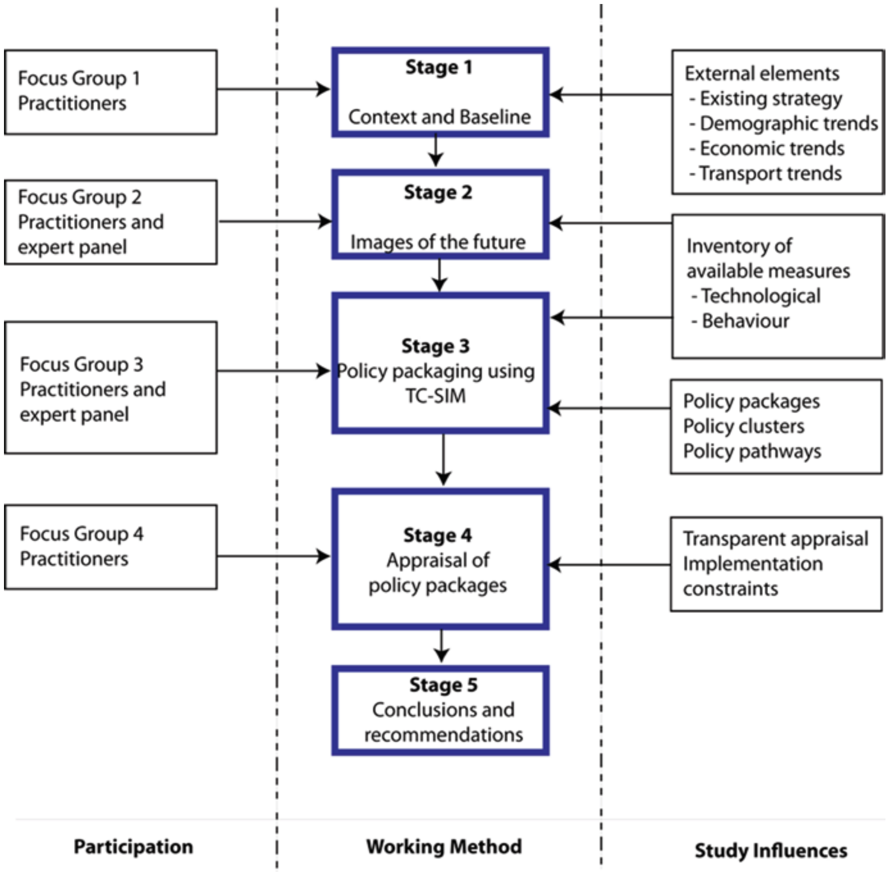

Fig. 4.1 The study process

4.3 The London Baseline

London aims to become a model sustainable global city that can combine population growth with economic prosperity to create a fair and vibrant society, and at the same time substantially reduce its carbon emissions. This political aspiration has created a huge challenge, namely how such a future can be delivered. There is no shortage of action and targets, as can be seen in Table 4.1.

Within London, the transport sector accounts for about 24% of ground-based CO_2 emissions (9.6 $MtCO_2$, 2006), with car travel accounting for 49% and road freight another 23%. In carbon terms, London is much more efficient than any other city in the UK, as it has a much higher level of public transport use, and as it has lower levels of car ownership than expected given its relatively high income levels. Registered cars in London are used less than elsewhere in the UK. So London is already in a better position (lower transport CO_2 emissions than elsewhere in the UK), but this

Table 4.1 Base data and publications

London	2006	2050
Population	7.5m	9.2m
Economic growth (indexed)	100	200–250
Carbon emissions	44 $MtCO_2$	8.8 $MtCO_2$

London publications	UK national and international publications
Transport 2025 (Tfl 2006a)	Kyoto protocol 1997
Mayor's Transport Strategy (TfL 2006b)	Pathway towards 60% by 2050 (DTI 2003 and 2006)
London Plan (GLA 2004)	Climate Change Act 2008
Climate Change Action Plan[a] (GLA 2007)	UK low carbon transition (DECC 2009)
Mayor's Transport Strategy (TfL 2009)	Low carbon transport (DfT 2009)
	Meeting carbon budgets (CCC 2009)

Note: The two Transport Strategies for London represent the different views from the Mayor's, the first from Ken Livingstone and the second from Boris Johnston

[a]The legally binding UK target in the Climate Change Act (2008) is for a 80% reduction in carbon emissions (1990–2050). The average annual emissions in the carbon budget period including 2020 (2018–2022) are at least 34% below the 1990 baseline

Table 4.2 CO_2 emissions (2005)

	UK	London
All emissions (tCO_2 per person per annum)	9.86	6.09
Population (millions)	56.0	7.5
Personal travel (tCO_2 per person per annum)	1.168	1.000
Freight and aviation (tCO_2 per person per annum)	1.132	

makes it even harder to achieve substantial further reductions (Table 4.2).[1] The London baseline for transport is to reduce the levels of CO_2 from 9.6 $MtCO_2$ (2006) to 4.0 $MtCO_2$ (2025), a 60% reduction on 1990 levels. The Business as Usual (BAU) is estimated to be 11.7 $MtCO_2$ with no interventions, meaning that the reduction targets on these levels is over 65%.

In building the two visions of the future, there are a number of drivers of change that need to be considered. As noted above, the population of London will increase to 2025, but there will continue to be changes in household structure, ageing, migration, and a more active population. All these factors will influence travel. In addition, it is expected that the economy of London will grow in the long term (Table 4.1), and it will strengthen its position as a global financial and network centre. This global role might also need to be balanced against the desired for increased social and cultural cohesion with an increase in London's local identities. Technological innovation and the digital and network society will also influence development and patterns of activity, as will the role that London (and the UK) plays as an international centre. There may also be clear moves towards more

[1]In 2007, 24% of London trips were by walk, 33% were by public transport and 41% were by car. The corresponding figures nationally were 24% walk, 10% public transport and 65% car.

sustainable lifestyles, with taxation being more consumption and carbon-based. All these factors provide important inputs to the two images of the future that have been developed and discussed with academics and practitioners.

The future is, by definition, uncertain, but the interest here is in trend-breaking visions, built around attractive cities of the future, that have a strong economy, societal cohesion and awareness of the associated environmental costs – this is the vision of a sustainable London.

4.4 Images of the Future

4.4.1 Image 1: Perpetual Motion

Under Image 1 London is developed with a strong emphasis on technological change. The demand for transport remains strong and mobility, including air travel, continues to grow. There is a ready acceptance of new technology, both in the home and the workplace, but particularly in transport with a keen desire to overcome the consequences of CO_2 emission increases through clean technology. However, this concern is not backed up by major lifestyle changes; only marginal changes occur using information and communication technologies (ICTs) to reduce the need to travel for certain activities (e.g. some use of teleconferencing and home shopping). Mobility levels remain unaffected; particularly travel by private car in the suburbs.

The main aim of transport policy is to achieve the required CO_2 emissions target with a minimum of change in terms of behaviour. Car traffic still grows and dominates in terms of modal share, with trip lengths increasing and occupancy levels remaining about the same as in 2000. The main changes are in pushing hard on hybrid and electric technologies and alternative fuels so that the overall average emissions profile of the total car stock reduces to 100 gCO_2/km or below in 2025.

There is also considerable investment in alternative fuels to reduce the carbon content of existing internal combustion engines (ICEs) and the non-electric parts of hybrids. Niche electric vehicles also have a limited role for low-speed vehicles in central London, provided that their energy source is renewable. The cost of fuels overall is on the rise, but this increase affects those car users who continue to consume fossil fuels. New materials are used to make vehicles lighter. Although behavioural change is also acknowledged as being important, the general view is that little lifestyle change is required, apart from clear pricing signals to encourage less fuel consumption and a switch to cleaner technologies (Table 4.3 – Image 1).

4.4.2 Image 2: Good Intentions

Under Image 2 London develops with a strong emphasis on environmental and wider sustainability objectives. Economic and social considerations are still important, but they are not pursued at the cost of environmental goals. Slowly, the importance of

Table 4.3 Images of the future – London

Image 1: Perpetual motion	Image 2: Good intentions
Strong emphasis on technological change	Lifestyle changes with acceptance of behavioural change
Demand for transport strong – mobility grows by car, within lower density outer London	Less use of car – more use of cycles and public transport – high occupancy vehicles
Trip lengths and occupancy do not change – but more suburban living	Higher density development, clustered around the public transport network
Hybrid and electric vehicles (for cars, buses and vans). Cars <100 gCO_2/km	Vehicle leasing (rather than ownership) and car sharing
Costs of fuels rises – lighter materials	Trip lengths reduced – importance of local neighbourhoods and employment centres
Emissions-based road pricing in London	Cleaner cars and other vehicles (130 gCO_2/km)
	Road pricing and high costs of using cars – and much higher transport costs

designing the urban environment for less travel and efficient use of resources achieves greater importance. Over time, technology systems become essential to deliver carbon efficiency.

Within London, the central activity zone is an important centre for growth, but growth is also concentrated in the suburbs, with local polycentric growth. Societal benefits accrue from a society integrated more at the local level. People in this scenario are environmentally aware and more careful in their use of resources. This Image is also market-driven, but has a much stronger social and environmental emphasis, and is focused on improving the quality of life. The transition to the technological society is moderated by greater social intervention. The economy is a knowledge-based economy, producing specialist products for hi-tech businesses. It is accepted that behavioural change is the essential basis needed to address the required CO_2 emissions targets. However, technology is also important – there is realism though in terms of expected application.

In the transport sector, the expectation in this image is that there will be a slight reduction in the total amount of travel distance by each person in 2025 and again to 2050, but the effect of this will be offset as population will have increased in London. The main reduction has not taken place in the number of trips made, but in the length of trips. The distribution has changed, with some growth in long distance trips, but these are more than compensated for by the increase in shorter more local trips. The desire for less travel (and distance for freight distribution) links in with the greater social awareness and conscience of the population, and the importance of community and welfare objectives. The lock-in to car dependency (as found in Image 1) is broken with social priorities pushing for greater use of public transport and other clean modes of transport.

There is less dependence on technological solutions, but cars become cleaner over the period (130 gCO_2/km or below for the total car stock by 2025) through new taxation and pricing incentives to use more efficient and cleaner technologies, with tax reductions for not owning a car or for participating in car-sharing schemes. Real fuel prices increase over the period; increases in oil prices are an effective driving force in achieving carbon-efficient transport (Table 4.3 – Image 2).

4.5 Policy Packaging and TC-SIM

A wide range of policy levers are available to help reduce transport CO_2 emissions and move towards the images of the future. These work best within packages, allowing complementary measures to work together (Hickman and Banister 2007). A transport and carbon simulator (TC-SIM) is developed in the VIBAT London study to help explore the packaging of policy options. TC-SIM is a participation tool which includes a scenario building and policy discussion platform, with a spatial base, around which decisions in relation to possible future scenarios and policy packages can be made. The 12 policy packages (PP) considered cover – PP1: Low emission vehicles; PP2: Alternative fuels; PP3: Pricing regimes; PP4: Public transport; PP5: Walking and cycling; PP6: Strategic and local urban planning; PP7: Information and Communications Technologies; PP8: Soft measures ‘smarter choices’; PP9: Ecological driving and slower speeds; PP10: Long distance travel substitution; PP11: Freight transport and PP12: International air travel.

Each policy package can be selected at a variety of levels of intensity of application – typically a ‘low’, ‘medium’ or ‘high’ level of application. The assumption in terms of background traffic growth is that traffic grows year on year as an extrapolation of recent trends. Relative to the rest of the UK, London is different in that traffic growth has been limited in recent years, and it appears to have stabilised near the top of the ‘S’ curve of traffic growth.

The BAU application is assumed to be the Reference Case (Scenario 1) in T2025 (TfL 2006a). This broadly represents the current fully funded investment strategy for Transport for London (TfL) and is thus the best representation of current BAU. It does, however, represent a significant amount of transport funding – approximately £2–7 billion per annum to 2025 (TfL 2006a).

The modelling behind TC-SIM has been developed to allow quantification of the potential impacts of a range of policy interventions in combinations as mutually supporting policy packages. It uses and combines a variety of data sources, including London Travel Survey (LTS) modelling runs, a spreadsheet of transport CO_2 emissions developed by TfL, a vehicle fuel penetration spreadsheet developed for the UK Department for Food and Rural Affairs (Defra) and a number of other databases (see TC-SIM modelling assumptions paper – Ashiru et al. 2009).

4.5.1 Quick Hits

To achieve the ambitious targets set, it is important to use the full range of policy options available, and to explore the means by which substantial savings can be made in the short term. It is not just a matter of reaching targets set at some distant point of time in the future, but to see real savings made in the short term. The global warming impacts of carbon dioxide relate to the concentrations of gases in the atmosphere, and these are increasing over time, hence the increasing use of interim carbon budgets as well as longer term targets (CCC 2009).

For example, a comparison can be made between the planned reduction profile and a uniform reduction over the whole period to 2025 or 2050, with the calculations based on the methodology of 5 year allocations developed by the Committee on Climate Change report (CCC 2008). As there are actual figures for 18 years (1990–2008), the deficit can be easily calculated for the period 1990–2005.

Assuming a uniform reduction, the total amount available for transport in London over the 38 years (1990–2027) is 259 $MtCO_2$. The actual amount used already (1990–2008) is 168.3 $MtCO_2$. The amount available for the next 20 years (the first four budget allocation periods) is about 90 $MtCO_2$ – so the current target per year is 4.5 $MtCO_2$ (under 50% of the current actual levels). Each year, this target gets reduced if it is not met, making it that much harder to achieve.

At the current levels of CO_2 emissions in transport for London, the total allocation (259 $MtCO_2$) will be used by 2018, some 10 years before the target date. The proposed pathway (the slow path – 5% + 10% + 30% + 60% reductions over each of the four budget allocation periods) means there will be a deficit of 56 $MtCO_2$ by 2027. With a fast path approach (10% + 30% + 45% + 60% reductions), the deficit will be 36 $MtCO_2$ by 2027. Reaching the target requires immediate fundamental action and a pathway of 45% + 55% + 60% + 60% reductions over the four budget allocation periods (Fig. 4.2).

Using the cumulative approach and budgeting for 5 years means that it is already impossible to reach the 60% reduction levels set for transport in London. It is possible to achieve the target itself, but this ignores the 'additional' carbon emitted over the period because of the pathway adopted. It is essential to make immediate substantial cuts if this problem is to be overcome. The 'slow path' being adopted in London leaves a substantial (22%) carbon deficit for transport in London (2027).

In the short term, the opportunities for the quick hits rely on two policy options, one relating to the full range of pricing options and the other to slower travel. The pricing options include substantially raising the costs of travel to truly reflect the full environmental costs, including the co-benefits of the reductions in accidents, noise levels, other pollutants (principally oxides of nitrogen and black carbon), health and the quality of life in London. It would also cover costs relating to parking and the use of space by vehicles, including London wide road pricing that reflects the carbon costs of the vehicle. The increased costs of using polluting vehicles would be matched by incentives to switch to public transport, where there would be substantial increase in levels of investment. There would be incentives to lease low-carbon vehicles.

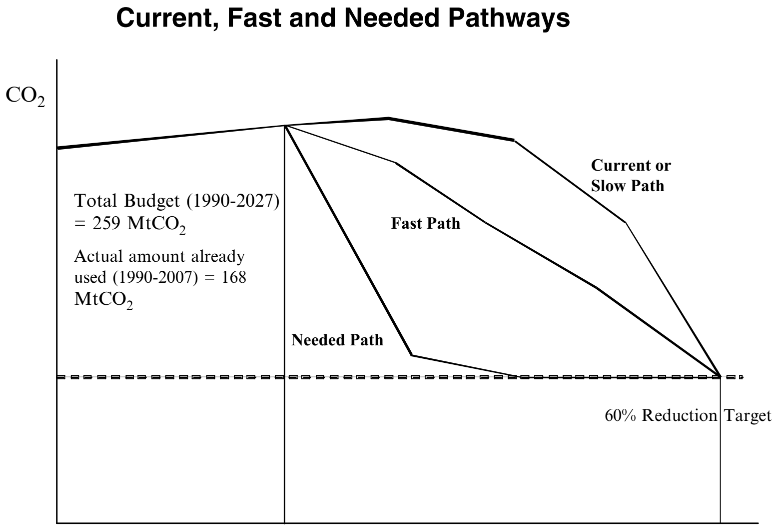

Fig. 4.2 Different pathways to target achievement in London

In addition to increasing the costs of travel and the incentives to use low-carbon modes of transport, there would be a clear aim to slow travel down in London and to increase the reliability of travel, reduce stop/start driving and the levels of all emissions. Slower travel would also help reduce accidents and make alternatives to the car more attractive. Health co-benefits could be enhanced through a greater use of active transport, with substantial priority being given to walking and cycling as modes of transport.

From TC-SIM it is estimated that 13% of the carbon-reduction target could be achieved by these two measures on their own if they are applied immediately at a 'high' level. In the longer term, other measures relating to urban form and structure, and to the introduction of electric and hybrid vehicles to the fleet of vehicles in London, would increase the total carbon-reduction levels to 60% by 2025 through a 'high' level of application of all policy packages.

4.5.2 Aviation

Within the TC-SIM model, ground-based aviation is included,[2] but one of the policy packages covers domestic and international aviation. A rather severe allocation

[2]Ground-based aviation covers planes taxiing, taking off and landing at each of the London airports – here we count just Heathrow and London City, but there are other airports just beyond the Greater London boundary such as Gatwick, Stansted and Luton. Between 1990 and 2007, emissions rose by more than 20% from 0.9 $MtCO_2$ to 1.1 $MtCO_2$.

process has taken place, so the figures presented give a worse case picture. The method used comes from the Climate Change Action Plan (GLA 2007), and it allocates half the carbon emissions from any international (or domestic) flight landing at London's airports to London residents' emissions. This assumes that the travel is all undertaken by Londoners (not true) and that those passengers interchanging to other services also count against the London flights (this overestimates London's responsibility). It would be possible to reduce the strength of the assumptions made, but the carbon emissions would then need to be allocated to UK regions or to other international locations.

Various options are included in the TC-SIM model to reduce the impact of international aviation, through reducing the demand for particular types of journey (awareness programmes), pricing (raising the levels of airport flight taxes) and reducing supply (restricted airport growth). Adding the CO_2 emissions associated with international air travel raises the baseline BAU by 35 $MtCO_2$ (2025). The target achievable through a 'medium' level of application of the policy packages meant that a 32% reduction in transport CO_2 emissions was possible (1990–2025), but this figure reduces to 8% with the inclusion of international aviation emissions.

Even if the supply reduction option is included, this figure is only slightly better at 11% (i.e. this means very difficult policy choices in the air sector, such as no third runway construction at Heathrow). By raising the levels of intervention in other policy packages to the 'high' level and with high oil prices ($140 per barrel), it is possible to reach the 60% target without including international aviation emissions, but this is reduced to 22% if the medium level of international aviation intervention is included. So it is difficult to achieve the 60% target if international aviation is not included, but impossible if it is included.

4.6 Conclusions

There are several policy pathways towards substantial improvements in carbon efficiency in the transport sector in London. All represent significant breaks against current trends, and even though they are likely to be very difficult to implement, certain conclusions can be drawn.

Current trends mean that the transport sector continues to perform poorly in contributing to cross-sectoral carbon-reduction targets. The clear message is to work more effectively across the broader range of policy packages available and at a higher intensity of application relative to current trends. A balanced package of measures, implemented now and at a 'high' level, will achieve the 60% CO_2-reduction target. The key challenge here is the successful application of strong policy interventions across a wide range of policy levers. Heavy investment in upgrading public transport and other infrastructure is required to move beyond a 40% reduction in emissions.

Low emission vehicles and alternative fuel penetration are likely to remain the most important policy levers, as they tackle carbon efficiency in the dominant mode of travel (the private car). The main difficulty here is in achieving any level of success in penetration to the mass market. The motor industry and government need to develop mechanisms to achieve this, including mandatory targets for manufacturers. The successful market penetration for the 100 gCO_2/km car and 125 gCO_2/km light goods vehicle would need to be seen as a mandatory, and minimum, requirement for the agreed future year (2025).

Behavioural measures also provide substantial opportunities. These include pricing regimes, increased use of public transport, walking and cycling, ecological driving and slower speeds and more efficient freight transport. Urban planning and soft measures have the potential to perform very important roles as supporting measures to other policy packages, enabling higher levels of success in implementation.

There is little current understanding about the potential for synergies between policy levers and packages, but the achievement of the 60% and the 80% targets, together with the pathways needed to get there, is dependent on value added being achieved in the actions taken. In addition, the dangers of lock-in to particular futures and the rebound effects where potential benefits are reduced through additional compensatory travel being undertaken need to be considered. There are considerable uncertainties over the real scale and nature of the changes that can be expected, and it is often difficult to model the effects. The values used in the TC-SIM are taken from best practice and from evidence in a range of studies in the UK and the EU.

In the transport sector, the record of achieving any substantial CO_2 reductions has been poor, even though some progress has been made in certain cities. There are two key underlying issues that need to be addressed. The first is that the public needs to radically change their attitude towards a carbon-intensive transport system and to start travelling in much more carbon-efficient ways. The means of knowledge dissemination, communication, participation in decision-making and marketing of policy options and futures all need to be considerably enhanced. Tools such as TC-SIM, applied to different contexts, could play an important role in testing different options with a range of different users.

The second challenge is the need for leadership at all levels of government to demonstrate that change is necessary and that overall benefits to cities from a low-carbon future can strengthen other priorities. This leadership challenge extends beyond the public sector to business and industry as the real benefits from a low-carbon transport system should be reflected in greater efficiency in production and distribution processes. The huge challenge now is to map out and discuss a variety of policy pathways to carbon efficiency in the transport sector, and then to achieve a level of consumer and behavioural change consistent with that strategic vision.

London has had a long reputation for being a ‘dirty’ city, from the time when the fumes from the Thames in the nineteenth Century gave it the name ‘the Great Stink’. More recently, it was only in the 1950s that it shed its image of having high levels of air pollution, when it was popularly called the Big Smoke (Banister 2009). But even now it is often in violation of clean air requirements, so action is needed now to combat the oxides of nitrogen and black carbon, as well as carbon dioxide, as all of these are damaging to health as well as the environment. Plans are now being discussed for more bans on the most polluting vehicles, an extension to the low emissions zone, new bicycle highways, cleaner buses and a new generation of electric vehicles.

These changes on their own are not likely to be sufficient, and as the London population and economy starts to grow again, it is likely that both the targets for reductions in CO_2 and the pathways proposed will not be enough. A fundamental change is required in public and private attitudes and behaviour, together with inspirational leadership, to balance the overriding (but mistaken) conviction that it is only through technological innovation that substantial carbon reductions in transport will be achieved.

References

Ashiru O, Hickman R, Banister D (2009) TC-SIM modelling assumptions. Working Paper. Halcrow Group, London

Banister D (2009) The big smoke: congestion charging and the environment. In: Richardson H, Bae C-H (eds) Road congestion pricing in Europe: implications for the United States. Edward Elgar, Cheltenham, pp 176–197

CCC (Committee on Climate Change) (2008) Building a low-carbon economy – the UK's contribution to tackling climate change. CCC, London, December

CCC (Committee on Climate Change) (2009) Meeting carbon budgets – the need for a step change. CCC, London, July

DECC (Department of Energy and Climate Change) (2009) UK low carbon transition. DECC, London, July

DfT (Department for Transport) (2009) Low carbon transport: a greener future – a low carbon strategy for transport. DfT, London, Cm 7682, July

DTI (Department of Trade and Industry) (2003) Energy White Paper. Our energy future – creating a low carbon economy. Department of Trade and Industry. Stationery Office, London

DTI (Department of Trade and Industry) Foresight/Office of Science and Technology (2006) Intelligent infrastructure futures: the scenarios – towards 2055. Department of Innovation, Universities and Skills, London

GLA (Greater London Authority) (2004) The London Plan. Greater London Authority, London

GLA (Greater London Authority) (2007) Action Today to Protect Tomorrow: The Mayor's Climate Change Action Plan. Greater London Authority, London

Hickman R, Banister D (2007) Looking over the horizon: transport and reduced CO2 emissions in the UK by 2030. Transport Policy 14(5):377–387

NEAA (Netherlands Environmental Assessment Agency) (2009) Getting into the Right Lane for 2050: a primer for debate, Report produced for the European Parliament by NEAA, Stockholm Resilience and Stockholm University

Saxena S (2009) Pathways to a sustainable future – Delhi 2030. Draft DPhil submission, School of Geography and the Environment, University of Oxford

TfL (Transport for London) (2006a) Transport 2025: transport vision for a growing world city. Transport for London, London

TfL (Transport for London) (2006b) The Mayor's Transport Strategy. Greater London Authority, London

TfL (Transport for London) (2009) The Mayor's Transport Strategy. Greater London Authority, London.

Chapter 5
Getting into the Right Lane for Low-Carbon Transport in the EU

Karst Geurs, Hans Nijland, and Bas van Ruijven

5.1 Introduction

Stabilising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, achieving an affordable and secure energy supply, and feeding the world population are among the greatest challenges of our time. The Netherlands Environmental Assessment Agency and Stockholm Resilience Centre conducted a study titled *Getting into the Right Lane for 2050* to examine the European Union of today, from a global perspective, to look at long-term visions on the world of 2050, and to identify key decisions on the near term on global land resources and low-carbon energy systems, including transport.

To limit the increase in mean global temperature to 2°C, greenhouse gas emissions in high-income countries need to be 80–95% less in 2050 than in 1990. This study uses a vision for 2050 to achieve at least 80% CO_2 emission reduction within the EU. The distribution of emission reductions over sectors is an inherent part of this vision and not necessarily the most cost-effective. Emission reductions in transport amount to an ambitious 80%.

From this starting point, backcasts have been made of the pathways to the 2050 vision and the opportunities and challenges on the way. This approach of working back from vision to strategy is ambitious and differs from more conventional forecasting. It is typically applied to complex, long-term issues. The focus is on policy actions needed today and the implications for mid- and long-term policies of the EU.

The approach taken in this study is to view the EU from a global perspective, as one of the several economic blocks in 2050. By 2050, the EU will be equalled economically by new players and outgrown in terms of population. But as a major importer of goods and services from economic blocks such as India and China, the

K. Geurs (✉)
Department of Civil Engineering, Centre for Transport Studies,
University of Twente, Enschede, The Netherlands
e-mail: k.t.geurs@utwente.nl

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EU is likely to exert considerable influence on production standards worldwide. While alternative expectations and views are possible, implicit in this study is that the future EU is a pro-active and consistent player on the world stage. The EU acts on the basis of values that go ‘beyond GDP’ and with a reputation for regional integration and global interest.

In *Getting into the Right Lane* three interrelated themes are examined. The first theme is *land resources*, including water, and the EU’s role in a world providing food for all without further loss of biodiversity. This implies improving agricultural productivity in order to close ‘yield gaps’ in all regions, containing biodiversity loss worldwide on the way to 2050. It also implies a strategy of diversity in EU land and agriculture policies. The second theme is *energy* and envisages a low-carbon energy system in the EU in 2050. This amounts to 80% decrease in domestic emissions of greenhouse gases by 2050 and connects with the EU’s need to improve energy security. The third theme is *transport*, with a vision for 2050 of low-carbon transport in Europe.

This paper focuses on the vision of and the pathways towards low-carbon transport systems in the EU. As well as being a major contributor to carbon dioxide emissions in the EU, transport also has significant societal costs including congestion, air pollution, and accidents. There are synergies between achieving low-carbon transport and reducing other societal impacts, but these are not discussed here.

The analysis in the study is mainly based on the existing scenario studies and secondary material, e.g. existing transport projections for the EU transport sector and technological developments. There has been no original modelling work, and indeed forecasting over a period up to 2050 with so many uncertainties is unlikely to be a precise science. Two studies have been commissioned for *Getting into the Right Lane*, and served as important inputs for the analysis. The first study was a review of sustainable transport futures for transport and options available, and a discussion of the role that the EU should play in leading the debate and in taking effective action (Banister 2009). The second study examined the role of the European transport sector within a competitive EU economy (Rothengatter 2009). The analysis on climate change, energy, and land resources was largely based on modelling and other tools used by the Netherlands Environmental Assessment Agency in recent global outlooks (see PBL 2008; OECD 2008).

The rest of this paper is structured as follows: in Sect. 5.2 we depict the future of European transport according to some accepted scenarios. CO_2 emissions from the EU-transport sector rise in all the scenarios. Sect. 5.3 describe a contrasting low-carbon vision for transport in Europe in 2050, and Sect. 5.4 describes the pathways to reach such a low-carbon transport, where big emission reductions are required. Those pathways are not always straightforward and certain. Uncertainties are described in Sect. 5.5. A low-carbon transport sector is closely interlinked with a low-carbon energy sector. These interlinkages are described in Sects. 5.6 and 5.7. The latter one focuses on the issue of biofuels, with links to land use and biodiversity as well. Section 5.8 shows the critical path towards low-carbon transport: what needs to be done now and what does the EU need to do? Finally, the chapter ends with overall conclusions.

5.2 Transport Projections Under Business as Usual

5.2.1 Transport Scenarios for 2050

Passenger and freight transport have, before the economic crisis, increased year on year, as shown in Fig. 5.1. Up until 2000, growth in freight transport kept pace with growth in GDP, but between 2000 and 2005 demand for transport led to substantial growth, exceeding growth in GDP. This growth reflects the substantial increase in commodity trading and especially container freight, following EU enlargement and market integration.

Transport projections up to 2050 are inherently uncertain, but some scenario studies conducted for the EU transport sector up to the year 2050 (Petersen et al. 2009; Banister 2009) have common results. Firstly, international aviation and maritime transport is projected to be the fastest growing transport modes. Air passenger kilometres are forecast to double Petersen et al. (2009) or triple between 2005 and 2050 (Banister 2009). Maritime transport is expected to grow substantially, with tonne kilometres increasing within and between the Member States by about 90% between 2005 and 2050. Maritime transport between Member States and the rest of the world is projected to increase by 150% between 2005 and 2050 (Petersen et al. 2009). Worldwide, maritime transport is projected to grow by 150–300% by 2050, particularly due to container shipping, which is projected to grow by 425–800% by 2050 (Buhaug et al. 2008).

Secondly, of surface transport modes, *road freight* in the EU is a forecast to the strongest increase by about 60% between 2005 and 2050, and long-distance road freight (trips longer than 150 km) to more than double (Banister 2009). Passenger

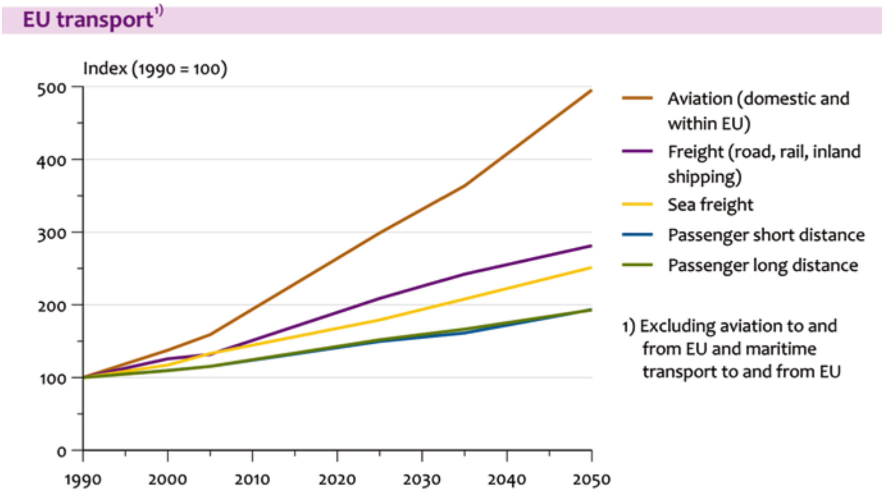

Fig. 5.1 EU transport, excluding international aviation and maritime transport to and from the EU (*Source*: Banister 2009)

car travel is projected to increase less strongly up to 2050, by about 40% (Petersen et al. 2009) to 70% (Banister 2009). Projections for *rail transport* differ significantly. Projections for rail passenger transport range from 30% (Banister 2009) to double (Petersen et al. 2009), between 2005 and 2050. Growth in *rail freig*ht ranges from 25% (Banister 2009) to treble current levels (Petersen et al. 2009).

Note that these projections do not incorporate the impact of the current financial and economic crisis. Growth in transport, particularly in freight transport, is likely to be delayed by about 5 years. The projections presented here, thus, are on the long run, slightly biased upwards. Figure 5.1 presents the EU transport projection as developed by Banister (2009). This scenario was developed based on the outputs from earlier EU transport scenario projects ETAG (Schippl et al. 2008) and Tremove (to 2030). This scenario is used in *Getting into the Right Lane* as base scenario, and used as input for a CO_2 emission projection for the EU transport sector (see next Section).

5.2.2 Baseline CO_2 Emission Projection for the EU Transport Sector

Greenhouse gas emissions from transport, excluding international aviation and maritime transport, increased by 27% over the period from 1990 to 2006, compared to a reduction of 3% in emissions across all sectors (EEA 2009). A projection of CO_2 emissions from transport, excluding international aviation and maritime transport to and from the EU, is presented in Fig. 5.2. Carbon dioxide emissions from the EU transport

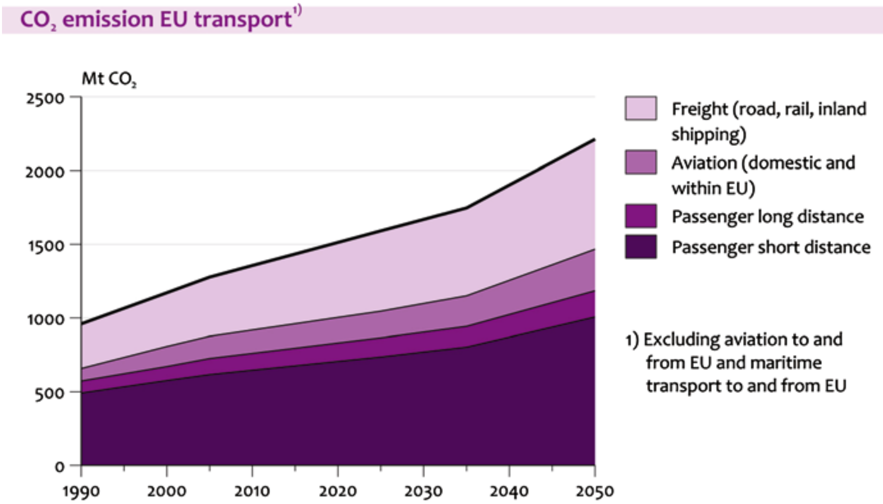

Fig. 5.2 Projected carbon dioxide emissions from EU transport, excluding international aviation and maritime transport to and from the EU (*Source*: Banister 2009)

sector, excluding international aviation and shipping, are projected to more than double (Banister 2009; Fig. 5.2). The largest growth in carbon dioxide emissions, over the last decade, has been from the international aviation and maritime shipping, which are not regulated by the Kyoto Protocol. Despite significant improvements in energy efficiency (albeit slowly diffused through the fleet), carbon dioxide emissions from international shipping are projected by IMO to increase by 10–25% in 2020 and by 125–220% in 2050, under baseline assumptions (Buhaug et al. 2008).

Under the Kyoto protocol, passenger air travel outside the EU is not included in EU statistics on carbon dioxide emissions, but is five to six times higher than kilometres flown within the EU (Petersen et al. 2009). If these emissions are included, emissions from EU aviation by 2050 would be roughly equal to road freight transport in the EU.

5.3 A Vision for a Low-Carbon Transport Sector in the EU

Transport currently accounts for a third of all final energy consumptions in Member States and for more than a fifth of greenhouse gas emissions (EEA 2009). Although carbon dioxide emissions in the EU decreased slightly between 1990 and 2006, emissions related to transport have risen by about 30% (EEA 2009). As transport is one of the fastest growing sectors in the economy, energy consumption and greenhouse gas emissions are projected to increase significantly up to 2050. Action is needed to reduce emissions in line with the climate change goals.

The vision for 2050 used in Getting into the Right Lane is that of low-carbon transport in the EU by decreasing carbon dioxide emissions from all transport modes – road and rail passenger travel, aviation, road freight, and shipping. Low carbon in this vision means 80% less carbon dioxide emissions by 2050, compared to 1990 levels. This is neither a forecast nor a blueprint, but a vision of low-carbon transport in Europe in 2050. This target equals the EU average decrease in greenhouse gas emissions as envisaged in this study. But it is more difficult to achieve, in view of the steep growth as projected for EU transport, without new policies. In fact, to achieve the target of 80% emission reduction relative to 1990 levels amounts to reducing emissions by almost a factor of 12 below those in the baseline scenario, by 2050.

The potential emission reductions of technological measures are primarily taken from the IEA's BLUE Map scenario (IEA 2008), but with different penetration rates, particularly for biofuels. The BLUE Map scenario uses a 50% CO_2 reduction target for the transport sector worldwide.

There main instruments to achieve the envisioned large-scale CO_2 emission reduction for the transport are:

1. Large-scale introduction of low-carbon fuels, such as hydrogen, electric traction, and biofuels.
2. Improving vehicle energy and logistic efficiency.
3. Reducing traffic volumes and shifting to more energy-efficient modes, such as rail transport

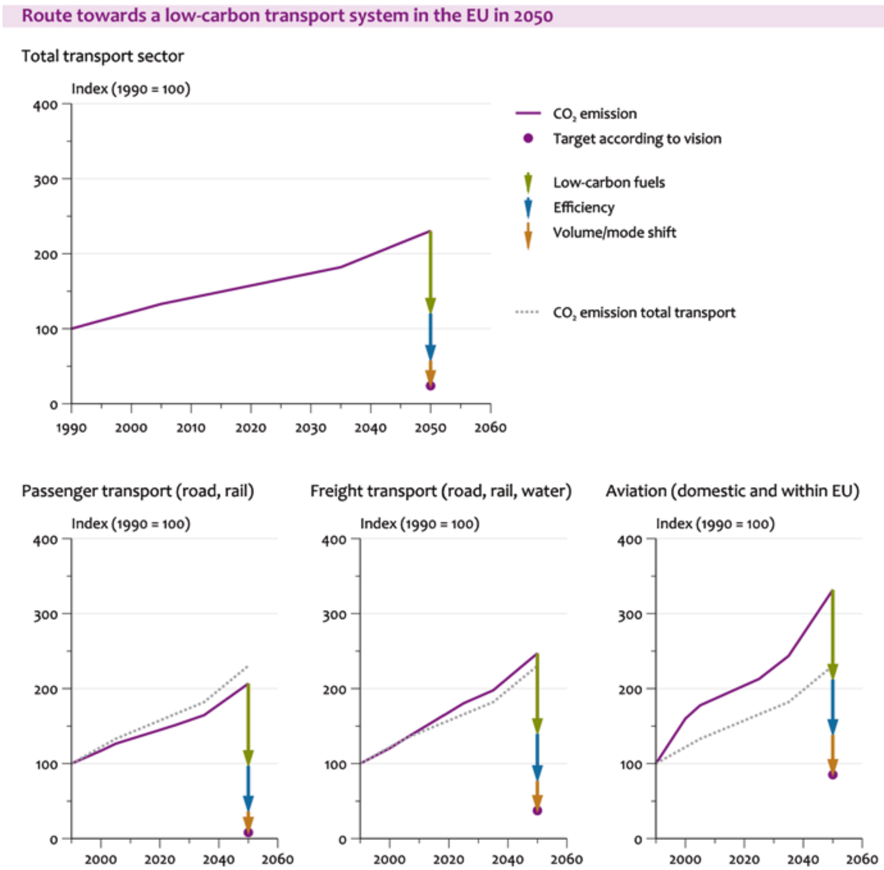

Fig. 5.3 A vision on low-carbon transport in the EU in 2050

The vision for low-carbon transport, based on 80% reduction in carbon dioxide emissions, is presented in Fig. 5.3. It includes emissions outside the EU territory from aircraft and ships fuelled in the EU. In achieving the 80% reduction target by 2050, reduction of carbon dioxide emissions is not the same in all transport modes. Passenger transport contributes most to the overall target. Road freight, aviation, inland shipping, and maritime transport contribute less to the overall reduction target because fewer cost-effective technologies are available. In short:

- *Road passenger transport* reduces carbon dioxide emissions by 95%, relative to the baseline scenario in 2050 (by a factor of 20–25). Current cars are replaced by electric vehicles and/or fuel-cell vehicles with hydrogen from low-carbon sources. Both technological routes require low-carbon or zero-carbon power generation technologies.

- *Road freight transport* reduces carbon dioxide emissions by about a factor of 6, relative to the baseline scenario, by 2050, resulting from a complete shift to advanced bio-diesels and maximum improvement in vehicle energy and logistic efficiency, and, to a small extent, from mode shifts to rail freight and shipping. Changes in logistic organisations result in higher truck utilisation and fewer kilometres.
- Emissions from *maritime transport and aviation* are reduced by a factor of 6 and 10, respectively, relative to the baseline scenario, by 2050. This is achieved through a 50–75% use of advanced biofuels and a combination of technological, logistic, and operational measures, including speed reductions (50–60% reduction in carbon dioxide emissions per vehicle km). Further emission reductions in aviation result from changes in travel behaviour.

5.4 Pathways to Low-Carbon Transport in 2050

There is a wide range of low-carbon technologies moving towards commercial production or in various stages of development that could be applied to different transport modes to reduce energy consumption and carbon dioxide emissions. Further reductions in emissions can be achieved by improving energy and logistic efficiency, and with modal shifts. As well as reducing emissions, low-carbon transport will make transport in the EU less vulnerable to volatility in oil supply and price.

5.4.1 Electric Traction and Hydrogen for Urban Transport

Almost complete decarbonisation of passenger road transport is technically feasible by 2050 (King 2008). Most promising technological options are full-electric vehicles and fuel-cell vehicles, with hydrogen produced from low-carbon sources (van Ruijven et al. 2008), for cars, buses, and urban freight transport, such as urban delivery trucks, at least in the near to medium term. However, to compete with fossil-fuel vehicles and fossil-fuel alternatives, several technological hurdles have to be overcome, and the cost brought down considerably for wide-scale application. While progress is being made, both electric and hydrogen passenger vehicles still have a long way to go in the development and commercialisation process. Commercialisation of the hydrogen cell is more problematic, largely because of the new infrastructure development required. The most likely route to making the transition from fossil fuels is gradual replacement of current fossil-fuel cars by hybrids, plug-in hybrids, and then by full-electric and/or fuel-cell vehicles. Electric and hydrogen road transport, whether full electric, (plug-in) hybrid, or hydrogen fuel cell, bring additional environmental benefits. These technologies produce less noise at low speeds, reducing noise nuisance and air pollution in urban areas.

On the critical path to achieving near-zero carbon transport in urban areas is a sufficient supply of clean power after 2030. Because of the slow pace of change where major infrastructure investment is involved, decarbonising the energy sector needs to be even higher on the agenda than is the development of low-carbon vehicle technologies. See for a further discussion on transport and energy sector linkages Sect. 5.6.

5.4.2 Bio-Fuels for Road Haulage, Aviation, and Maritime Transport

The current state-of-the-art technology indicates few options for achieving substantial reduction in carbon dioxide emissions by 2050, for long distance road freight transport, shipping, and aviation. Neither electricity nor hydrogen is well suited for long-distance road freight transport because of storage capacity. Hydrogen as jet fuel will require total aircraft redesign and vast changes in infrastructure (IEA 2008). In addition, the global warming effect of increased water vapour at high altitude needs to be investigated. Fuel-cell utilisation in inland shipping is complicated because of the large quantities of hydrogen needed and the limited on-board storage space. Currently, some of the best options to reduce carbon dioxide emissions are advanced bio fuels manufactured from a wide range of biomass sources. There is, however, a high degree of uncertainty surrounding wide-scale use of biofuels, such as second-generation and third-generation biofuels, biomass-to-liquid jet fuels, and hydrogen and fuel cells (see Sect. 5.5).

Further policies are needed to ensure smart use of biofuels in reducing carbon dioxide emissions across the economy. For instance, in the current EU policy framework for road transport, fuel targets carry the risk that the car users may consume too much biomass in relation to other transport modes (trucks, aviation, and shipping), as well as other sectors, such as heat and power. Thus, direct links need to be made between the EU vehicle-efficiency targets and fuel targets.

There is an urgent need to prepare the way for low-carbon aviation and maritime transport by 2050. These slow-changing transport modes are growing rapidly in terms of volume and emissions. Thus, every effort is needed to promote the development and adoption of low-carbon fuels for aviation and maritime transport. However, total emission reduction awaits biofuels becoming commercially available, and sufficient land becoming available for biofuel production. See Sect. 7.7 for a further discussion of biofuels, land resources, and biodiversity.

Achieving emission reduction in aviation requires a shift to bio-kerosene. At present, there is no ‘bio’ equivalent for kerosene. An aviation biofuel has been developed, and several test flights have been carried out, but without conclusive results. The European Commission has called for tenders on more research to evaluate the feasibility of these biofuels. Nevertheless, a substantial shift to bio-kerosene would achieve emission reductions in aviation (see 2). In IEA’s BLUE Map scenario, biomass-to-liquid fuels are assumed to account for 30% of aviation fuel by 2050, provided carbon prices are high enough. To achieve a reduction in carbon dioxide emissions in aviation, relative to the 1990 levels, however, much higher levels of advanced biofuels will be needed, at least 50–75%.

The cost-effectiveness of EU policies on biofuels can be improved by closely linking current biofuel targets with EU vehicle-efficiency targets. This could be achieved by establishing a carbon-intensity obligation for all fuels, such as in the California's Low-Carbon Fuel Standard where carbon-intensity of fuels is reduced through a system of tradable credits, also applicable to biofuels. The EU could also set up a wider road transport obligation which links carbon intensity of fuels to vehicle efficiency, possibly through tradable credits. Ultimately, road transport could be covered by a 'cap and trade' scheme such as the current ETS.

5.4.3 Improving Vehicle Energy and Logistic Efficiency

Next to a substantial shift to biofuels, a significant contribution can be made to the near zero-carbon target by improving the technical and logistic efficiency of heavy-duty road freight vehicles. Efficiency improvements of 15–30% have been estimated using vehicle hybrid technologies (De Lange et al. 2008; Lensink and De Wilde 2007; Hanschke et al. 2009). This potential is difficult to achieve for long-haul freight vehicles, because hybrid technologies are not very effective for vehicles operated at constant speed and power.

However, carbon savings can be achieved by improving logistic efficiency in road freight transport and modal shift to rail. Different logistic organisations, such as green, reverse, and cooperative logistics, have great potential to increase truck utilisation and reduce truck kilometres (Rothengatter 2009). Here, smart logistics are assumed to reduce intensity (transport input per unit of GDP) of road freight transport induced by higher fuel costs.

Logistic efficiencies to achieve maximum potential of technological and operational measures in international shipping, including speed reduction, may reduce emissions by up to 60% per tonne kilometre by 2050 (Christ 2009; IEA 2008).

The BLUE Map scenario, assuming a 'maximum technology' case, includes 10% improvement in technical efficiency, beyond the baseline scenario, by 2050. This represents a total improvement of 35% in fleet fuel efficiency on the current average and an additional 10% reduction in global aircraft energy use through the optimisation of operational systems. According to CCC (2008), a production aircraft in 2025 flying in an improved operational environment can be 40–50% more fuel efficient than a new production aircraft flying in a 2006 operational environment. However, because of the long lifetime of aircraft, the potential reduction in carbon dioxide emissions in 2050 is modest.

5.4.4 Cutting Traffic Volumes and Shifting Transport Modes

Technology alone will not be sufficient to achieve an 80% reduction in carbon dioxide emissions from transport by 2050. Low-carbon transport requires full engagement and participation of all stakeholders to bring about changes in behaviour. It will also be necessary to reduce demand for transport and to stimulate a modal shift in both passenger and freight transport. This is particularly the case if European emissions include transport emissions caused by EU residents outside EU territory.

Thus, changing consumer preferences is an essential element in achieving a low-carbon transport. Changes in transport volume and mode shifts are assumed to contribute about 15% to the emission reduction target. This involves reducing short-distance passenger travel and long-distance passenger and freight transport, particularly air travel. For instance, reducing car use in urban areas for short distances requires a shift to non-motorised and public transport, and would need to achieve as much as a 20% reduction in car use in urban area and carbon dioxide emissions.

Even with optimistic assumptions on energy-efficiency improvements and use of advanced biofuels, significant reductions in air travel growth are needed in order to reduce carbon dioxide emissions from aviation to below 1990 levels. Here, growth is assumed to decrease from a forecasted tripling of air passenger kilometres between 2005 and 2050, to a doubling or less.

Pricing is a key factor in bringing about change. Demand for air travel can be reduced by eliminating all subsidies and introducing taxes and charges and/or including aviation in a global carbon trading system which results in sufficiently high carbon prices (e.g. all permits are auctioned, and the cap is progressively lowered by reducing the amount of permits auctioned each period). Also, growth in air travel will partly be curtailed by higher fuel prices based on a higher share of bio-kerosene which is likely to remain more expensive than jet fuel. In addition, incentives are needed to partly shift passenger air travel to high-speed rail between European cities.

5.4.5 Re-aligning Infrastructure Development

Currently, a significant proportion of the EU budget goes to co-financing investment in Trans-European networks (TEN-T). The overall cost of 28 priority projects is about 400 billion euros, of which 270 billion euros has yet to be invested. TEN-T investments have, however, not been fully successful in achieving EU policy goals. Firstly, according to the TEN-T policy review (European Commission 2009), planning of the Trans European Network has not been driven by genuine European objectives, resulting from a lack of funding and sovereign responsibility by the Member States in infrastructure planning (subsidiarity). Secondly, the economic efficiency of TEN-T investment is subject to debate. The EU project TIPMAC has, for example, shown that the net economic impact of the TEN-T programme is very small in the period up to 2020. This is largely because a number of transport projects on the corridor list will have difficulties generating enough transport benefits in the next two decades (Rothengatter 2009). Furthermore, TEN-T policy has not provided a sound basis for an effective contribution to climate change objectives. Within a low-carbon transport system, TEN-T policy should contribute more to reducing carbon dioxide emissions, and thus to EU climate change objectives, financing projects only with a proven economic rationale and with environmental benefits.

In this respect, more attention needs to be given to stimulating electric public transport. Investments in electrified high-speed rail, serving as a substitute for air travel, will help achieving low-carbon transport, provided the power is produced from low-carbon fuel sources and seat occupancy levels are high enough. To achieve significant shifts from road to rail transport, at least 10% of projected investment in road infrastructure should go to rail infrastructure (Rothengatter 2009).

5.5 Balancing Potential and Uncertainty of Measures

To achieve an 80% reduction in carbon dioxide emissions in transport by 2050, relative to 1990 levels, new solutions are needed. Continuous incremental technological improvements can provide substantial emission reductions but are not sufficient. However, the potential emission decrease from new policies and technological options is more uncertain than from the existing policies and from the incremental technological changes. From a strategic point of view to reach the vision of 2050, options can be clustered according to their potential emission reduction and the degree of uncertainty in emission reduction potential, the costs, or the side-effects. As illustrated with some examples in Table 5.1, there are:

Table 5.1 Examples of carbon dioxide mitigation options clustered by emission reduction potential and uncertainty in potential, costs, and/or side effects

CO_2 emission reduction potential	Uncertainty in potential, costs, or side-effects	
	Small to moderate	Moderate to large
Small to moderate	• Current carbon dioxide-efficiency standards • Pricing measures, e.g. ETS for aviation and shipping, EU-wide road pricing for trucks • Energy-efficiency measures for road freight, shipping, aviation • Logistical-efficiency measures, e.g. green logistics • Land-use planning	• First-generation biofuels (ethanol, bio-diesel) • Current commercial jet biofuels
Moderate to large	• Plug-in hybrid cars • Heavy oil biofuel substitutes for inland shipping and maritime transport	• Full electric cars • Fuel-cell hydrogen road vehicles • Second-generation biofuels for road vehicles (ethanol, bio-diesel) • Second-generation and third-generation jet biofuels • Biomass-to-liquid biofuels with carbon capture and storage

- A range of technology options that may deliver large-scale emission reductions over time, but are associated with a high degree of uncertainty, such as second-generation and third-generation biofuels, biomass-to-liquid jet fuels, and hydrogen and fuel cells. These technologies require further technical progress leading to performance improvement and cost reduction, and also require radical changes in areas such as vehicle production, fuel supply, and agricultural systems. Supporting innovation for these technologies, support from EU and Member States for relevant R&D projects, and effective carbon pricing policies will be crucial.
- Options that have a low emission reduction potential and a low degree of uncertainty in technology or cost. Uptake of these technologies may lead to a small increase in vehicle or transport prices which may be offset by fuel savings. These technologies and measures are considered 'no-regret' measures for the EU on the way to low-carbon transport. They include carbon dioxide standards for new vehicles, energy-efficiency measures, ETS for international aviation and shipping, EU-wide road pricing schemes, and land-use planning.
- Technologies and policy measures that have a high emission reduction potential and a low degree of uncertainty in technology or costs. In these cases, industry and consumers will have to accept the cost in order to benefit from reduction in carbon dioxide emissions. This is the case for biofuels substitutes in heavy-duty vehicles and shipping. Use of biofuels (essentially FAME or bio-crude) in the maritime transport and heavy-duty road vehicles does not pose any fundamental or insurmountable technology challenges. The key barriers to biofuels are economic rather than technical, particularly for biofuels replacing marine diesel fuel (AEA 2007; Christ 2009).
- Some technologies have low potential for emission reduction and major side-effects. This is the case for the first-generation of biofuels and current commercial jet biofuels. These technologies have low and uncertain reduction potential and thus should not be further pursued by the EU.

5.6 The Transport Sector in a Low-Carbon EU Energy System

5.6.1 A Low-Carbon Energy Sector

In the study Getting into the Right Lane, a low-carbon energy system is envisioned for the EU energy system in 2050. An 80% reduction on 1990 levels in energy-related carbon dioxide emissions is assumed within the EU. In this envisioned low-carbon energy system, the end-use of energy is based predominantly on non-carbon energy carriers such as electricity or hydrogen from low-carbon sources or biofuels. The use of fossil energy is centralised to enable application of carbon capture and storage technology. Large renewable energy farms are interlinked in a European high-voltage electricity grid connecting Member States to distant energy sources, to reduce the impacts of intermittency and enable the use of the cheapest renewable resources. In this low-carbon energy system, diversification of energy sources leads to increased security of supply through reduced dependency on imported fossil energy.

The global energy model TIMER (de Vries et al. 2001; van Vuuren et al. 2006) was used to consistently link energy demand, supply, and trade. These calculations are based on the scenario of the OECD Environmental Outlook (OECD 2008), with specific adjustments to simulate the envisioned energy system. The main assumptions for the energy sector are a rapid increase in the share of electricity particularly in passenger transport and buildings and carbon taxes leading to aim specifically to 80% reduction in carbon dioxide emissions in the EU. The transport sector is assumed to reduce emissions by 80%, shifting towards carbon neutral road passenger transport and biofuels for heavy transport modes, as described in Sect. 5.4.

5.6.2 Transport and Energy System Linkages

Achieving low-carbon transport in the EU in the coming decades is closely linked to measures in the energy sector in three ways. First, regardless of which non-carbon energy carrier is used for rail, urban transport, and medium-distance transport (electricity or hydrogen), it has to be produced with low-carbon emissions. Yet, roughly the same amount of energy would be required to produce low-carbon electricity or hydrogen. Secondly, failure to decrease carbon dioxide emissions from transport will most likely need to be compensated in the energy sector. Thirdly, retaining options for hydrogen as an energy carrier in transport will affect design features of the future power grid.

5.6.3 What If EU Transport Sector Is Less Successful in Reducing CO_2 Emissions?

Emission reductions in transport amount to an ambitious 80%. Such reductions are possible, but what are the consequences when the transport sector does not deliver this target? Considerable doubts remain whether a sufficient decrease in carbon dioxide emissions from transport is feasible without a broad, frontal approach to achieve policy coherence, EU-wide, and for aviation and maritime transport, globally. Many scenario studies assume less-ambitious reduction targets, particularly for international transport. For example, IEA's BLUE Map scenario projects worldwide CO_2 emissions from maritime transport to remain fairly constant at the 2005 level, and a doubling of CO_2 emissions from aviation by 2050, relative to 2005 levels, assuming major efficiency improvements and a substantial share (30%) of advanced biofuels in overall fuel use (Fig. 5.4).

With regard to reductions in greenhouse gas emissions, economic sectors can be seen as "communicating vessels": if emission reductions are smaller in transport,

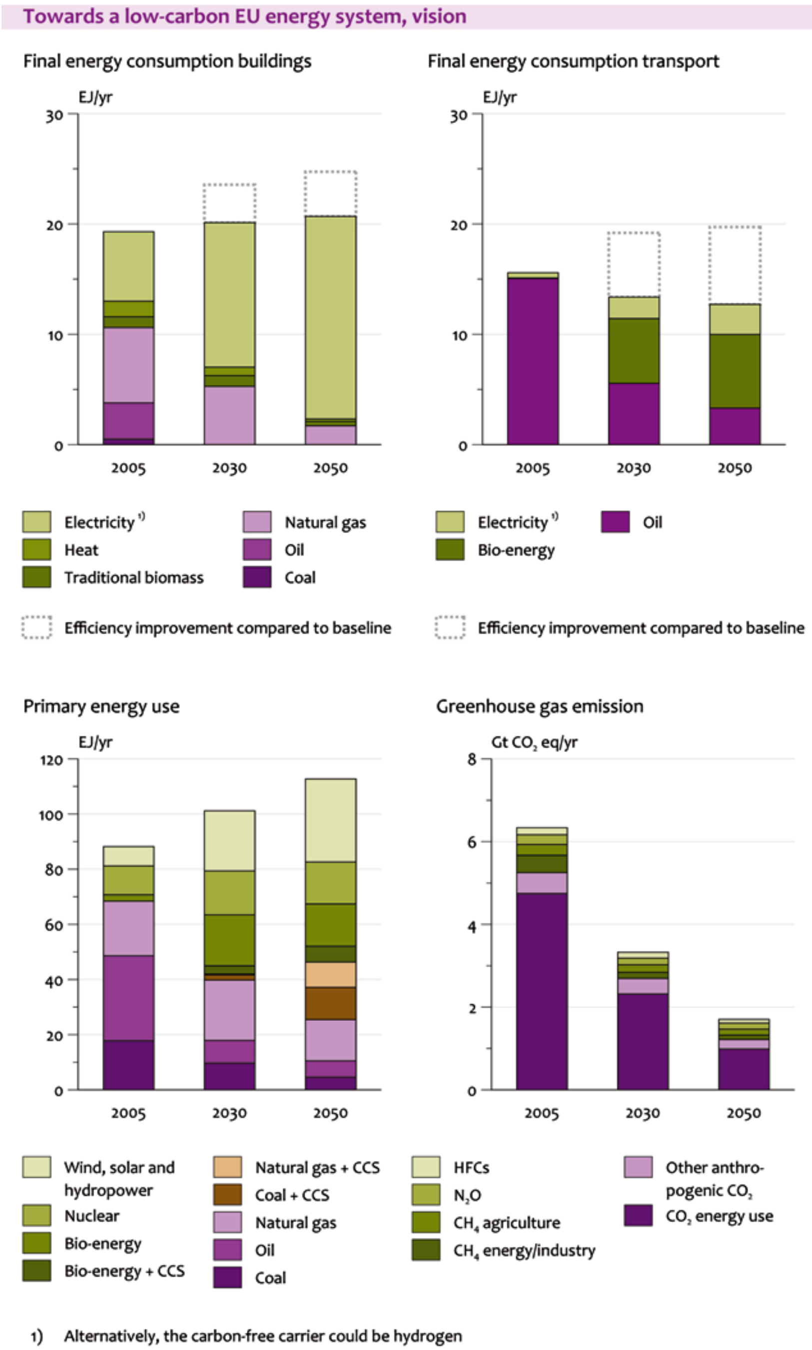

Fig. 5.4 A vision of a low-carbon energy system in the EU in 2050

then the power sector needs to achieve greater emission reductions (up to 100–120%). Negative emissions can be achieved in the power sector by using bio-energy in combination with carbon capture and storage. The use of wood-based bio-energy in power plants with carbon capture and storage generates is attractive as it creates a double benefit in decreasing carbon dioxide emissions: firstly taken up by crops, followed by subsequent storage. These net 'negative emissions' facilitate high emission reductions in the power sector.

5.7 Biofuels, Land Resources, Food, and Biodiversity

Many studies on climate mitigation have identified bio-energy as a key option to reduce greenhouse gas emissions and as an economic opportunity to reduce poverty in the developing countries. Based on the energy security considerations, policy makers have focused on stimulating the use of bio-fuels in road transport. This push for bio-fuels, mainly in 2008 with blending proposals in the USA and fixed renewable targets for transport in the EU, has led to scientific and societal debate on whether bio-fuels are a sustainable solution. The debate is dominated by issues such as risk of biodiversity loss, increase in food prices (Dornburg et al. 2008), the greenhouse gas balance of bio-fuels being negatively influenced by N_2O emissions (Smeets et al. 2009), and indirect changes in land use (Fargione et al. 2008; Searchinger et al. 2008).

Given the limitation in bio-energy potential and likely negative side-effects of energy-crop production, bio-energy needs to be directed strategically to applications that maximise its contribution to decreasing carbon dioxide emissions and minimise the required inputs. Currently, bio-fuel seems to be one of the few feasible low-carbon or zero-carbon options for aviation, shipping, and road freight before 2050. But is there sufficient global potential for bio-energy production, taking into account restrictions on for example land resources and nature protection?

Estimates vary widely on the global potential for bio-energy production. The long-term potential could be as low as 100–500 EJ/year, taking account of uncertainties in yield increase, sustainability criteria, water availability, fragile states (e.g. civil wars reducing investment opportunities), and other external factors (Dornburg et al. 2008; WBGU 2009). Based on the integrated modelling analysis of land-use and energy (van Vuuren et al. 2009, 2010) and because of uncertainties in production potential, this study limits the use of bio-energy to the lower end of the range. This is 100 EJ/year global bio-energy production, partly based on waste and residues, and partly on specific cultivation (Fig. 5.5). This could require about 3 million km^2 of land. For comparison, the current total EU agricultural area is approximately 2.2 million km^2.

A global bio-energy production of 100 EJ/year is sufficient to fuel long-distance road transport, aviation, and shipping, and to produce a sufficient amount of bio-energy to be used in power plants to achieve the vision of low-carbon energy and transport systems in the EU.

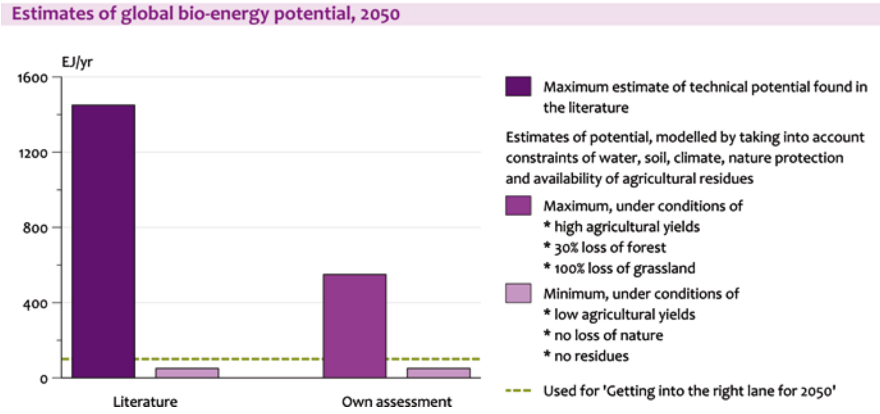

Fig. 5.5 Assessment of bio-energy potentials (*Source*: van Vuuren et al. 2009b)

Targeting bio-energy to long-distance road freight transport, aviation, maritime transport, and the power sector enables large carbon mitigation with a small volume of bio-energy inputs and minimal pressure on nature and food production. This requires the EU to extend bio-energy strategies with specific targeted applications. Thus, technology development of second-generation and third-generation bio-fuels could best be aimed at advanced bio-diesels for shipping and trucks and bio-kerosene for airplanes such as FT diesel or algae-based fuels. To achieve this, it requires a long-term EU vision on the application and production of bio-energy and a bio-energy directive that stimulates innovation in the direction needed for the long-term, and the current renewable energy directive to be aligned with a long-term vision on transport in the EU.

5.8 The Critical Path to Low-Carbon Transport in the EU

Achieving low-carbon transports in the EU in 2050 requires policy action in the coming decade, to set transport in the right lane to achieve this goal, because of the long lifespan of vessels and aircraft, many of which in operation today will still be operative in 2050. There is no single option to bring the emission reduction target within reach. The key elements to bring about the 80% decrease are technological options and a reduction of the increase in transport demand, for example, through pricing mechanisms. Thus, a package of policies is essential. The following steps are on the critical path – actions to be taken in the near-term future – to achieve this vision:

1. The EU needs to formulate a coherent policy on achieving low-carbon transport and energy systems, addressing the risks, vulnerability, security, and resilience associated with diversified energy carriers for transport in Europe. This policy

should become the basis for an integrated EU approach to both transport and energy aimed at facilitating transition to production of advanced vehicles and low-carbon energy carriers. On the critical path to low-carbon urban transport is a sufficient supply of clean power after 2030, as well as a host of standardisation issues. Because of the slow pace of change where major infrastructure investment is involved, decarbonising the energy sector needs to be even higher on the agenda than is the development of low-carbon vehicle technologies. A long-term policy framework to decrease carbon dioxide emissions from transport will provide stakeholders with a degree of certainty about carbon reduction in relation to other objectives.

2. The EU needs to take a leadership role to achieve international agreements for reducing emissions from aviation and shipping. A global strategy is the most effective, but also the most difficult approach in reducing emissions from these transport modes. It involves including international aviation and maritime transport in an emission-trading scheme with the objective to tighten targets over time and to allocate rights through auction and not allocation. It would mean a more effective emission trading scheme than the current EU-wide scheme, and would also include shipping. If a global trading system is not possible in near future, then an effective EU-wide scheme needs to be in place as a first step towards such a global system.
3. A great deal of R&D is being done in the private sector and EU initiatives are needed to strengthen efforts to identify emerging and promising technology, such as batteries and other energy storage technologies. Support is needed to bring these technologies to market. In this respect, partnerships with vehicle manufacturers may be particularly useful, giving them a stake in developing and commercialising new technologies. In addition, substantial R&D needs to be stimulated and financed on bio-kerosene (third-generation biofuels). Furthermore, effective carbon pricing is needed to support innovative low-carbon transport technologies, such as biofuels for heavy-duty road transport and maritime transport. This approach will yield new technologies that could become future standards in developing countries and in transition countries which are having difficulties in meeting low-carbon goals.
4. With restricted worldwide capacity for biomass production, bioenergy needs to be concentrated where it can contribute most to mitigating carbon dioxide emissions, and where there are few options are available. Technology development of bio-fuels could best be aimed at advanced bio-diesels for shipping and trucks and bio-kerosene for airplanes such as FT diesel or algae-based fuels. To achieve this, the current renewable energy directive needs to be aligned with a long-term vision on transport in the EU. Cost-effectiveness of EU transport policies can be improved by closely linking current biofuel targets with EU vehicle-efficiency targets. King (2008) suggests that this could be achieved by establishing a carbon-intensity obligation for all fuels, such as in the California's Low-Carbon Fuel Standard where carbon-intensity of fuels is reduced through a system of tradable credits, also applicable to

biofuels. EU could also set up a wider road transport obligation which links carbon intensity of fuels to vehicle efficiency, possibly through tradable credits. Ultimately, road transport could be covered by a ‘cap and trade’ scheme such as the current ETS.

5. Given the size of allocated budgets for Trans-European transport infrastructure, revising TEN-T transport policies is a priority in the short term. Infrastructure built in the coming decade will still be operational in 2050 and beyond. A key issue is to provide a stronger link between TEN-T policy planning, development, and climate goals, as proposed in the Green Paper on future TEN-T policy. The implication is that the EU would co-finance only those projects with a proven economic rationale and with environmental benefits, thus shifting investment from road to rail infrastructure.

5.9 Conclusions

Low-carbon transport presented in the vision for 2050 significantly reduces carbon dioxide emissions from transport, makes EU transport systems better able to adapt to future changes in energy supply and climate, improves robustness and resilience and increases long-term competitiveness of the EU economy. It will also trigger cleaner and quieter cities in Europe. A decarbonised energy sector and international agreements in shipping and aviation are crucial.

The current economic crisis is affecting transport more than most other activities, and this creates opportunity for changing business models and for the emergence of a new long economic cycle with different dynamics. But as yet, this is not substantiated. Given the longevity of transport infrastructure and spatial patterns, betting on the benign effects of such a paradigm is a risky strategy. Setting incentives to adjust transport to a long-term sustainability path is crucial, for instance, to reduce the transport intensity of freight transport. Rather than pushing investment in a crisis phase, a long-term sustainability strategy for infrastructure development is needed, because infrastructure built in the coming decade will still be operational in 2050.

Considerable doubt remains whether a sufficient decrease in carbon dioxide emissions from transport is feasible without a broad, frontal approach to achieve policy coherence, EU-wide. Such doubts are generated by the feasibility of carbon reduction options, projected steep growth in transport demand – passenger and freight transport – and the scarcity of evidence that this trend can be reversed at the level of the economy as a whole. Thus, establishing a broadly supported ambition to achieve low-carbon transport is on the critical path, including leadership to allocate responsibilities to vehicle manufacturers, fuel companies, and consumers. It also needs to enforce clear accountability and put in place the policies and frameworks to allow and enable others to fulfil their roles.

References

AEA Energy & Environment (2007) Low carbon commercial shipping. AEA Didcot

Banister D (2009) Getting in the right lane. Low carbon European transport beyond 2050. Paper. Transport Studies Unit, Oxford University, Oxford

Buhaug Ø, Corbett JJ, Endresen Ø, Eyring V, Faber J, Hanayama S (2008) Updated study of greenhouse gas emissions from ships. Phase 1 Report, International Maritime Organisation, London (Cited in Christ P (2009) Greenhouse gas emissions reduction potential from international shipping. Discussion paper No. 2009-11, Joint Transport Research Centre, Paris)

Christ P (2009) Greenhouse gas emissions reduction potential from international shipping. Discussion paper No. 2009-11, Joint Transport Research Centre of the OECD and International Transport Forum, Paris

Committee on Climate Change (2008) Building a low-carbon economy – the UK's contribution to tackling climate change. HMSO, Norwich

De Lange R, Verbeek R, Passier G, Kattenwinkel H (2008) Mogelijkheden tot CO2 normering en brandstof differentiatie voor het vrachtverkeer. MON-RPT-033-DTS-2008-02646, TNO Industrie en Techniek, Delft

de Vries HJM, van Vuuren DP, den Elzen MGJ, Janssen MA (2001) The TIMER IMage Energy Regional (TIMER) model. National Institute for Public Health and the Environment (RIVM), Bilthoven, pp. 188

Dornburg V, Faaij A, Verweij P, Banse M, van Diepen K, van Keulen H, Langeveld H, Meeusen M, van de Ven G, Wester F, Alkemade R, ten Brink B, van den Born GJ, Van Oorschot MMP, Ros J, Smout F, Van Vuuren DP, van den Wijngaart R, Aiking H, Londo M, Mozzaffarian H, Smekens K, Lysen E, van Egmond S (2008) Biomass Assessment – Assessment of the global biomass potentials and their links to food, water, biodiversity, energy demand and economy: inventory and analysis of existing studies. PBL, Bilthoven

EEA (2009) Transport at a crossroads. TERM 2008: indicators tracking transport and environment in the European Union. EEA Report No. 1/2008, European Environment Agency, Copenhagen

European Commission (2009) TEN-T: a policy review. Towards a better integrated trans European transport network at the service of the common transport policy. Green Paper. COM(2009) 44. Commission of the European Communities, Brussels

Fargione J, Hill J, Tilman D, Polasky S, Hawthorne P (2008) Land clearing and the biofuel carbon debt. Science 319(5867):1235–1238

Hanschke CB, Uyterlinde MA, Kroon P, Jeeninga H, Londo HM (2009) Duurzame innovatie in het wegverkeer – Een evaluatie van vier transitiepaden voor het thema Duurzame Mobliteit. ECN, Petten

IEA (2008) Energy technology perspectives. Scenarios and strategies up to 2050. International Energy Agency, Paris

King J (2008) The King Review of low-carbon cars. Part II: recommendations for action. HMSO, London

Lensink SM, De Wilde HPJ (2007) Kostenefficiëntie van (technische) opties voor zuiniger vrachtverkeer. ECN-E-07-003, ECN, Petten

OECD (2008) OECD Environmental Outlook to 2030. OECD, Paris

PBL (2008) Lessons from global environmental assessments. Netherlands Environmental Assessment Agency (PBL), Bilthoven, 2008

Petersen MS, Enei R, Hansen CO, Larrea E, Obisco O, Sessa C, Timms PM, Ulied A (2009) Report on Transport Scenarios with a 20 and 40 Year Horizon. Final Report TRANSvisions. Tetraplan A/S, Copenhagen

Rothengatter W (2009) European transport in a competitive economy. Paper for Netherlands Environmental Assessment Agency Karlsruhe

Schippl J, Leisner I, Kaspersen P, Madsen AK (2008) The future of European long distance transport. European Technology Assessment Group, Karlsruhe

Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J, Tokgoz S, Hayes D, Yu T-H (2008) Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319(5867):1238–1240

Smeets EMW, Bouwman AF, Stehfest EE, van Vuuren DP, Posthuma A (2009) Contribution of N_2O to the greenhouse gas balance of first-generation biofuels. Glob Change Biol 15(1):1–23

van Ruijven B, Hari L, van Vuuren DP, de Vries B (2008) The potential role of hydrogen in India and Western Europe. Energy Policy 36(5):1649–1665

van Vuuren DP, van Ruijven BJ, Hoogwijk MM, Isaac M, de Vries HJM (2006) TIMER 2.0, Model description and application. In: Bouwman AF, Hartman MPM, Klein Goldewijk CGM (eds) Integrated modelling of global environmental change. An overview of IMAGE 2.4. Environmental Assessment Agency (MNP). Bilthoven, Netherlands

van Vuuren DP, van Vliet J, Stehfest E (2009) Future bio-energy potential under various natural constraints. Energy 37(11):4220–4230

van Vuuren DP, Bellevratb E, Kitousc A, Isaac M (2010) Bio-energy use and low stabilisation scenarios. Energy J 31:193–222

WBGU (2009). World in Transition – Future Bioenergy and Sustainable Land Use. Berlin, German Advisory Council on Global Change

Chapter 6
Japanese Efforts to Solve Environmental Problems with a Focus on the Transport Sector

Motoyuki Suzuki, Yoshitsugu Hayashi, and Hirokazu Kato

6.1 Preface

Since World War II, Japan has grown its economy by developing industries, aiming to be a fully developed country. During this period, we have experienced various environmental problems, industrial pollution, and regional environmental deterioration, and have solved these problems step by step. When we are asked how to deal with new global environmental issues, it is important for us to learn from our past experiences which may correspond to new phenomena, and to convey the lessons to succeeding generations.

The purpose of this chapter is to give an overview of Japanese environmental issues since the era of high economic growth and changes in countermeasures against those problems, and then to describe the development of problems specifically in the transport sector.

First, Fig. 6.1 shows the relation between development and environmental issues in Japan in the latter half of the twentieth century.

6.2 From the Start of Industrialization to High Economic Growth: Latter Half of Eighteenth Century to the 1960s

6.2.1 Early Industrialization

The Industrial Revolution started in the UK and spread throughout the world. In Japan, after the opening of the country, the new government of the Meiji Restoration encouraged introduction of Western European technologies to build up a new nation under the slogan of "Wealth and a Strong Military." Traditional

M. Suzuki (✉)
Central Environmental Council of Japan, University of Tokyo, Tokyo, Japan
e-mail: suzuki@ouj.ac.jp

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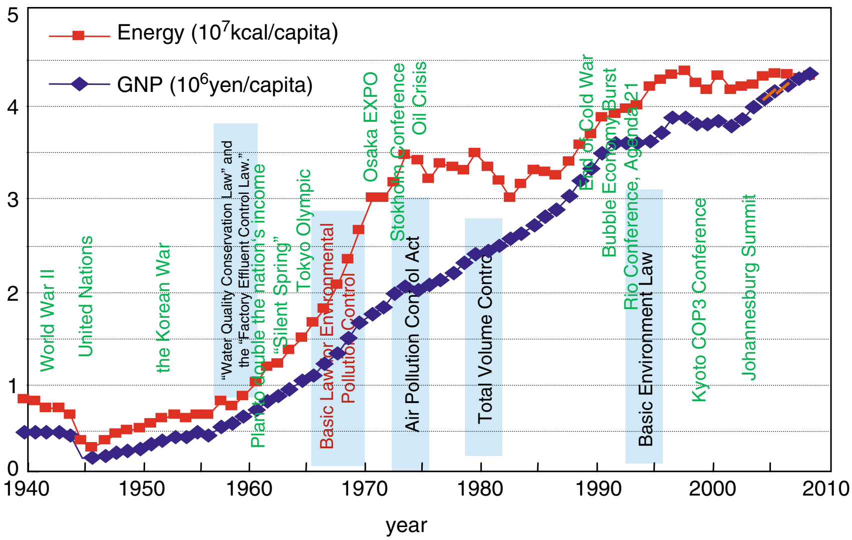

Fig. 6.1 Development and environmental issues in Japan after mid-twentieth century

industries from the Edo period, such as copper refining, iron-making and textile weaving, were modernized with the introduction of advanced technologies and developed gradually.

One of the major affairs symbolizing the era was the Ashio Copper Mine Poisoning case. Sulfur dioxide emitted from the process of refining copper ore killed the forest, and denuded the mountains, resulting in increased sediment runoff during heavy rainfall. Discharged water from the hydrometallurgy that included a lot of poisonous metal ions such as copper ions entered people's bodies directly through drinking water causing a horrible disaster and also deteriorated the ecosystem in the Watarase Basin and agriculture and fishing in the community.

Smoke from mines was a serious environmental problem in the early twentieth century as in the Besshi copper mine and in the Hitachi mine. Serious air pollution around plants was always a contentious issue between industry and communities until World War II.

6.2.2 High Economic Growth Period

After World War II, Japan rose from the ashes of defeat and achieved a remarkable economic recovery. Driven by the special procurement boom in the Korean War from 1950 to 1953, the real per capita GNP, which had fallen to less than half of the prewar level, recovered to the pre-war level in 1957. Further economic growth, dubbed an "Economic Miracle" was achieved by the income-doubling program under the Ikeda administration from 1960, and continued till 1975 recording real economic growth rates of more than 8% (Fig. 6.1). Behind this success were the government's policies such as tax cuts, lower interest rates, a favorable environment for corporate investments, and free trade promotion to gain international competitiveness. It is true that this rewarded industries such as the electric appliance industry for its technological advancement and brought comfort and convenienceto Japanese households, but it also accelerated a massive outflow of the working-age population from rural villages to cities, and increased industrial pollution.

The Edogawa Plant of Honshu Seishi (the current Oji Paper Company) discharged a massive amount of contaminated water to the Edogawa River seriously damaging the local fishery and brought about conflicts between the plant and the community in 1958. In the same year, the government enacted two water quality-related laws: the "Water Quality Conservation Law" and the "Factory Effluent Control Law."

6.3 From Development of Industrialization to High Economic Growth

6.3.1 Industrial Pollution and Efforts to Overcome

The Kitakyushu area known for Yahata Iron and Steel Works is an industrial belt with a cluster of cement, ceramic, and chemical enterprises. Around 1960, heavy emissions from factories, known as "seven-color smoke" were regarded as a sign of wealth. In 1963, Kitakyushu City was incorporated by merging five neighboring communities. After the merging, strengthened industrial capacity, particularly for the coal industry, brought about serious consequences: Air was polluted by soot and dust and untreated effluent from factories was discharged into Dokai Bay, which was known as a "dead sea" because even ship propellers would melt in it due to high acidity. Kitakyushu City actively worked on the pollution and started to show some improvements from the 1970s. It is now regarded as one of the few important model cities for environmental conservation.

Around 1960, the "Four Big Pollution Diseases" cast a dark cloud over Japanese society: Itai Itai Disease, Minamata Disease, Second Minamata Disease, and Yokkaichi Asthma.

Itai Itai disease was caused by cadmium poisoning due to the Kamioka mine in Hida City, Gifu Prefecture. Cadmium was densely accumulated in the rice harvested downstream in the city of Fuchu, Toyama Prefecture since it received irrigation water from the Jindugawa River that was heavily contaminated by effluent from the mine from refining sphalerite into zinc. In 1955, people who had eaten the contaminated rice started to show softening of the bones, and the disease was named for the severe pains ("itai" means "ouch") continually caused in the joints and spine.

Minamata disease is a neurological syndrome caused by mercury poisoning. It was caused by the release of organic mercury, particularly methyl mercury, in the industrial wastewater from Japan Nitrogen Fertilization Company's acetaldehyde production plant. This highly toxic chemical bio-accumulated in fish in Minamata Bay, which when eaten by the local people resulted in neurological damage. In 1956, it was reported as an "epidemic of an unknown disease of the central nervous system" by the local public health office. Similar pollution occurred along the Aganogawa River and the Kanose Plant of Showa Denko was identified as the polluter. The disease was called the "Second Minamata Disease."

In Yokkaichi, Mie Prefecture, companies including Showa Yokkaichi Sekiyu formed a large-scale petrochemical complex in the 1950s at the former naval fuel depot site in which enormous amounts of gasoline, petrochemical materials, kerosene, and light oil were consumed. In addition to those materials, heavy oil that deposited at the bottom of rectifying column was used as cheap fuel for the utilities and plants that included sulfur, trace heavy metal, and nitrogen oxides generated in the burning process. The surrounding community was heavily polluted by the emissions causing asthma, and a similar incident occurred in Kawasaki and other industrial areas.

To cope with those cases, each company identified as a polluter had to take concrete actions which were supported by technological advancement. However, at the initial stage, each process of investigation to determine the cause or technological countermeasures was not carried out smoothly. In almost all cases, companies that caused such problems began operation without predicting development of such serious problems, and later serious damages came to light. At the time when problems appeared, as those problems had never been before, there were various arguments among researchers to investigate the cause-and-effect relationship.

As for the Four Big Pollution Cases, the government (at that time, the Ministry of Health and Welfare) officially recognized the cause-and-effect relationship of Minamata disease as organic mercury, and the relationship of Itai Itai disease with cadmium in 1968, and following the inauguration of the Environmental Agency, a compensation system for victims of industrial pollution has been established. During that period, technologies to prevent emission of pollutants from the manufacturing process were also developed. For example, wet and dry flue gas desulfurization (FGD) and de-nitrification of exhaust was made available. Since power utilities had to treat a massive amount of flue gas to comply with the standard they set up huge treatment facilities, even overwhelming the size of the power plants.

Pollution problems, except for criminal cases, are generally regarded to be caused by unintended factors, which cause unexpected big damage to society. Accordingly, the most important thing for pollution problems is quick response to the matter and to decide the countermeasures at the earliest possible stage when the number of patients is as small as possible. Then, the social burden to compensate the patients for a long period thereafter would be lessened, and the right of ordinary citizens to live safely and pleasantly will be secured. After that, the lessons from those experiences must be established as human knowledge for future generations. This is necessary so that the same or similar mistakes will never be repeated. In this regard, we would like to strongly stress the necessity of transferring the knowledge and technologies to developing countries that are in the midst of industrialization.

The facts we experienced that unintended factors caused serious problems suggest the necessity to consider responses in advance for unexpected matters which might happen in the future, especially to consider a preventive framework for management of chemical substances.

6.3.2 History of Pollution Control Measures

In 1967, the Basic Law for Environmental Pollution Control was enacted based upon the experiences gained through tackling pollution problems. This law was most significant since it defined seven types of pollution problems to be solved by the central government: air pollution, water contamination, soil degradation, noise, vibration, soil subsidence, and odor. A prevention act for each problem was also formulated. Moreover, the Environmental Quality Standard was established as an administrative environmental goal accompanied by the Effluent Standard to achieve the goal by numerically regulating the pollutants and land use and by setting rules for pollution disputes.

In the early days of the Basic Law for Environmental Pollution Control, there was a so-called "harmony clause" that asserted pollution control should be harmonized with the need for a sound and healthy economy, since economic development should be given priority over other activities to gain national strength. However, unable to ignore growing criticism and public opinion in favor of requiring pollution prevention, the 64th Diet Session (Extraordinary Session) discussed pollution-related legislation intensively. This session was later called the "pollution session" since the harmony clause was removed and many other prevention laws were revised and improved.

In 1971, the Environment Agency was established to deal with environmental issues based on two basic acts, the Basic Law for Environmental Pollution Control and the Nature Conservation Act (1972).

Intensive actions were taken regarding effluents and emissions from industrial facilities in the 1970s by coordinating these prevention measures.

As is shown in Fig. 6.2, the percentage of water areas not meeting environmental standards for toxic substances dramatically decreased. This trend is also visible in air pollution, and the remarkable progress in de-sulfurization and de-nitrification mentioned above were also achieved in the 1970s.

This level of success was made possible through intensive application of water treatment facilities for industrial effluent and air-quality control equipment for air pollution. Private investment for pollution prevention increased from 300 billion yen in 1971 to more than 1 trillion yen in 1975 accounting for 20% of all private capital investment.[1]

[1]Annual Report on the Environment (1976) Fig. 2–4.

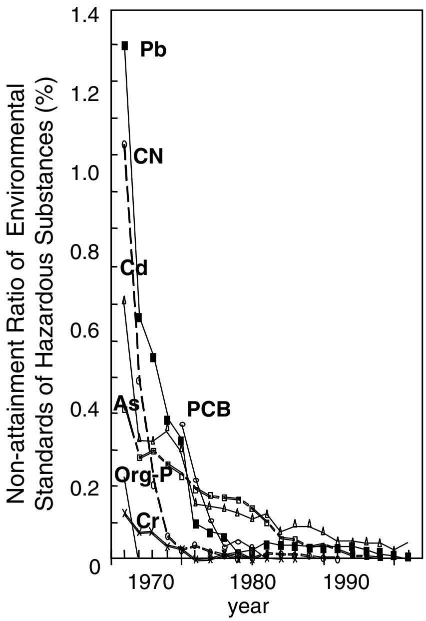

Fig. 6.2 Improved environment concerning hazardous substance in water after Enforcement of Clean Water Act (1970–1992)

At the early stage, industry reacted negatively to the requirement to invest in pollution-prevention equipment out of fear of economic disincentive, but in fact it contributed significantly to the development of industry since a clear definition of the national environmental policy promoted invention of innovative technologies.

6.3.3 United Nations Conference on the Human Environment (Stockholm Conference)

In 1972, the United Nations Conference on the Human Environment was held in Stockholm, the first such conference on a global scale. The UN Economic and Social Council decided to hold this conference in 1970 since pollution problems were gaining public attention worldwide, triggered by the warning of the book, Silent Spring. (Carson 1962) Troubled with Baltic marine pollution, Sweden hosted the conference from the 5th to 16th of June in which the Declaration of the United Nations Conference on the Human Environment[2] and the United Nations Environment Program was initiated.

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[2] Declaration on the Human Environment: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1503&l=en.

The Club of Rome can take credit for supporting the UNCHE by publishing Limits to Growth (Meadows et al. 1972) that shocked the world using mathematical models to warn of imminent depletion of nonrenewable resources.

6.4 Growing Urbanization and Deepening Regional Environmental Problems: From 1970 to the 1990s

6.4.1 Total Volume Control

It was true that toxic substances had been well managed by controlling specific points of pollution, but when it came to environmental standards for the living environment such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD), which are indicators of water quality for organic contaminants, the record of achievement had not been so significant.

Water areas were also loaded with effluents coming from densely populated areas, including industrial belts. The most serious water contamination was seen in "closed water environments" since there was no circulation of water driven by intrusion of outer sea water.

Since total volume of incoming contaminants determined water quality, controlling concentrations of incoming contaminated water at each point was not adequate. It was necessary to take measures in the form of total volume control.

In 1973, the Act on Temporary Measures Concerning Water Contamination came into force and the goal set for Seto Inland Sea contamination was to halve the total COD volume from industrial effluents from the 1972 level. Late in 1978, the temporary act was upgraded to special law status and this led to a compilation of the 5-year plan starting in 1979. Revision of the Water Quality Pollution Control Act in 1976 also contributed to the 5-year plan. While the temporary act only covered the Seto Inland Sea, the special act also covered Tokyo and Ise Bay regarding total COD reduction volume. But as there was no visible improvement in the environment, nitrogen, and phosphorus as well as COD were covered for the total volume control in the fourth (1999) and fifth plan (2004).

Air was also seriously contaminated by sulfur dioxide in the heavily industrialized areas, exceeding the tolerable level of the environment control standard. In 1972, an ordinance was issued in Mie that included total volume control. At the national level, total volume control was also introduced with the revision of the Air Pollution Control Act in 1974.

6.4.2 Worsening Automobile Emissions and Countermeasures

From 1955 to 1975, approximately 8 million people moved to large cities, which resulted in various environmental problems due to increased human activity.

Around 1970, children could not go out on days when photochemical smog such as photochemical oxidants broke out like mist, since their eyes and tracheas might be damaged by such irritants. In the Kanto area, nitrogen oxides (NOx) and hydrocarbons (HCs) generated in urban areas and industrial belts proved to be the cause of irritation of eyes and tracheas. The smog went up the Kanto Plain generating oxidants through photochemical reaction. This resulted in emission control on NOx. In 1978, an environmental control standard for nitrogen oxides was introduced, followed by the introduction of total volume control in 1981.

By that time, automotive exhaust gas was regarded as a major source of NOx. In Japan, air pollution in 1960s was mainly attributed to industrial emissions, which diverted public attention from automotive emissions and delayed legislative action. It was only in 1973, 5 years behind the Air Pollution Control Act of 1968, that the Automobile Exhaust Gas Regulations were enacted.

In the United States, air pollution was considered to be a social evil much earlier than in Japan. The Clean Air Act Extension of 1970 was proposed by Senator Edmund Muskie (Muskie Act) that forced reduction of CO, HC, and NOx emissions by 90% for vehicles produced in 1975 and 1976, compared with those produced in 1970 and 1971. Moreover, it was proposed in 1972 that vehicles produced in 1976 and after had to reduce NOx emissions to 0.4 g/mile or less.

Even though it seemed impossible to meet these standards, Honda developed vehicles that complied with the standards by the use of CVCC technology. But the American Big Three protested the enactment and as a result the Muskie Act was scrapped in 1974. However, due to engineering improvements, the standards proposed by the Muskie Act were finally met in the USA in 1995.

In Japan, on the contrary, engineering capabilities were upgraded to meet the regulations set by the Japanese version of Muskie Act released in 1978. This has paved a way for Japan to gain a dominant market share in the automobile industry. Automobiles in Japan in 1980 were 37.33 million, a significant increase from 18.92 million in 1971, but in the same period CO concentrations were down from 6.0 parts per million (ppm) to 3.0 ppm on average at roadside air pollution monitoring stations.

In 1978, however, the environmental standard for NOx was eased from 0.02 ppm to 0.06 ppm. This implied a retreat of environmental regulations in the late 1970s and 1980s, and as a result, there has been no significant improvement in NOx emissions after 1980, which was mainly attributed to slow action on diesel vehicles that constituted the majority of trucks (Fig. 6.3).

Diesel engines are the most thermally efficient internal combustion engine, providing vehicles excellent fuel efficiency and saving oil. But this type of engine also generates noise, soot, and NOx because diffusive combustion takes place in the combustion chamber when the fuel is burned at a high compression ratio and at a high air–fuel ratio. Gasoline vehicles can control generation of soot and CO, as well as the air–fuel ratio, and treat NOx with three-way catalysts, but this is difficult for diesel vehicles.

Air pollution caused by vehicles became increasingly serious, particularly in the areas along trunk roads. For example, a provisional injunction (that later developed

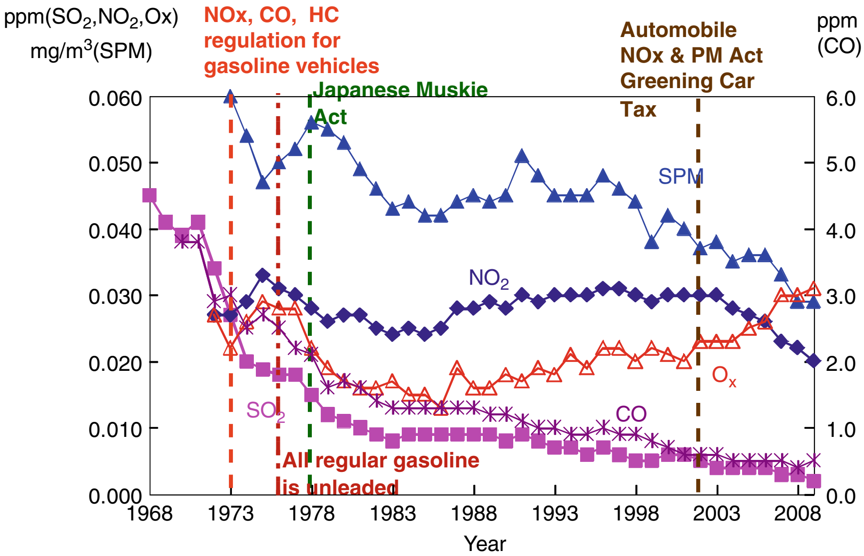

Fig. 6.3 Yearly changes of PPM concentration of air contamination in Nagoya (Average value of all the measuring points)

into a lawsuit) was filed seeking to suspend the construction of the Hanshin Expressway above the Route 43 in Amagasaki. In the 1980s, there was no specific measure taken to besides refurbishing structures such as barriers along the roadside.

In the latter half of the 1990s, there were some movements toward legal settlements, such as a verdict on the Route 43 Nishi–Yodogawa River case and its settlement, and a verdict on the Kawasaki pollution case and its settlement, where in both cases the government defeat was finalized.

In 1992, the Automobile NOx Control Law was enacted covering metropolitan Tokyo and the Kansai region. This law was designed to promote low-emission vehicles. It did not allow vehicles underperforming the latest NOx standard to pass the safety inspection.[3] Moreover, particulate matter (PM) was also included in 2001, since PM had been suspected of being a health hazard, and coverage was extended to Metropolitan Nagoya under the Automobile NOx and PM Control Law.

Tokyo and three other prefectures in Metropolitan Tokyo have been regulating the concentrations of suspended PM emitted by diesel commercial vehicles running on their roads since 2003 to comply with the latest version of the National Long Term Regulation. In other words, vehicles that do not comply with the latest regulations cannot enter the major part of Metropolitan Tokyo. The decline in diesel vehicles in Japan since 2003 indicated in Fig. 6.4 could be explained by this regulation.

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[3] Automobile Inspection and Registration Association: Number of Automobiles in Japan.

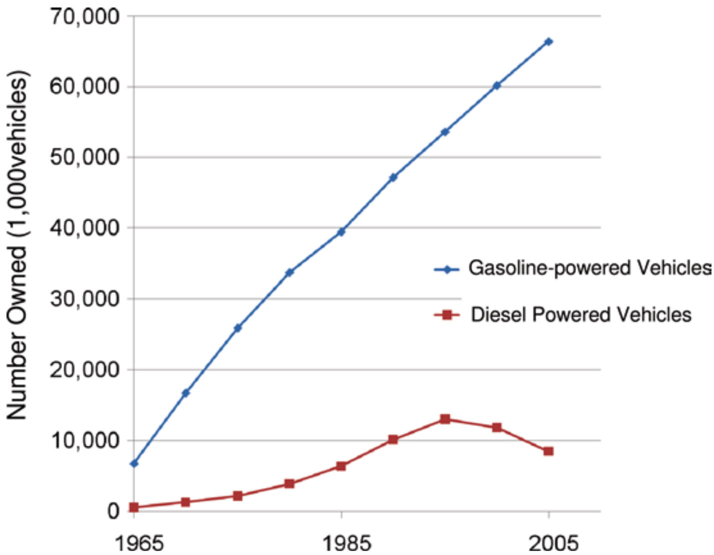

Fig. 6.4 Changes of ownership of gasoline-powered and diesel powered vehicles in Japan

At the same time, technologies to reduce soot and NOx have been under development for future commercialization.

6.5 Awareness of Global Environmental Problems and Actions

6.5.1 International Actions Against Climate Change

In the 1990s, as the economy became more and more borderless, people became increasingly aware of the global environmental problems that had been discussed by the Club of Rome and at the Stockholm Conference.

Global climate change simulations were made possible by the invention of the supercomputer due to the remarkable progress of computer technology at the end of the twentieth century. It was Dr. James Hansen, of NASA, who warned of the danger of global warming at the US Senate in 1988.

In the same year, the Intergovernmental Panel on Climate Change (IPCC) was established to study global climate change by concentrating the wisdom of international scientists. It releases an assessment report every 6 years.

The latest report was released in 2007 as the fourth assessment report or AR4[4] that states that warming of the climate system is unequivocal and that most of the observed increase in global temperatures is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

[4]Report of the 1st Working Group of AR4: http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

6.5.2 The United Nations Conference on Earth and Development (Earth Summit)

Twenty years later after the UNCHE, the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in 1992, in which the Rio Declaration[5] consisting of a preamble and 27 principles was adopted. The Rio Declaration states basic principles, such as the equal right to development for the present and future generations in the third principle, and protection of the ecosystem in the seventh principle covering common but different responsibilities. A significant achievement of the Rio Conference was the adoption of Agenda 21 to implement the Rio Declaration along with the signing of the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) and adoption of the Statement of Forest Principles. There are 40 chapters in the Agenda 21 and each chapter has 6–136 paragraphs. To ensure the implementation of Agenda 21,[6] the Commission on Sustainable Development (CSD) was created.

The concept of sustainable development was defined in a report issued in 1987 by the World Commission on Environment and Development (WCED) titled Our Common Future.[7] The definition, "meeting the needs of the present generations without compromising the ability of future generations to meet their needs" was spread widely and this spirit was also taken up by the UNCED. The term "sustainable development" was first used in the World Conservation Strategy in 1980[8] which was co-developed by the IUCN, UNEP, and WWF and was defined as well-balanced conservation relationship between development, living organism, and ecosystem focusing the importance of sustainable use of biological resources.

6.5.3 Basic Environment Law and Actions for Global Problems by Setting the Ministry of Environment

In Japan, the Basic Environment Law passed the Diet and immediately came into force after the UNCED in 1993. This law covers the global environment comprehensively, substituting for the Basic Law for Environmental Pollution Control and incorporating some parts from the Nature Conservation Law.

The law established principles of the environmental policy. These are as follows:

1. The blessings of the environment should be enjoyed by the present generation and passed on to the future generation.

[5] http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm.

[6] http://www.un.org/esa/dsd/agenda21/.

[7] http://worldinbalance.net/intagreements/1987-brundtland.php.

[8] http://data.iucn.org/dbtw-wpd/edocs/WCS-004.pdf.

2. A sustainable society should be created in which environmental loads by human activities are minimized.
3. Japan should contribute actively to global environmental conservation through international cooperation.

It not only defines the responsibility of each stakeholder, such as the central government, local governments, businesses and citizens, but also policies concerning environmental conservation such as the Basic Environmental Plan, Environmental Standard, Environmental Pollution Control Program, and Economic Measures. The Basic Environmental Plan is formulated every 6 years based on the Basic Environment Law. The third plan has been under development since 2006.

Then, the government newly established the Environmental Ministry by transferring the Waste Section in the Health and Welfare[9] Ministry to the Environmental Agency due to the reorganization of central ministries. In the process, five councils were incorporated into one as the "Central Environmental Council."

The "Strategy for an Environmental Nation in the 21st Century" decided at the Cabinet Meeting in 2007 stipulates a strategy for the immediate future to be followed and a basic strategy for realizing a "sustainable society" as the future model in three dimensions: "Low-carbon Society," "Sound Material-Cycle Society," and "Society in harmony with the nature." To comply with these directions, regarding the goal of a low-carbon society, for example, the government issued a proposal to reduce emissions of greenhouse effect gas generated by human activities on the globe to half that of 2005 by 2050 to meet the policy established by the IPCC. Furthermore, with regard to a low-carbon society, the Hatoyama Cabinet, started in 2009, publicly promised to reduce 1990 emissions by 25% by 2020.

Concerning the greenhouse effect gas, we are now endeavoring to achieve the targets set by the Kyoto Protocol, and the industrial sector, the residential sector, the business sector and the transport sector are each requested to develop technologies drastically and to build a systematic structure to incorporate such technologies into the social system.

In the residential sector, drastic approaches for spread of photovoltaic power generation, spread of ecological household electric appliances, and energy saving for houses or buildings themselves are requested. In this connection, our manner of living must also be thoroughly reviewed.

In the transport sector, in addition to adjusting emission standards for diesel automobiles, hybrid cars, which are expected to improve fuel efficiency dramatically, have been developed and production vehicles of this type have been introduced to the market since about 2003. The registered number of the hybrid cars exceeded 500,000 in 2008, and with the effect of the tax cut for fuel efficient cars, which was enacted in 2009, details of which will be described later, the registered number is expected to exceed one million in 2011. The market for electric cars can be also expected to dramatically develop with the technology breakthroughs in

[9] Annual Report on Health and Welfare (1961, 1976).

small-sized large-capacity batteries. Since the technological system needed for electric cars is quite different from that for traditional gasoline engine driven cars, the social impact caused by the spread of electric cars will be significant. Details of the transport sector will be described in the next chapter.

Concerning the movement toward a Sound Material-Cycle Society, waste problems, which have been worsening with urbanization and development of industry will suggest some hints for future directions.

Technologies to create value from waste will be demanded, and the building up of systems for recycling resources, such as for recovering rare metals contained in electronics and other valuable resource, will be needed. Ultimately, with regard to recycling of resources, we must go forward toward a zero-emission society, in which the concept of "wastes" will not exist, by controlling the entire cycle of resource use, from the upstream site, that is, extraction of natural resources, through production and to consumption.

6.6 Transport Activities and Climate Change

6.6.1 Effort to Reduce Greenhouse Effect Substance in the Japanese

Transport sector carbon dioxide emissions in the transport sector in Japan have been about 20% of the total. Figure 6.5 shows the changes in the index of carbon dioxide emissions in Japan by sector by converting the figure of 1990–100. The transport sector shows a higher increase in 1990s than other sectors, but in the 2000s the index of the sector turns downward. The turn is mainly caused by reduction of emissions in privately owned cars, almost 90% of emissions of passenger transport, which is more than half of the transport sector.

Carbon dioxide emission has been increasing with the development of motorization, because privately owned automobiles emit more carbon dioxide per passenger trip than public transport, and because automobiles are apt to encourage frequent travel or transport. Carbon dioxide emissions generated by passenger trips in 2007 increased by 34.8% compared to 1990, but the figure turned downward from 2002, for two reasons: (1) the number of privately owned cars and kilometers traveled per vehicle, both of which had been increasing year by year, decreased in 2003, and (2) average fuel economy of new Japanese cars increased by 25% in the 10 years since 1995 (Fig. 6.6). On the contrary, carbon dioxide emission generated by freight transport in 2007 decreased by 6.7% compared to that of 1990. Like passenger trips, the emission amount slightly increased in the 1990s, and decreased in the 2000s, but the reduction ratio is smaller than for passenger transport.

Table 6.1 shows a variety of measures to reduce environmental load, such as carbon dioxide, generated by transport activities. (Meadows et al. 1972) Each line shows a measure, and each column shows the effect of the measure in determining the amount of emission in the environmental load.

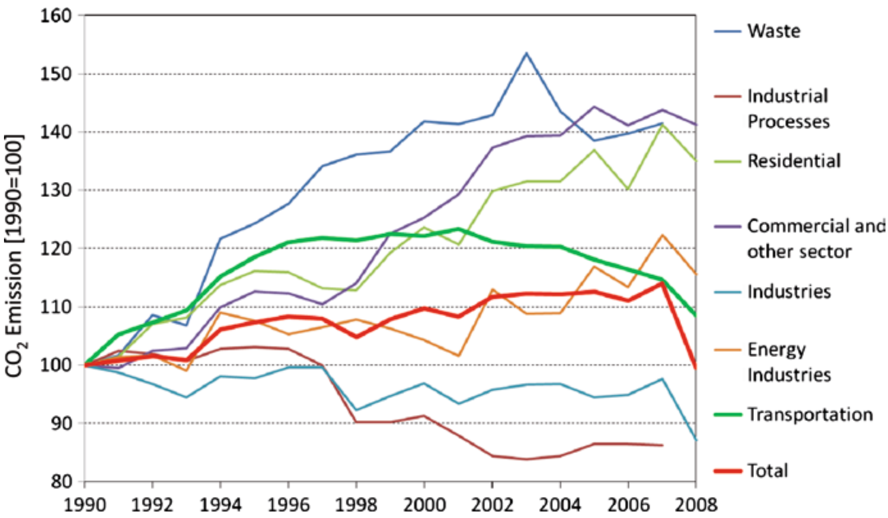

Fig. 6.5 Changes of carbon dioxide emissions in Japan (1990–2008)

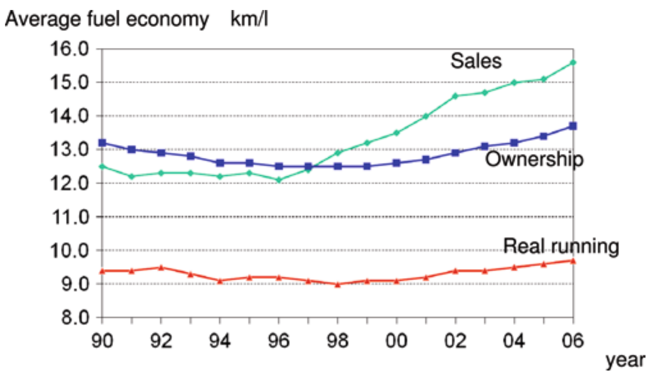

Fig. 6.6 Changes of average fuel economy of passenger cars in Japan (Data by Ministry of Land, Infrastructure, Transport and Tourism)

Japan has basically reduced environmentally hazardous substances by technological innovation of vehicles and of fuel and by its broad application in complying with the Japanese version of the Muskie Law in 1970. This will be similarly applied to reduction of carbon dioxide emissions. I will describe it in the following section.

On the contrary, government policies directly affecting transport activities, such as to reduce total transport demand, to reduce usage of automobiles, to improve transport measures substituting for automobiles, or to improve the network of roads, were adopted in 2005 to comply with the Kyoto Protocol after its ratification and put into effect. Those policies have been revised several times. With regard to the target accomplishment plans for the Kyoto Protocol, a variety of plans have

Table 6.1 Classification of policy instruments for transport

	Strategies				
	Reduce need	Reduce car use	Improve alternative modes	Improve road network	Improve vehicles and fuels
Technology: Infrastructure vehicle/fuel	• Transit-oriented development (TOD) • Housing near jobs	• Pedestrian and bicycle paths • Community roads • Park and ride	• Rail and bus infrastructure • Light rail transit (LRT) • Bus rapid transit (BRT) • Bicycle	• New roads • New parking facilities	• Low emission vehicles • Alternative fuels
Regulation: Management control service	• Land use regulations • Suburbanization control	• Access permits • Parking restriction • Traffic calming	• Tram/bus priority • Public transport service improvements	• Traffic management • Urban traffic control	• Emission regulations • Restriction of low-quality fuel • Vehicle inspection system
Information: Advice awareness communication	• Teleworking • Internet shopping	• Awareness campaign • Car sharing	• Real time public transport information • Rental cycle	• Driver route guidance • Safety guidance • Traffic information provision	• Eco-consciousness
Economy: Pricing taxation	• Land taxes	• Road pricing • Parking charge • Fuel taxes • Vehicle taxes	• Fare policy • IC card	• Road pricing • Parking charges	• Fuel taxes • Green taxes

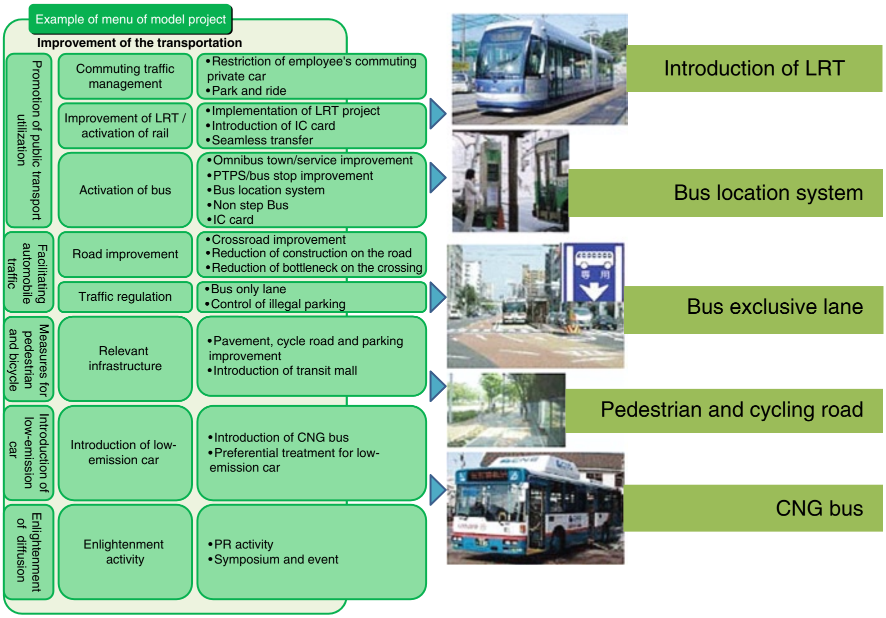

Fig. 6.7 Detailed measures of “EST model project” in Japan

been proposed, but few have been implemented. Although the government has been carrying out Environmentally Sustainable Transport (EST) model projects in 27 areas since 2005 to promote various policies, as illustrated in Fig. 6.7, the effects of the projects so far are limited.

6.6.2 *Effects of Policy to Encourage Spread of Fuel-Efficient Cars*

Following the oil shock, improving the fuel efficiency of automobiles was undertaken at once, as Japan depends on imports for 99.9% of her oil supply. But, in the period of economic upturn, the so-called bubble-economy, from the late 1980s to the early 1990s, the average fuel efficiency worsened, because advances in fuel efficiency showed slow progress and consumers preferred larger cars. This seemed to be the result of an automobile- and consumption-tax rate reduction for ordinary-sized cars to the same tax rate as for small cars. Since the collapse of the bubble-economy, users again began to prefer fuel economy. The preference has been encouraged by affirmative taxation for low-emission and fuel-efficient automobiles, which was called the “greening of the automobile tax system,” and was introduced in 2001.

In Japan, fuel efficiency targets for automobiles have been regulated by the Energy Saving Act, the formal name of which is “Act on Temporary Measures for Promotion of Rational Uses of Energy and Recycled Resources in Business Activities." In 1979, when the law was passed, the intention in deciding the targets was to average the existing figures of the products. But when the law was revised in 1999, the idea of the leading runner approach, that is, to aim for the best products currently commercialized was introduced. Specifically, the target to improve fuel efficiency by 22.8% in average for all types of vehicles compared to the 1995 value was decided. As a result of the target setting, fuel efficiency of new models, which had been rather behind until that time, began to be rapidly improved. To accelerate the trend, the greening of the automobile tax system, which is favorable for fuel-efficient and low-emission models by reducing tax rates of the automobile acquisition tax and automobile tax (for owning cars), was implemented.

Taxes related to automobiles in Japan are imposed at each step – acquisition, ownership, and usage (to purchase fuel) – and had been treated as a specific tax for maintenance or management of roads or as a part of revenue for local governments, but those taxes have been incorporated into the general budget since 2009. Fuel tax was originally intended to be an incentive to reduce consumption of fuel, and taxes for acquisition or owning of automobiles were not related to fuel efficiency, but the tax rates are determined in proportion to displacement of engine, weight, and selling price.

The green taxation plan maintains the conventional framework of determining tax rates; however, while it reduces the tax amount for automobiles which realize reduction of emission of polluting substances remarkably lower than the emission standards, or automobiles which realize the new standard of fuel efficiency for 2010, it increases the tax amount for older automobiles, which are thought to have more environmental load. Since the green taxation plan was introduced, 17 models out of the top 20 models sold in 2001 were eligible for tax reduction. Contrary to prior predictions that the tax revenue reduction would be offset by a revenue increase, actually, the tax revenue of the year was reduced remarkably, and consequently, the standards for reducing the tax amount are to be strengthened from next year. From the viewpoint of lessening environmental load, the result was evaluated as successful because emission of polluting substances was reduced much more than expected.

Furthermore, the government has been encouraging the spread of fuel-efficient cars, mainly focusing on hybrid cars by reducing tax and providing a subsidy for fuel-efficient cars for 1 year from 2009, but the period has been extended for a half year.

Thus, the green taxation plan for automobiles is recognized as an incentive for both manufacturers and users to choose low-environmental load cars.

6.6.3 To Realize a Low-Carbon Transport System by Expanding Railroads

Japan depends on railroad transport for passengers within big cities or between areas more highly than other foreign countries. These are the results of complex of policies implemented far before the environmental issues have been raised, and are evaluated as the helper at present to restrain environmental load produced by automobiles.

Most of the major cities in Japan constructed railroad transport networks for passengers and freight since the industrial revolution, and most of them were owned and managed by private sectors. Since the twentieth century, cities have adopted policies to centralize the operation of public transport system in their cities by themselves. Underground rail-road systems, started afterward, have been constructed by cities in principle. The centralization policy of public transport system in urban area contributes to unification of network system and securing convenience.

As the special feature of Japanese railroad system, which may not be seen in other countries, electric railways owned and operated by private companies expand to the suburbs of major cities. For example, in the area of Nagoya with a population of about ten million, the passenger transportation volume in number of passengers on the privately owned railways is quite high at about 45% of the total, compared with 35% for the municipally owned subway systems, and 20% for JR Tokai (formerly the National Railways until 1987). The same tendency is seen in the Tokyo Metropolitan area (40% of passenger trips on privately owned railways) and in the Osaka area (50%). Although the total length of subways in Tokyo is about 350 km, almost same length as in Seoul or Shanghai, in addition to the subways, Tokyo has other railway systems connecting central Tokyo to suburban cities with total length of more than 2,000 km, which share the responsibility for passenger transport with the municipal subways. This is quite unique, and is not seen in other major cities. In addition, the railways of suburban railway companies' and those of the Tokyo Metropolitan subways are connected to each other, which enables the railway systems to be cooperatively operated. The passengers show little resistance to changing the trains at the terminal stations. All these factors contribute to restricting the inflow of automobiles from suburban areas to the central city.

There are two main reasons that the private railway companies can continue in business far after the spread of motorization: one is on the demand side, and the other is the railway companies' strategies. In addition to massive demand for transport due to high-density housing in suburban areas accompanied by inflow of population to metropolitan areas, the difficulty of using automobiles for commuting due to insufficient road systems and parking lots in the inner city is responsible for a high share of railway demand, which enables high capacity utilization by railways and supports the profitability of the railway business.

Furthermore, railway companies have bought a great amount of land along the route of planned railroad lines and developed real-estate businesses or distribution businesses. Thus, a business model to internalize development gains realized along the new railway lines by the railway operator enables railway companies to continue their businesses independently. The simultaneous progress of construction of new lines and development of housing complexes along the lines can prevent commuters from becoming dependent on automobiles.

However, with regard to passenger transport among areas, mass transit on the Shinkansen has been achieving quite high environmental performance.

The Shinkansen has been constructed continually since its inauguration in 1964 between Tokyo and Osaka, and the present length of its lines as of March 2011 is estimated at 2,387 km. The trains run 300 km/h at the highest and are supported by variety of systems to attain the highest safety. Traveling by Shinkansen within the range of longer than 1 h and shorter than 3 h has an advantage to traveling by airplane or automobile. For example, the share of the Shinkansen for the 2.5 h between Tokyo and Osaka is almost 90%.

The carbon dioxide emission of Shinkansen travel per person per kilometer is about one-tenth that of travel by privately owned passenger car or of airplane. As the Shinkansen requires massive construction of infrastructure and manufacturing of trains, we must also consider carbon dioxide emissions generated for the preparation. According to our research, the Shinkansen is clearly preferable to airplanes when daily ridership exceeds 4,000 people.

However, recent progress of motorization and cost increase for preparing infrastructure have been lessening the profitability of railway systems, and as a result, construction of new lines for urban railways and the Shinkansen is becoming harder. In Japan, the railway businesses are self-supporting in principle, and subsidies for construction or operation of railway companies using public funds are quite limited.

While there is no system to subsidize the public benefit of reducing environmental load, if the high costs of maintaining railway systems are to be transferred to passengers through their fares, the number of passengers will decrease. As a result, emissions of environmental load per passenger will be increased, and consequently, effects of reducing environmental load will be lessened. Thus, from the viewpoint of reducing carbon dioxide, we would like to stress the necessity of expanding public subsidies for construction of new lines and operation costs, according to the circumstances.

With regard to freight transport, the share of railway transport is quite low at present. Drastic measures to stimulate changeover to railway transport especially among urban areas will reduce the environmental burden.

6.6.3.1 Addendum: To Aim for Sustainability Under Limited Conditions

In this chapter, we described the Japanese experience of various types of environmental problems, which we encountered during the process of economic growth and our solutions to those problems. Also, regarding environmental problems in the transport sector, we explained that various measures, not only regulatory, but also economic policies that stimulate automobile manufacturers to reduce environmental burden, are implemented to achieve goals. Furthermore, the long history of construction of passenger transport systems, mainly based on railroad systems prior to motorization, now helps us to reduce carbon dioxide. These experiments suggest some direction for developing countries.

Let me add one point. These measures have been responses after problems arose or results which happened to be adapted to circumstances what we did not assume beforehand. Until now, resolving environmental problems that emerge suddenly has been a challenge, and we have had to carry out countermeasures expediently. However, global environmental problems are difficult to deal with after the problems become obvious. Adjusting expanding human activities to the Earth's limited natural resources, and harmonizing them to realize a sustainable society, are quite new challenges for mankind. To face these new challenges, we may need a new way of thinking, called "backcasting," to visualize the final features as the landing site and to design routes to approach the site from now on.

Efforts to lessen carbon dioxide emissions in the transport system in Japan have mainly depended on improvements in automobile technology. However, in the future, the "backcasting" way of thinking is required in the transport sector, such as a spatial structure that does not produce unnecessary transport, or promotion of lifestyles or production forms to avoid unnecessary transport, or shifting to low-carbon modes of transport.

References

Carson R (1962) Silent spring. Houghton Mifflin, Boston

Meadows DH, Meadows DL, Randers J, Behrens III WW (1972) Limits to growth. Club of Rome, Universe Books, New York

Part IV
Developing and Transition Countries: Changing from Followers to Leaders

Chapter 7
Urban Transport and the Environment in Developing Countries: Complexities and Simplifications

Ali Huzayyin

7.1 Introduction

Impacts of transport on the environment in major cities of developing countries include not only those related to air quality, greenhouse gases, and noise levels as usually reported, but also other important ones such as pedestrian/vehicle conflict and visual intrusion disturbing city life, e.g., travel safety, traffic delay and city image. Many policies and relevant countermeasures are applied whether locally or through international aid and can be classified under groups according to the attributes they relate to, for example, mode related, fuel and power related, traffic supply and demand related, Non-Motorized Transport (NMT) related, and sustainable transport related. These have brought about results that are in some cases remarkable and in some others not so successful. These are discussed from the experience of selected main cities in developing countries. Knowing the barriers that prevent or impede policies and countermeasures is a key issue. Cities have various constraints, mainly institutional and behavioral, and also those that result from the "immediate-term-solution-vision" of policy makers, city managers and the residents alike. Therefore, in spite of the extent of success of mitigation policies and countermeasures, concerned authorities and researchers should try to answer questions of relevance. Why have some policies proved to be unsuccessful? And, why have the successful ones proved to be so? Are the successful policies sustainable? Or do they soon lose their effectiveness and not last as envisaged?

The concept of a novel "goal" of policies and countermeasures of mitigation of urban transport impacts on the environment that are "applicable," "implementable," "successful" and "sustainable" is introduced. Stepped questions that guide the

A. Huzayyin (✉)
Civil Engineering Department,
Faculty of Engineering, Cairo University, Cairo, Egypt
e-mail: ali_huzayyin@yahoo.com

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process of achieving this goal are explained, and examples of recent application of the same philosophy as the above-mentioned steps are outlined.

Designing the policies and estimation of the expected impact of the related countermeasures is not a simple task. Not only are many policies and countermeasures formulated and tested, but also many actors and variables are engaged in policy decisions, policy implementation and monitoring, control and updating of countermeasures. For better understanding, the actors are categorized under seven groups and the variables under five groups. It is also obvious that many effects on the urban environment that result from mobile sources and transportation systems do exist and threaten the livelihood of the cities.

The analyst and policy designer is therefore faced with the obligation of arriving at "Policies" that are to be the responsibility of many "Actors," and that result from many "Variables" can exert many "Effects." This is what we call in the current paper the "PAVE" four-dimension problem. For testing the impact of policies and related countermeasures, the analyst needs to model the effects of suggested mitigation policies (and countermeasures) that result from dealing with many variables that shall be implemented, monitored, and controlled by many actors in order to exert many possible sound effects on the environment. The PAVE problem is explained, and a process for simplification of the application in cities of the developing countries is outlined, indicating among others, the need to examine policy objectives to ensure they are attainable. The paper ends with a brief summary of the findings and recommendations related to enhancing international cooperation between developing countries bilaterally, and with the industrialized world in a multilateral fashion, including not only cites, but also researchers and research institutions.

7.2 Overview on Environmental Impacts of Urban Transport

The impact of transport on the environment in congested cities of developing countries is reported in many previous works, (Huzayyin 2001; Huzayyin and Ashour 2004). It is estimated that in developing countries, 0.5–1.0 million people die prematurely because of exposure to urban air pollution, in addition to millions of cases of respiratory illness in large cities, (Kojima and Lovei 2000). The same reference mentioned an economic damage of air pollution between \$1 and \$4 billions annually in cities of Asia. This represents 10% of urban income in Bangkok, Kuala Lumpur and Jakarta.

Because of vehicle age and bad maintenance, air pollution and greenhouse gases are serious problems in some cities. In Pune and Bangalore, India, a random check of 1,092 new vehicles indicated that 44 and 42% of the vehicles failed the emission test, respectively (Khan and Udayakumar 2000). A sample of 100 taxi cabs in Cairo showed that the average age of the vehicles was as high as 16 years (Huzayyin and Osman 2000). In Sao Paulo, the contribution of all transport modes in the CO content is 98%. Contribution of the private car alone compared to all transport modes in the city is 86% (Madar et al. 2000). In Delhi, although it is reported that CO levels are acceptable, those of SO_2 are more than the WHO standards in other cities. SPM (Suspended Particulate Matter) is 9–10 times more than WHO limits, and ozone exceeds the 8- and 1-h limits in several cities particularly in winter, (Badami 2000). Motorized two wheelers (M2Ws) contribute much to air pollution compared to buses, as they constitute 67% of veh.km and only 16% of pass.km, while the corresponding shares of buses are 10 and 70%, respectively. The share of M2Ws in air pollution reaches 30% of CO, 51% of HC and 30% of SPM produced by all modes. Akinyemi and Medani (2000), reported that for 10% increase in two-stroke motor cycles in congested areas, there is an increase of 20–55% of CO, 32–38% of SPM and 73–160% of HC, which is quite considerable. Compared to four-stroke motor cycles, these percentages are only 11–47%, 2–10% and 15–60% for CO, SPM and HC, respectively.

In Santiago de Chile (O'Ryan et al. 2001), mobile sources are responsible for 92% of CO emission, 71% of (NO_X) and 46% of volatile organic compounds (VOC) and directly responsible for only 7% of SPM, and hence, over 80% of emissions are caused by transport. In Metro Manila, levels of air pollution come from mobile sources with estimates of 116,000 tons of PM10, 39,000 tons of SO_X, 140 tons of lead, as well as undetermined amounts of CO, HC, NO_X and VOC, (Asian Development 1998). In 1999, in Jakarta, mobile sources contribute to 8% of the total particulate matter, 80% of total SO_X, 36% of total NO_X, 80% of total HC and 87% of total CO (Aboeprajitno 2001).

Furthermore, pedestrian/vehicle conflict is a serious environmental impact of transport in many cities of developing countries. Irrespective of the finding that between 30 and 40%, on average, of daily person trips by all modes in major cities of developing countries are NMT, mainly walk, and is even more in middle size cities, this effect is unfortunately often ignored. Main attention is usually given to greenhouse gas emissions for their global effects, as well as to local air pollution. The above mentioned considerable share of pedestrian movement in daily trips, and the narrow streets contribute to this problem, which cause high accident rates, and accident potential in addition to vehicular traffic delay. The latter leads to more energy consumption and increased emissions as well. As for noise levels, it is reported (Sarkar and Rohatgi 2000) that in Delhi 55% of noise is due to vehicular traffic, and that existing levels are as high as 80 dB(A), and that passenger car noise equivalents for bus and three wheelers (3W) is 7.08 for each of those modes, and two for trucks (Sundaram and Verma 2000). The boom of building many flyovers and elevated roads in many cities during the past 30 years to reduce traffic congestion lead to serious visual intrusion and adverse impact on city image (Huzayyin 2001, 2003), as the superstructures obstruct the view across city skies.

Perhaps it is the time to direct field observations and data gathering to serve the purposes of sound modeling, and monitoring of the impact and the results of application of mitigation policies and countermeasures, rather than to address proving a well-known situation (Huzayyin 2001). Research effort should be directed to more understanding of the complexity involved in formulating mitigation policies and countermeasures, and the need for simplification of appropriate application in the context of urban areas in developing countries.

7.3 Previous Policies, Complementary Requisites, Extent of Success and Constraints

The literature gives many examples of policies and countermeasures (PCs) that were tried or recommended for reducing the impact of urban transport on the environment in developing countries. Examples include, but not limited to, (Wangwongwatana and Warapetcharayut 2000; O'Ryan et al. 2001; Aboeprajitno 2001; Huzayyin 2001; de Melolvares 2002; Huzayyin and Ashour 2004 and GEF 2005). Huzayyin (2001, 2003) gives a classified list of many of those PCs, which is summarized hereinafter. *PCs related to transport modes*: include replacing the two stroke two wheelers by four stroke engines, banning old vehicles imports, fleet renewal programmes, engine tuning to meet emission standards, and introducing privately operated high quality buses connecting high income areas with metro to encourage modal shift from the private car. *PCs related to fuels and powers* concentrate on encouraging taxis to convert to CNG, and use of solar power for LR (Light Rail), conversion of two wheelers to electric battery engine. *Traffic related PCs* include those related to "supply management" and "demand management." The former includes, traffic management measures, bus priority and cargo inter-modal facilities, and the latter range from simple to sophisticated demand management, such as staggered working hours, measures to encourage increasing car occupancy and pricing. *PCs related to NMT* include widening sidewalks, ban sidewalk occupancy, provision of safe crossing, national campaigns to demonstrate NMT benefits, pilot projects for NMT tracks, upgrading bicycle maintenance, and introduction of micro-pedestrian zones in central areas. Finally, *sustainable transport related PCs* revolve around encouraging the integration of environmental, economic, and equity impact assessment into decision making, polluters must pay policies, and capacity building for local institutions' engineers to coordinate transport and land use.

Complementary requisites to support PCs of mitigation of transport impact on the environment are necessary for their success (Huzayyin 2001). These include, for example, establishing electronic *database* to help the city transport engineers to design appropriate policies, and the relevant countermeasures and policy makers to introduce appropriate regulations. In addition, *awareness* campaigns for policy makers, top management, and the public constitute an important need in many cities. Innovative environmental evaluation methods to demonstrate benefits of environmentally friendly transport systems in a quantifiable objective manner, is yet another challenge facing transport and environment researchers. Decisions on environmentally friendly transport systems, as metros and light rail transit, can be turned down merely on economic and financial grounds, ignoring the massive environmental benefits (in addition to social ones) that can, if quantified, outweigh the costs in the long run. This topic warrants further work, and is a persisting challenge for researchers.

Based on lessons from the experience of developing countries, the extent of success of application of mitigation PCs are discussed (Huzayyin and Ashour 2004). Success/failure varies according to the city, and the type of policy or measure.

For instance, in Jakarta, because of the economic crisis, the compulsory emission test is not possible on all vehicles. Institutional strengthening and facilities for implementing and enforcing the law are needed, (Aboeprajitno 2001). However, introduction of CNG taxies has been happening with continuous success in Jakarta and Cairo. For instance, in Greater Cairo, the converted cars, mostly taxis, to CNG increased from about 200 to 39,000 in just 10 years between 1996 and 2006, respectively, and the number of CNG fueling, stations in Egypt at large increased from 17 in 2000 to 87 in 2004; most of which are in Greater Cairo. The success is attributed to many elements the most important of which is the designed and implemented policies to encourage taxi drivers to shift as explained in detail in (Huzayyin and Osman 2000). Sao Paulo made considerable progress in controlling car pollutants with the consolidation of a National Automotive Vehicular Air Pollution Control Program since the early 1990s, leading to fleet emissions control for all production in 2002. However, due to a natural delay in implementing national regulations on environmental certification for this category of vehicles, only less than 20% of this fleet (post-1996) met limits similar to EURO I and EURO II, (de Melolvares 2002).

The Regional Environmental Commission of Santiago de Chili launched the Greater Santiago Air Pollution Prevention and Decontamination Plan in 1998 to meet air quality standards by 2011. After two years, half of the measures advanced according to schedule, because success depends on the relationship between the commission and government agencies that observe transport activities, and the support from businesses and voters (O'Ryan et al. 2001). Behavioral adaptation imposes extra costs, and adversely affects some interests and, hence, political and educational efforts are necessary. In 2008, in Egypt, although there were modern taxi cabs, in the market were some of 2007 models, the Environment Affairs Agency (EEAA) introduced a pilot policy to reduce old ones. The policy constitutes a financial scheme for the drivers of the old taxis to hand over the cabs toward an initial payment as part of a very soft loan, and to be handed brand new air conditioned replacement vehicles. The very old cabs (more than 30 years) are to be obliterated for industrial recycling through proper arrangement by EEAA. When those are replaced, the scheme then turns to those of more than 20 years, and so on. Assessment of this pilot led to improved policy incorporating banks, car manufacturers, and advertizing agencies. In 2009/2010, more than 14000 taxis (30% of old fleet) were replaced by 2010 models (Huzayyin and Salem 2010).

Some *constraints and barriers* exist and impede the success and sustainability of implementation of PCs (Huzayyin and Ashour 2004). First, *lack of political* "*will*" and "*determination*" among decision making bodies affects taking right decisions at the right time, and delays mobilization of resources, etc. Next, the "*immediate-term-solution-vision*" of residents and authorities constitutes a serious constraint facing sustainability of PCs. This implies dedication to immediate improvements (not only environmental) regardless of what can happen in, or what is reserved for, the future. *Lack of locally* "*generated* and *dedicated fund*" for environment improvement programmes is yet another constraint against sustainability and success of PCs. Depending on international aid is "unsustainable"; after termination of foreign aid and technical assistance, the related programmes come to a halt.

Institutional deficiency is another constraint demonstrated by the non-existence of a special agency for environmental affairs in some countries. Hence, its duties are done by the central or local government, sometimes employing non-specialized staff. In countries where environment agencies exist, sometimes they are not well staffed/equipped, and depend mainly on project bases international aid; neglecting improving own skills, raining technical capabilities and establishing dedicated funds. In addition, the *institutional interference* between different bodies involved, and the *overlap* between regional and national levels dealing with environmental matters add to the complexity, (Badami 2000). Furthermore, the *numerous actors* involved in formulation of different PCs is another barrier adding to the difficulty of coordination of activities required to avoid overlapping works and harmonizing environmental programmes. Furthermore, *lack of information* limits the capability of city authorities and technical departments to convince legislative councils to approve funding for environmental improvement PCs. This can result from insufficient technical capability and non-existence of fund for data collection, updating and processing. Finally, in some societies, *drives, and other road user behavior* coupled with *difficulties of enforcement of traffic regulation and environment PCs,* impose a serious constraint for PCs implementation and achieving acceptable environmental standards.

7.4 Applicability, Implementation, Success and Sustainability: a Novel Goal of Mitigation Policies and Countermeasures

In spite of their effectiveness, efforts to reduce the effects of transport on the urban environment are still impeded by the above mentioned constraints, which reduce the benefits compared to cost of implementation. In addition, it is clear that implementation and guaranteeing sustainability are not as easy as defining PCs (Huzayyin and Ashour 2004). For instance, it is easy to say "replace the two stroke two wheelers by four stroke engine," but is it easy to implement this policy? Would users of the former agree to convert? And if they agree; what is the cost? And who would pay? Another example, if the policy is to "encourage walk" includes: (a) widening sidewalks and (b) banning occupancy of sidewalks by street venders and car parking; then if streets are narrow, measure (a) is "applicable" but not "implementable." If the city authority is capable of enforcing the relevant regulations, then measure (b) is "applicable," "implementable" and "successful." But if the city cannot enforce banning the occupancy of the side walks, then the policy though "implementable," yet it would be "unsuccessful." If a policy is calling for "encouraging CNG buses" depending on foreign aid that is available for limited years, then "sustainability" of this policy is questioned, although it can be "successful" for as long as the foreign support is sustained.

Therefore, distinction must be made between "applicability," "implementability," "success" and "sustainability" of the adopted PCs of mitigation of the impact of transport on the environment. Answers to a set of related successive questions (Huzayyin 2003; Huzayyin and Ashour 2004) are necessary for achieving this novel "*goal*" that is introduced for reaching applicable, implementable, successful and sustainable PCs. These are explained below.

First, to what extent are the formulated policies and the adopted measures *applicable*? If some of the policies are *inapplicable*, what are the *reasons* behind this unfavorable situation? How we can reach a favorable situation by making the "*inapplicable*" *applicable*? And what does this involve of requirements if they are not absolutely totally inapplicable? Secondly, are all the applicable policies and the adopted countermeasures *implementable*? If not, how we can make the "*applicable*" *implementable*? Or in other words, what does this involve of physical measures, cost, institutional strengthening and others? And are those possible for the city under consideration? Besides, why are some of the already implemented policies *successful*, while others are not? Or can the city provide the needed capabilities and conditions that can make the unsuccessful policies and countermeasures succeed? And what does this involve? In addition, are all the successfully implemented policies and countermeasures *sustainable*? And how can the "*successful*" but "unsustainable" ones be made *sustainable*? Is this possible and at what cost?

Accordingly, the point here is to move wisely through appropriate search from one step to the other, answering one question after the other, and adopting the needed actions that leads to the above mentioned "goal" of a winning situation as indicated in Fig. 7.1. It is strongly believed that this is not easy, and requires wide experience, knowledge base, information, modelling tools for estimation of expected results of implementation, and technical capabilities. Perhaps also and not less important, is the need for exercising determination and practice from the involved designer of the policies and the countermeasures as well as decision makers. Later in Sects. 7.5 and 7.6 the complexities of achieving this goal are discussed, and a simplification process is outlined in Sect. 7.7.

It is worth noting, however, that the philosophy given above, rather than the detailed steps in Fig. 7.1, is followed in references (World Bank and UNDP 2000) and (GEF 2005). The former, sets out air quality measures and policies based on realistic considerations to make them applicable. The latter reference sets out carefully designed applicable and implementable pilot projects, which can be successful and sustainable, if performed as indicated in the design, and if the warrants for accomplishment are observed as given in the reference including institutional commitment among others. These pilot projects serve the cause of sustainable transport in Cairo and two other provincial capitals in Upper Egypt and the Delta, and also nationwide. They address urban area modal shifts of high income groups from the private car to high quality bus, applicable bus integration with metro, incremental introduction of micro pedestrian zones, new parking policy, and institutional development and NMT corridors applications. In addition, a pilot policy and measures for freight transport management at the country level are suggested to reduce empty load truck travel. This five-year project started 2009 and many replications are envisaged after assessment of the pilots.

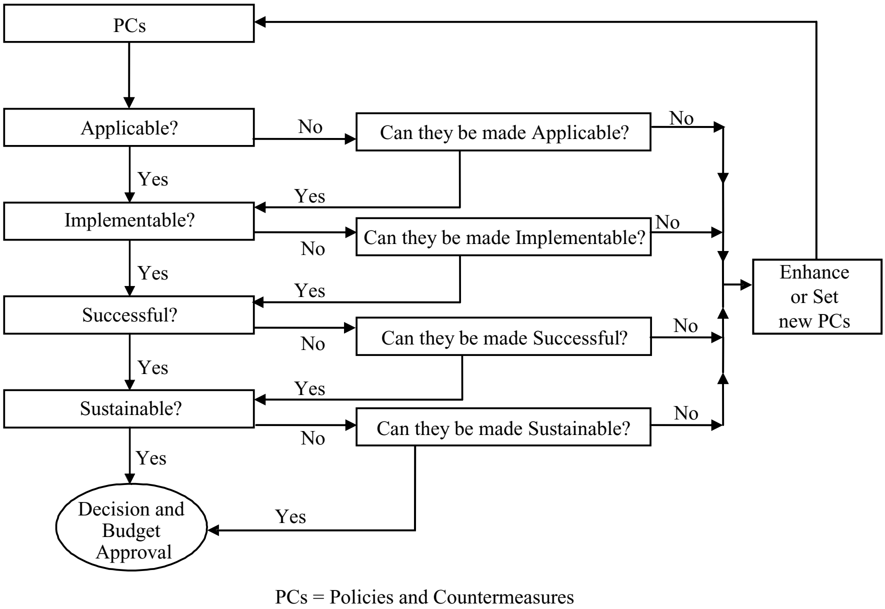

Fig. 7.1 Stepped questions in search for achieving the "goal" of polices and countermeasures of mitigation of transport impacts on the environment that are "applicable," "implementable," "successful" and "sustainable"

7.5 Involved Actors and Variables

Many actors and variables are involved in the formulation of policies and the design of the corresponding countermeasures, setting out environmental standards, monitoring, and follow up of environmental quality and the applied PCs. This adds up to the complexity, and delays the search for achieving the goal illustrated in Fig. 7.1. Many examples of the involved actors and variables are listed in (Huzayyin 2001).

The actors can be listed under seven groups: *central government* (ministries of transport, the environment, industry, energy, etc., and legislative elected councils (Parliament, etc.), local *government* (governor, city council, city engineer (i.e., technical section), etc.), *operation side* (transit companies, parking operators, etc.), *industry side* (vehicle manufacturers, maintenance workshops, companies of converting vehicles to CNG operation, etc.), *NGOs side*: (environment societies, women guilds, public health societies, drivers unions, etc.), *education, training and research institutions*: (schools, Universities, Research institutions, Driving Schools, etc.) and *aid agencies*: (national and international funding and technical assistance agencies, etc.).

The variables can be listed under five groups: *mode related variables* (type of mode, vehicle characteristics, type of fuel, etc.), *traveler style and behavior related* *variables,* driving style [acceleration, deceleration, cruise and idle], driver behavior [speed, stop/start, changing lanes, use of horn, understanding and obeying traffic rules, etc.], pedestrian behavior [walk speed, crossing behavior, etc.], *transport infrastructure related variables* network [design, characteristic], terminals [parking lots/garages design, bus terminals design], street features [lanes, lane widths, horizontal curves, vertical curves, gradients, surface condition, sidewalk width, sidewalk surface condition] and bridges, flyovers and elevated roads [location, entrance and exits design, surface condition, etc.], *traffic characteristics, management and regulations related variables* speed, delay, headway, queue length, composition, etc., signals, signs, intersections design, one-way systems, pedestrian facilities, etc., regulations on vehicle mechanical check and on traffic flow rules, etc. regulations of vehicle licensing (e.g., age, make and type of fuel, etc.), and *nature conditions related variables* (meteorological [e.g., temperature, wind direction, wind speed, humidity], topographical [gradient, hills, valleys, rivers and canals; e.g., water stream speed, water life and water used for irrigation], etc.).

The above actors and variables are involved in many impacts of transport on the urban environment. Some works are overlapping and/or interrelated between more than one actor, and some works of one actor complement or contradict works of another actor. Also, some variables have effects on air pollution and global warming, while others affect noise, water pollution, visual intrusion and city image, and increased pedestrian/vehicle conflict. Besides, a variable may have more than one impact, e.g., traffic delay affects air pollution and city image. The intention in this paper is to direct the attention of the reader to the extreme complexity of devising policies and measures that lead to the above-mentioned winning situation.

7.6 Complexity of the Analysis Required for Policy Design

The current section demonstrates how complex is the analysis needed for appropriate design and estimation of impacts of policies of the reduction and control of the adverse impacts of urban transport on the environment, whereas in the following section simplification of the analysis is considered. Complexity stems from the existence of many Policies (and countermeasures) for mitigation of the adverse effect of transport on the environment. In addition, many Actors are involved in implementing those PCs and setting out the environmental standards, monitoring the impacts, running/operating transport modes and systems affecting the environment, etc. Furthermore, numerous Variables cause the adverse impacts of urban transport on the environment exist and many Effects of transport on the environment are observed in cities of the developing countries and need to be faced and mitigated by appropriate policies. These effects can be classified under nine Groups: *air pollution* causing local effect on air quality, *greenhouse gases* causing global warming effects, *noise*, *visual intrusion*, *pedestrian/vehicle conflict*, *traffic safety*, *stress and frustration* of road users, *water pollution* in cities operating river ferries and sea ports cities and *vibration*.

Accordingly, a complex 4-Dimensional (4-D) problem has to be dealt with. We denote this as the “PAVE” problem; referring to having to deal with Policies to be designed, applied and monitored by Actors in order to control involved Variables (many of which lie in hands of actors as well, e.g., transit operators for bus engine tuning and traffic police for vehicle licensing regulations) to reduce and monitor the Effects of transport on the urban environment (Huzayyin 2003; Huzayyin and Ashour 2004). The complexity of this huge multidimensional situation is clear from the big numbers of the policies, the actors, the variables and the effects that have to be addressed. So, trying to construct a four-dimensional interaction matrix between the “PAVE” elements is formidable and non-manageable, even if some of the elements are not exhaustively interacting with one another. In addition, some variables can have more than one effect. For instance, any variable of vehicle characteristics (e.g., age or engine condition) can lead to more than one effect (e.g., CO_2 emissions, air pollution and noise). Also, PCs may have more than one effect as the policy to enforce using pedestrian crossing, for example, reduces pedestrian/vehicle conflict which in turn reduces delay and emissions. Many effects can be controlled by one PC, as CO_2 emissions and air pollution can be controlled by say replacing two-stroke M2W by four-stroke engine, banning imports of old vehicles, improving vehicle technology, etc. Similarly, in many cases one actor can be responsible of many actions, e.g., training institutions responsible of creation of awareness, improving driver behavior, capacity building of policy makers and others.

Such complex problems make it difficult to design policies (and relevant countermeasures) that achieve the introduced goal; of policies being applicable, implementable, successful and sustainable; which reduce the effects of transport on the environment. It is equally complex to model the expected impact of PCs, before decisions and budget allocation for implementation. This is obviously needed, so that the designer and the decision maker are convinced with the expected outcome, and can equally convince public acceptance and elected councils approval. Therefore, simplification is important, particularly in the context of the cities of developing countries.

7.7 Simplified Process, Complementary Requirements and Pragmatic Issues

As it is important to find out how to simplify the above explained complexity, it is equally important to investigate practical ways to handle the challenge to achieve *balance* between “*immediate vision*” of policy makers, city managers and the public, and the considerations of “*future needs*,” between “*simplifying the analysis*” and “*comprehensiveness*” so as not to loose a needed variable or to neglect an important actor, and between the ambition of setting out “*ideal objectives* and *policies*”, and the importance of being “*pragmatic*” in view of the prevailing city constrains and the technical and financial capabilities. A suggested simplified process is outlined below bearing in mind the above mentioned critical balances.

The suggested simplified process constitutes the following steps:

- Identify the location and/or corridor which needs intervention to reduce environmental impacts of transport, depending on field observations, and in view of careful prioritization exercise if more than one location or corridor needs such intervention.
- Define achievable objectives that need to be satisfied for the chosen location/corridor. For example, attainable limits of CO_2 emissions are more pragmatic than imposing ideal levels that cannot be practically achieved, as it may necessitate abolishing all old cars outright. It is far more appropriate to declare a humble objective that can be achieved than to adopt a super objective that cannot be realized.
- In connection with the above step, long term objectives should consider community needs other than only those related to the environment (Huzayyin 2001). Although it is good to take ambitions and expectations further up, yet dreaming too much can lead to regulation of current and future constraints. A good example of this view is given addressed in (Badami 2000), which suggests a long-term objective as follows: "to minimize pollution effect on health and welfare" subject to: (a) low cost on users, the government and the industry and (b) minimum compromise on accessibility and mobility for the public; of which the majority are poor.
- Reduce the number of variables by eliminating irrelevant ones, based on focusing on the location/corridor under consideration and the defined attainable objectives.
- Based on the above, set out preliminary PCs.
- Identify a list of actors expected to be involved in the defined PCs, i.e., those responsible of taking decisions, setting environmental standards, budget approval, implementation and monitoring. In addition, the actors on which the PCs are to be applied, e.g., transit operators, taxi companies should be identified as well. This is to be done in connection with the context of the considered location/corridor, so as to ensure reducing the number of actors rather than addressing actors expected not to be involved.
- Examine the technical, human recourse, powers and financing capabilities of the identified actors in order to assess the potential of their success in implementing and monitoring the proposed PCs. This can lead to enhancing the preliminary PCs or design alternative ones for testing.
- Make sure of: (a) the "willingness" of city authority to continue supporting the PCs and (b) their seriousness in adopting a "futuristic vision." This is necessary in order to investigate the potential of the "sustainability" of the proposed preliminary PCs.
- In view of the above; the preliminary PCs should be reviewed and adjusted to overcome any obstacles that can affect the four important aspects of the goal as explained in Sect. 7.4, and presented in Fig. 7.1.
- If the preliminary PCs do not end up with the winning goal achievement, then it is necessary to enhance and/or introduce new PCs, and opt for repeating the process.

– Finally, the adjusted PCs are to be assessed against their anticipated effects. The estimation of the effects is to be reached using simple binomial mathematical models as an analytical simplified evaluation tool, rather than multinomial ones. This means using a simple model to link land use and transport in order to predict trip generation, followed by simple conversion of person trip generation into vehicles trips (mainly private cars), followed by a model to estimate the corresponding energy (mainly by private car) consumption, and ending with a simple model to estimate air pollution and greenhouse gas emissions.

7.7.1 Complementary Requirements

The above approach should be complemented by four requirements to handle additional complexities. Realizing that a variable can have more than one effect, full *understanding* of the nature of the variables and their effects allows "in depth" analysis in order to formulate/design appropriate PCs. Furthermore, because many of the individual PCs can have more than one impact on reducing/controlling some of the effects of transport on the environment, *rationalizing* the decisions on the implemented policies is required to avoid duplication and wasting cost and resources which make the PCs unsustainable. Perhaps two complementary actions can help so much in rationalizing decisions. First, is the creation of a powerful institutional entity and mechanism at the national/local government and second, is to make the right technical staff available in order to provide decision makers with the required support for rationalizing decisions. Here human resourse training is essentially important. In addition, as some of the effects can be controlled by one PC, *harmonizing* the different PCs, and eliminating duplication and waste of resources is again important to ensure sustainability of the solutions. This is another duty of the above mentioned institutional entity. Finally, as many of the actors can have more than one role to play, the fourth complementary requirement calls for regular authorized *coordination* between the actors. This is a further duty of the recommended institutional entity in order to guide and observe the coordination. In this respect, the entity should assume an overall supervisory role and handle the delicacies between different actors; watching for avoiding conflicts of interest and unhealthy competition and creation of the right work environment.

7.7.2 Pragmatic Issues for Consideration

Bearing in mind the above discussion, pragmatic issues for implementation are discussed below. In urban areas in developing countries, the practiced effects of transport on the environment are similar in nature and sometimes in magnitude as well. Besides, though the involved variables and actors are many, yet they can differ from one country to another. Firstly, lessons and experience should be transferred and exchanged between cities as problems are of common nature. Establishing bilateral and multilateral communication channels and agreements can help much in that respect, coupled with coordination from international agencies. South/South cooperation must be established. Currently cooperation is mainly, or only, North/South. In addition, effort is needed in two directions: (a) to study the results of implemented PCs and (b) to investigate why and how to implement others that may have been tried with favorable outcome in another country. Again, exchange of information and transfer of experience are very important for drawing lessons to be learned; avoiding the mistakes and capitalizing on the merits.

The collective impact of a group of PCs exerts sound impact on improving the quality of the urban environment. The difficulty here is in selecting the group of PCs that can work together in harmony to minimize the addressed impact, i.e., PCs that complement and not contradict one another. The measures that can be designed for each mitigation policy are important for the success of implementation and maximizing the benefits of the policy. Decision-makers should give full guarantees to avoid distorted implementation or implementation without guaranteeing needed warrants as effective enforcement, for example. As time grows, the measures should be monitored and enhanced if necessary.

For practical reasons, the agency that adopts a policy and its complementary measures should assign a dedicated permanent staff and budget to take charge of these measures. Furthermore, the formulated policies should also be in harmony with the urban transport policies adopted mainly to achieve transport objectives in the city under consideration (Huzayyin 2001). Examples of the latter include those related to transit performance, traffic demand management, future transportation, etc. The importance of the policies to consider the interaction between transport impacts on other warrants of healthy transportation as safety, cost, energy, and accessibility and policies addressing these impacts are also indicated in (Badami 2000). Finally, policies should also be in harmony with other policies related to environment protection and improvements adopted in the city, and the country, under consideration as those related to industrial emissions and waste disposals control, vegetation of urban vacant lands, control of random urban development and reservation of city image, etc.

7.8 Closure

The paper addresses policies and countermeasures of mitigation of urban transport impacts on the environment. It gives a gradual path for the analyst to move successively and wisely from applicable to implementable to successful, and eventually to sustainable policies and countermeasures, by trying to provide answers to a set of questions that represent a real challenge. This is a novel goal that is difficult to achieve, as it may appear from the beginning. The complexity of the analyses is also due to the multiplicity of policies, actors, variables and effects and the interactions between many of those elements. The given simplification approach for the analyses and design of policies and countermeasures, and the complementary issues that lead to applicable, implementable, successful, and sustainable policies is strongly recommended, particularly in the context of developing countries. It is equally necessary for governments and cities to seek practical decisions and solutions to remove the constraints and the barriers of implementation of the policies and countermeasures outlined in the paper, each in the context of its work environment and available resources. Of particular importance is the creation of a mother agency to assume a supervisory role to coordinate the many actors involved, and to rationalize and harmonize the policies and the countermeasures.

As many of the reasons, the variables and the effects of urban transport on the environment are similar in type, nature and magnitude in many cities of the developing countries, transferable lessons and exchange of experience is needed. It is hoped, therefore, that South/South cooperation should take place to achieve this aim. South/North/South cooperation between countries, cities and/or institutions from two developing countries aided by counter part city/institution from a developed country is a further upgraded cooperation. The latter can serve as a catalyst for cooperation between the former two that facilitate the exchange of experience as well as providing two tier transfer of technology for the two. Currently, merely bilateral North/South cooperation is in effect.

There is room here not only for decision makers and top officials, transport and environment agencies and technicians; but also for researchers from Universities and research institutions to form the cooperation partners. The latter are encouraged to carry out research in areas around the complexities of the "PAVE" problem and assessment and the implication process described in this paper, and to compare notes on the difference and similarities between the countries of the developing countries, and on how to benefit from the industrialized country experience, bearing in mind local constraints and prevailing difference and specificities. Perhaps also helping to raise awareness among politicians and the society at large is yet another duty of researchers that is often ignored.

References

Aboeprajitno A (2001) Air quality management in Jakarta, Interactive Database for Emission Analysis (IDEA), Urban Transport Development in Indonesia. (http://www.pcd.go.th/count/airdl.cfm?FileName=DIESEL2_IAIA-IDEA-Brief.pdf)

Akinyemi EO, Medani TO (2000) Investigating the effect of motorcycle traffic on air pollution in Asian and African cities, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 341–350

Asian Development Bank (1998) Report on Metro Manila Air Quality Improvement Sector Development Program, motor vehicles pollutants and their effect on pour health. http://www.geocities.com/injunred/pollution.html

Badami M (2000) Urban transport and air pollution: lessons from the Indian experience, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 193–202

Global Transport Facility (GEF) and UNDP (2005) Sustainable Transport Project for Egypt, Project Document

Huzayyin AS (2001) Transport and environment quality in cities of the developing countries: enough criticism/more action. J Int Assoc Traffic Saft Sci (IATSS) 26(3):175–184

Huzayyin AS (2003) (unpublished) Transport and environment quality in cities of the developing countries: enough criticism/more action, A call for a revised research agenda. Lecture delivered at the Department of Geotechnical & Environmental Engineering, University of Nagoya, Japan

Huzayyin AS, Ashour N (2004) Transport and urban environment in developing countries; the situation is known, pragmatic policies and understanding of related elements are needed. Paper presented to the World Conference on Transport research WCTR 10, Istanbul, 2004

Huzayyin AS, Osman O (2000) Compressed natural gas as an environment friendly fuel for urban transport: policy lessons from a developing country, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 761–766

Huzayyin AS, Salem H (2010) Past and present trends of urban transport and related energy consumption, greenhouse gas and pollution emissions in Greater Cairo. Reviewed papers track, World Conference on Transport Research WCTR 12, Lisbon, 2010

Khan A, Udayakumar P (2000) Urban public transport and environmental economics; evolving a model: a tale of two Indian cities, Pune and Bangalore, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 161–168

Kojima M, Lovei M (2000) Urban air quality management: the transport-environment-energy nexus, World Bank Note, Draft

Madar JL et al (2000) Forecasting pollutant emissions by automobiles in three large metropolitan areas: Sao Paulo, Montreal and Paris, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 169–176

Olimpio de Melolvares Jr (2002) Particulate Matter Control in the Sao Paulo Metropolitan Region, Environmental Agency for the State of Sao Paulo, CETESB

O'Ryan R, Turrentine TS (2001) Greenhouse gas emissions in the transport sector 2000–2020: case study for Chile, ITS-Davis

Sarkar PK, Rohatgi R (2000) Road traffic characteristics in Delhi urban area, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 131–136

Sundaram TK, Verma SA (2000) Transport policy and environmental considerations, Urban Transportation and Environment. Proceedings of CODATU IX Conference, Mexico City, pp 137–142

Wangwongwatana S, Warapetcharayut P (2000) Air pollution management in Thailand, Air Quality and Noise Management Division, Pollution Control Department, Ministry of Science. http://www.cleanairnet.org/caiasia/1412/csr/thailand.pdf

World Bank, UNEP, UNDP (2000) Operational program number 11, Promoting environmentally sustainable transport, Global Environment Facility Document, World Bank, UNEP and UNDP

Chapter 8
Carbon Dioxide Emissions from Urban Road Transport in Latin America: CO_2 Reduction as a Co-Benefit of Transport Strategies

Lee Schipper, Elizabeth Deakin, and Carolyn McAndrews

8.1 Latin America and the Caribbean in the Global CO_2 Context

Today, Latin America is a small contributor to the world's emissions of greenhouse gasses (GHG). However, the region's car ownership, use, and emissions are higher than would be predicted on the basis of population or GDP, and car traffic clogs the streets and pollutes the air of many Latin American cities. Furthermore, Latin American carbon emissions from transport – mostly cars – are predicted to grow threefold by 2030 as both auto ownership and vehicle-kilometers traveled expand. The total emissions will still be small compared to those of OECD countries, but they will not be trivial.

As a heavily motorized and urbanized part of the developing world, Latin American cities suffer from notorious congestion and air pollution as Fig. 8.1a–b, from Mexico City and Porto Alegre Brazil symbolize, as well as poor enforcement of traffic laws and difficulties with walkability, shown in Fig. 8.1c–d. Yet Latin America has also become one of the birthplaces of Bus Rapid Transit (Hidalgo and Grafiteaux 2008), not only in Curitiba Brazil (Fig. 8.1e) but now in an increasing number of large cities, as the bus from Transmilenio moving in stuck traffic in Bogota in Fig. 8.1–f symbolizes.

Reducing the CO_2 emissions from urban transport in Latin America as population and incomes in urban areas grow is a challenging goal, but it is one that many cities are already pursuing. Substantial additional gains seem achievable. Latin American cities face and find that most of the strategies for improving mobility and reducing transportation externalities will also reduce carbon emissions, compared to a "business as usual" alternative. The carbon reduction from transportation investments compares favorably in many cases to those achievable through vehicle and fuel switching.

L. Schipper (✉)
Global Metropolitan Studies, University of California, Berkeley, CA, USA
e-mail: schipper@berkeley.edu

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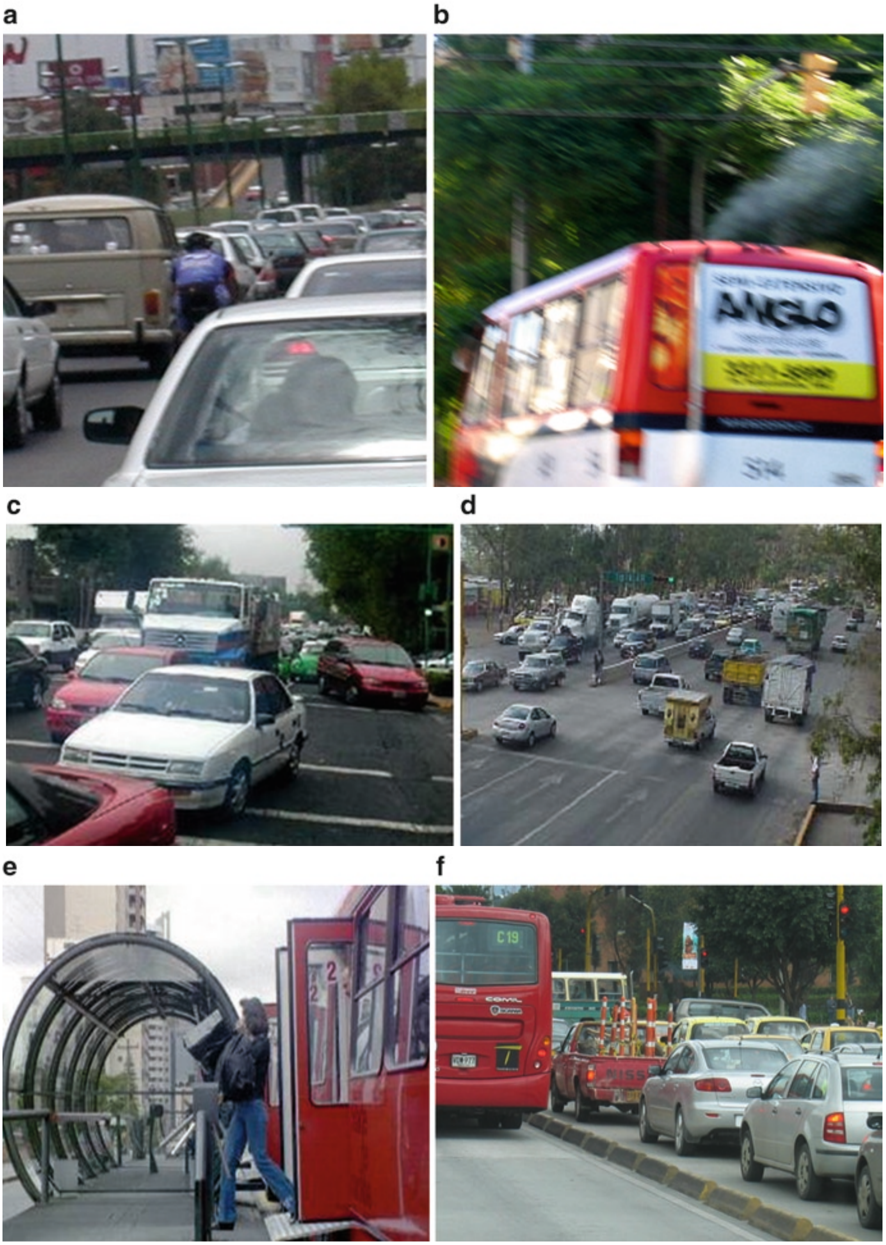

Fig. 8.1 (**a**) *Left:* Cyclist in heavy traffic on the Circuito Interior Mexico City. (**b**) *Right*: Smoking bus in Porto Alegre, Brazil. Photographs courtesy of Lee Schipper. (**c**) *Left*: Cars in Contra-flow Lane of Eje Central, Mexico City, hurrying to exit the lane as a bus moves against their flow. Photo Lee Schipper. (**d**) Pedestrians trying to cross the P Periférico in Guadalajara Photo Carolyn Mcandrews. (**e**) *Left*: Buses unloading in Curitiba. (**f**) *Right*: Transmilenio bus scoots by a traffic jam in Bogotá. Photos courtesy of L. Schipper, except 1f courtesy C. Mcandrews

This paper first charts out aggregate indicators linking high motorization to high CO_2 emissions for Latin America's GDP. We estimate the share of traffic and emissions in urban areas to show that light duty vehicles (LDVs), principally cars, dominate both and are the principal cause of congested streets. In discussing mitigation, we suggest that direct actions to reduce emissions in individual vehicles must be complemented with measures slowing the growth in use of individual vehicles, measures justified by good transport policies.

8.2 Global GHG and CO_2 Trends: Where Is Latin America?

There is broad consensus that GHG are warming the planet (Intergovernmental Panel on Climate Change (IPCC) 2007). Many human activities produce GHG emissions, but roughly two thirds of the total anthropogenic emissions comes from fossil fuel combustion for transportation, buildings, and industry (2005 data). Figure 8.2 shows the origin of CO_2 emissions from all fossil fuel combustion in the world. About half of the total CO_2 emissions comes from OECD countries (excluding Mexico), about 20% from China, and only 7% from Latin America, including Mexico and the Caribbean. On a per capita basis, the world average was 4.3 metric tons of CO_2/capita, while that from Latin America was only 2.5 tons/capita (Intergovernmental Panel on Climate Change (IPCC) 2007). In this work, carbon or carbon dioxide is always given in metric tons of CO_2. Conversion from quantities of fuel (in liters, tons, or energy units) is made with coefficients supplied by the IPCC.

Figure 8.2 shows global CO_2 emissions another way, by main energy consuming sector (as shares) in 2006. Figure 8.3a shows the pattern for Latin America only (including Mexico) in the same year. Interestingly, as Fig. 8.3b shows, road transport represents a full one third of the total CO_2 emissions in Latin America, higher than the world average share. In these portrayals, emissions from electricity production have been allocated by the IEA to sectors where the electricity is consumed.

In explaining differences in CO_2 emissions among regions or countries, the most obvious factors are population and degree of development, as measured by per capita income. But a host of additional factors share in explaining differences – geography and local climate, degree of urbanization, land uses, fuel mix, and the efficiency of energy use. (International Energy Agency 1997) Differences in policies, available technologies, and fuel prices shape the latter factors.

Using data from (International Energy 2009), Fig. 8.4 shows that regional differences in the ratio of transport emissions to GDP (and its changes over time from 1990 to 2006) are large. Some regions show increases in the ratio, while others have achieved substantial decreases. For Latin America, the ratio of road transport CO_2 emissions to GDP has declined only slightly, by less than 0.5%/year during the years shown. In other words, transport emissions in Latin America have increased at almost the same rate as GDP has grown. Emission

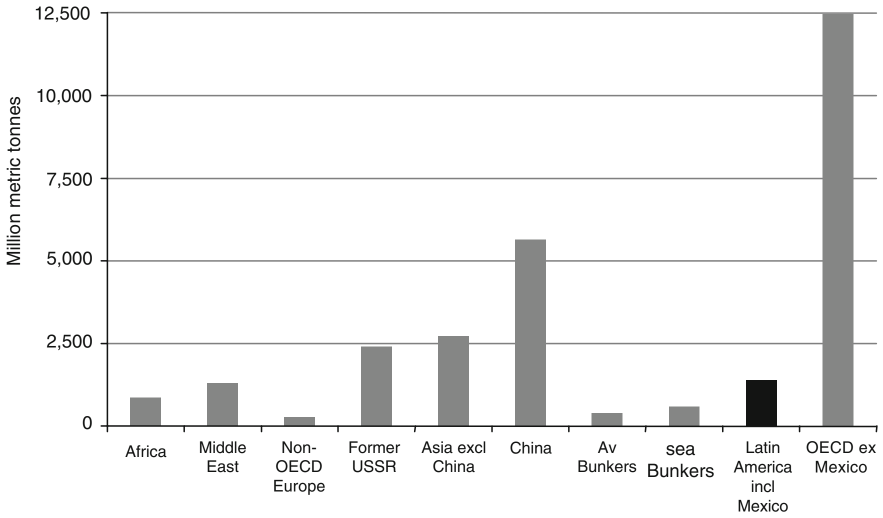

Fig. 8.2 Emissions from all fossil combustion by country or region in 2006. *Source*: International Energy Agency (IEA) (2009a)

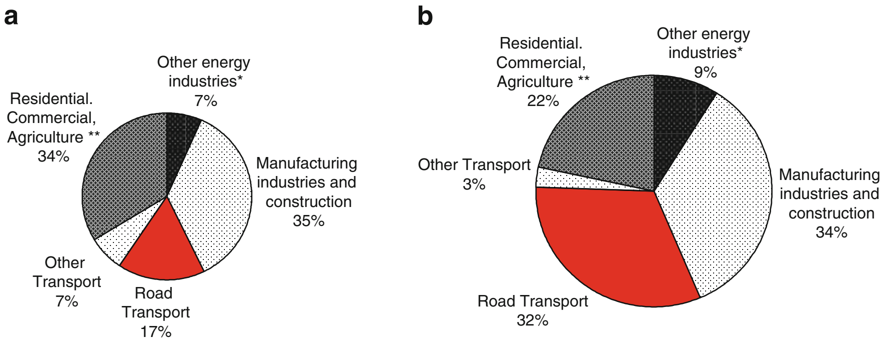

Fig. 8.3 (**a**) and (**b**) CO_2 emissions for entire world by sector in 2006 (total 4.3 tons/capita) and Latin America (2.5 tons/capita)

increases were largely due to the rising importance of fossil fuels for transport, especially in populous Brazil, where use of ethanol from sugar cane could not keep pace with the demand for automobile fuels after 1990. Emissions from other sectors in Latin America grew less rapidly than those from road transport, increasing the importance of road transport to overall Latin Americans emissions. Can this trend be reversed?

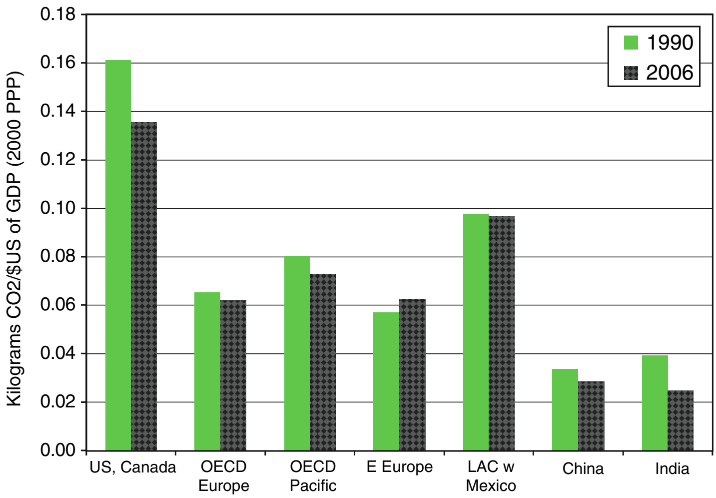

Fig. 8.4 Ratio of road transport CO_2 emissions to GDP for regions, 1990 and 2006. *Source*: IEA (2009). *Note*: 1990 data for India are from 1996, as previous years contain diesel used in stationary sectors

8.3 Road Transport in Context in Latin America: Motorization and Emissions in Urban Regions

An understanding of CO_2 emissions from road transport in the region requires a clear picture of the vehicle fleet and vehicle use (in vehicle-km). Data on vehicle ownership and yearly usage have been developed by International Energy Agency for the World Business Council for Sustainable Development's "Sustainable Mobility Project" (SMP) (World Business Council for Sustainable Development 2004) and are used here, with some modifications.

8.3.1 Vehicle Ownership

Figure 8.5 shows LDV ownership in different regions of the world, relative to both population and GDP, in 2005. Among the developing regions shown, Latin America had a per capita ownership of LDVs of 86 vehicles per 1,000 people – mostly private cars, SUVs, and light trucks. Relative to its GDP, Latin America has the highest motorization in the developing world. The high level of motorization in Eastern Europe is explained in large part by a rapid increase in cars bought after 1990, and stronger presence of Western European automobile manufacturing in Eastern Europe after that time. Even though China and India have much larger populations, the per capita auto ownership is so low that the total numbers of LDVs in those two countries were still well below the number in Latin America in 2005.

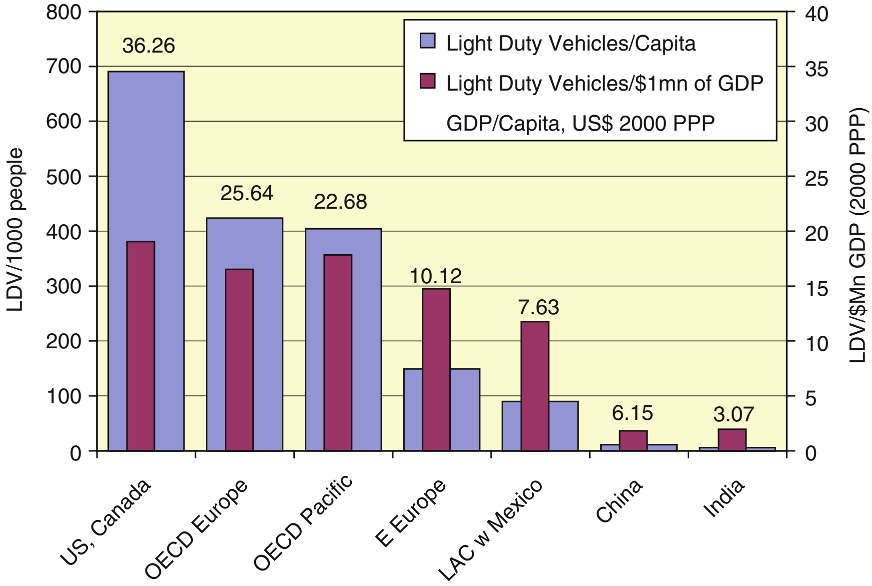

Fig. 8.5 Light duty vehicle ownership vs. income and population, 2005, selected regions. *Source*: IEA MoMo Database (Fulton et al. 2009). *Notes*: 10–20% of these light duty vehicles are commercial vans or pickups. GDP/Capita in USD $1000 (2000 PPP) shown above each region

8.3.2 Vehicle Use and Emissions in Latin America

Data estimated by World Business Council for Sustainable Development (2004), and more recently refined by the International Energy Agency (Fulton et al. 2009), provide information on vehicle types, their energy intensities, and the average km driven each year for Latin American countries. Estimate of vehicle utilization (passengers/vehicle) give total travel by mode. The total fuel use for each particular fuel and vehicle type is calculated using the estimated numbers of vehicles, distance/vehicle, and fuel/distance, with national road fuel use as tabulated by the IEA used as the control total. CO_2 emissions by vehicle type can be calculated from these data. Table 8.1 presents their results. For the region as a whole, about half of road transport emissions are for passenger traffic, the other half for freight travel. The dominant vehicle type is LDVs, most of which are passenger cars.

For this study, we estimated the urban share of traffic (VKT) and emissions, as well as passenger kilometers traveled. The term “urban area” is used loosely here to exclude emissions arising from long-distance intercity road traffic, as well as traffic confined to rural areas. To develop these estimates from the SMP data in Table 8.1, we assumed that 80% of car, motorcycle, and minibus use and fuel consumption is in or around urban areas, largely because the incomes to support car ownership as well as mini-bus use are 80% in urban areas. We estimate that 50% of large bus traffic is in cities, while that 90% of the truck activity, the other half of

Table 8.1 Road transport emissions in Latin America in 2000 by vehicle type: the role of light duty vehicles

Vehicle type	Vehicles (100,000)	km/year	Energy (EJ)	Emissions Mtons CO_2	Share of total CO_2 emissions (%)
LDV pass.	40,127	13,000	2.11	155.4	41.7
Motorcycles	6,948	7,500	0.05	3.0	0.8
Minibuses	930	40,000	0.21	14.1	3.8
Buses	511	40,000	0.20	14.5	3.9
LDV freight	4,459	13,000	0.23	16.2	4.4
Med truck	5,385	22,000	1.15	77.6	20.8
Heavy truck	2,314	50,000	1.38	92.2	24.7
Total			5.33	372.9	

Source: WBCSD Sustainable Mobility Project and IEA. *Note*: 1 EJ (exajoule=10^18 j) = 24 MTOE (million tons of oil). Data adjusted to include Mexico. Emissions for rail were included in the original Sustainable Mobility Project spreadsheets but are omitted here

the bus activity, and 10% of car traffic is intercity. To estimate passenger kilometers, we assume the vehicle occupancies shown in the table. Assuming two passengers per car is reasonable, consistent with European experience in the early 1970s (Schipper and Marie-Lilliu 1999).

SMP did estimate fuel use/km for each vehicle type. Since congestion tends to be much worse in urban areas than elsewhere, and congestion tends to boost fuel use per km, it was tempting to raise fuel use per km for the urban share. On the other hand, urban vehicles (and roads) may be somewhat newer, cleaner and better maintained than those in rural areas, which would reduce fuel use/km. For simplicity we let these factors balance, and adopted the SMP intensities for urban vehicles. Since urban rail, mostly electric-powered, contributes very little to emissions from electricity generated to run it even in countries and cities with the most urban rail, e.g., European countries (or cities like Paris and London), we excluded rail systems. See (Schipper and Marie-Lilliu 1999).

Table 8.2 shows the results. It appears that about 60% of all road transport emissions in Latin America appear to be associated with urban areas, with LDVs responsible for well over half of the urban emissions. Further, we estimate that in 2000, two trillion passenger km were produced in these motorized modes in Latin America urban areas.

Data from major metropolitan regions of Latin America are consistent with these estimates of urban traffic and emissions. Table 8.3 and Fig. 8.6 show the data for Mexico City in 2006. The data comes from the region's emissions inventory, which is updated every other year (del Distrito Federal 2004).

These data show that in Mexico City, CO_2 from transport arises overwhelmingly (68%) from individual vehicles, i.e., cars, pickups, taxis and motorcycles. Traffic is also dominated by these individual vehicles, which account for almost 83% of VKT. Interestingly, Mexico City car ownership is lower than that in many other large Mexican cities, so the share of emissions in LDVs may be even higher in other Mexican urban areas where there are more cars per capita. This also

Table 8.2 Estimated urban share of traffic and emissions by vehicle type, Latin America 2000

Vehicle type	Urban share of VKT (%)	Urban VKT, billion	Vehicle occupancy people	Passenger km, Billion	Emissions Mtons CO_2	Share of urban CO_2 (%)
LDV and motorcycles	80	453	2	907	127	61.5
Mini buses	80	30	20	595	11	5.5
Buses	50	10	50	511	7	3.5
Light truck	80	46			13	6.3
Medium truck	50	59			39	18.8
Heavy truck	10	12			9	4.5
Total		510		2,013	208	100*

*Very small share of emissions from urban rail systems and trolley bus electricity excluded.
Source: Original calculations. LDV, or light duty vehicles, include all cars, vans, pickups and SUVs, of which an estimated 10% are for strictly commercial purposes and counted under LDV freight

Table 8.3 CO_2 emissions, vehicles, and traffic, Mexico City, 2006

Vehicle type	Mtons CO_2, all fuels	Vehicles (100,000) all fuels	Billion VKT, all fuels
Cars	10.49	3,395.8	46.31
Taxis	2.60	155.1	10.38
VW bus colectivos	0.70	39.7	2.64
Other colectivos	0.74	36.1	2.54
Pick up	0.83	133.4	3.48
Other veh < 3 t	0.63	81.6	1.80
Truck tractors	1.63	60.9	1.38
Buses	1.87	43.1	1.79
Other Veh < 3 t	0.54	100.8	2.20
Motorcycles	0.37	180.7	4.47
Total	20.40	4,227.3	76.98

Source: Mexico City Emissions Inventory (SMA, 2006). Colectivos are 10–35 passenger vans and small buses

implies that the light duty personal vehicle fleet in other Mexican cities is an even greater contributor to CO_2 emissions than it is in Mexico City.

Patterns for Santiago de Chile (Escobar 2007; Goicoechea 2007), Bogotá (Giralto 2005; Suarez 2006), and Sao Paulo (Melor de Alvares 2008; Vasconcellos 2008) are similar. LDVs account for less than 25% of travel, but more than 60% of VKT and CO_2 emissions in these urban areas. LDVs are at the heart of congestion in Latin American cities (as in most of the world): Unfortunately, Fig. 8.1a and e are representative of the region. High car use and high levels of congestion are key reasons why surface transport by bus or trolley sharing the same roadways is slow, and in this case the cars even slow the contra-flow bus lane.

This review of available data provides a strong link between high light duty (car) ownership and use and high CO_2 emissions from urban transport suggested by the regional data for Latin America. If the same LDVs are the main components of

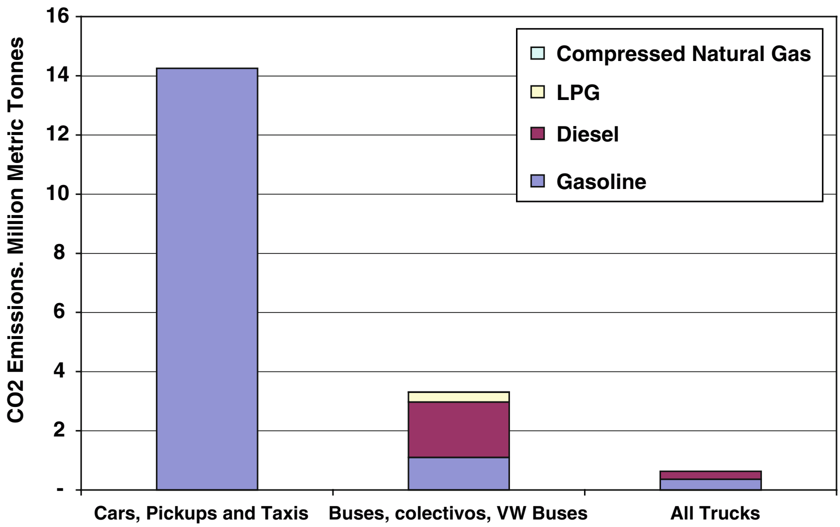

Fig. 8.6 CO_2 emissions from the main classes of transport emitters of CO_2, Mexico City Metropolitan Area, 2006. *Source*: Mexico City SMA Emissions Inventory estimated by vehicle, distance, and fuel intensity

traffic congestion and many other traffic and transport related externalities, such as air pollution and accidents, then we may be justified in saying that the high CO_2 emissions relative to incomes is a symptom of broader transport problems related to the dominance of private cars in urban traffic in Latin America.

8.3.3 Projections of Vehicles and Emissions to 2030 and Beyond

Present trends in the Latin America region point to increasing auto ownership and use. Latin America will probably approach Europe's level of motorization of the1960s by 2030, but with far more urban regions of over five million that Europe has even now. In 2004–2006, Latin America had four urban agglomerations with over ten million (Mexico City, Sao Paulo, Buenos Aires, and Rio were all about ten million). Europe had just one, Paris (just below ten million). Between five and ten million, Latin America had Lima, Bogotá, Santiago and Bel Horizonte, while Europe had London and Madrid, with Barcelona at 4.9 million. Latin America had eight more cities among the world's 100 largest urban areas, Europe three more. (United Nations and Population Division 2007) Traffic in these largest cities tends to be the most congested. Thus the prospects for future traffic problems in the face of growing motorization in all these large Latin America cities are daunting.

Figure 8.7 shows SMP projections for LDV ownership for 5 year intervals, 2000–2050 (World Business Council for Sustainable Development 2004; Fulton et al. 2009).

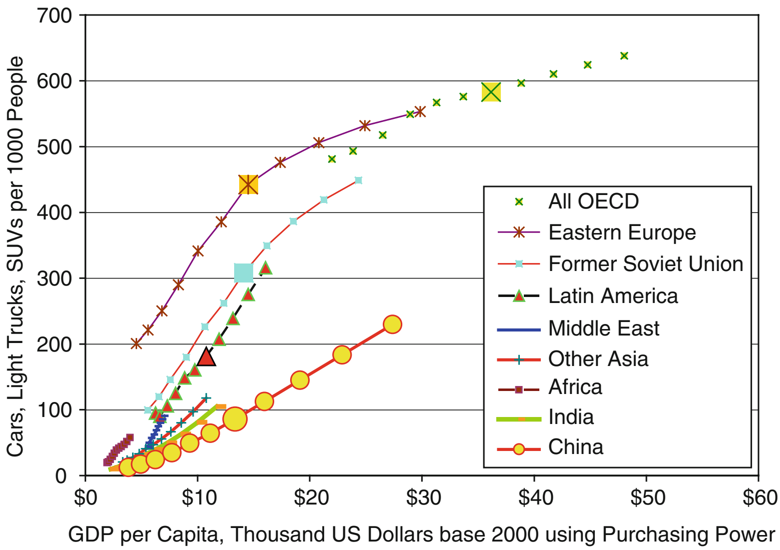

Fig. 8.7 Sustainable Mobility Project projections of future light duty vehicle ownership by region. *Source*: del Distrito Federal (2004)

Per capita GDP is on the horizontal axis. The points for 2030 for Latin America, China, the OECD, the Former Soviet Union and Eastern Europe, have been enlarged to stand out. That the slope of the curve for Latin America is steeper than that for most other developing regions means car ownership is expected to increase rapidly relative to GDP.

According to this projection, by 2030, Latin America's per capita income will almost double, with per capita LDV ownership – predominately cars – rising to 200 per 1,000 when Mexico is included, the level of "Eastern Europe" as defined by WBCSD. Further, World Business Council for Sustainable Development (2004) and Fulton et al. (2009) project that most of the growth will be in cars and light duty trucks, not two wheelers that characterize Asia. This means that relative to GDP growth, emissions could continue to rise faster in Latin America than in other developing countries, where fuel-efficient motor scooters and e-bikes are a major portion of motorization.

The same projections foresee a more than tripling of total LDV VKT in Latin America by 2030 and a sixfold increase by 2050. The VKT growth is pushed up by growth in population, and LDV ownership increases are supported by rising affluence. The estimates are consistent with historical evidence from Europe and North America (Schipper and Marie-Lilliu 1999; Millard-Ball and Schipper 2010). The projections also see Latin America maintaining the high ratio of LDV to GDP implied by its present position in Fig. 8.7. However, the projections behind Fig. 8.7 did not foresee any major changes to transportation policy that could slow the rise in LDV use. This must mean that left untreated, congestion and other transport problems in urban regions simply will get worse.

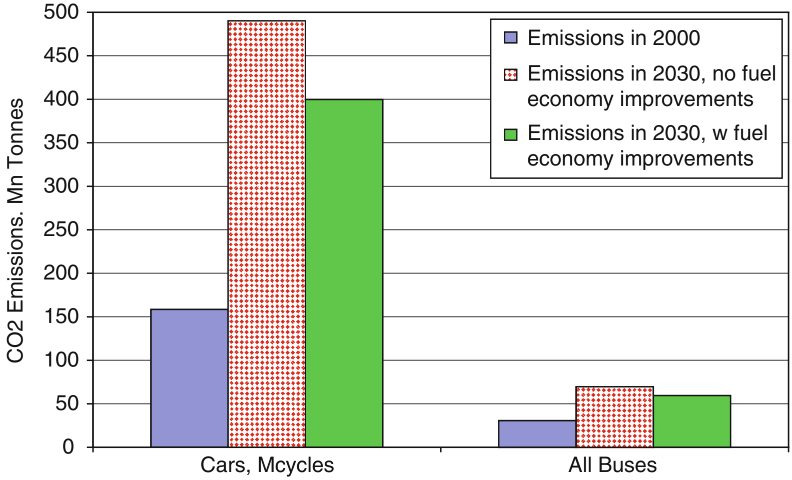

Fig. 8.8 Sustainable Mobility Project estimates of co_2 emissions from Latin America Road Transport. 2000 actual and 2030 projected. *Source*: World Business Council for Sustainable Development (2004)

In fact, when the projections for vehicles, VKT, and fuel economy for each mode are combined, but no other mitigation is included, emissions from passenger vehicles in Latin America are forecasted to more than double by 2030 despite improvements in vehicle fuel economy (Fig. 8.8). The third bar in Fig. 8.8 has fuel economy improvements built in, while the second bar does not. By 2050 (not shown), emissions are expected increase to four times their current value. Emissions from trucks, not shown, grow less rapidly than those for cars, while emissions from buses are not seen as growing much at all. Indeed, while opportunities to reduce emissions per vehicle-km or passenger-km in buses should not be ignored, those reductions would be minor compared to the growth in emissions from LDVs. Is there any alternative?

8.4 Mitigation of CO_2 Emissions: Complementary Strategies

The SMP projections shown in Fig. 8.8 do imply some restraint in CO_2 emissions. On-road fuel economy of LDVs in Latin America is projected to improve from an estimated 11.8 l/100 km in 2000 to about 9.4 l/100 km by 2030 and to 8.3 l/100 km over 50 years. The improvement is a drop of some 20% in fuel use per km. For comparison, the EU hopes that by 2030 its fleet will use less than 6.5 l/100 km on the road, below the present value of 7.8 l/100 km, also a 20% improvement (Schipper 2010). Since cars in Latin America are smaller and less powerful than those in the EU, the high fuel intensity for LDVs in Latin America may seem odd. The explanation appears to be poor traffic conditions, seen in the relatively high in-use fuel intensities of small cars in the Mexico City, Sao Paulo, Bogotá, and Santiago emissions inventories. Models used to simulate fuel use in traffic in Latin America, like MODEC (Goicoechea 2007; Osses et al. 2000) or COPERT and Mobile 6 Mexico (Copert 2009; Rogers 2006) show rising fuel use/km with greater congestion. If congestion continues to worsen in Latin American cities, this gap between vehicles' potential fuel economy and real-world performance will increase, erasing some of the benefits of improved vehicles. Conversely, measures that reduce congestion lead to improvements in in-use fuel economy (Skabardonis 2004).

Latin American governments may begin to address the issue of fuel economy directly. Lacy (2008) for example, has developed a proposed set of fuel economy standards for Mexico, consistent with the improvements in fuel economy that went into the projections in Fig. 8.8. As noted, this step still leaves emissions from road transport in Latin America more than double over the same period. Even a major increase in fuel efficiency over and above the projected levels would still result in significantly increased emissions in Latin America. This means that there is reason to consider additional interventions to boost fuel economy. Still, the large projected increase in car ownership and use is far greater than foreseeable improvements in fuel economy. Can this growth in CO_2 emissions be reduced further by reducing growth in car use?

The answer is "perhaps," if policy makers recognize that is that CO_2 per se is not a driving factor compared for transportation with other externalities or transport variables. Figure 8.9 illustrates this for a specific project in Mexico City, Metrobús (Schipper et al. 2009). Shown are the components of reductions in CO_2 emissions from introduction of a BRT corridor along one of Mexico City's busiest routes. Included are the emissions of all vehicles in the corridor before the BRT lanes were created, and after. Roger's original estimates (Rogers 2006), subsequently updated by him (Rogers 2009) show that this project reduced emissions in the corridor from all traffic by 10%. Of those reductions, about one-third came from the direct substitution of 90 large articulated buses for over 300 small buses ("A" "B" and "C" in Fig. 8.9), one-third came from bus riders who used to take cars for the same journeys ("D"), and one-third came from smoother resulting traffic in the corridor, including some increases arising from problems for cross and left-turning traffic ("E"–"H"). No special steps were taken go use low-carbon fuels, hybrid buses, or other technological options aimed specifically at fuel saving or CO_2. It is encouraging that these reductions occurred without any special effort to save CO_2. These reductions illustrate the co-benefits of transport strategies that come at no "cost" to save the CO_2, i.e., they are justified alone as transport measures.

When the results are monetized, the perspective changes. Table 8.4 shows the results. The National Institute of Ecology (Instituto Nacional de Ecología (INE) 2006) estimated time savings using a value of time of approximately 60 US cents/h and other values for reduced road wear and health benefits of lower air pollution. Excluded are any value to fewer crashes and reduced loss of life, important variable not addressed in the INE study. To the benefits, we add the value of fuel saved by buses, parallel traffic, and consumers who left their cars at home. In addition we

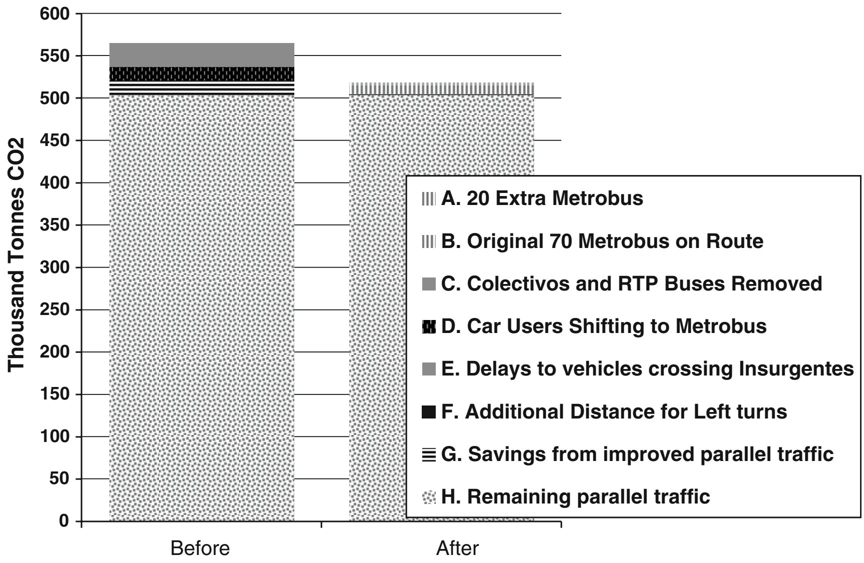

Fig. 8.9 Emissions in Insurgentes corridor before and after metrobús. *Source*: Rogers (2006) and (Instituto Nacional de Ecología (INE) (2006) as tabulated in (Schipper et al. (2009). *Notes*: Legend explanations: A and B are the emission from Metrobús after; C is the emissions of the transit vehicles removed; D is the emissions imputed before drivers switched to Metrobús; E and F are the extra emissions from delays and circuity imposed by Metrobús. G shown as emissions in the corridor before that were saved because traffic on Insurgentes is smoother after Metrobús is put in place. H gives the remaining emissions from all parallel traffic on Insurgentes

Table 8.4 Annual benefits of metrobús project

Nature of annual benefit or savings	Low CO_2 value (USD \$5/ton)	High CO_2 value (USD \$85/ton)
Time savings of bus riders	\$1.32	\$1.32
VKT external costs – reduction in traffic	\$2.19	\$2.19
Air pollution reduction/health benefits	\$3.00	\$3.00
Fuel savings from bus switch	\$3.68	\$3.68
Fuel saving, mode switch car to bus	\$3.66	\$3.66
Fuel savings to parallel traffic	\$1.56	\$1.56
CO_2 reduction from bus switch	\$0.09	\$1.75
CO_2 reduction, mode shift car to bus	\$0.13	\$2.58
CO_2 reduction in parallel traffic	\$0.05	\$0.87
CO_2 reduction, total value	*\$0.27*	*\$5.20*
Reduction in accidents/death (not estimated)		
Total first year annual value US\$ Million (2005)	\$15.69	\$20.62

Source: CO_2 and fuel calculations made in this study, based on Rogers (2009) and Nordhaus (2008) as complied in Schipper et al. (2009)

include the CO_2 savings from Fig. 8.9 at a value of \$5/metric ton of CO_2 and at \$85/ton. The former value is what Mexico City received for savings from a carbon fund lower than what an economic study of climate change uses (Nordhaus 2008). The latter is the much higher estimate developed by the Stern Report (Stern 2006). It is notable that even when CO_2 is valued at the high end it only comprises about 20% of the total benefits shown; at the lower end its value almost cannot be seen. Estimates form the US, Canada, and Europe find the same relatively low value of the CO_2 externality, when compared with other externalities of transport on a per kilometer basis (Parry et al. 2007; Transport Canada 2008; MacKenzie et al. 1992; Maddison et al. 1996) With CO_2 valued so low compared with other transport benefits, CO_2 saved from improved traffic and transport can be seen as an important co-benefit of good transport strategies, but will not be a driving force in project selection and design.

In considering what buses to use for Metrobus, Schipper et al. (2009) considered how much energy and CO_2 emissions would have been saved if parallel hybrid buses were employed. Based on experience of hybrids in other regions, it was estimated such vehicles would have saved an additional 3,000 tons of CO_2/year. These savings, however, would have cost at least an additional \$10 million for the hybrid buses then available. Even counting the significant savings of fuel, adding the hybrid option would be expensive. While it should be considered, planners should also ask whether the same expenditures, if devoted to better station access, or other aspects of Metrobus service might actually be more cost effective by attracting more riders. Considering technical options for saving CO_2 and fuel, together with options that improve overall system performance, might reveal system improvements that give more total benefits than CO_2-oriented technology measures alone.

8.5 Summary: The Transport – CO_2 Challenge for Latin America

Present levels of CO_2 emissions from road transport in Latin America are high by developing world standards. Not coincidentally, per capita ownership and use of LDVs in Latin America are also high. In urban regions, around 70% of CO_2 emissions from road transport arise from the use of LDVs, which are by far the most common vehicle on the streets, and in general the greatest contributors to both congestion and pollution as well. What the aggregate data shows is that the high CO_2 emissions from road transport in Latin America can be seen as a symptom of transport problems caused by high car ownership and use. Addressing these transport problems likely would reduce car use and fuel consumption somewhat, which would reduce CO_2 emissions as well.

The data and trends-extended forecasts for vehicle ownership and use, fuel economy improvements, and predicted emissions present serious challenges for transport policy-makers in Latin America and elsewhere. Without additional interventions, emissions will grow substantially during a period where combating global warming would necessitate their increased traffic in urban regions, which in turn implies worsening congestion and other transport problems (unless increases in road capacity keep pace with or exceed traffic growth).

If reductions in transport emissions are to be achieved, many analysts now conclude that the growth in individual vehicle use must be moderated, and transit vehicle use and non-motorized travel increased in relative importance. Further reductions in CO_2 emissions can be accomplished through changes in urban development and transport paths, not just in Latin America but around the world. Such changes could reduce growth in vehicle ownership, vehicle use, or both.

Additional CO_2 reduction can be attained through well-planned urban transport investments. Many Latin American cities are already steering transport growth in more carbon-efficient directions by investing in high quality public transportation and new facilities for bikes and pedestrians. These travel choices improve accessibility for a large portion of the population while managing traffic, cutting pollution, and moderating CO_2 emissions.

Latin American leadership in implementing new travel options is creating models from which others can learn. Cities such as Curitiba and Bogotá are already widely emulated for their creative investments in urban planning and bus rapid transit. These activities improve transport while reducing carbon emissions, and their success puts pressure for change on countries that have been slow to adopt carbon reduction policies.

The challenge for authorities in Latin America and other regions is to make the transport changes suggested by the externalities illustrated in Table 8.4 for their own value and reap the co-benefits of lower CO_2 emissions. Currently, the rewards of a third party paying for the CO_2 savings would be small compared to the rewards from saved fuel and time. Can authorities make these changes if the rewards from carbon reduction alone are so small? And given the slow progress in improving transport all through the developing region, as argued in this paper for Latin America, can carbon make a difference? A recent World Bank Urban Transport Strategy makes the case for strong measures to make individual vehicle users face the externalities they cause on other travelers, who are the majority in Latin American and other developing cities (The World Bank 2008). Following their advice may provide larger carbon restraint as a co-benefit than any other group of measures.

Hidalgo and Grafiteaux (2008) charts out the progress of bus rapid transit as one of many important transportation measures spreading in cities around the world. A more recent update for Mexico alone by the “Fonadin” (the national fund for infrastructure (Mier y Tieran 2009) projects more than 2.2 million new trips/day on BRT and over 1.2 million trips/day on rail lines in Mexico’s major cities. Such changes must of necessity take road space (and other resources) from cars. The experience from Metrobus suggests the good outcome there gives political momentum to this refocusing of transport planning and infrastructure development.

Additional investments in transportation facilities and services that increase access and quality of life while also cutting carbon would benefit cities in Latin America and around the world. Transit, pedestrian and bicycle facilities, improved traffic management, and coordinated transport and land use are important low-carbon access and mobility strategies. Most cities could also gain by strategically coordinating transport investments, creating networks of transit operating on traffic-managed streets and arterials conveniently reached by bikeways and pedestrian ways, and serving mixed-use neighborhood and commercial district centers. In addition, most cities could benefit from pricing policies for fuels, parking, and other transport services that better reflects marginal social and economic costs. Such pricing is not only efficient, but can generate revenue that can be used for further transport improvements.

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References

Copert (2009) COPERT 4. The EU model for vehicle emissions. Accessed July 2009 at http://lat.eng.auth.gr/copert/

Escobar, Jaime (2007) Actualización del Inventario de Emisiones de Contaminantes Atmosféricos en la Región Metropolitana 2005. DICTUC, Pontificia Universidad Católica de Chile. Santiago: Commisión Nacional Del Medio Ambiente Región Metropolitana

Fulton L, Cazzola P, Cuenot F (2009) IEA MoMo Model and its use in the ETP 2008. Energy Policy (October 2009) (in press)

Giralto, Liliana Andrea Amaya (2005) Estimación del Inventario de Emisiones de Fuentes Móviles Para la Ciudad de Bogotá e Identificación de Variables Pertinentes. Master's Thesis. Bogotá: Universidad de los Andes, Facultad De Ingeniería, Departamento de Ingeniería Civil y Ambiental

Goicoechea C (2007) Private communication regarding MODEC model and data for Santiago, Chile

Hidalgo D, Grafiteaux P (2008) Bus rapid transit systems in Latin America and Asia: results and difficulties in 11 cities. Transportation Research Record

Instituto Nacional de Ecología (INE) (2006) The benefits and costs of a bus rapid transit system in Mexico City. Final Report. March 2006. Website accessed May 2009 at http://www.ine.gob.mx/dgicur/calaire/descargas/metrobus_bca.pdf

Intergovernmental Panel on Climate Change (IPCC) (2007) Fourth Assessment Report. World Meteorological Organization, Geneva

IEA (2009) Transport, Energy and CO_2. Moving towards Sustainability. International Energy Agency, Paris See http://www.iea.org/papers/2009/FlyerTransport2009.pdf

International Energy Agency (2009a) On line statistics. Accessed July 2009 at http://data.iea.org/IEASTORE/DEFAULT.ASP

International Energy Agency (1997) Indicators of energy use and efficiency: understanding the link between energy use and human activity. OECD, Paris

Lacy R (2008) Propuesta de Normatividad en Materia de Rendimiento de Combustibles y de Emisiones de Bióxido de Carbono para Vehículos Ligeros Nuevos. Centro Mario Molina, Mexico City. See also summary accessed 31 May 2009 at http://www.bancomext.com/Bancomext/aplicaciones/directivos/documentos/RodolfoLatinAmericay.pdf

MacKenzie J, Dower R, Chen D (1992) The going rate: what it really costs to drive. World Resources Institute, Washington, DC

Maddison D, Pearce D, Johansson O, Calthorp E, Litman T, Verhoef E (1996) Blueprint five: the true costs of road transport. Earthscan, London

Melor de Alvares, Olimpio (2008) Personal communication regarding State of Sao Paulo Emissions Inventory Data

Mier y Tieran C (2009) Programa de Apoyo Federale al Transporte Masivo PROTRAM. Presentation to Cuidades Bajas en Carbono, Center for Sustainable Transport, Mexico City. Ministry of Public Works, Mexico City

Millard-Ball A, Schipper L (2010) Are we reaching peak travel? Transport Reviews (November)

Nordhaus W (2008) A question of balance: weighing the options on global warming policies. Yale University Press, New Haven

Mauricio O, O´Ryan R, Cifuentes L (2000) Analisis de Evaluaciones y Reevaluaciones Expost, Vi Etapa. Departamento de Ingeniería Mecánica, Universidad de Chile. Santiago, Chile

Parry IWH, Walls M, Harrington W (2007) Automobile externalities and policies. J Econ Lit 45(2):373–399

Rogers J (2006) Mexico, Insurgentes Avenue Bus Rapid Transit Pilot Project. Document version: 1.7. Submission to UNFCCC, January 4, 2006. Metrobús, Mexico City. See http://cdm.unfccc.int/UserManagement/FileStorage/JG4E4YKSZ09A2X1OZXTA8C7XTKQ6YQ

Rogers J (2009) Personal communication regarding updated information from Metrobús analysis

Schipper L (2010) Automobile use, fuel economy and CO_2 emissions in industrialized countries: Encouraging trends through 2008? Transport Policy 18 (2011):358–372

Schipper L, Marie-Lilliu C (1999) Carbon-dioxide emissions from transport in IEA countries: recent lessons and long-term challenges. KFB, Stockholm, LBNL-43764

Schipper L, Deakin E, Mcandrews C, Scholl PL, Trapenberg Frick K (2009) Considering climate change in Latin American and Caribbean urban transportation: concepts, applications, and cases. Prepared for the Latin American Caribean Department of the World Bank. Global Metropolitan Studies, Berkeley

Secretaría del Medio Ambiente del Gobierno del Distrito Federal (2004) Inventario de Emisiones de la ZMVM, 2004. http://www.semarnat.gob.mx/gestionambiental/calidaddelaire/Documents/Inventarios/inventario_emisiones_zmcm_2004.pdf. 2006. Data communicated by Director Victor Hugo Paramo, August 2008

Secretaría del Medio Ambiente del Gobierno del Distrito Federal (2006) Inventario de Emisiones de la ZMVM, 2004. http://www.semarnat.gob.mx/gestionambiental/calidaddelaire/Documents/Inventarios/inventario_emisiones_zmcm_2004.pdf

Skabardonis A (2004) Traffic signal control systems. In: Gillen D, Levinson D (eds) Assessing the benefits and costs of ITS: making the business case for ITS investments. Kluwer Academic, Boston

Stern N (2006) Stern review: the economics of climate change: executive summary. http://www.hm-treasury.gov.uk/stern_review_report.htm

Suarez J (2006) Bus rapid transit as a pathway to sustainable transportation: contributions from Bogotá and Mexico City. Master's thesis, University of Delaware, Newark

The World Bank (2008) A strategic framework for urban transportation projects: operational guidance for World Bank staff. Prepared by Slobodan Mitrič. Transport Papers. Washington, DC TP-15

Transport Canada (2008) Estimates of the full costs of transportation in Canada. TP 14819E. August 22, 2008. http://www.tc.gc.ca/pol/en/aca/fci/FinalReport.htm. Website visited May 30, 2009

United Nations, Population Division (2007) World urbanization prospects: the 2007 revision population database. http://esa.un.org/unup/index.asp?panel=2. Website accessed June 5, 2009

Vasconcellos Eduardo (2008) Personal communication regarding Sao Paulo mode shares, fuel use, and emissions based on 1997 travel survey

World Business Council for Sustainable Development (2004) Mobility 2030: meeting the challenges to sustainability: the Sustainable Mobility Project. http://www.wbcsd. org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=NjA5

Chapter 9
Spatial Planning Strategy Towards Low-Carbon City in China

Haixiao Pan, Yang Tang, Jinyu Wu, Yuan Lu, and Yangfei Zhang

9.1 Introduction

As the urbanization process tends to proceed at a quicker pace in China, (National Bureau of Statistics of the People's Republic of China 2007) it is predicted that, as of 2050, China's urbanization level shall exceed 70%, a record that no country in the world has shared (Sustainable Development Strategy Study Group 2003). With the soaring economic growth and urbanization process, various pressures from environment, society, and regional development are imposed on China's urban development. How to solve various contradictions arising in the urbanization process, especially urban energy consumption and waste gas emission while maintaining the fast and steady economic growth has become a matter of great concern for the Chinese government (Zhu 2007).

During the eleventh 5-year plan period, the energy consumption per unit of GDP will decrease by 20% or so, and the total emissions of major pollutants by 10% (Jin 2008; Huang 2005), the <Program Outline of the Eleventh Five-Year Plan of National Economy and Social Development> pointed out. Research shows that due to the locking in effect of the urban spatial structure, the energy needed and the emissions of carbon dioxide and other greenhouse gases generated by urban transportation in western countries is very difficult to control. Although technical advancement may reduce energy consumption and waste gas emissions of cars, if the locked relationship between the use of cars, the improvement of a citizen's standard of living and social economic growth remains, the benefits from the technical advancement will be balanced out soon. In case the urban motorization level rises up rapidly in China with the accelerated urbanization process, if no effective planning strategy is taken for the future, the uncertainty of global oil resource supply and environment issues will become restraints to urban development.

H. Pan (✉)
Department of Urban Planning, Tongji University, 1239 Siping Road,
Shanghai 200092, China
e-mail: hxpank@online.sh.cn

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9.2 Urban Planning Towards Lower Carbon Emission

Urban planning may exert long and structural influence on the urban development. Once established, the physical environment of a city may be hard to change, and will have profound impact on people's social life and economic activities. Adjustment to the industrial structure, healthy lifestyle, and technical innovation helps reduce the energy consumption and the emission of carbon dioxide in the fields of manufacture, daily life, and other recreation activities, but cannot change the travel generated by the urban spatial structure allocation and the corresponding energy consumptions and emissions. Once the urban spatial structure is set up, as determined by the urban planning, it will be very difficult to conduct structural adjustments to the corresponding travel.

At present, almost all Chinese cities have large-scale construction, environment reconfiguration, and adjustments to their spatial structure. Over the ages, urban planning has grown into an important basis that guarantees healthy and orderly urban development in China. As a positive response to the target of "Low-Carbon City", and considering that we are in a period of rapid economic growth where urban planning is still playing a guiding role, if the implementation of sustainable urban planning strategy can be guaranteed, then perhaps, China's cities will be able to seize significant opportunities to follow a model of urban development different from those for the western countries. There are a lot of studies on technology to reduce CO_2 emission in industry production (Zheng 2005). This research is more focused on spatial structure and the integration of land use and transport to reduce CO_2 emission in regional planning, citywide master planning, and detailed residential planning.

9.3 Regional Planning Under the Target of Low-Carbon City

As the urbanization proceeds at a quicker pace, the population moves to cities more rapidly, and cities start to spread to surrounding areas. The functional change of inner city land use, the migration towards the suburban areas, and the construction of industrial parks, enlarge the living and working range in cities and make the rural–urban contact even closer, alongside the increasingly heavier travel demand. In some developed countries, the periphery areas of some metropolises bear much higher intensity of car travel than core cities. Without effective spatial planning strategy, and given long travel distance and poor transit services, cars will occupy the dominant part in the mode split, which explains why the energy consumptions in urban transport and travel remain high in some western countries.

Due to the fact that urban planning, land use planning, and regional development planning are formulated by different bodies, while the spatial planning and transport planning are in the charge of different departments in China, there is a weak horizontal or vertical linkage, which greatly weakens the integrity of the planning. What is more, the compilation process of regional planning still involves strong concept of planned economy. As is shown in Fig. 9.1, weak control over regional planning shall lead to high vehicle-kilometer and energy consumptions.

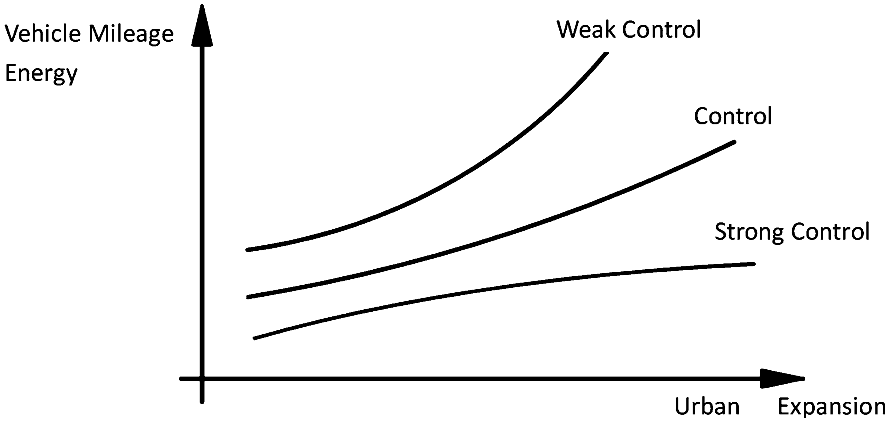


Fig. 9.1 Urban expansion, planning control and energy consumption

In addition, some regional planning concepts need further deliberation. In regional planning, the typical spatial organization form of urban system, which features simple endocentric construction with multiple satellite cities or towns, as is shown in Fig. 9.2a, b is often adopted, with the expectation that the travel may generate mainly within the areas of cities and towns.

However, given the situation that the present development of regional towns and villages is mainly dependent on the highway network (see Fig. 9.3), people tend to rely on cars more. As a result, arbitrarily, the travel scattered at the entire regional space, as is shown in Fig. 9.3, in a disorderly state.

On the premise that disorderly travel has taken shape, it will be a difficult and arduous task to reorganize the regional spatial structure and transportation system (see Fig. 9.4). What the regional spatial planning strategy aims at is guiding the regional trips towards a more orderly direction.

In our opinion, a reasonable urban development mode in China should be the corridor development model that combines with the urban rail system or regional transit system, as is seen in Fig. 9.5, where spatial integration and control of car use are conducted so as to fulfill the target of energy saving, as the spatial development of Copenhagen's finger plan (Cervero 2007) (Fig. 9.6).

The 2007 annual report on sustainable transportation development in the central cities of China, proposed to replace former urban–rural transport development mode, which now focused merely on highways, with the integration of urban and rural passenger transport. In quick response, Chengdu City conducted in time the reform of the transport management system; with a basic transit system established which could cover all the suburban areas, and a 70% coverage rate to key peripheral towns (Lu 2008). Similarly, Shaoxing City, in Zhejiang Province also started to establish a new transit network, which would be convenient, clear and orderly, and would enjoy the mutual connection and resource sharing between urban and rural areas (Wang 2007a).

It should be emphasized in the planning that the regional transit network should fit in the regional spatial structure. Suppose transit adopted the corridor mode,

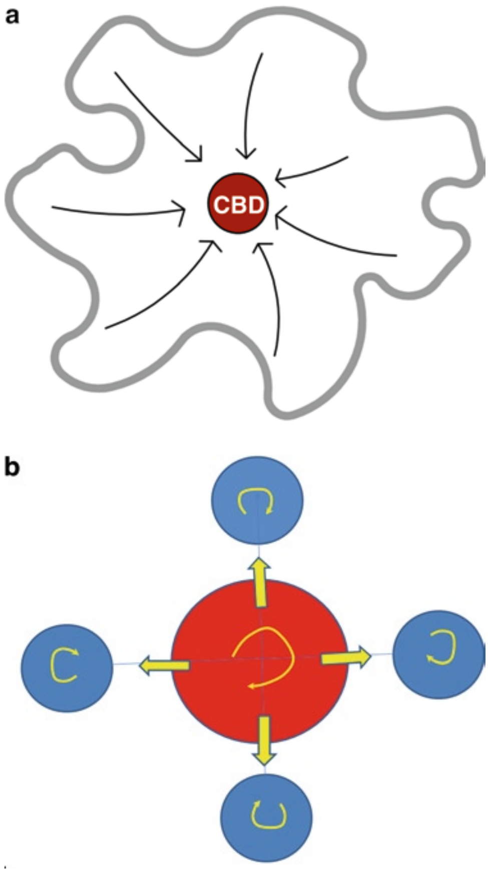


Fig. 9.2 (**a**) Endocentric structure (GTZ) (**b**) Satellite town model

while the regional spatial structure maintained the grid road pattern, it would quite likely encourage car travel. As is shown in the contrast between the Grand Stockholm area and the San Francisco Bay Area, which Robert Cervero conducted, although both areas possessed almost the same size of regional metro systems, cluster development was rarely found in the proximity of the Metro Stations in the Bay Area. Generally, the car travel mileage per work day of a typical Bay Area resident stood at 2.4 times that of a Grand Stockholm resident, and the average travel distance of residents in the Bay Area and Grand Stockholm stood at 44.3 and 18.4 km, respectively (Cervero 2007).

In addition, only when the adjustment to the regional spatial structure fits into the planning for employment and residences can our target of low-carbon urban development come true. Guided by the traditional central place theory, many residences move out to the peripheral suburban areas, despite the job locations remaining unchanged. As a result, the regional travel trips may take on the feature of tide flow and long distance. Take Beijing for example. In 2005, the travel distance of Beijing

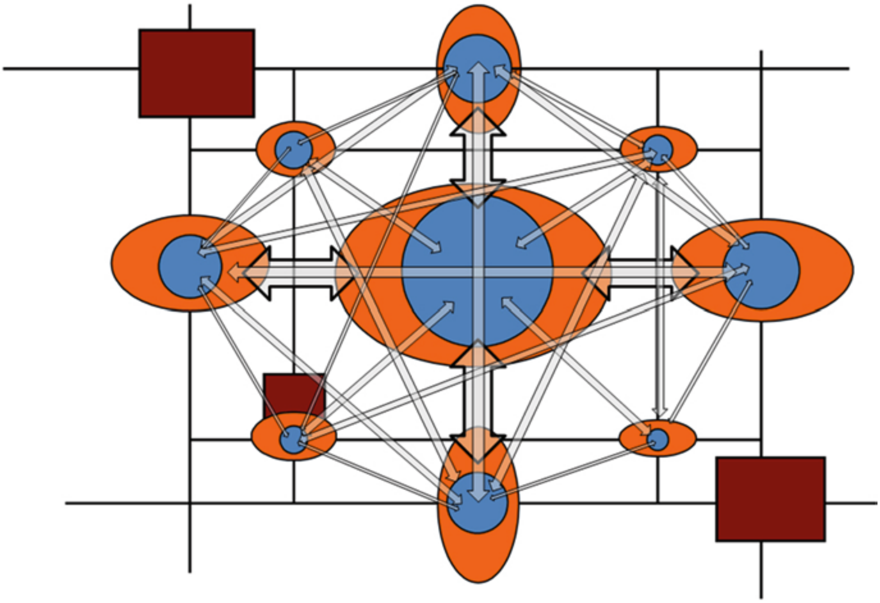
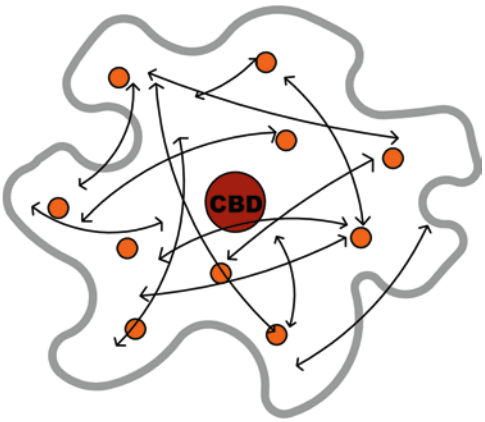


Fig. 9.3 Regional spatial structure and road network

Fig. 9.4 The flow of traffic (GTZ)



residents reached 9.3 km per trip (excluding walking), up 16.25% from 2000. The highest passenger flow ratio between the two directions of Shanghai metro line No.1 at peak time once reached 6.7:1 (Fig. 9.7). It is imaginable that once the incomes of the employees who live in the suburbs, or even outer suburbs are increased, there will be a sharp and amazing change in their individual motorization level.

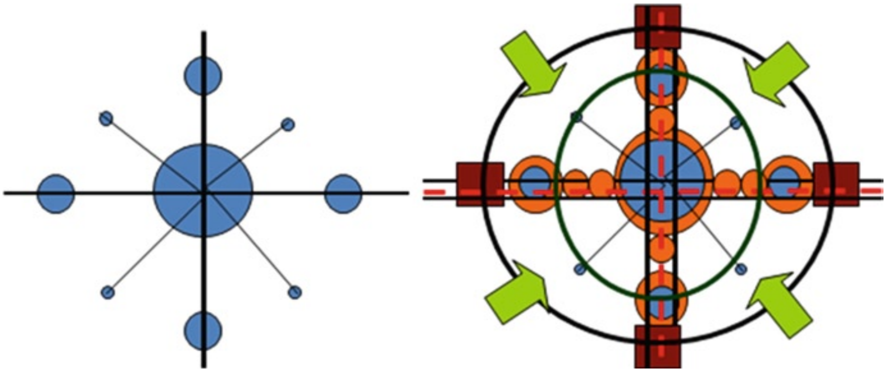


Fig. 9.5 From satellite town to corridor development

Fig. 9.6 Copenhagen finger plan

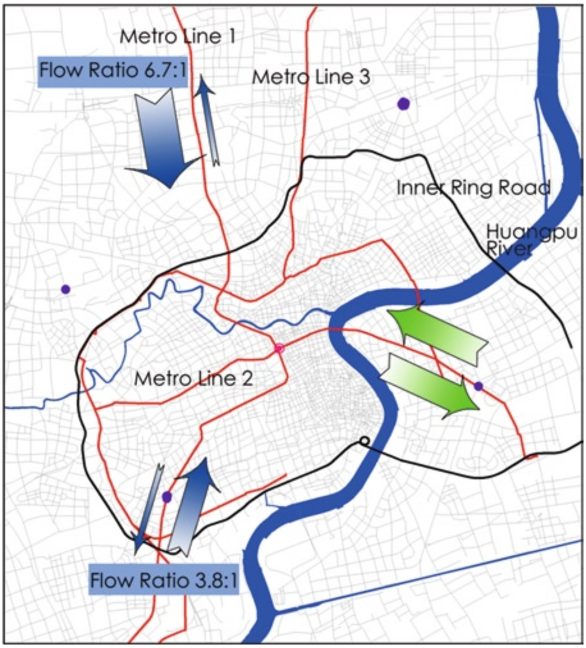


Fig. 9.7 Comparison of bi-direction passenger flow of rail transit in Shanghai

It has been verified that the job-housing balance of a city and its functional self-balance, which remained the emphasis of traditional planning theory, cannot reduce its reliance on cars. Instead, a highly-efficient transit system should be adopted to connect effectively the cities and towns so as to form regional balance. For instance, Stockholm enjoyed a lower car use rate than the famous British New Town Milton Keynes, which laid great emphasis on being self-contained and balanced, while at Milton Keynes a majority of its employed population worked locally, about three fourths of whom commute by car, and merely 7% takes the transit system (Cervero 2007).

9.4 Low-Carbon Urban Spatial Structure Under Master Planning

Firstly, let us consider the urban density. More and more researches have proved that a city may realize compacted development through density control so as to reduce travel, and fulfill the target of low-carbon development. As is shown in Fig. 9.8, all cities in the world, where car travel is taken as the dominant means of transport, energy consumption remains high.

Although the past several decades have witnessed a grand success of strict urban density controlling in China, recently, as land economy is taken as a shortcut to great fortune, this traditional tool seems to have lost its previous function. An optimistic

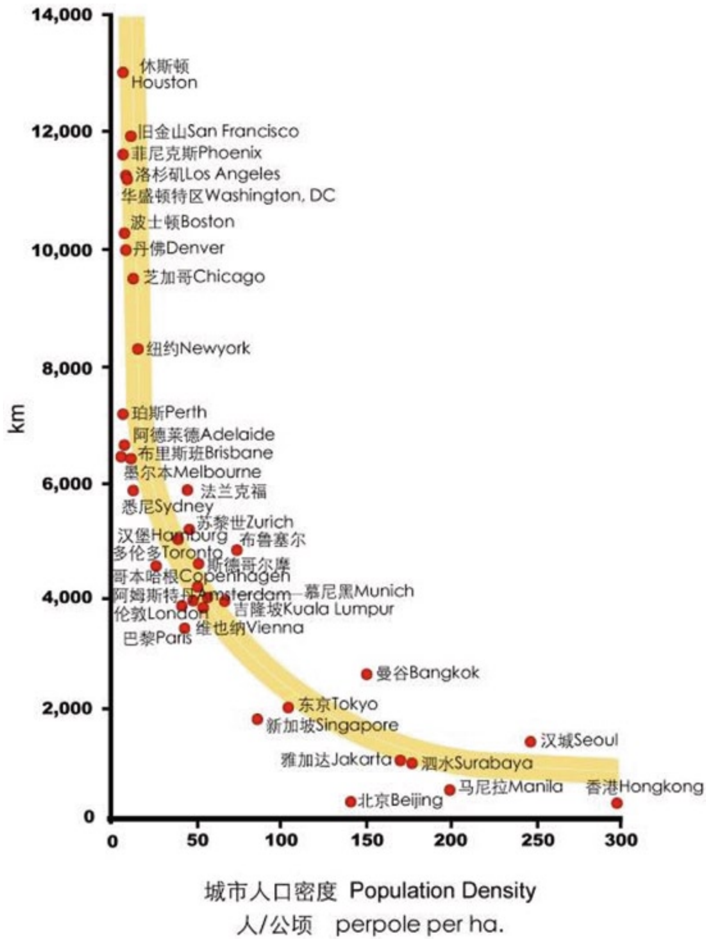


Fig. 9.8 Urban density and vehicle-kilometer

bias in population projection (there is uncertainty in population projection), under the circumstance that the density conforms to the standard, has expanded greatly the urban land use scope, hence resulting in the physical decreasing in urban density. Since 2003, the national average of urban construction land has exceeded the upper limit prescribed in the <Standard for Classification of Urban Land and for Planning of Constructional Land> (120 m^2 per capita) (Wang 2007b).

Urban boundary is used to control urban sprawl in China. In 1994, Beijing Municipal Government granted an official approval to Beijing Municipal Commission of Urban Planning for the <Application for Carrying out Forestation on the Urban Planned Greenbelts>. This choice, though influenced by the Garden City Theory, did not go ahead as the planners scheduled. As of May 2003, more than 30 real estate projects had been completed in Beijing's greenbelts (Xueyan LI 2002).

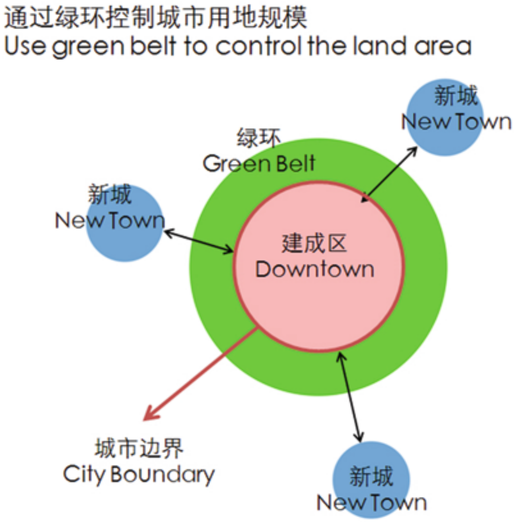


Fig. 9.9 Greenbelt and satellite town

Due to uncertainty of the population growth and urban development, the growth control over greenbelts allows the periphery areas a tendency to develop into New Town or Satellite City. Isolated from the centric city with even bigger space distance, the New Town has difficulties in organizing public transit in Fig. 9.9. In addition, given the regional development mode that focuses on the highway network under weak control, which we just discussed above, travel by car will be boosted.

Concentrating on the new development around the public transit hub, the transit corridor oriented space expansion mode, separated by green wedges, not only helps organizing transit and realizing the controlled compact sprawl, but also allows a development along the corridor by sections and sequences, and in combination with the actual demands of urban development.

Secondly, the spatial form of a city, to a great extent, depends on its transportation system. As certain urban spatial structures need corresponding transportation systems, the formation of the spatial structure of a low-carbon eco-city requires a supportive green transportation system. In fact, transportation system has been an indispensable part of the urban spatial structure system ever since.

It is widely accepted that the general rule of transportation and land use planning of sustainable development is to reduce travel demands and travel distance, advocate walks, cycling, public transit and restrict cars (The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) 2005). Our government has brought out the state policy that priority shall be given to the development of public transit, but it should be made clear that the priority for public transit shall be granted to the important transportation corridors first, since it might be difficult to achieve the quality of public transit service everywhere in the city (Fig. 9.10).

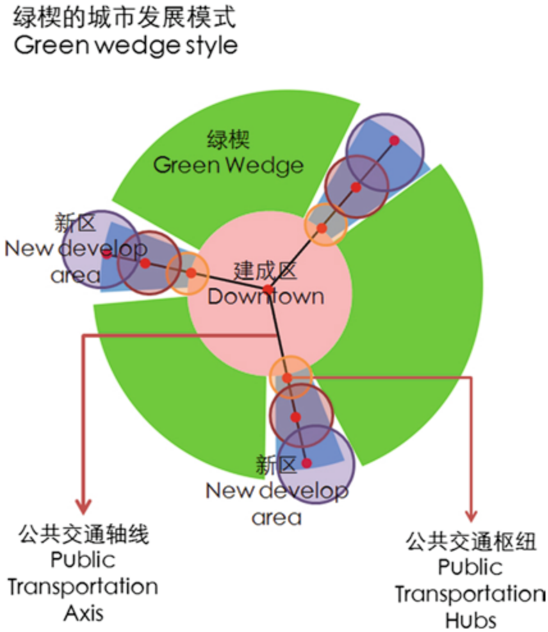


Fig. 9.10 Public development axis with *green* wedge

In allusion to the current urban development in China, we hold that the construction of a city should, first and foremost, be friendly to pedestrians and cyclists, strive to develop high performance public transit, and meanwhile improve the city image and control the growth of private cars. Frankly speaking, during the process of urban spatial planning and transportation planning, the priority to the considerations shall be given in the following order:

POD > BOD > TOD > XOD > COD

The first consideration shall be on the creation of good walking environment while the second, cycling-oriented development. Based on them, the third consideration will fall on the transit-oriented development, and what follows will be the image improvement project and the growth of car traffic.

In the entire transportation constitution, the focus should be mainly on cycling. In Netherlands, over 30% of all travel trips, and about one fourth of the travel trips to the metro stations are by bike (Cervero). Although bikes are also widely used in Shanghai, people who ride a bike to the metro station for transfer, accounts for merely less than 10% of the total number of metro passengers (Department of Urban Planning 2007). In China, a good number of cities either have such plans or are under way of metro system construction. As is known to all, the metro line construction needs enormous investment. If the metro network can be combined with the cycling system, the catchment area of the metro may be expanded greatly, resulting in a smaller scale of the metro system and a saving of funds and resources.

Rarely seen in the world, bike travel plays an important role in the major Chinese cities. Chinese cities must promote bike travels and especially strive to maintain the environment for the same in the urban spatial planning (such as small-scale neighborhood, mixed land use, etc.), rather than merely provide bike lanes. Giving up bikes is equal to giving up the future of sustainable development in Chinese cities.

Finally, emphasis will be laid on three important principles of land use planning for low-carbon cities.

9.4.1 The Mixed Land Use Aimed at Short Distance Travel

Short distance travel can only be realized through the functional diversity and the mixture of multiple functions in land use. Mixed land use may encourage public transit. In the research on 59 large-scaled suburban office development projects in the US, Robert Cervero found that for every 20% increase in the share of floor space that is devoted to retailing or business activities, there is a 4.5% increase in the share of trips by vanpool or public transit.

It is to be noted here that functional partitioning is still used in the urban master planning, which may lead to a misinterpretation that every functional partition has its individual land use. It is also notable that the mixed land use is aimed to increase short travel. As is shown in Fig. 9.11, seemingly land mixture, it is not sure that the long distance travel from one's residential place to work place, can be avoided. Thus an advocate of the concept of "effective mixture" shall be made, especially when it is based on the reduction to the long-distanced work travels.

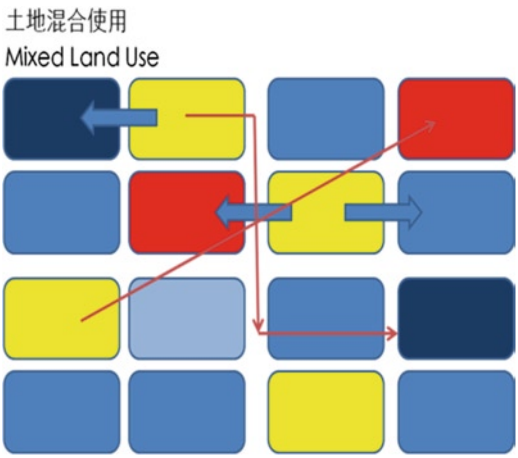


Fig. 9.11 Mixture of land use

9.4.2 Friendly Block Scale for the Use of Pedestrians and Cyclists

In terms of the urban block scale, the construction mode of big neighborhoods, or Wide Street in China, resembles more car travel-oriented communities. There has been an ever-lasting debate on reasonable block scale. Research in the U.S. has shown that an American's daily walking distance is quite limited. In contrast, Chinese residents on an average walk further than the Americans every day. As a survey in Beijing shows, the average transfer distance for bus at Beijing is more than 350 m, 16% of the passengers walk more than 1 km, and more than 30% over 500 m. Bus passengers may spend 7.95, or 8.41 min, respectively to reach either end of their bus stops (530–560 m or so) on too long walking distance, which, without doubt, is associated with the overlarge block scale and less dense public transport networks.

As is shown in Fig. 9.12a, the density of city street network may change with the distance to the city center. Similarly, the block scale should changes with its distance to the city center. The farther it is from the city center, the bigger the block scale will be. However, the scale should not be too big. When the distance to the city center reaches a critical distance, the land use should be reorganized to build a new activity center relying on the public transit hub, and plan a friendly block scale for walking and bike travels, as is suggested in Fig. 9.12b.

9.4.3 Determining the Development Intensity with the Accessibility Level of the Public Transit

In the urban master planning, once the transportation mode split and transportation network are determined, whether the accessibility of public transit to different areas of the city is strong or weak shall be established accordingly. The transit-oriented urban structure encourages the combination of the public transport hubs, and the urban or regional centers which are concentrated by the public purpose projects. We are to transfer the urban structure from under the leadership of the traditional Central Place Theory to the Multi-polar Network Nesting Structure. However, in the current phases of master plan and regulatory plan, either the location of the city activity centers, or development intensity are determined at random, in ignorance of the importance of taking the transit accessibility as the basis, and the possibility of encouragement of high energy consumption travel means or even severe traffic jam. Therefore, in relevant studies, we put forward the indicator of "spatial coupling consistency"(Pan and Ren 2005) which was well expressed in the Cloud Nine Shopping Mall case, and has led the areas around Zhongshan Park into an important district center in Shanghai very soon with the introduction of two metro lines.

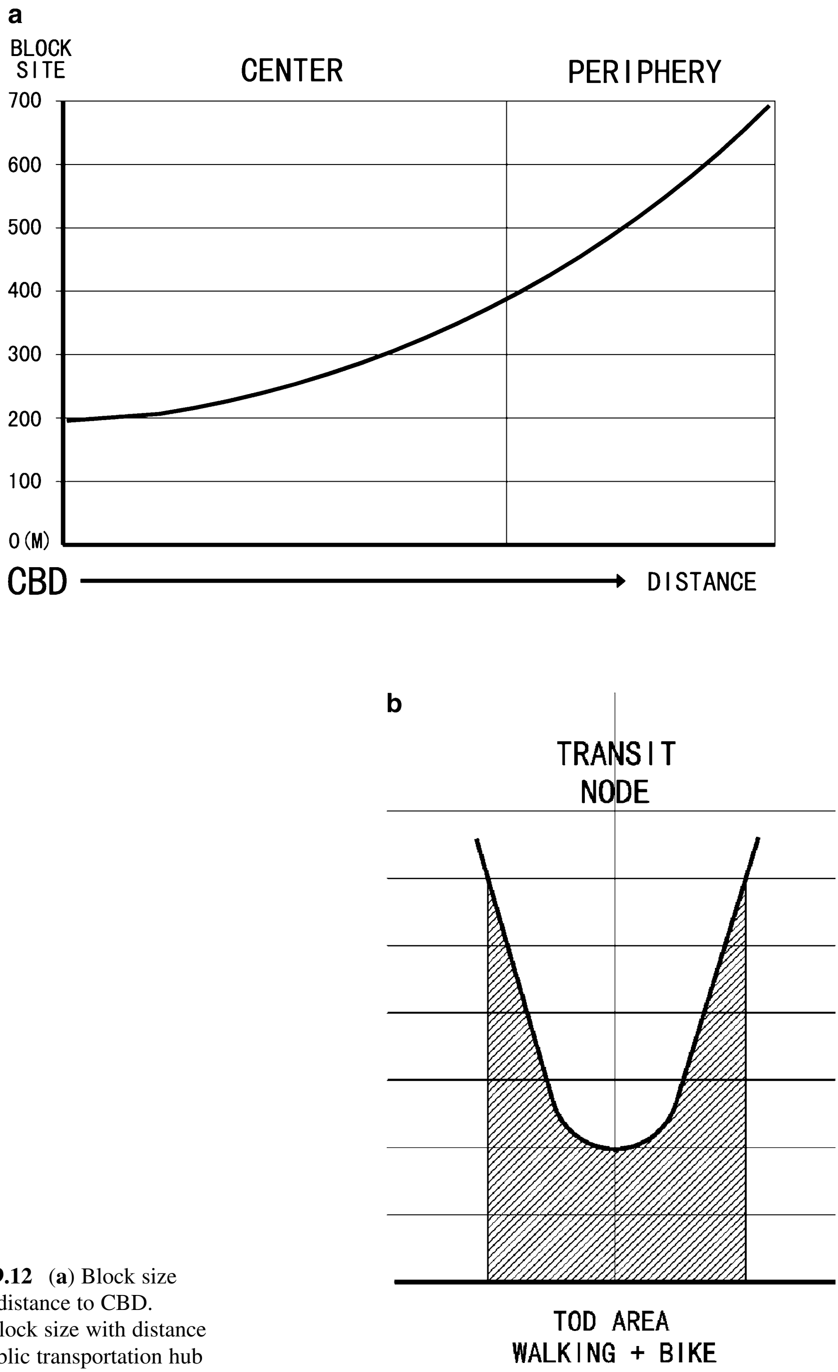


Fig. 9.12 (**a**) Block size with distance to CBD. (**b**) Block size with distance to public transportation hub

9.5 Residential Area Planning and Low-Carbon City

In the coming three or five decades, more rural populations will migrate to cities, an indication that cities need not only more jobs but also infrastructure of bigger capacity. Meanwhile, there will be a demand for more residential area, with the residential area per capita increased from 13.5 m^2 per capita to 26.1 m^2 per capita from 1998 to 2005, and the total amount of residential construction constantly rising up. The ever-increasing housing demand shall exert significant impact on the urban structure, urban form and the low-carbon city development.

In 1994, the <Code of Urban Residential Areas Planning and Design>(GB50l8-93) specified the scale and development intensity for all kinds of residential developments (low-rise, mid-rise and high-rise), avoiding the waste in land use and guaranteeing certain compactness of the urban development, while the Climate Zone Division Code put forward the minimum requirements for housing in the respect of sun exposure. In addition, some provisions were offered to provide standards for supporting public facilities, playing a positive role for improving the urban living standards in China.

In comparison with the target of low-carbon city, two main problems exist in current residential area design in China, of which one arises due to the insufficiencies in the <Code of Urban Residential Areas Planning and Design>, while the other exists because of the problem with the residential area planning and design itself.

Design Code, based on which the supporting public facilities to the current urban residential area planning are equipped, greatly lags behind the current demand for urban residential space. The Code also fails to give instructions on aspects such as the flexibility of the public facilities and the regional differences. For example, we hope people will send their child to the neighborhood school provided according to the neighborhood concept in residential area design. But people chose the better school, at a greater distance. There is less concern about the connection between the school and the public transport service, so that there are too many cars in front of the school (Fig. 9.13).

The parking space ration, as the Code provides, shall be no less than 10% of the apartments, but no upper limit is given. Besides, the code also stipulates that the layout of community parking lot or garage shall be convenient for the residents to use, with a service radius of no more than 150 m. Without doubt, these provisions are based on encouraging car using, hence not conductive to promoting energy-saving and low-carbon travel means.

In addition, there are some questions which need to be discussed in the detailed plan of residential areas.

Firstly, the scale of the residential areas is increasing continuously. During the urban construction process, the development of big blocks enjoys some advantages, such as the integral organization of the transportation system, large green space, etc. The specific boundary and gated management of the communities make the stops of the public transit only outside of the communities, which causes great

Fig. 9.13 Full of car in front of a school

inconvenience to the residents. However, to some extent, big blocks encourage car travel and reduce walks and bike rides. As a result, a multitude of traffic flow in the residential areas flood the main streets from the community entrance or exit, causing traffic congestion, and increasing energy consumption and gas emission (Fig. 9.14).

Secondly, unitary land function works out huge residential communities jointly with big blocks. Designed for residential living, such communities usually give few considerations to the mixed land use and the provision of enough jobs for a certain area, causing vast traffic and long-distance commute, leading to urban traffic congestion and increasing traffic energy consumption. Take Anting New Town for example (Zhai 2006), covering 5 km^2 in total, and 2.38 km^2 for the first phase project. The New Town sees significant improvements in energy saving, building and waste drainage, etc., in comparison with the traditional housing, thanks to the adoption of some advanced energy-saving and environmental-protection technologies. However, unitary in land use, the New Town lacks necessary service facilities and jobs, extending commute traffic of the residents. The public transit is inconvenient, since it usually takes 1½ or 2 h or so to commute to the downtown area by bus. Considering the difficulty for the public transit to reorganize their lives and schedules, it is more convenient to use cars as the New Town is close to the entrance of a motorway. Most residents choose to take taxis or drive private cars for commute. Therefore, the energy saved through the advanced building technologies are canceled out by the energy further consumed in the transportation sector.

Finally, in low-density suburban residential areas, land price and development intensity is lower than the centric areas; some suburban areas have witnessed low-rise and low-density detached houses and villa communities. Meanwhile, given the operation economy, public transit network is usually quite loose in suburban areas. Necessarily, the development of low-density housing and loose transit network will

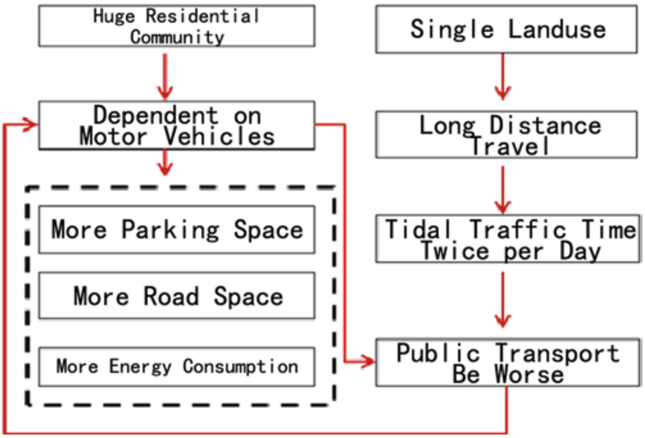


Fig. 9.14 Huge block and its impact on energy consumption

lead to a series of issues such as the big block, low percentage of public transit travels, high percentage of private car rides, etc. In addition, excessively low development density may exert great influence on the intensive land use and the use of car as well.

9.6 Suggestions for Urban Planning Reform Under the Target of Low-Carbon City

To sum up, under the target of building low-carbon cities, some issues covering different aspects exist in current urban planning in China, worthy of further reflection and studies. Based on the analysis aforesaid, we hereby push forward some policy suggestions as follows:

- To take effective control of the disorderly travel and reduce transportation energy consumption, it is a must that we should combine the urban system planning with the regional public transit system, and establish regional corridor for the development of public transit.
- Effective mixture in land use should be encouraged to avoid huge or unitary function partitioning and improve the percentage of short travels.
- In the future, the structure of low-carbon Chinese cities shall be based on the trunk public transit system and be friendly to the cyclists, giving up cycling means giving up the future of Chinese cities for more sustainable development.
- To form the urban spatial structure, the theoretic basis shall be transferred from the Central Place Theory to the Multi-polar Network Nesting Theory. The construction of large public facilities shall be combined with the public transit hubs, while the spatial coupling consistency may be adopted to measure up the coordination between the urban public centers and public transit hubs.

- The development intensity of the urban blocks shall depend on the accessibility of the public transit, a basic basis to determine the indicators for the regulatory planning.
- During the urban planning process, five 5D principles as follows shall be persisted in: namely POD > BOD > TOD > XOD > COD.

References

Cervero R (2007) The transit metropolis. China Architecture & Building Press, Beijing

Department of Urban Planning (2007) Survey Report along Metro

Huang H (2005) Cutting energy consumption: 20% is not easy. Outlook 43:20–21

Jin S (2008) WWF starting the China low-carbon city development project. Environ Prot 2A:22

Lu HP (2008) The Annual Report on Sustainable Central City. People's Transport Press, Beijing

National Bureau of Statistics of the People's Republic of China (2007) China statistical yearbook 2007. China Statistics Press, Beijing, p 1028

Pan HX, Ren CY (2005) Spatial match of urban rail networks and urban activity center. Urb Plan Forum 4:76–81

Sustainable Development Strategy Study Group (2003) Chinese Academy of Sciences

The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) (2005) Sustainable transport: a sourcebook for policy-makers in developing cities. China Communications Press, Beijing

Wang J (2007a) The integration process of the urban and countryside transit in Shaoxin City. Trans Bus China 7:65–67

Wang J (2007b) Assessments and countermeasures on the standards of urban construction land, in urban planning and design. Tongji University, Shanghai

Xueyan LI, X.L. (2002) The unexpected appearance of the housing development in the Green Belt Area. Beijing Daily, Beijing

Zhai Y (2006) Estate or Town? The supporting facilities in Anting Newtown are put to the test by the property owners. China Business News, Shanghai

Zheng ML (2005) The principle of urbanization based on economic restructure. Stat Decision Making 5:96–98

Zhu C (2007) Holding an objective view of the grim situation of China's energy conservation & pollution reduction. Sino-Glob Energy 5:1–6

Chapter 10
Transport and Energy: The Indian Perspective

Sanjivi Sundar and Akshima T. Ghate

10.1 Energy Consumption in the Indian Transport Sector

Increasing population, economic growth, and structural shifts in the Indian economy have led to an increase in the transport demand over the last three decades. In the 1990s, as India's economy expanded by 6–7% a year, transport demand grew by about 10% annually. The rate of growth, however, varied across modes, reflecting structural changes in demand for different modes (ADB 2007). Road transport emerged as the dominant mode for the movement of both passenger and freight traffic in the last three decades and the share of railways in both passenger and freight traffic declined steadily. The growing demand for road transport accompanied by rapid urbanisation and motorisation has led to heavy dependence of the transport sector on fossil fuels and has raised serious concerns about energy security and the state of the environment.

The sector is primarily dependent on petroleum products for meeting its energy requirements. The transport sector was the second largest consumer of commercial energy after industry and accounted for 18% (36 MTOE) of the total commercial energy consumed in the country in 2004/05 (204.1 MTOE). Transport sector also had the largest share (35%) in the consumption of petroleum products in 2004/05 (TERI 2009). About 98% of the energy needs of the sector are met by petroleum products and the remaining by electricity. Although the consumption of petrol and diesel has grown at a rate of 7.3% and 5.8% per annum, respectively, between 1980/81 and 2004/05, the use of alternative fuels in the transport sector has remained insignificant (Planning Commission 2006).

S. Sundar (✉)
The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodi Road, New Delhi, India
e-mail: ssundar@teri.res.in

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10.1.1 Road, Rail, and Water Transport

Even as the share of railways in the transportation of both freight and passengers in India has declined sharply over the years, the share of coastal shipping and inland waterways has remained static and marginal. The National Transport Policy Committee (NTPC) set up by the Planning Commission in 1978 had advocated a share of 72% to rail and 28% to road in freight transport on the basis of resource costs, break-even points, and fuel costs (Planning Commission 1980). However, the recommendations of the Committee were not implemented and the share of the railways in passenger and freight transport declined from 27.8% and 61.9%, respectively, in 1980–1981 to 12.9% and 38.6%, respectively, in 2004–2005 with the share of road transport increasing correspondingly. In 2004–2005, the share of road transport was 86.7% in passenger movement followed by railways and airlines with a share of 12.9% and 0.4%, respectively. In the case of freight movement, roads again emerged as the dominant mode with a share of 61.2% followed by railways (38.6%), airlines (0.02%) and water transport (0.2%) (Planning Commission 2007) (Figs. 10.1 and 10.2).

India has a coastline of about 7,517 km and inland waterways of about 14,500 km, and these offer an excellent opportunity for large-scale water transportation. However, coastal traffic has a share of just 80 million tonnes or 9.4% and Inland Water Transport (IWT) a share of a mere 0.2% of the total freight movement within the country. The potential for water transport has not been adequately exploited in India.

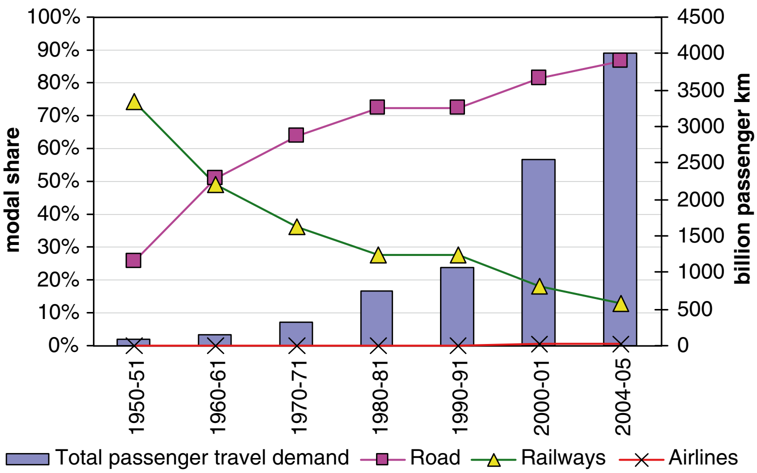

Fig. 10.1 Trends and modal shares of different modes in passenger traffic. *Source*: Planning Commission (2007)

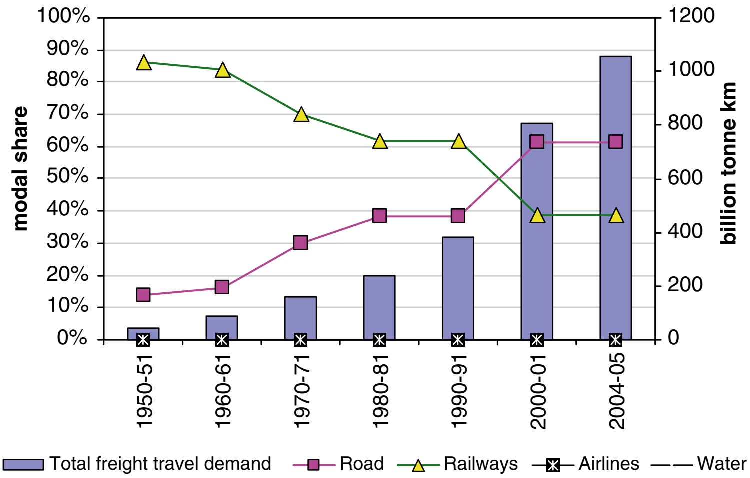

Fig. 10.2 Trends and modal shares of different modes in freight traffic. *Source*: Planning Commission (2007)

10.1.2 Urban Transport

The Urban Transport scenario in India captures the impact of growing urbanisation, increasing per capita income and rising aspirations on transport demand, motorisation, and energy consumption. India is rapidly urbanising. There are already 35 million plus cities and the number is projected to increase to anywhere between 80 and 90 by 2030 and around 120 by 2050. Due to the lack of integration of land use planning with transport planning, these urban agglomerations have become poorly connected urban sprawls resulting in an exponential increase in personalised motor vehicles, reduction in the use of non-motorised transport, growing dependence on fossil fuels and increase in air and noise pollution and road accidents.

Figure 10.3 shows the increase in the total number of registered vehicles in India during the period 1980–2006. The number of registered motor vehicles in India has risen from 4.5 million in 1980 to 89.6 million in 2006, an increase of about twenty times. Two-wheelers (i.e. motorcycles and scooters) and cars together accounted for about 85% of the total number of registered vehicles in 2006. The larger cities have a significant share of the total registered vehicles in the country. Twenty-three metropolitan cities, each with a population of over 1 million, accounted for about one-fourth of the total vehicles registered in 2006. As indicated in Fig. 10.4, about 41% of the total cars and 23% of the total two-wheelers in the country were in these metropolitan cities in 2006 (MoRTH 2009).

The public transport systems in Indian cities have not been able to keep pace with the increasing demand for urban transport. Inadequate and poor quality of

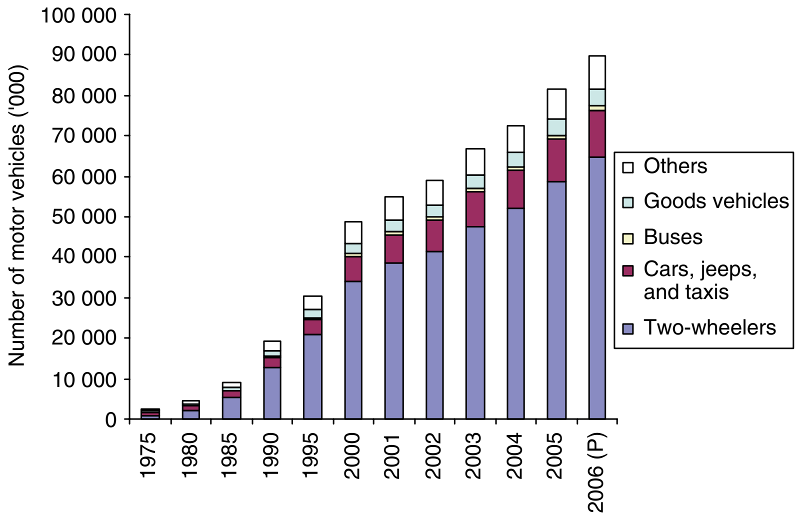

Fig. 10.3 Trends in total number of registered motor vehicles in India. *Source*: MoRTH (2009)

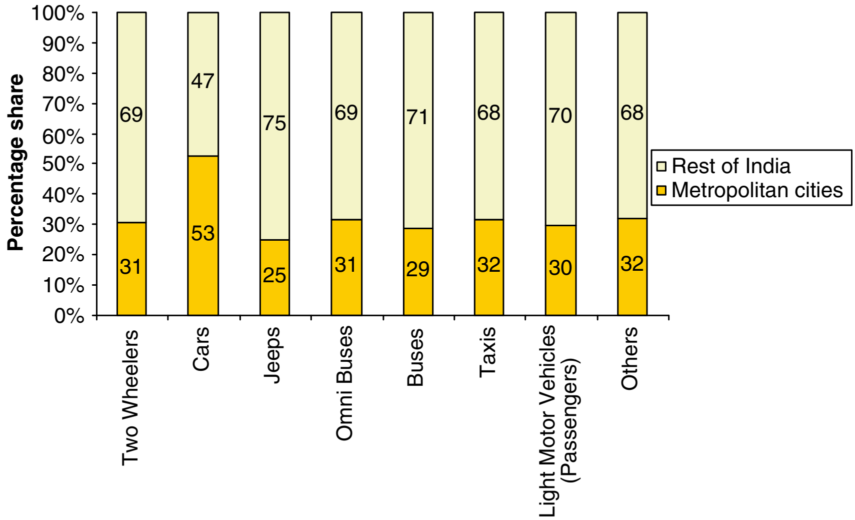

Fig. 10.4 Comparison of share of vehicles registered in metropolitan cities with the rest of the country in 2006. *Source*: MoRTH (2009)

public transport have encouraged the use of personalised vehicles. In most cities, dedicated public transport is absent and a combination of paratransit modes such as sport utility vehicles (SUVs), jeeps, three wheelers, etc. act as public transport. Dedicated city bus services are known to operate only in 17 cities and metro rail transport exists only in 4 of the 35 million plus cities (Singh 2005). The share of buses in the total vehicle fleet of the country has declined from 11% in 1951 to 1.1% in 2001 (MoRTH Various Years).

10.2 Impact of Current Trends in Transport Growth on Fuel Consumption and Energy Security

The growing dependence on road transport for movement of freight and the increasing reliance on personal transport to meet urban mobility needs have contributed to an increase in the consumption of petroleum products. As pointed out earlier, the sector is already the second largest consumer of energy in the country. If the current trends continue, the sector's share in India's total commercial energy consumption could grow from 18% in 2001 to 31% by 2031 (Fig. 10.5), and the share in total petroleum product consumption could increase from 36% in 2001 to 64% in 2031 (Fig. 10.6) (TERI 2006). India is currently importing about 76% of its oil requirements of 141 million tonnes and the extent of imports could increase to approximately 90% of about 730 MT by 2031 (TERI 2006) unless immediate and effective action is taken to reduce the growth in the consumption of petroleum products by the transport sector. Failure to do so will severely undermine India's energy security.

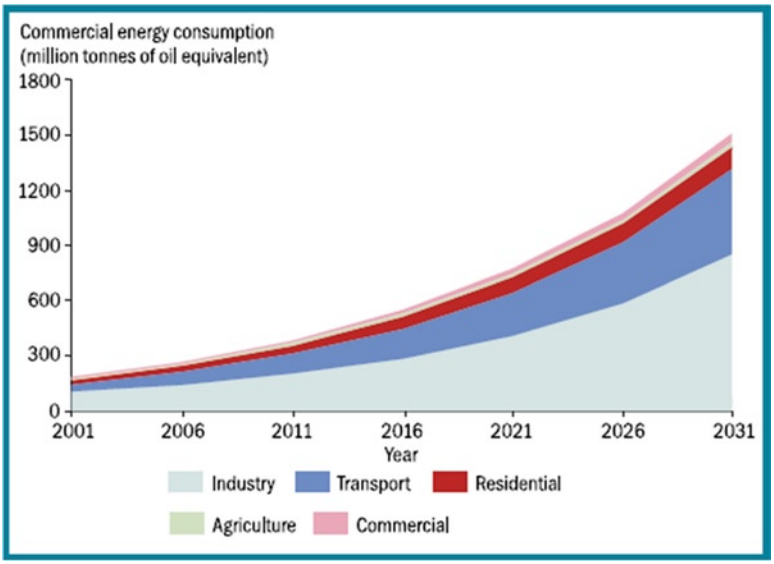

Fig. 10.5 Sector-wise consumption of commercial energy in India in the BAU scenario. *Source*: TERI (2006)

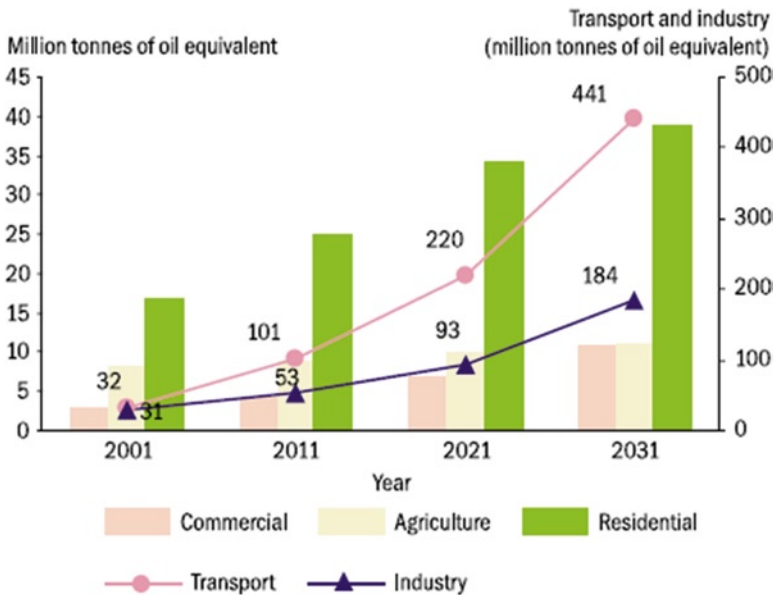

Fig. 10.6 Sector-wise consumption of petroleum products in India in the BAU scenario. *Source*: TERI (2006)

10.3 Key Policy Initiatives in the Transport and Energy Sector

10.3.1 Integrated Development of Transport Sector

Efforts to promote and achieve efficient modal mix date back to 1978 when the NTPC was set up to formulate a National Transport Policy for the country. The recommendations made by the Committee in 1980 highlighted the need for an optimal mix of transport modes and a subsequent investment policy, based on comparative costs, to achieve the recommended modal mix. However, for a variety of reasons, including the lack of an integrated approach, the recommendations of the Committee were not implemented. The intermodal shares of road and rail continued to be skewed in favour of road transport. In 2001, the Planning Commission appointed a *Task Force on Integrated Transport Policy* with the aim of formulating a policy that encourages competitive pricing of and coordination between different modes and provides for an integrated, cost-effective and energy-efficient transport system. The report of the Task Force outlined the broad directions in which each mode of transport should be developed for realising the optimal inter-modal mix as well as freight-passenger mix.

In addition to the initiatives taken by the Planning Commission to formulate an integrated approach to transport, sector-specific initiatives have also been taken by the concerned ministries to remove bottlenecks in the sectors concerned, improve their efficiency, and enhance their share in the movement of passenger and freight traffic.

10.3.2 Increasing the Share of Railways

With an aim to remove the capacity bottlenecks in the critical sections of the railway network in the country, the *National Rail Vikas Yojana* was announced by the government in 2002. The Yojana (Plan) envisaged massive investments to eliminate capacity bottlenecks on the Golden Quadrilateral and Diagonal stretches to provide strategic rail communication links to ports, construction of mega-bridges for improving communication to the hinterland and development of multi-modal transport corridors. The government also launched the *Indian Railways Modernisation Plan* (IRMP), 2005–2010, which envisaged modernisation of passenger and freight services of the railways.

To meet stiff competition from low-fare airlines and the road sector, the railways have come up with an investment strategy for capacity augmentation. This involves construction of dedicated freight corridors (DFCs) that separate freight traffic from passenger traffic on trunk routes and facilitate the speedy movement of both passengers and freight. A special purpose vehicle, Dedicated Freight Corridor Corporation of India Ltd., has been set up to implement the DFC project of the Indian railways. The railways are also establishing High-Speed Rail in select corridors to compete with airlines.

10.3.3 Improving Water Transport Infrastructure

To give a boost to the development of IWT sector in India, the Government of India formulated the Inland Water Transport Policy in 2001. The policy proposes a number of incentives for private sector participation and recommends various policy measures for accelerating the growth of IWT.

In the Port sector, the National Maritime Development Programme (NMDP) was launched by the Government in 2005 to implement specific initiatives and schemes for the development of ports. The program envisages projects in Major Ports in India such as construction/upgradation of berths, deepening of channels, rail connectivity projects, equipment upgradation/modernisation schemes, etc. that would help to augment port capacity and improve efficiency and productivity.

10.3.4 Promoting Energy Efficiency Within the Road Sector

Recognising that improving energy efficiency within the roads sector is critical, the Government of India has been taking several steps to encourage fuel efficiency in road transport. The national permit system for goods vehicles has been streamlined together with e-payment for the collection of composite fee to facilitate barrier-free movement of vehicles across the country. A scheme to assist the states to set up model inspection and certification centres to ensure fitness of in-use vehicles has been drawn up to improve the fuel efficiency of in-use vehicles. Mandatory fuel economy standards are being developed for new vehicles and are expected to be notified soon. In addition to this, emission norms are being tightened throughout the country in line with the Auto Fuel Policy, 2003. The Policy gives a roadmap for progressively tightening vehicular emission norms and upgrading fuel quality over a period of time. In line with this policy, Bharat Stage (BS) IV emission norms (Euro IV equivalent norms) will be implemented in 13 mega cities and BS III emission norms (Euro III equivalent norms) in the rest of the country with effect from 1 April 2010.

10.3.5 Initiatives in Urban Transport Sector

The planning and management of urban transport falls within the jurisdiction of state and city governments who lack the expertise and funds to plan and deliver sustainable low-carbon transport systems that address the mobility needs of their citizens. No guidance or funding was provided by the national government to the States and city governments in the planning and delivery of urban transport systems. In 2006, the Ministry of Urban Development (MoUD) for the first time formulated a National Urban Transport Policy (NUTP). The Policy called upon city governments to draw up urban transport plans that:

- Focussed on people and made an equitable allocation of road space
- Ensured integration of land use planning with transport planning
- Accorded priority for the use of Public Transport
- Provided for investments in public transport and non-motorised modes
- Promoted intelligent transport systems (ITS), cleaner fuel and vehicle technologies for cities
- Built capacity to plan and deliver sustainable urban transport systems.

In December 2005, the Government of India had launched the *Jawaharlal Nehru National Urban Renewal Mission* (JNNURM), which aimed to rejuvenate 63 cities and establish a model for urban reform and rejuvenation. The Government of India agreed to fund transport projects from the Mission provided cities came up with Comprehensive Mobility Plans (CMPs) that were consistent with the NUTP. This visionary decision of the Government of India to fund transport projects in Indian cities provided these projects were consistent with the NUTP could go a long way to improve the quality of urban transport in India.

The *National Mission on Sustainable Habitat* of the National Action Plan on Climate Change (NAPCC) announced by the Prime Minister also emphasises promotion and strengthening of public transport systems through various promotional, regulatory and fiscal measures. The Mission lays emphasis on linking urban development with transportation planning to reduce transport demand. The key actions proposed in the mission are:

- Promoting the use of coastal shipping and inland waterways, apart from encouraging the attractiveness of rail-based movement relative to long-distance road-based movement
- Promoting modal shift towards public transport and better urban planning for reducing the need to travel and to shorten travel distances
- Encouraging energy R&D in the Indian Railways
- Introducing appropriate transport pricing measures to influence purchase and use of vehicles with higher fuel efficiency and alternate fuels
- Tightening regulatory standards such as enforcing fuel-economy standards for automobile manufacturers
- Establishing mechanisms to promote investments in development of high capacity public transport systems
- Abandoning of old vehicles to be made illegal and responsibility for handing over the end-of-life vehicle to collection centres fixed on the last owner of the vehicle
- Setting up of a demonstration unit to take up recycling of vehicles, especially two wheelers, which require new techniques
- Setting up a Combustion Research Institute to facilitate R&D in advanced engine design
- Providing tax benefits and investment support for recovery of materials from scrap vehicles

10.3.6 Integrated Energy Policy of the Country

In 2006, an Integrated Energy Policy (IEP) report for the country was released, which provided a broad framework for guiding the policies governing the production and use of different forms of energy from various sectors. The policy propagates demand management in an environmentally and economically viable manner. The policy is an umbrella policy and covers various energy intensive sectors. In the transport sector, IEP suggests improvement in energy efficiency of vehicles and enforcement of minimum fuel efficiency standards for all vehicles. To improve energy efficiency of vehicular fleets, IEP suggests instituting an Efficient Motors Programme that focuses on manufacturers and targets market transformation by providing incentives to supply energy-efficient motors. IEP recommends use of fuel-efficient vehicles such as hybrids in addition to promoting the already existing commercial flexi fuel vehicles.

As is evident from the previous section, the government has undertaken various initiatives to address issues related to transport sector's energy consumption. However, lack of an integrated policy and fragmented responsibilities between ministries/departments dealing with transport have led to slow pace of implementation and sometimes conflict of interests. There are also issues related to the capacities of different agencies to implement policies. Also, at present policies do not provide for any specific interventions or fiscal incentives to effect modal shifts or promote inter-modal connectivity and this has resulted in a uni-modal growth.

10.4 Way Forward

An integrated approach to the movement of freight and passengers to ensure increase in the share of water and rail transport cannot be drawn up unless a new Transport Policy is formulated on the basis of current data and future projections based on that data. A National Transport Policy was last formulated in 1980. Since then, the pattern of production and consumption of major commodities such as steel, cement, fertilisers and petroleum products have changed considerably resulting in a change in transit distances and in the use of transport modes. The pattern of urbanisation and urban transport have changed. Technology has changed. There is, therefore, a compelling need to initiate a new exercise to draw up a national transport policy that takes into account these changes and addresses the needs of 2030/2050.

That integrated policy needs to lay emphasis on promoting the growth and development of coastal shipping and Inland water transportation and address all relevant issues. If necessary, this policy should be underpinned by a Water Transport Act. The policy should also address the following issues to strengthen the *Indian Railways*:

1. Augmenting capacity on high-density corridors
2. Increasing productivity through signalling synchronisation, etc
3. Promoting containerisation of freight and introducing competition in container movement
4. Adopting commercial and customer-oriented practices
5. Modernising the Railway Act to facilitate market interventions
6. Corporatisation of the railways to subject the system to the rigours of the financial and capital markets
7. Establishing an independent regulator for the railways to rationalise tariffs and facilitate private sector participation

Intermodal shift between road transport and other more energy-efficient modes cannot take place unless it is targeted and specifically supported. The Marco Polo programme in the European Union (EU) as modified and improved over the years has resulted in a shift of freight from road transport to water and rail transport in the EU. Similar programmes need to be conceptualised and implemented in India. As per TERI (2006) estimates, a 15% shift of freight movement from road transport to rail transport would result in a reduction in consumption of approx. 190 Mtoe by 2031. Similarly, a 23% shift of passenger movement from road to rail transport would result in a reduction of approx. 100 Mtoe (54%) in energy requirements by 2031. India should aim to increase the share of the railways from the 2001 level of 42% to 60% in freight transport and from 23% to 50% in passenger transport by 2031and make specific interventions to effect this intermodal shift.

Cities need to arrest their current pattern of transportation growth to bring down their energy consumption by adopting the "*Avoid, Shift and Improve*" approach to transport planning and management as articulated by the Bellagio Declaration (May 2009) and advocated by the Asian Development Bank (ADB 2009). The approach focuses on:

- Avoiding the need to travel by reducing travel demand, trip numbers and trip lengths (Avoid)
- Shifting travel to more energy-efficient and environment-friendly modes (Shift)
- Improving the efficiency and sustainability of modes (Improve) (ADB 2009)

Key action areas that cities need to address are:

- Integrate transport and land use planning
- Improve and augment public transport and non-motorised transport systems (in terms of both capacity and quality)
- Discourage use of personal vehicles by using appropriate policy and transport demand management measures
- Ensure efficient movement of traffic by better traffic management including the use of ITS
- Encourage use of clean fuels and technologies
- Adopt mandatory standards for fuel economy in new cars
- Tighten emission standards and ensure adherence to standards
- Promote use of information technology as substitute for physical mobility

Ideally, there should be *one ministry* for transport to deal with all modes of transport. Unfortunately, in India there are as many as four Ministries – Railways, Civil Aviation, Roads, Shipping and Ports, and Urban Development dealing with different transport modes and mode-specific issues and the Ministry of Heavy Industry dealing with automobiles. In the states and cities also responsibility for transport is fragmented between and within departments and agencies. They often tend to function in silos and do not share a common platform to put India's transport sector on a sustainable low-carbon path. If it is not possible to set up an integrated Ministry for transport, there should at least be a *Group of Ministers or senior officials* to look at all transport issues in an integrated manner with the specific objective of making the transport sector energy efficient, environment friendly and sustainable.

International cooperation, technical assistance and capacity building can also go a long way in promoting sustainable urban transport in cities in India and other developing countries. There are several good examples of sustainable urban transport systems in the developed world, examples of successful integration of land use planning with transport planning etc. that the developed world can share with developing countries. Unfortunately, both the bi-lateral donors and multi-lateral financial institutions such as the World Bank and the regional developments banks have focussed their lending on major transport infrastructure projects such as highways, motor ways, bridges, ports, etc. without looking at the impact that these projects might have on energy efficiency, the environment and on sustainability concerns. Lending for infrastructure projects in developing countries has largely been contractor/consultant driven and not guided by the best interests of the recipient countries. This approach needs to change quickly and dramatically and development assistance should focus on promoting sustainable transport systems and solutions.

Global funding that is now available to combat climate change by reducing CO_2 is also not easily available for transport projects. In fact, out of about 1,400 projects that have received CDM funding so far there are only two transport projects. The transport sector, which is a major contributor of CO_2, has not received the attention and funding that it deserves largely because of difficulties in establishing a baseline and in measuring reductions in CO_2. Unless conscious efforts are made to put transport on a sustainable and low-carbon path, even modest targets for CO_2 reduction cannot be achieved. It is, therefore, vital to include transport in the climate change negotiations and include climate change concerns in transport planning, and evolve imaginative and innovative financing arrangements to fund sustainable transport projects. These financing arrangements should factor in co-benefits into the project revenues and also provide for simple arrangements to measure and reward project proponents and funding agencies for CO_2 reduction.

The growth of the transport sector in India has been skewed in favour of road transport resulting in serious concerns about energy security and the environment; the relentless growth in road transport has also raised local concerns such as air and noise pollution, congestion, road safety, etc. Policy initiatives are now being taken to correct this trend and make transport more sustainable. These initiatives must address the issues that have been listed in this paper and be implemented in an integrated manner through appropriate institutional arrangements. These national initiatives must be encouraged, supported and funded by international financial institutions and global funding arrangements.

References

ADB (Asian Development Bank) (2007) Profile of the Indian transport sector. Operations Evaluation Department, Asian Development Bank

ADB (Asian Development Bank) (2009) Rethinking Transport and climate change. Asian Development Bank

MoRTH (2009) Road Transport Year Book (2006–07). Ministry of Road Transport & Highways (MoRTH), Government of India (GoI), New Delhi

MoRTH, (Various Years) Road Transport Year Book (Various Years) New Delhi: Ministry of Road Transport & Highways (MoRTH), Government of India (GoI)

Planning Commission (1980) Report of the National Transport Policy Committee. Government of India, New Delhi

Planning Commission (2006) IEA–Integrated Energy Policy 2006. [A Planning Commission Report]. Planning Commission, Government of India, New Delhi, p 182

Planning Commission (2007) Report of the working group on road transport for the 11th five year plan. Planning commission, Government of India, New Delhi

Singh SK (2005) Review of urban transportation in India. Journal of Public Transportation 8(1)

TERI (2006) National Energy Map for India: Technology vision 2030. Report prepared by TERI for the Office of the Principal Scientific Adviser, Government of India. The Energy and Resources (TERI) and Office of the Principal Scientific Adviser, Government of India, New Delhi

TERI (The Energy and Resources Institute) (2009) The Energy Data Directory and Yearbook (TEDDY2009). TERI, New Delhi

Chapter 11
The Role of Rail Transport for Sustainable Urban Transport

Yoshitsugu Hayashi, Xianmin Mai, and Hirokazu Kato

11.1 Introduction

The share of rail transit system users in Tokyo metropolitan area is more than 50%, while less than 2% in Bangkok in 2009 (Office of Transport and Traffic Policy and Planning 2010). Why such a big difference has been created? It highly depends on the habit of people in travel and the pattern of population density.

Urban form is affected by the mode and layout of transport infrastructures. Among various transport infrastructures, level of rail transit system service is a determinant factor of pattern of suburbanization (Hayashi 2006). The priority and timing of accomplished transport infrastructures have affected the citizens' travel habits. In those mega-cities where the development of rail was ahead of roads, rail-based travel habits of citizens were formed in advance, resulting in avoiding excess reliance on private cars and consequent environmental problems.

In many developing mega-cities, with continuous expansion of urban built-up areas, the growing demand for new transport infrastructures have attracted great attention and large amount of investments of government and foreign aid. Under rapid urbanization, it is of great importance to promote the priority of constructing rail transit infrastructures in these critical stages of development, when their transportation systems have not yet become stable and fixed, leaving great flexibilities.

However, in reality, the necessity to establish efficient rail transit systems is often overlooked in developing mega-cities. On the one hand, in domestic financing domain, it is hard for domestic governments and private cooperation to invest in rail construction spontaneously. The great benefits of rail transit systems cannot be well captured by the investors under current financing systems (Hayashi 1989). Hence, this kind of investments is generally a huge amount, but with low economic rate of return. On the other hand, among the international investment mechanisms, there are still big obstacles for them to be successfully applied in transport sector

Y. Hayashi (✉)
International Research Center for Sustainable Transport and Cities, Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan
e-mail: yhayashi@genv.nagoya-u.ac.jp

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(McAndrews et al. 2009; Golub and Kelley 2009). The reforms on Clean Development Mechanism (CDM) and Official Development Assistance (ODA) for better financing for sustainable transport are under discussion (Krambeck 2010; Acharya 2003; Donoso et al. 2006), but it has not attracted much attention yet. Rethinking the international financing for rail transit infrastructure construction is important and urgent.

This paper analyses the land use-transport mechanisms to cause chaotic congestion in developing mega-cities, and proposes land use-transport instruments and financing public transport as way out from catastrophic increase of CO_2 emissions caused by chaotic congestions. First, “AVOID, SHIFT and IMPROVE” are proposed as three crucial steps. Particularly, to construct rail transit systems in early stages in developing mega-cities is of great importance. Second, financing system for rail transit infrastructure construction should be reformed. The value capture mechanism can be introduced into domestic financing, to reclaim the windfall benefits brought by constructing rail transit infrastructures. And special measures for transport sector should be placed in the international financing mechanism, such as CDM and ODA, to encourage more funding for rail transit infrastructure construction.

11.2 The Land Use-Transport Mechanism to Cause Chaotic Congestion

Everyone expects better life with economic growth. However, the reality is always reverse in many developing mega-cities as illustrated in Fig. 11.1. Economic growth raises household’s income to afford cars and to promote car ownership. At the same time, car ownership attracts people to live locating in a sprawl manner far from the city center and public transport systems. This makes public transport systems, such as rail and bus transit systems, suffer from low patronage and also from higher cost of construction of their infrastructure due to increasing land values. In this way,

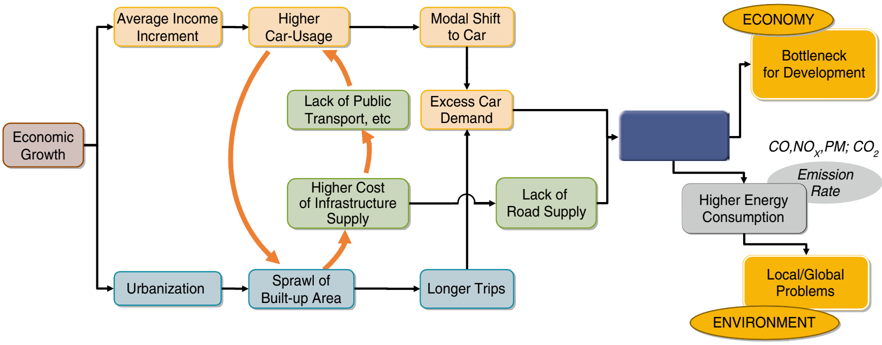

Fig. 11.1 Development and environmental issues in Japan after mid-twentieth century

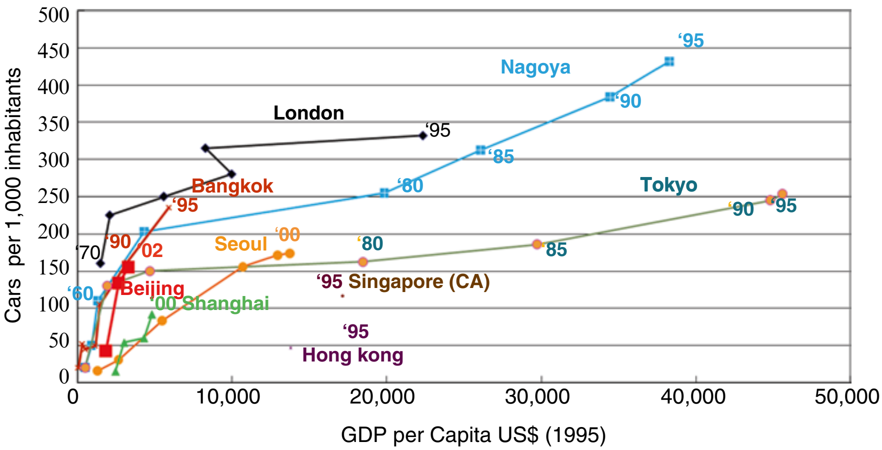

Fig. 11.2 Economic growth and motorization (Hayashi and Roy 1996)

urban land use-transport systems will fall into a vicious circle to produce more and more congestions and emissions, and even economic bottlenecks.

This vicious circle may turn worse in the near future for car ownership and will continue to grow, especially in Asian developing countries. It has been studied that the car ownership in a city generally starts to grow obviously after its per capita GDP reaches 2,000 USD (Fig. 11.2). And IEA's research presents that the car ownership of developing countries in 2050 will be 20 times larger than that in 2010. In the scenario of business as usual, the vicious cycle of more car ownership and more serious traffic congestions will not stop.

Serious traffic congestion exists in many developing mega-cities. It seems common that the road supply can hardly catch up with the demand growth caused by increasing car ownership. Hence, together with the increase in the total car numbers, there often appear more and more congestions on roads. Bangkok was a typical case of heavy traffic congestion in its late 1980s and early 1990s, without urban rail transit systems. During the peak hours, it was almost unable to move in a car in Bangkok at that time. While the car ownership in Bangkok rose from 100 cars/1,000 inhabitants in 1986 to more than 200 cars/1,000 inhabitants in 1993, the average speed of cars during peak hours decreased drastically from 15 km/h (9 min/km) to 7 km/h (4 min/km) (Fig. 11.3). As a similar drop in speed is seen, around 6 km/car would be the turning point to vicious circle.

Traffic congestion comes also together with the high energy consumption in road transport sector, and therefore leads high CO_2 emissions. In 1988, when the traffic congestion was nearly at its worst situation in Bangkok, the energy consumption of road traffic was much higher than other cities in the same period. The average energy consumption of cars in Bangkok was 0.17 liter/km, and the total energy consumption for road transport during half a day was 627 TOE (Hayashi and Roy 1996). The amount was four times higher than Tokyo in the same time.

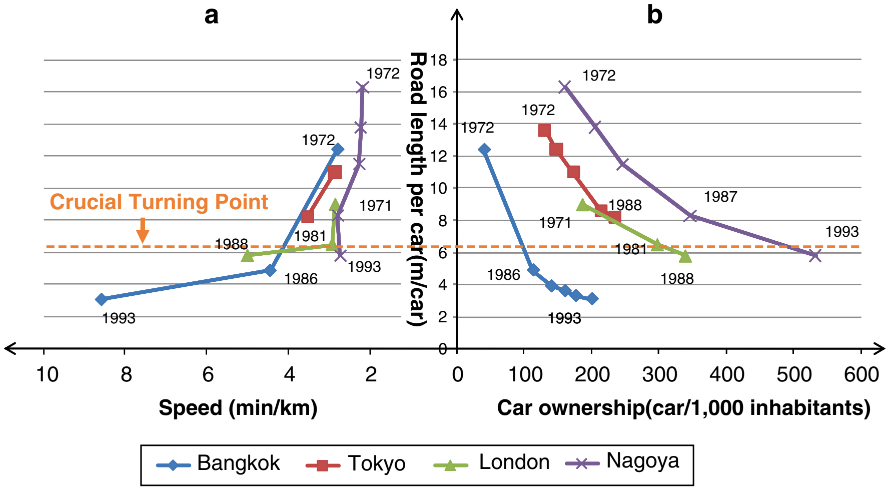

Fig. 11.3 Yearly changes of PPM concentration of air contamination in Nagoya (average value of all the measuring points)

This kind of vicious circle of recurring urban sprawl and traffic congestion has happened not only in Bangkok, but also many developing mega-cities almost without urban rail transit systems have been suffering from the serious congestion problems, which are highly related to limited road supply and progressive car ownership.

From these evidences, we should keep road supply-demand ratio above 6 m/car. If each city can continue to invest in road supply at the same speed as that of car ownership, the curves in Fig. 11.3b must be flat. But it is almost impossible.

11.3 Land Use-Transport Instruments as Way Out from Catastrophe

Here, our purpose is to make the urban land use-transport systems sustainable in terms of CO_2 emission.

There are three steps to get a way out to reduce CO_2; (1) AVOID trips, (2) SHIFT the mode from high-carbon mode to low-carbon one, and (3) IMPROVE the mode by technology and policy. In this chapter, we will extend ideas to AVOID, SHIFT and IMPROVE, respectively.

11.3.1 Avoid

The priority of constructing rail transit instead of road will show impacts on the residential location choices of people as well as the urban sprawl manner, to avoid unnecessary car ownership increase and congestions.

When road constructions take priority in a city, the citizens easily form a dependence on using private cars, which is called as “preconception” in psychology research. Once preconception of the transport mode choice habits are formed, it would be very hard to change. Hence, it is pivotal that sufficient rail transit systems should be built before per capita GDP reaches 2,000 USD in developing cities, when the rising of car demands has not yet started (Fig. 11.2).

Four developed and developing mega-cities are selected for comparison, which are Tokyo, Bangkok, Shanghai, and Beijing. Figure 11.4 shows the sequences of rail and road construction in those case cities, in which the time series is from the earliest year with available data to recent years. The vertical axis is the percentage in the total current length of roads or rails.

Rail construction got the highest priority in Tokyo where almost 80% of today’s rail transit system network had accomplished in 1960 at its very early stage of economic development when the road network was only 10%.

On the contrary, in the other three cities the rail construction lagged behind road construction, particularly in Bangkok. When Bangkok met its worst road

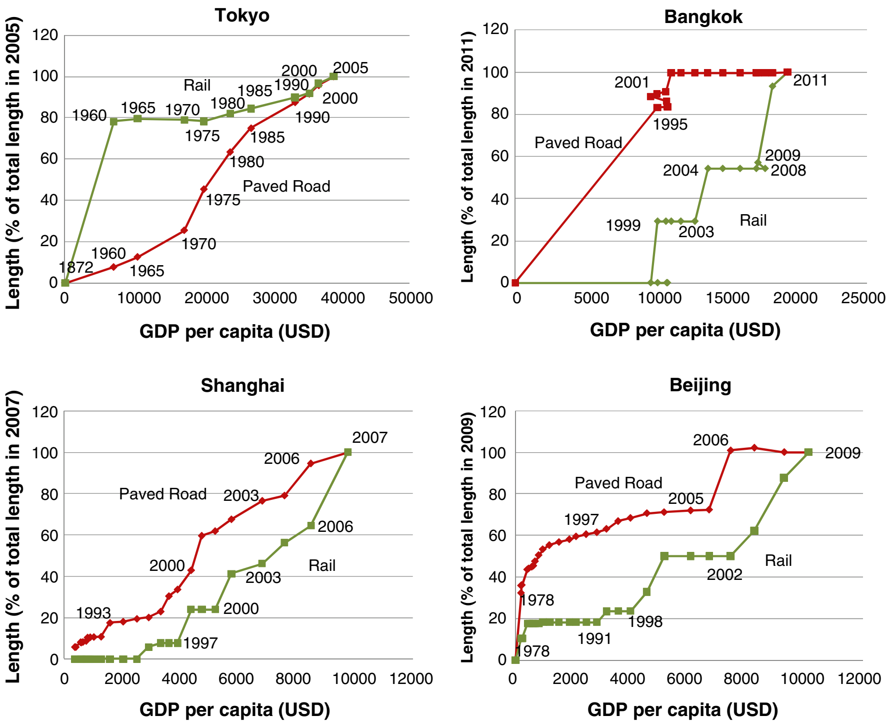

Fig. 11.4 Time sequences of rail and road construction in Tokyo, Bangkok, Shanghai and Beijing [Data sources: Institute for Transport Policy Studies (1960–2005), Japan Statistic Bureau (1960–2005), Shanghai Municipal Bureau of Statistic (2009), Beijing Municipal Bureau of Statistic (2009)]

congestions in 1990s, there were no urban rail transit systems in the city. Comparing the two cities in China, the road constructions in Beijing were slightly ahead of that in Shanghai.

The lags of rail construction have an important relationship with heavy road congestion in these cities. Benefited from its priority strategy given to the rail transit system, Tokyo suffered less from the road congestion during its urbanization process. On the contrary, Bangkok encountered the world famous congestion in its 1980s with highly car-dependent transport system, when it has no urban rail transit system. It can be observed that the slowest development on urban rail transit systems has led to the poorest traffic condition in Bangkok. When comparing the two Chinese cities, the reason that Beijing suffers from heavier traffic congestions can be explained by its earlier completion road network, which formed the car use habit of the citizens at the beginning of rapid urbanization.

Tokyo is quite lucky to have given a priority to improving rail transit system. It is unimaginable if such a large city as Tokyo does not have an efficient rail transit system. It would be a catastrophe that more developing mega-cities keep on making the same mistakes in transport by overlooking the importance of constructing rail transit infrastructures, which have already been suffered by many cities.

11.3.2 Shift

11.3.2.1 Which Mode Is Better to Invest for Less Congestion?

In many cases in making urban transport policies in developing mega-cities, people tend to invest on expanding road capacity to relieve road traffic congestions. However, it is often overlooked that improving rail transit system could also absorb the traffic demand and therefore relieve road congestion by reducing the car usage demand. Which one is better to invest, directly in road or indirectly in rail, is discussed theoretically, using demand and supply curves in road and rail markets by showing the differences of two policy scenarios: investment on improving road capacity or rail capacity (Fig. 11.5).

As we can see from the lower part of Fig. 11.5, rail transit systems have higher construction cost at the very starting point of operation. However, the cost for expanding rail transport capacity per person-km is often less than that of roads.

The green line scenario is investing in improving capacity of rail transit system. Investment ($C_{Ra}{}^{2} - C_{Ra}{}^{1}$) can bring the benefit of enlarging rail passenger volume ($V_{Ra}{}^{2} - V_{Ra}{}^{1}$). This can correspondently reduce the road traffic volume by ($V_{Ro}{}^{1+} - V_{Ro}{}^{2+}$), and reduce average car travel time by ($t_{Ro}{}^{1} - t_{Ro}{}^{2+}$). The red line scenario is investing in improving road capacity. Investment ($C_{Ro}{}^{2} - C_{Ro}{}^{1}$) can bring the benefit of enlarging road passenger volume ($V_{Ro}{}^{2} - V_{Ro}{}^{1+}$), and reduce average car travel time by ($t_{Ro}{}^{1} - t_{Ro}{}^{2}$).

It is clear that in the ranges of bigger passenger volumes where supply curve is steeper than demand curve in road market, the investment on improving rail transit

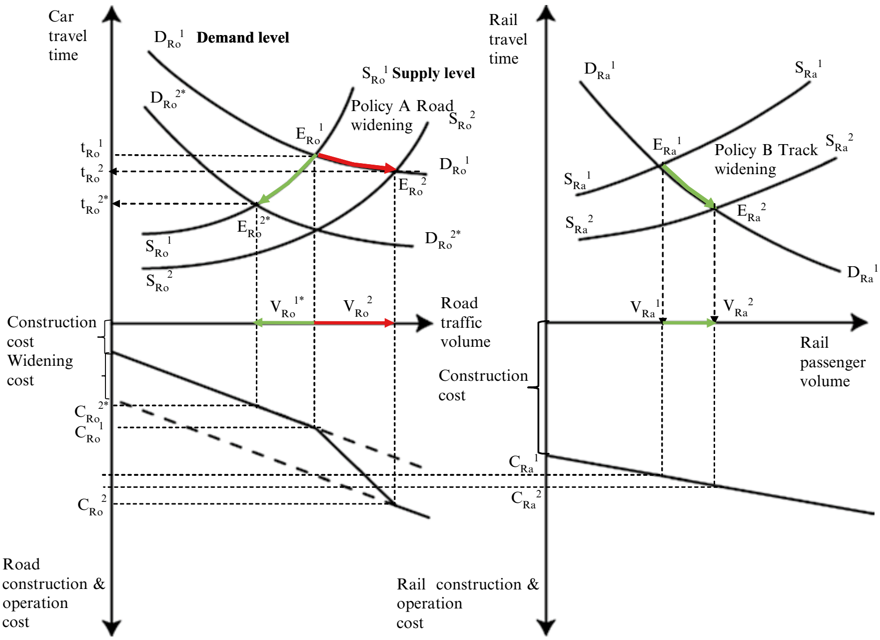

Fig. 11.5 Theoretical model for rail and road construction

systems rather than the one direct on road can get a better investment return. In two scenarios, the increased amounts of passenger volume are almost the same, while the rail investment ($C_{Ra}^{2}-C_{Ra}^{1}$) is much less than the road investment ($C_{Ro}^{2}-C_{Ro}^{1}$), and the travel time improvement brought by rail investment ($t_{Ro}^{1}-t_{Ro}^{2+}$) is much larger than that of road investment ($t_{Ro}^{1}-t_{Ro}^{2}$).

11.3.2.2 Which Mode Is Better to Invest for Less CO_2 Emissions?

The explanation by dual market systems is applicable not only for rail transit systems, but also for a variety of public transport systems. To judge which system is most carbon efficient, we have examined a lifecycle CO_2 in different levels of demand density.

According to our former research, in urban transport, the per person-km carbon dioxide emission of each transport mode varies according to the urban population density (Fig. 11.6). It is pointed out that the higher the population density is, the greater the advantages to improve rail transit system are.

In the case of more than 7,000 persons/km^2 of population density in built-up areas, the optimal transport mode is mainly rail transit, including heavy railways and Light Rail Transit. Moreover, when population density is more than 11,000 person/km^2, the subway/AGT(Automated Guideway Transit)/Monorail is highly recommended. Only when the population density is below 3,500 person/km^2, cars

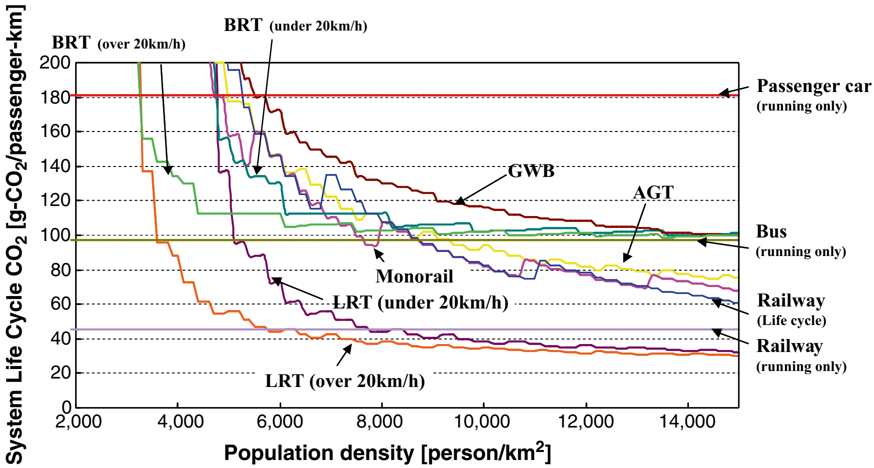

Fig. 11.6 Optimal mode choice based on lifecycle CO_2 and trip density (Osada et al. 2006)

are regarded as the most optimal transport mode for low CO_2 emissions. The population density of 3,500 person/km^2 is usually considered as very low-density development areas. In most developing mega-cities, the population density is often much higher than that, hence the rail transit systems are highly recommended for them, while the cars are not recommended.

11.3.3 Improve

If we really need to use cars, a high carbon system in densely inhabited areas, due to the reasons such that there are no public transport systems available for some pairs of origins and destinations, we should technologically improve engines, fuels and networks.

As we may see, in the result of analysis, technological progress of vehicle engine and energy would be far from enough to achieve the reduction target of CO_2. In this forecast, it is assumed that (1) number of vehicles are referred from Ministry of Land, Infrastructure, Transport and Tourism (Japan) and IEA (China), (2) vehicle-km is proportional to number of vehicles, (3) one scenario is that CO_2 emission rate per vehicle is the same as that in 2010, and the other scenario is that frontier technology of vehicles and their energy (EV, FCV, and CCS) will be improved and popularized. In Japan, it was declared that its target as revealing 80% CO_2 reduction in 2050 compared with 1990. However, the maximum reduction is obviously lower than 80% if only by technology progress. In China, the CO_2 emission will still increase dramatically if only by technology progress. Therefore, we do need to parallel promote the instruments for AVOID, SHIFT and IMPROVE.

11.4 Financing Public Transport Systems as Way Out from Catastrophe

Financing for rail transit infrastructure construction can be classified into domestic parts and international parts, and also be classified into private parts and public parts (Table 11.1). As the level of finance in green transport in developing mega-cities is too low, we need a substantial reform of ODA for drastic increase in public financing and CDM for attracting private investments in rail transit systems. While we need such international fund, enhancement of domestic financing is important at the same time.

Current investments in rail transit infrastructure construction are mainly from domestic public funding. There are still bottlenecks for the application of rail transit systems to private funding and international funding. The key issues of the reforms are as follows:

Lowering barriers for investment
Reclaiming the windfall benefits
Green subsidy
Green priority in transport infrastructure investment

In this chapter, reforms for value capture in domestic private funding and those for ODA and CDM in international funding are proposed, respectively.

11.4.1 Promoting Value Capture

Value capture for rail transit system investments means to capture the increasing property values and commercial profits by virtue of the improvement of the rail transit. It has been discussed as a promising alternative way for rail transit system funding for a very long time (Hayashi 1989; Smith and Gihring 2006). Sun Yat-sen's

Table 11.1 Financing methods for urban rail transit systems

	Public	Private
Domestic	National rail transit systems – Full public financing Third sector rail transit systems – Partial public financing	Private rail transit systems – Fare revenue – Value capture – *Commercial activities (such as department stores)* – *Pre-purchase and development of residential areas near stations*
International	ODA	CDM (Kyoto Mechanism)
	Financing by international organization – World Bank, ADB, etc.	PFI – BOT, etc.

"Equal Right to Land" theory is recommended as a fundamental theory for value capture practice.

According to our former research (Hayashi 1989), the benefits of constructing and operating a new rail transit line consist of (a) user benefit in new line, (b) user benefit in existing lines and in other modes, (c) increase of real property value, and (d) increase of profits from real property. Thus, the groups of beneficiaries who should pay are (1) rail operators, (2) users of alternative rail transit systems or modes, (3) developers, (4) municipality and prefecture, (5) inhabitants, and (6) enterprises. And the forms of fund transfer are (1) fares, (2) loans, (3) subsidies, (4) lending capitals, (5) bonds, (6) enterprise charges to support constructions, and (7) provision of land.

Sun Yat-sen's "Equal Right to Land" theory, which origins from Henry George theorem (Trescott 1994) gives a useful fundamental theory for effective value capture. Sun's theory consists of two main principles: make the best possible use of land, and share the profit of land. To reveal these two principles, two kinds of taxes are introduced, which are land value tax and land capital gain tax of which tax base is value increment (Hayashi 2006). The land value tax can be raised if the current land use cannot make the maximum profits of the land or does not fit the requirements from the government. The land capital gain tax is used to collect the windfall benefits and to return them to the investor in betterment, namely private rail operators.

The introductions of land value tax and land capital gain tax to reclaim the benefits brought by rail operator investment can be the basic reform proposal for domestic private financing for rail transit system.

11.4.2 Reforming the Rule for Approval of CDM

The CDM is one of the market-based mechanisms defined in the Kyoto Protocol. The CDM allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tone of CO_2. These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol (UNFCCC 2010a). CDM is the main source of mitigation finance to date for developing countries, as it may raise 18 billion USD (15 billion to 24 billion USD) in direct carbon revenues, depending on the price of carbon by 2012 (World Bank 2010).

Because of the uncertainty in getting CER and the high risk of loss in transport projects, now there are only three projects approved in transport sector among 2,270 CDM projects (UNFCCC 2010b). Therefore, in the CDM mechanism, new policies with inclination to transport projects, especially those to promote rail transit systems, are necessary. To deal with the uncertainty of corresponding carbon dioxide emission reductions in transport projects, a set of Programmatic CDM is proposed to replace Project CDM. To deal with the low rate of return on carbon dioxide emission reductions in transport projects, the Risk Hedge Fund is proposed to subsidize transport projects of CERs donated by the projects in all sectors.

11.4.3 Project CDM to Programmatic CDM

The Programmatic CDM is a new scheme to realize a program which consists of a bundle of similar projects. It calls for counting the CER not in a single transport project, but together in several transport projects carried out during a period of time. Compared with traditional project CDM, Programmatic CDM can absorb the risks of each individual CDM project, reducing uncertainty in credit of CO_2 emission proposed in transport sector. Programmatic CDM is supposed to enhance the competence of rail transit-related projects.

11.4.4 Risk Hedge Fund

Risk hedge fund is proposed to help avoid the risk of loss in the process of mitigating CO_2 emission in transport sector. This risk hedge fund might be donated by several countries, or be donated from 1 to 2% of other CDM projects' profits. This fund should be established to finance a certain percent of CDM projects in transport sector, especially rail transit promoting projects.

ODA is defined as grants or loans to countries and territories on the Development Assistance Committee (DAC) List of ODA Recipients (developing countries) and to multilateral agencies which are: (a) undertaken by the official sector; (b) with promotion of economic development and welfare as the main objective; (c) at concessional financial terms (OECD 2010a).

Based on the existing changes in ODA to pay more attention on "Green Growth," further support for "Green ODA" transport funding is proposed.

11.4.5 Reform in ODA for "Green Growth"

DAC has set up DAC Network on Environment and Development Co-operation (ENVIRONET), which promotes and facilitates the integration of environment and climate change into all aspects of development co-operation, creating a successful shift toward "Green Growth" (OECD 2009a).

First, a climate lens is suggested to be applied in ODA activities. It is an analytical process to enable a policy maker to decide whether the policy is at risk from climate change (OECD 2009b). Second, since the *2005 Paris Declaration on Aid Effectiveness*, aid delivery has shifted from project interventions to more programmatic forms (OECD 2009b). Third, data started to be collected on aid targeting the objectives of the Rio Conventions (Rio markers), which identify the activities targeting biodiversity, climate change and desertification, in the Creditor Reporting System from 2004 (OECD 2004). The annual average amount of fund targeting on climate change mitigation had been 3,479.9 million US$ between 1998 and 2007, and had a significantly increase in 2008, reaching 8,409.7 million US$ (OECD 2010b).

11.4.6 ODA Funding for Economic and Sustainable Development: Supporting "Green Transport"

The ODA is undoubtedly a core source of international transport funding aid. Transport and storage account for 11% of total bilateral ODA in 2007–2008, which is 4.4 billion USD (OECD-DAC Secretariat 2010). However, most of these funding are used in constructing roads instead of rails. Therefore, we propose a CO_2 reduction crediting mechanism for ODA system that credit is given to those ODA project to contribute to CO_2 reduction by its reduced amount. The credit may be shared by the donor country and recipient country for both sides to be given incentives to seek for low-carbon transport to ensure the aims at a "Green ODA." This must turn the trend of transport ODA as to keep the share of rail transit systems most appropriate against road to minimize CO_2 emission.

11.5 Concluding Remarks

According to the analyses and discussions above, conclusions of this paper can be summarized as follows:

1. While urban land use-transport systems in developing mega-cities often fall into a vicious circle to cause catastrophic increase in CO_2 emissions due to chaotic congestions that we found it occurring at 6 m road supply per car or under, improvement of rail transit systems can contribute to help jumping out of this vicious circle. Under the situation where passenger transport demand is large as well as car ownership is growing due to increasing income, which often happens in developing mega-cities, investment in rail transit systems can release road congestion more effectively than the direct investment in road systems, and therefore mitigate more CO_2 emission in transport sector.
2. Among the three steps of AVOID, SHIFT, and IMPROVE to get a way out of catastrophe, the importance of priority to constructing rail transit systems is highlighted. The priority and timing of improvement in alternative transport infrastructures affect on the citizens' travel habits. Completion of higher density of rail transit stations attracts population to live in a compact manner near there and to reduce the car ownership and consequently to raise the rail transit share along the corridor. It is of great importance to give priority to constructing rail transit infrastructures, which can help to realize the Leap-frog to sustainable transport in developing mega-cities.
3. The financing system for rail transit infrastructure construction acts also as a way out of catastrophe of mega-city getting into chaotic traffic congestion and thus emitting unacceptable amount of CO_2. It should be reformed to properly reclaim benefits of constructing rail transit systems, making invisible windfall benefits to be visibly reclaimed to encourage more investors to fund rail transit spontaneously. Value capture should be effectively applied in rail transit

infrastructure construction and operation projects in domestic financing. For international financing, such as CDM and ODA, innovative turning the funding toward "Green Transport" is urgently necessary. Programmatic CDM and Risk Hedge Fund need to be adopted in the CDM mechanism, and "Green ODA" which includes CO_2 reduction crediting mechanism is recommended to shift more fund to rail transit systems.

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References

Acharya SR (2003) Official development assistance (ODA) in transport sector: challenges and opportunities. Proceedings of the Eastern Asia Society for Transportation Studies 4: 1572–1586

Beijing Municipal Bureau of Statistic (2009) Beijing statistical yearbook 2009

Donoso P, Martínez F, Zegras C (2006) The Kyoto Protocol and sustainable cities: potential use of clean-development mechanism in structuring cities for carbon-efficient transportation. In: Transportation research record: Journal of the Transportation Research Board, No.1983, Transportation Research Board of the National Academies, Washington, DC, pp 158–166

Golub A, Kelley J (2009) Exploring potential inequities between the burdens and benefits of climate change abatement policies in the transportation sector. In: Transportation Research Record: Journal of the Transportation Research Board, No.10-3426, Transportation Research Board of the National Academies, Washington, DC

Hayashi Y (1989) Issues in financing urban rail transit projects and value captures. Transp Res A23(a):35–44

Hayashi Y (2006) No regret land-use and transport strategies to meet future stages of economic development, urbanization and automobilization. Reg Dev Dialogue 27(1):135–146

Hayashi Y, Roy J (eds) (1996) Transport, land-use and the environment. Kluwer Academic Publisher, Dordrecht

Institute for Transport Policy Studies (1960–2005) Urban transport annual report 1960–2005

Japan Statistic Bureau (1960–2005) Japan statistical yearbook 1960–2005

Krambeck H (2010) Evaluation of role of carbon finance in developing country transport-sector projects. Transportation Research Board 89th Annual Meeting, Washington, DC

McAndrews C, Deakin E, Schipper L (2009) Climate change and urban transportation in Latin America: an analysis of recent projects. In: Transportation Research Record: Journal of the Transportation Research Board, Transportation Research Board of the National Academies, Washington, DC

OECD (2004) Reporting directives for the creditor reporting system – Addendum Rio Markers

OECD (2009a) Climate change and development: key principles to inform climate change financing

OECD (2009b) Integrating climate change adaptation into development co-operation: policy guidance. OECD Publishing

OECD (2010a) DAC glossary of key terms and concepts. www.oecd.org/dac/glossary. Accessed 20 Jun 2010

OECD (2010b) Aid commitments targeted at the objectives of the Rio Conventions, USD million. www.oecd.org/dataoecd/48/20/45078729.xls. Accessed 18 Jun 2010

Office of Transport and Traffic Policy and Planning (2010) Extended Bangkok Urban Transport Model. Bangkok

Osada M, Watanabe Y, Shibahara N, Kato H (2006) Environmental load evaluation of variety of medium capacity passenger transport systems applying LCA. Infrastructure Planning Review 23(2):355–363

OECD-DAC Secretariat (2010) Statistics based on DAC members' reporting on the Environment Policy Marker, 2007–2008: Creditor Reporting System database

Shanghai Municipal Bureau of Statistic (2009) Shanghai statistical yearbook 2009

Smith JJ, Gihring TA (2006) Financing transit systems through value capture: an annotated bibliography. Am J Econ Sociol 65(3):751–786

Trescott PB (1994) Henry George, Sun Yat-Sen and China: more than land policy was involved. Am J Econ Sociol 53(3):363–375

UNFCCC (2010a) Home page of United Nations website on Clean Development Mechanisms. http://cdm.unfccc.int/about/index.html. Accessed 20 Jun 2010

UNFCCC (2010b) CDM statistics. http://cdm.unfccc.int/Statistics/index.html. Accessed 20 Jun 2010

World Bank (2010) World Development Report 2010: development and climate change. The International Bank for Reconstruction and Development/The World Bank, Washington DC

Chapter 12
Financing Technology Transfer

Reiner Koblo

12.1 Introduction

According to the World Energy Outlook (IEA 2004), the transport sector accounts for approximately 34% of energy and 62% of oil consumption in OECD countries. In many developing countries, this share is still considerably lower (India 9% and 34%, China 11% and 39%). With the high economic growth over the past decades and the positive perspectives in future development, the transport sector of those countries is already showing the highest growth rates in energy consumption, and it continues to show the highest growth rates in the future (see Fig. 12.1).

Within the transport sector, the highest growth can be found with road transport. Road transport is not only one of the most energy-inefficient modes of transport but also one that produces through its high dependency on fossil energy large volumes of greenhouse gases (GHGs). Road transport counts for nearly 80% of all GHG generated by the transport sector.

Besides the fact that with growing wealth in the society, private car transport has a high priority for the population, further reasons for the high increase in road and air transport are missing energy and CO_2-efficient transport alternatives. Figure 12.2 shows specific CO_2 emissions for different transport mode alternatives. The lowest CO_2-emission rates can be found with rail and public transport modes. Those are also the modes with the lowest energy consumption. Especially if these transport modes are introduced in densely populated urban areas or regions or if, in the case of freight transport, high loading rates can be achieved, the specific energy consumption per passenger-km or tonnes-km is very low. Thus, urban mass transit and railways represent the most climate friendly alternatives.

R. Koblo (✉)
KfW Entwicklungsbank (KfW Development Bank), L3c2 Sector Division Transport and Communication Asia, Palmengarten 5-9, 60325 Frankfurt, Germany
e-mail: reiner.koblo@kfw.de

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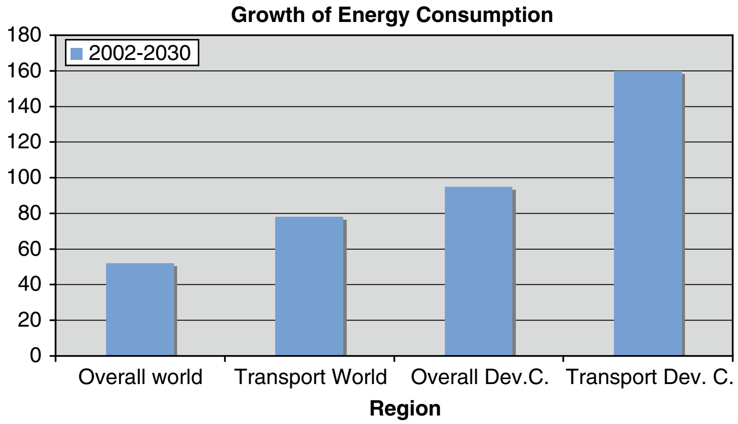

Fig. 12.1 Growth perspectives of global energy consumption (*Source*: IEA, World Energy Outlook 2004)

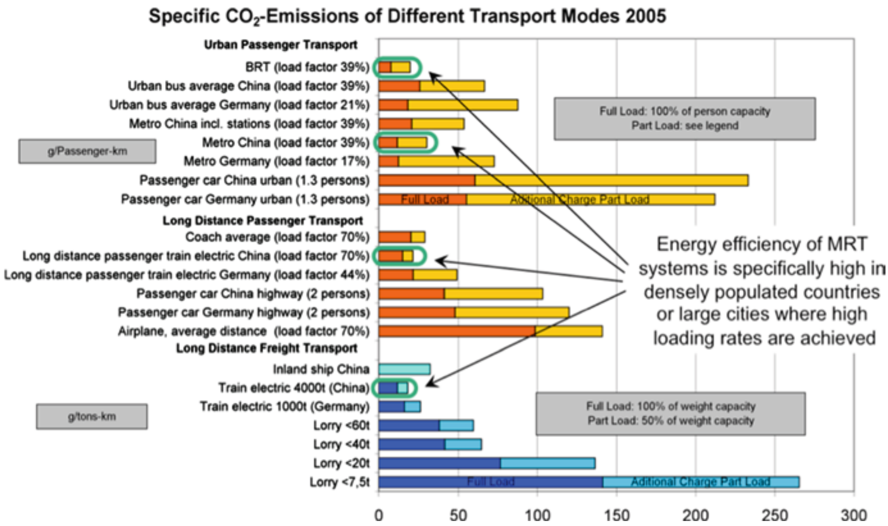

Fig. 12.2 Specific CO_2-emissions of different transport modes (*Source*: ifeu 2009)

In most developing and emerging countries, those environment-friendly and energy-efficient modes often do not exist or the existing infrastructures and services are old, inefficient or do not correspond to the needs of the people or the economy.

In addition, infrastructure investments in public or rail transport are often rather extensive, and planning, construction, as well as operation require know-how that is often not available. The following text will show what options for technical improvements are possible and what role development cooperation can play in this field.

12.2 Promotion of Energy-Efficient Transport Systems

To shift the increasing transport demand in developing countries to more energy-efficient and environment-friendly modes, these modes must first of all exist and further become more attractive to the users. This can be done by

- The improvement of existing infrastructure of those modes
- The implementation of new infrastructure for environment-friendly modes
- Improvement of rolling stock and introduction of other more efficient technology or organization and management of the respective transport services

The following text will illustrate a few examples on how this can be done practically.

12.2.1 Improvement of Existing Transport Systems

To be attractive and competitive to road and air, rail transport must show a sufficient reliability, speed, and comfort (in the case of passenger and high-valued goods transport), high capacity (in the case of bulk goods transport), and a competitive price.

Regarding rail infrastructure, there are several options to improve the attractiveness of railway services:

- Electrification of railway lines with modern electrification technology (this is vital for a reliable operation of long tunnels and bridges)
- Reliable and low-maintenance fixed installations and equipment
- Modern track maintenance technology
- Modern operation management and signalling technology

An example for such an improvement is the electrification and modernisation of the operation management and signalling on the railway line Harbin – Dalian, China, that was implemented in 2000 (Fig. 12.3).

The following map shows the location of the line (Map 12.1):

Before the improvement, it was only possible to run trains at a relative low speed, capacity was limited and not sufficient for the increasing demand. With the implementation of parallel motorways and other new roads, the competitiveness of the railways was continuously decreasing.

The line improvement project encompassed the following elements:

- Electrification of existing 950 km railway line that connects 25 major cities
- The new system is characterised by low maintenance requirements and high availability

After the completion of the improvements, the line capacity could be increased by 20% (now 152 train pairs per day), 40% freight train capacity increase (now 5,000 tons per train). The maximum train speed increased from 100 to 160 km/h.

Fig. 12.3 Implementation of line electrification

Map. 12.1 Location of Dalian–Harbin railway line

The increased attractiveness of the line resulted in about 30% increase in passenger and freight transport performance (from 1995 to 2005) and CO_2 emissions could be reduced in the range of 0.5 million tons p.a.

12.2.2 New Rail Infrastructures Avoid Detours

In the past, it was not possible or too expensive to build railway lines through mountainous areas with longer tunnels or through difficult geological terrain, e.g. swamps. As a result, the track alignment made long detours and steep gradients did not allow for higher speed. Today, modern construction equipment allows for straight and low-gradient railway tracks even in difficult geological and topographical areas, i.e. track length can be shortened, low gradient allows for low energy consumption and high-capacity trains.

In the case of densely populated cities, modern tunnel boring machines allow the construction of underground railways or metro lines with a minimal impact on the road traffic at the surface.

An example for a long distance railway line that applied such new construction equipment is the new high-speed railway line Wuhan – Hefei, China.

As shown by Map 12.2, the old existing railway line made a long deviation to the south mainly due to a difficult mountainous area (up to 1,800 m), steep valleys and some swamp areas. The old non-electrified line has a length of 556 km, it has a relative low capacity, high gradients and many curves that only allow for low speed. The transport demand of the two cities with a good economic perspective is considerably high with a fast-growing perspective (Wuhan: 4.3 million inhabitants and Hefei: 4.5 million inhabitants).

The newly build high-speed line now shows a length of only 356 km.

The difficult geological conditions required modern construction equipment and a specific electrification technology that enables for a reliable power supply in long tunnel sections. In total, the new line shows 119 km bridges and 64 km tunnels (Fig. 12.4).

The double track electrified line significantly increased the line capacity. The 200 km shorter line with low gradients and without narrow curves allows for high speed, e.g. passenger trains between the two cities now only need 2 h instead of 8 h. Thus, the new railway line is competitive to road and even to plane transport. In addition, the new railway connection will reduce CO_2 emissions in the range of 1 million tons p.a.

Map. 12.2 Location of Wuhan He fei railway line

Fig. 12.4 Modern bridge construction equipment

12.2.3 Modern Rolling Stock

Modern rolling stock also has a considerable potential to reduce energy consumption and GHG emissions. In urban public transport modern metro and light rail vehicles can provide *longer trains* with a higher capacity and thus a lower energy consumption per transported passenger-km. Further increase in energy efficiency can be provided by *light weight vehicles*. Compared to traditional vehicles, weight reductions of about 20% are possible. This results in a reduction of energy consumption in the range of 10–18%. In addition, *regenerative braking systems* provide a further source of energy saving. The new Chinese metro vehicles of standard type A combined those three aspects of energy saving. They have first been operating on Shanghai Metro lines 1 and 2 as well as on Guangzhou line 1.

12.2.4 Other Modern Technologies

There are a number of other possibilities in the fields of energy-efficient modern vehicle technology and operation management:

- *Operation Management*: Training of train and tram drivers in combination with electronic assistance systems are able to reduce considerably the energy needed for acceleration and deceleration. The potential energy saving is in the range of 10%.

  Modern *operation control technology* optimizes operation and reduces energy consumption.

- *Regenerative braking*: In *long distance*, *rail transport* energy reductions of about 8% can be achieved. It can be even significant higher with heavy freight trains on long downhill gradients.

  Regenerative braking save up to 30% energy in *urban and suburban rail systems.*

  High-performance capacitors (ultracaps) represent a rather new technology especially in urban transport that allows energy savings of 30% up to 46% (Problem: it is not yet a mature technology).
- *Hybrid technologies* for bus and rail vehicles enable energy savings of about 30%.

Mode shifts to energy-efficient rail and public transport can only be achieved if their competitiveness is strengthened. Attractiveness and safety of public transport can be achieved by, e.g.:

- Modern passenger information and automatic fare collection systems that increase the user friendliness of the systems
- Air conditioning of trains and stations plus platform screen doors increase considerably the comfort of train and public transport usage specifically in hot regions
- Escalators and elevators enable a comfortable usage of public transport for old and handicapped persons or mothers with child

12.3 Transport Policy

12.3.1 Transport System Choice

Transport needs increase rapidly in emerging and developing countries. Fast-growing mega cities in these countries often represent economic growth poles. The increasing wealth of the population leads to a growing transport demand. If there are no energy-efficient and environment-friendly transport alternatives available, the increasing demand will be directed towards road transport.

Figure 12.5 shows the typical development of public transport share (expected path) with growing income of the population. With low income, people have no alternative but to use an even badly organised and often not at all comfortable public transport. With higher income, they can afford faster and more comfortable modes of transport, i.e. usually road transport by private cars. If the city manages in an early stage of this development to provide an attractive and fast public transport, the trend towards falling share of public transport can be reversed. If no alternative to road transport exists or if it is only provided rather late, i.e. after the modal share of road is already very high, it is very difficult and also expensive to return to higher public transport shares.

New or improved public transport infrastructure systems must anticipate and adjust to future demand, i.e. their capacity must meet today's but also the future demand. In the case of fast-growing cities in developing countries, high capacity metro systems can be appropriate at least along the main corridors.

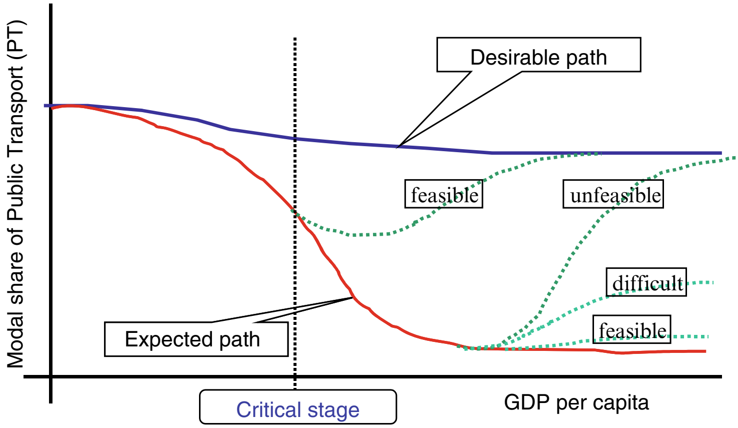

Fig. 12.5 Feasibility of public transport options (*Source*: Acharya 2005)

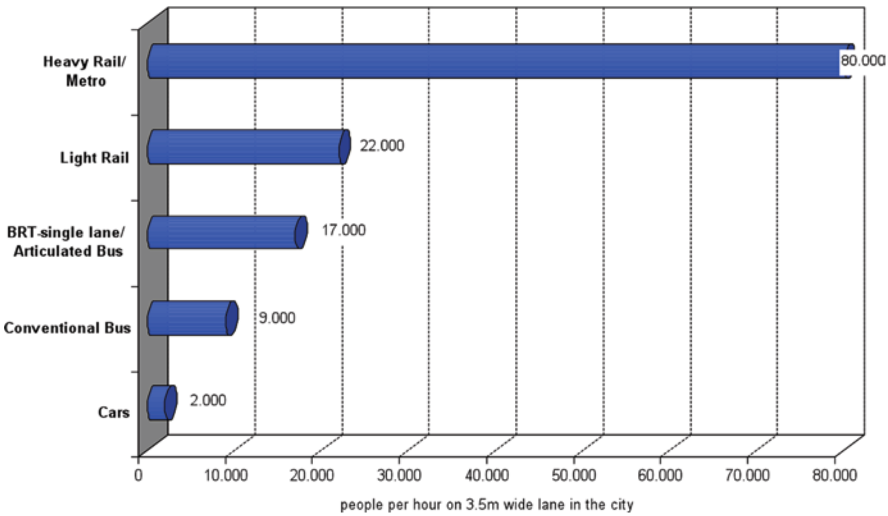

Fig. 12.6 Capacity of various transport systems (*Source*: Botsma and Papendrecht 2009)

Figure 12.6 shows the capacities of various transport systems. Bus Rapid Transit (BRT) and light rail systems already show about 10 times the capacity of private car transport. The highest capacity is provided by heavy rail transport (in the case of long distance transport) and by metro systems (in the case of urban transport). A metro system is able to move about four times the passenger demand of a BRT or light rail system. Usually, a combination of various systems is applied, e.g. high capacity metro along main "backbone" corridors and lower capacity systems as feeder systems.

12.3.2 Role of Development Cooperation

Although it would be required in a rather early development stage to provide a high capacity, attractive and environment-friendly transport system, the extensive funding needs usually do not match the funding capability of a city or a country. It is also difficult to attract private investment funds, as public transport infrastructures are usually financially not profitable.

In addition, there is often a lack of local capacity for an effective and fast implementation in terms of transport planning and policy.

Under such conditions, development cooperation could assist in affordable funding of energy-efficient transport infrastructure investments at favourable conditions to match the long maturities of such investments.

It is also vital for the success of a high capacity and environment-friendly transport system to design and integrate it into an overall urban and long-distance transport system development strategy.

12.4 Conclusions

12.4.1 Technology

Modal shifts to public mass transport and rail transport systems show highest potentials for an increase in energy efficiency and environmental friendliness.

Thus, new transport infrastructures for these modes should be established as an attractive alternative to road transport if they not yet exist. If these infrastructures do already exist, but at an inefficient old standard, they should be improved by modern technologies. Modern transport technologies usually already exist and are mature in industrialized countries.

Developing cooperation can assist developing countries to shift earlier and faster from older and less energy-efficient to modern transport technologies. As a side benefit, technology transfer can considerably improve the national technological capability by adapting the technology.

12.4.2 Finance

Public transport infrastructures often need larger investments with a relative low financial profitability. Those types of investments are usually not very attractive for private investors. Thus, public finance or support from international development cooperation is needed.

Although investments in infrastructure are not profitable, private operators can often provide efficient and profitable operation and maintenance.

It is important for the sustainability of investments in climate friendly transport modes that they are embedded in a broader planning and strategy approach, e.g. public transport coordinated with urban land use planning (to avoid long trips) as well as push–pull measures (such as parking management).

References

Acharya SR (2005) Public transport for sustainable mobility in Asian cities. Institute for Transport Policy Studies, Tokyo

Botsma H, Papendrecht H (2009) Traffic operation of bicycle traffic. TU Delft, Delft, GTZ, 2009

ifeu – Institute for Energy and Environmental Research Heidelberg in Cooperation with ICT, China (2009) Transport in China: energy consumption and emissions of different transport modes. ifeu, Heidelberg

International Energy Agency (IEA) (2004) World energy outlook 2004. International Energy Agency, Paris

Part V
Instruments for Carbon Mitigation Policy in the Transport Sector

Chapter 13
Internalizing External Costs of Transport with a Focus on Climate Change

Patrick Jochem and Werner Rothengatter

13.1 Introduction

Noise, air pollution, uncovered costs of accidents and congestion as well as climate change effects are the most important external effects of transport. Presently, climate change induced by a growing concentration of CO_2 in the atmosphere is the biggest challenge for mankind since the industrial revolution. CO_2 is not the only greenhouse gas (GHG[1]); however, the impact of other anthropogenic GHG is less significant. This is especially true for the transport sector, where currently the share of CO_2 on GHG emissions is about 99% (Eurostat 2010).[2] Comparing the reduction efforts in other economic sectors in the European Union (EU) with the transport sector in recent decades leads to the alarming result that other sectors have significantly reduced its CO_2 emissions while the emissions by the transport sector are still growing at high yearly rates (Eurostat 2008). Between 1990 and 2007, the transport sector increased its emissions by 24%, whereas industrial processes (−11%), energy generation, transformation, supply and use (−7%), as well as agriculture and waste (−11% and −39%, respectively) decreased their emissions (EC 2009). Overall, the share of transport in total GHG emissions in the EU was 21% in 2007 (EC 2009). In the global context, this share amounts even to 23% (JAMA 2008). Road transportation plays a crucial role accounting for more than 70% of the overall (direct) CO_2 emissions from transport in the EU-27 (EC 2009). When considering only transport within European borders, the share of road transport even exceeds 90% of the direct transport emissions (EC 2009).

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[1] Other GHGs are e.g., methane (CH_4), nitrous oxide (N_2O), haloalkanes, ozone, and aerosol particles.

[2] The increasing usage of biofuels might decrease this share in the future.

P. Jochem (✉)
Institute for Industrial Production (IIP), Karlsruhe Institute of Technology,
Kaiserstr. 12, 76131 Karlsruhe, Germany
e-mail: jochem@kit.edu

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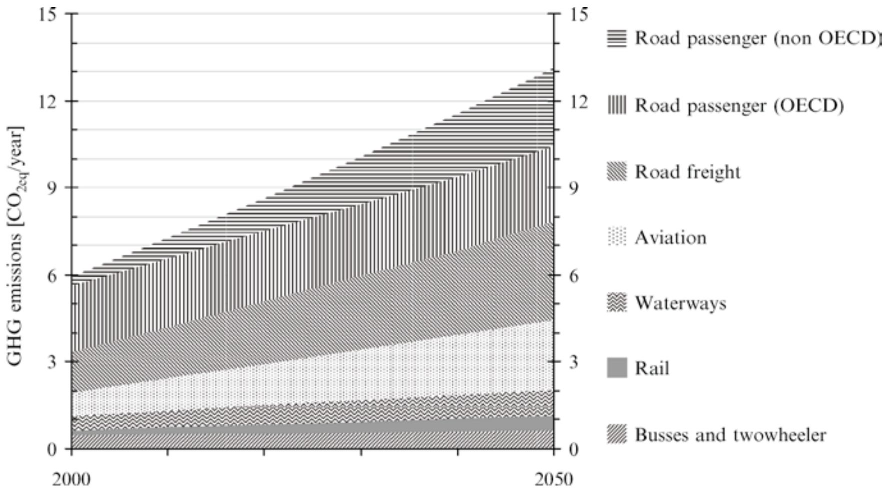

Fig. 13.1 Outlook of CO_2 emissions in the global transport sector until 2050 (WBCSD 2004)

The strong future increase in GHG emissions in the transport sector (see Fig. 13.1) is due in the first instance to the rapid growth of aviation, second to a raise in the global vehicle fleet from about 0.8 billion in 2000 to more than 2 billion in 2050, and third by the dynamics of freight transport in the process of globalization (from 20 trillion tkm in 2000 to 45 trillion tkm in 2050) (WBCSD 2004). Especially in transition countries the vehicle ownership rate is increasing rapidly. Currently, in the OECD countries, the vehicle ownership rate is about 500 cars per 1,000 inhabitants, whereas in China or India it is about 40 vehicles per 1,000 inhabitants. Due to the increasing incomes in these emerging markets a fast increase of this rate seems inevitable; some experts forecast a growth of vehicle km in these countries by the factor 10 until 2050. Environmentally, more friendly modes such as the railways are not expected to increase market share under status quo conditions (Schafer 2000).

But even for Europe, most studies forecast a further increase in transport emissions, despite a more moderate economic growth and partly declining population, if the cost and regulation regimes in the transport sector persist. From the current point of view, the considerable potential for shifting to smaller and more fuel-efficient vehicles (e.g., electric vehicles, Erdmann 2009; Jochem et al. 2010) or to other modes (BMU 2006; Schafer 2000; DeCicco and Ross 1996) is not seen to be significantly tapped. However, the technological options to reduce CO_2 emissions are substantially more expensive such that voluntary shifts to energy-efficient technologies will be limited (TNO et al. 2006). Therefore, it is not surprisingly that some studies have concluded that transport will be among the last sectors to bring its emissions down below current levels (among others Stern 2006, Annex 7c). Other studies have disputed this finding by demonstrating how the combination of demand and supply side approaches and the adoption of small-scale “soft” measures are cost-effective routes to demand reduction in this sector (CfIT 2007; Anable 2008).

The development of transport and its emissions sketched out above is more or less a perpetuation of current developments to the future, i.e., the scenario is based on the assumption that no new regulatory instruments are introduced or changes in the behavior of traffic participants occur. Alternative scenarios presume that the speed of transport development and the magnitude of externality production can be reduced substantially if the external costs are internalized by convenient policy instruments. This implies a four-step procedure:

1. Definition and scoping of external costs
2. Measuring the effects at the source
3. Following the impact path and quantifying the impacts on exposed people and nature
4. Economic appraisal of the impacts

Infras and IWW (2004) have analyzed the types of external costs and resulted in air pollution, noise, climate change, uncovered costs of accidents, impacts on landscape and biodiversity, separation effects and upstream or downstream effects. Furthermore, congestion costs are mentioned, which play a dominant role in neoclassical welfare economics. It is pointed out in Infras and IWW (2004) that congestion costs are of a totally different type, compared with the costs of the environment. Congestion costs occur through an interaction of agents in the transport networks, they are causing inefficiency while the associated additional costs are born by the agents themselves. Environmental costs, on the other side, are produced by the transport network users and imposed on third parties as well as on future generations.

In this article, we concentrate on the external effects of GHG, which are characterized by global production and accumulation, global impacts, complex causation mechanism, long-term impacts for many future generations, and the needs for global actions for mitigation. This means that narrow economic concepts of short-term (static) efficiency are not appropriate and have to be substituted by a long-term dynamic (adaptive) efficiency concept. This means that rather than setting prices right in the short run it is more important to set incentives right in the long run. Against this background of adaptive efficiency, the theory of ecological economics gives an orientation for the optimal trigger of economic instruments over time. They include the need of complementary of nature and economics, a consideration of irreversibility in natural processes and the coherent attention of potential irreversibility within the complex system of nature as well as an inclusion of accounting dynamic feedback mechanisms of the analyzed processes (Rothengatter 2003a:21).

In the following, we give a short introduction to the theory of external effects (Sect. 13.2). Then we identify the challenges for its introduction into the transport sector with respect to GHG emissions (Sect. 13.3). In this context, we highlight the measurement of external effects (Sects. 13.3.1 and 13.3.2) and the valuation principles (Sects. 13.3.3 and 13.3.4). Appropriate policy instruments for internalization of external climate effects are discussed in Sect.13.4. Section 13.5 concludes.

13.2 Theory of External Effects

The theory of external effects is a strong instrument for optimizing the amount of pollutants without controversy as long as the underlying assumptions are met. However, if these assumptions are violated, this strong instrument leads to misleading results. A profound knowledge of the underlying theory is therefore appropriate.

13.2.1 Historical Background and Definition of External Effects

Alfred Marshall introduced the term of "external economies" in the first issue of his "Principles of Economics" in 1890. According to Rothengatter (2000:79), Marshall's concern was to explain that even with the existence of increasing returns to scale (decreasing average costs) the paradigm of a perfect market economy would not be destroyed through monopolistic concentrations of the industry – as prophesied by Karl Marx. In the following decades, the notion of externalities was specified more precisely and in particular extended on the side of external costs. Pigou (1920) elaborated the concept congestion costs, starting with the famous "Pigou problem" of traffic assignment on two routes between origin and destination. The congestion externality is caused by involuntary interactions among road users and the fact that they do not take into account the impacts of their route choices on other users. Besides the congestion phenomenon, Pigou (1920) mentions already (antiquated) environmental externalities, as for instance the impacts of sparks emitted by locomotives, which could cause fire and destroy woods and cornfields.

The following scientific debate was characterized by substantially extending the list of possible external effects – as well external benefits as external costs – a vivacious debate on the needs of compensation and the elaboration of concepts for internalization of externalities to restore the welfare optimal economic equilibrium. The various examples, concepts, and compensation schemes have contributed to an overall fuzziness of the idea (see Papandreou 1994). The famous blossom-bee-example of Meade (1952) illustrates the problem of a clear scoping of externalities: Meade argues that the apple farmer needs the input of bees and the apiary needs the existence of apple trees; however, the mutual inputs are unpaid and the question is whether compensation payments are necessary to optimize the allocation in form of apple trees planted and bee colonies raised. It is obvious that including such phenomena into the scope of externalities would lead to a huge list of potential external effects, including many types of interaction effects and complementary relationships among input factors or implicit contracting of agents. Against this background, Rothengatter (2003b) has suggested a narrow definition of externalities, which implies that all phenomena within the defined scope call for compensation and internalization measures. External effects, by this definition, are characterized by three properties:

1. Involuntary interactions among agents who use a resource jointly of which the property rights are not defined.
2. Processing of the interaction outside the market, i.e., without trading of bargaining such that the costs occurring or benefits generated are not allocated to the responsible party.
3. Relevant market failure, which leads to reduced adaptive efficiency through false signaling.

This excludes the economics of density, which Marshall indicated, as well as most of the external benefits discussed in the literature, including the external benefits of transport. In particular, property (3) eliminates most of the interaction effects between transport and the production/service industries, which stem from complementary effects, scale economies or implicit contracting with mutual benefits for the involved parties in an uncertain environment.

13.2.2 Theoretical Concepts

There are three basic concepts for the economic analysis and treatment of external effects: The neoclassical concept by Pigou (1920), the theory of Coase (1960), and the concept of Ecological Economics (e.g., Farber et al. 1999).

Pigou (1920) characterizes an externality by the divergence between the marginal social product and the marginal private product. Such a divergence occurs if agents do not get allocated the costs or benefits which they are responsible for such that they neglect these effects in their decision making. The suggested remedy is a tax or a subsidy to balance the difference between social and private marginal costs. This concept relates to neoclassical welfare theory, which is based on a number of rigid assumptions. It is assumed that polluters as well as victims are price takers (i.e., sufficient high number of agents), the set of consumption complexes for each consumer is convex, closed, bounded, and contains the zero vector. The utility functions of consumers are twice differentiable, quasiconcave, and there is no saturation in consumption. The feasible production set for each firm is defined as a set of technical constraints that are twice differentiable and define a convex production possibility set (Baumol and Oates 1988:37). This implies that marginal costs increase with rising production volume. Market participants are rational utility maximizing agents (homo oeconomici) with complete information and for interactions of agents no administrational costs occur. As the Pigou concept is mostly taken as basic principle for coping with externalities[3], it is important to remember the very restrictive set of underlying assumptions.

[3] It is, for example, the basis for the recommendations of the White Paper of the EU Commission on Fair and Efficient Pricing for the Transport Infrastructure, published in 1998 and updated in 2006 (EC 2006).

Coase (1960) has presented a rather judicial perspective of treatment of external effects (summary of main points from Rothengatter 2003b):

1. Externalities arise if the property rights for a resource jointly used by several agents are not clearly defined.
2. Externalities are reciprocal, that is, the "perpetrator" and the "victim" are contributing to the magnitude of the effect.
3. And if (1) and (2) hold and it is assumed that transaction costs are negligible and there is an equal distribution of bargaining power of the stakeholders; then, the famous Coase Theorem holds: *An efficient allocation of resources will be obtained by allocating the property rights of the jointly used resource to one of the conflicting parties in a clear manner,* i.e., *either to the* "perpetrator" *or to the* "victim."
4. However, with respect to the empirical implementation, it can be assumed that relevant transaction costs occur. Therefore, an evaluation whether the gain from removing the externality is greater than the sum of losses and transaction costs is to be accomplished. In a policy scheme for reducing external costs, the least-cost principle has to be applied.

Therefore, Coase gives a valuable method for empirical conditions in recommending a cost-benefit analysis of the considered internalization instruments. This is opposed to neoclassical theory as it is a priori not clear whether charging the marginal external costs will lead to an optimization of welfare. Counterproductive effects are possible. Baumol and Oates (1988), for instance, highlight that a compensation of victims might attract people with low damage costs to increase their damage in moving to more polluted areas to receive the "average" compensation. As long as they do not displace people with high damage costs, this leads to an agglomeration around polluters. This decreases social welfare and hence the authors suggest refraining from the pure compensation (Pigou) approach. Another example is the possible crowding out and relocation effects following a congestion pricing scheme in a city center. A marginal cost-based pricing scheme might stimulate consumers and retail business to move outside the charged area, which at the end of the day might increase air pollution and climate impacts through an increase of total travel distances. These possible rebound effects have to be estimated through a cost-benefit analysis, as suggested by Coase.

The approach of *Ecological Economics* (e.g., Farber et al. 1999) stresses on the complementary of nature and economics, natural resources cannot be substituted with material resources and should therefore not be exhausted beyond critical thresholds. Natural processes are complex and partly irreversible and emissions (flows) can accumulate (stocks) and produce harm to future generations. For impacts of this type, a target-driven approach is appropriate. It implies that "safe minimum values" are set for every essential effect, which touches nonrenewable resources (nature, human health, and life). If prices (charges, taxes) are the only instrument, then they have to be set in a way that the safe minimum values are at least guaranteed (e.g.,: standard/price system of Baumol and Oates 1988). If several instruments are available, they have to be combined through a least cost strategy. Suppose that the strategies are characterized by increasing marginal costs if the intensity of the strategy is increased. Then the strategies can be ordered lexicographically and applied beginning with the lowest cost strategy and changing to the second lowest strategy as soon as the costs per unit of abatement are equal, etc.

13.2.3 Implications for Internalization of External Effects

The three theoretical concepts lead to substantially different internalization strategies.

Pigou's concept solves the externality problem by introducing a Pigou tax as the difference between marginal social costs and private costs, measured at the point of social optimum. After introduction of the Pigou tax, the individuals will behave in a socially optimal manner. This implies that marginal cost curves have to be quantified for every external effects and added up to achieve the social marginal cost curve. Furthermore, the demand curve has to be estimated such that the social optimum can be identified at the point of intersection of the demand curve with the social marginal cost curve.

While Pigou based his concept on a two routes problem, for which the optimal network problem can be easily transformed to a market analogy (in a market diagram with price and quantity at the axes), in reality we have to cope with large networks with millions of routes, multiple users, and multimodality. This implies that the simple textbook problem has to be extended to a most complex network optimization problem. As LeBlanc and Rothengatter (1982) have shown, it is rather a system and user-optimal network problem, which have to be solved and the differences between the marginal social costs and the individual average costs at the point of equilibrium for every link of the network should be optimized. Despite the progress of algorithms and computer efficiency, it is still a challenge to model these optimality problems appropriately for large-scale networks with complex demand interactions.

As soon as the rigid assumptions of the concept are not met in practice, the Pigou scheme often is modified. This concerns for instance:

1. Using average costs instead of marginal costs (e.g., in the case of traffic noise)
2. Adding mark-ups to the marginal costs (e.g., in the case of fixed costs to be recovered)
3. Differentiating the prices according to the (inverse) of the demand elasticities ("Ramsey Pricing")

With such adjustments, the optimality property of the pricing scheme is no longer given ("from first-best to second-best approaches").

The Coase concept starts with constructing a negotiation situation between the involved parties, the "perpetrator" and the "victim." In the absence of transaction costs, a negotiated agreement could be achieved, which includes a compensation payment and a production limit for the externality. However, as denoted above, if transaction costs matter (and other deviations from the neoclassical world are considered) every compensation solution has to be checked with respect to achieving a net welfare gain. For example, the London congestion charging scheme shows extremely high transaction costs of about two-thirds of the revenues. According to Coase, this scheme would have to be tested with respect to its net welfare contribution.

The approach of Ecological Economics is based on the definition of safe minimum values for critical externalities. These values may be developed by expert teams or by policy makers. In the case of noise or air pollution, the WHO has set standards for every type of emission (WHO 2003). In the case of road accidents, the European Commission has set the target to reduce fatal accidents by half within one decade. And in the case of GHG, the IPCC has prepared an empirical and (climate) modeling platform from which the necessary reduction values for CO_2 and other climate gases can be derived. If the world temperature should not increase by more than 2°C until the end of this century, a number of mitigation measures have to be taken and implemented world-wide. The second element of this approach is the least-cost triggering of the reduction strategies. This presupposes that the cost functions for all possible strategies are quantified, a lexicographical order of cost-efficient strategies is setup and a lower envelope for the cost functions is constructed. This implies using network and cost models, which are run iteratively to approximate the least cost combination of strategies.

13.2.4 Intergenerational Effects and the Problem of Social Discount

Even if a (unrealistic) good prediction of the interrelationship between GHG emissions and the resulting climate change is assumed, the economic valuation of the corresponding impacts in the far future are still impossible to be forecasted. This is mainly due to the following four problem areas:

1. Quantitative impacts for mankind: Future emissions of GHG depend widely on economic development and technological progress. The possible impacts depend on complex feedback mechanisms, which lead to a worldwide distribution on tipping points. The damages for mankind are dependent on the severeness of impacts and the intensity of adaptation measures (protection measures, migration of affected population). It is practically impossible to predict such changes for a century or more, such that scenarios have to be setup and a scenario, associated with a development trajectory, has to be selected which appears consistent and probable from present point of view.
2. Change of technology and prices: Damages are caused by resource consumptions following the application of particular technologies. Scarcity and relative prices of resources depend on technological progress and demand development. Whereas an improved technology leads, on the one hand, to a preserving of the resources and a decrease in price, it leads, on the other hand (therefore), simultaneously to a higher demand and a higher consumption of the resource

(rebound-effect). In particular, the construction of long-term scenarios for technological development leads to speculative futures, because radical innovations – as they may induce new "Kondratieff-cycles"[4] – cannot be predicted.

3. Change of preferences over time: The preference for exhaustible resources, in particular for a livable environment, may go up with increasing environmental problems in the future. With growing population also, the scarcity of land and water lead to increasing values of land in agglomerated areas and clean water.
4. Ethical problems and intergenerational equity: It is obvious that within one generation the value of a unit of consumption now is higher than that of tomorrow. This is expressed by a rate of discount. But in the context of intergenerational allocation of welfare, a high rate of social discount implies a shift of intertemporal consumption to the present generation. If the present generation, however, feels "empathy" with future generations, then the long-term rate of social discount will be very low.

The problem of social discount plays a dominating role in the debate between N. Stern and W. Nordhaus (2007). The result of the "Stern Review" (Stern 2006) that the benefits of an immediate mitigation policy with respect to climate change is five times of the cost to be invested is strongly dependent on the very low rate of social discount (0.1%). Nordhaus suggested a discount rate of at least 1.5%. Applying this rate of discount to impact scenario used by Stern for his economic analysis would lead to a drastic devaluation of future benefits (the present value of one dollar of benefits to be received in 100 years would be 22 cts, which is almost the factor 5). This means that a slight revision of scenario assumptions of the Stern Review would be sufficient to come to the conclusion that adaptation is the better choice in the economic sense rather than mitigation.

From this follows that the assumptions on ethical preferences of the present society play a dominating role with the estimation of present values of long-term future external costs of climate change. The state of discussion on international climate conferences and the announcement of reduction policy actions by many countries indicate – beyond the strategic hesitation of big transition countries – that empathy with future generations can be weighted so high that it is justified to set the social rate of discount close to zero.

13.3 Measurement and Valuation of External Costs of Transport with a Focus on Climate Change

The challenge to internalize external effects of transport rises and falls mainly with their measurement and right valuation. Whereas the measurement of GHG emission in transport is straightforward, the valuation raises considerable challenges.

[4] See the introductory paper of Rothengatter in this volume for a definition of Kondratieff-cycles.

13.3.1 Measurement of Emissions

Although the measurement of several local external effects such as noise or air pollution (e.g., particulate matter) is rather sophisticated, it is relatively easy for global-acting CO_2 emissions as the leading GHG: The production of CO_2 is directly linked with the consumption of fossil energy by transportation activities. As more than 90% of energy used for transport purposes is fossil energy, it is possible to construct direct relationships between transport activities, consumed energy (fuel), and produced CO_2. Although this simplification reflects most of the effect, it abstracts from other GHGs. However, for the aviation sector this simplification is not precise enough as high quantities of non-CO_2 climate gases such as NO_x, contrails, or water vapor are emitted (IPCC 1999). It is estimated that these climate gases make at least 50% of the emitted CO_2 of aviation, measured in CO_2 equivalents (IPCC 1999).

13.3.2 Measurement of Impacts

Measuring the impacts of GHG is challenging because of the complex coherence between the time sensitive amount of GHG emission and the climate as well as the other forecast problems pointed out in Sect. 13.2.4. It is not possible to identify unanimously the impact paths from the emission of CO_2 to the changes of environmental conditions at tipping points and finally the impacts on people exposed to the risks. The emission of GHG is not primary a flow problem, but rather a stock value with a tremendous time delay of some decades (IPCC 1999). The concentration of CO_2 in the atmosphere at a certain point in time is the critical value, not the additional flow. The current status of the CO_2 concentration in the atmosphere (about 350 ppm, IPCC 1999) seems not to be critical. However, in the long term, the ecological degradation of CO_2 concentration in the atmosphere is not fast enough compensate the current human emission rate of CO_2. This leads to a further increase of the concentration even if the emissions are stopped immediately. It is expected that a concentration of 650 ppm or more will occur by the end of this century under business as usual conditions. Reducing CO_2 emissions by 50% until 2050 would give a chance to limit the concentration to about 450 ppm and the increase of global temperature to about 2°C (IPCC 1999).

The next step of analysis is to identify the changes generated by reactions of nature to the increase of global temperature. The Potsdam Institute for Climate Research (Edenhofer et al. 2008) has published a map on potential worldwide changes of nature stemming from global warming (Fig. 13.2). From this map, it becomes obvious that these global tipping points (e.g., the methane outburst in Siberia or the performance of the marine carbon pump in the south east pacific, El Niño, etc.) are manifold and associated with a high degree of uncertainty.

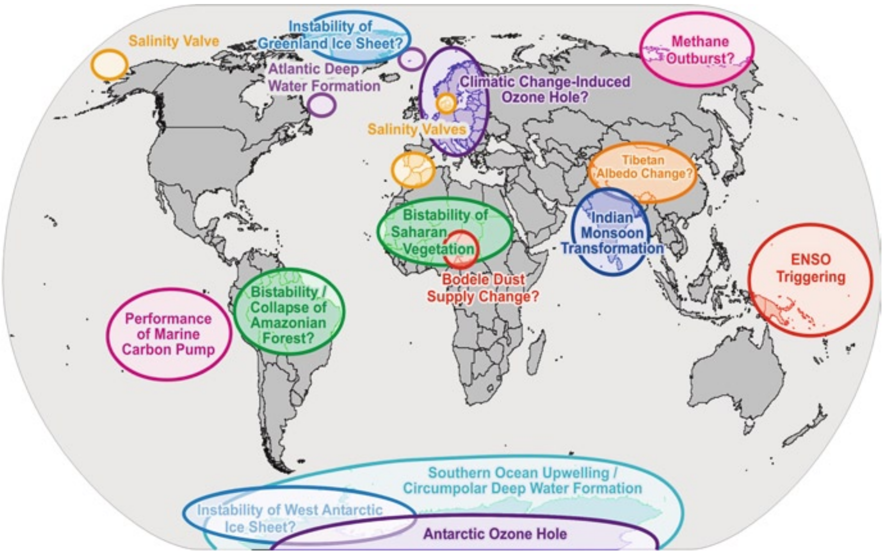

Fig. 13.2 Tipping points in the earth system (*Source*: Edenhofer et al. 2008)

The IPCC scenarios (IPCC 2007) give quantitative figures for the manifold kind of changes and their possible impacts on the living conditions of mankind. Based on this, the economic impacts can be estimated as done by Stern (2006).

13.3.3 Valuation of Impacts

As external effects are not processed through the market system, there are no market prices available for a direct economic valuation of such impacts. A number of possibilities are given to overcome this problem, as for instance:

1. Estimation of damage costs
2. Estimation of avoidance costs
3. Contingents methods (willingness to pay/accept, stated and revealed preference)
4. Hedonic pricing
5. Market game-based simulation methods

The approaches can lead to significant different results. Apparently, especially the first two are based on complete contrary principles. The amount of damage might differ strongly from the avoidance costs. The "Stern Review" (Stern 2006) estimates the damage costs, which might occur under business-as-usual conditions. This presupposes to transform the IPCC results into a monetary framework, which includes a number of uncertainties with respect to the economic transmission mechanisms. At the end of the analysis the economic value of a ton of CO_2 can be quantified with about 80 Euro, worldwide, on average.

But, as the damage cost approach requires to set up a very detailed scenario of the impact mechanisms including many uncertainties, many authors prefer the avoidance cost approach even though it does not consider future generations. This approach requires to set the reduction target and to estimate the costs of a least-cost mix of instruments to achieve the target. Infras and IWW (2004) start from the IPCC targets for CO_2 reduction (OECD countries: 80% until 2050) and result in a value of 140 Euro per ton of CO_2, which seems much higher than the Stern estimation. But considering that the Infras and IWW (2004) figures relate to EU 15 (European Union before extension through the accession countries), while the Stern figure includes the developing countries (for which a stagnation of CO_2 production is assumed) this difference diminishes.

13.3.4 Valuation Results for External Effects of Transport

It is interesting to compare the results of neoclassical approaches, based on Pigou's principle of charging the difference between marginal social and average private costs, and empirical values. Maibach et al. (2008) prepared a European handbook on external costs of transport for the European Commission, which gives an overview of published marginal costs for every type of external costs, expressed in Euro/vkm (see Fig. 13.3) and compared these costs with the effectively applied national charges.

This figure is based mainly on values estimated by the neoclassical Pigou concept and consequently congestion comes out as the most important externality in peak hours, while climate change appears to be almost irrelevant. This is due to the fact that most studies derive the price for a ton of CO_2 from the European

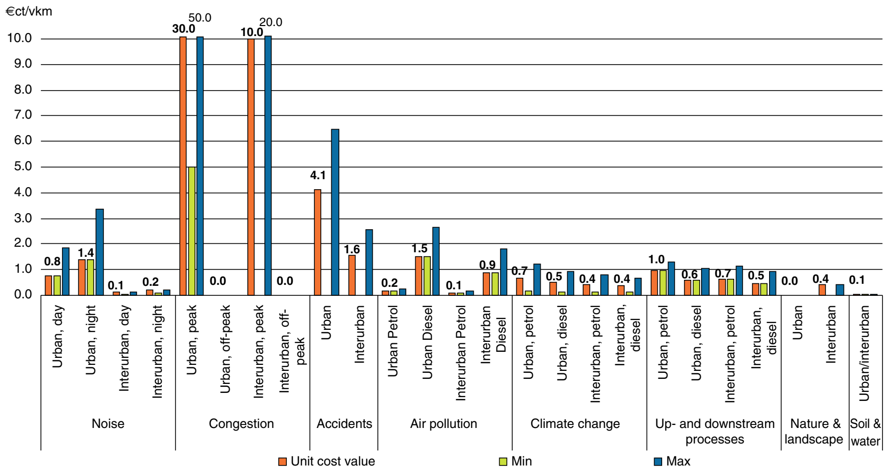

Fig. 13.3 Marginal external costs per cost category in €ct/vkm for passenger cars (in €2000) (*Source*: Maibach et al. 2008)

Emission Trading Scheme (EU-ETS) introduced in 2005 for some industrial sectors and electricity production. As too many certificates were allocated, the resulting certificate price was moderate. For instance, the comprehensive EU study UNITE (Bickel and Schmid 2002) uses a CO_2 price of 17 Euro/t. As already mentioned, the study of Infras and IWW (2004) for the International Union of Railways (UIC) exhibits higher values of CO_2 of up to 140 Euro per ton (see Fig. 13.4). Accordingly, the external costs of climate change become the second largest impact for individual passenger transport. This underlines the uncertainties connected with the valuation of external effects of transport.

Besides these different values for external costs, even the classification of modes is considerable different. The European Handbook for External Costs of Transport comes out with the result that aviation is an environmentally friendly transportation mode (Maibach et al. 2008:110), while the study by Infras and IWW (2004) characterizes aviation as most problematic from the environmental point of view.

Under these conditions, it is obvious that the question "which approach is right or wrong" cannot be answered. But it is clear that the valuation of CO_2 used in the Handbook (Maibach et al. 2008) is not consistent with the target set by the European Commission to reduce CO_2 until the year 2020 by 20% or even by 30% if other countries follow the EU reduction policy. The internalization of CO_2 externalities based on the Handbook prices (Maibach et al. 2008) would not lead to a significant change of traffic behavior. For instance, the mark-up for an air ticket price on medium distance in Europe would be 2–5 euros.

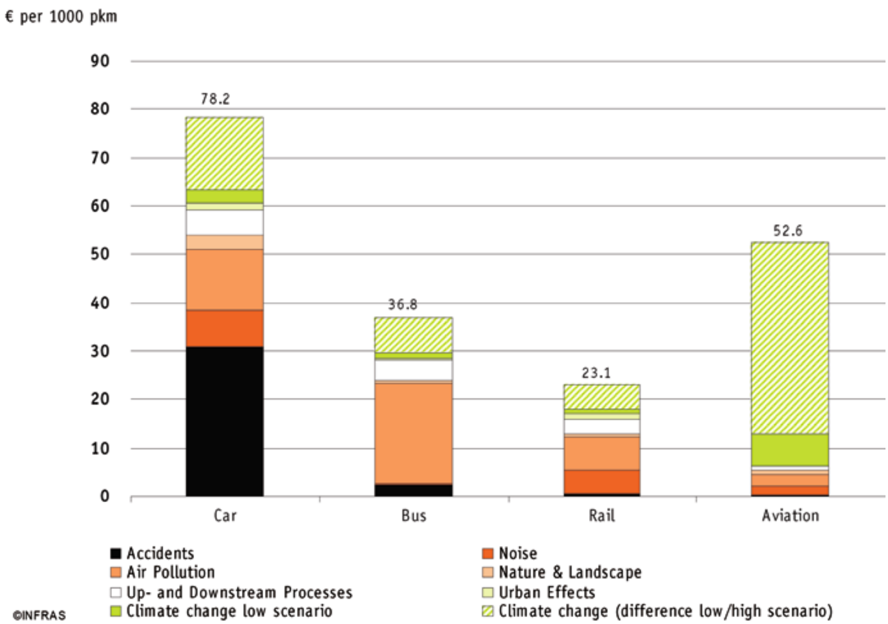

Fig. 13.4 External costs of transport assuming a price of 140 Euro per ton of CO_2 (*Source*: Infras and IWW 2004)

13.4 Policy Instruments for Internalizing External Climate Effects of Transport

For internalizing external climate effects of transport, four categories of policy instruments can be identified, which are depicted in the following:

1. Voluntary agreements and technological support
2. Regulations
3. Taxes and charges, as well as
4. Trading of emission certificates

These are depicted in the following.

13.4.1 Voluntary Agreements and Technological Support

European transport policy has relied for some time on the benevolent self-interest of the automobile manufacturers to improve fuel efficiency of vehicles. In 1998, the Association of European Automobile Manufacturers (ACEA) had published a self-commitment to reduce the average fuel consumption of newly licensed passenger cars to 140 g/km in 2008 (EC 1998). In reality, only 154 g/km was achieved which was mainly due to the trend to premium cars with higher weight and more horsepower (T&E 2008).

This underlines that the market is not contributing automatically to the climate goals. This is only the case in time phases of high fuel prices, which lead to increased market demand for fuel-efficient vehicles and an appropriate reaction of the suppliers. Such market reactions could be observed in the mid-seventies and early nineties when oil prices peaked. Cars with a low fuel consumption of 3 l/100 km were already on the market more than 10 years ago, which underlines that a change to low fuel consumption is not a technological rather than a market demand problem: The new fuel-efficient technology vanished from the market as soon as the relative prices of fuel went down. The lesson learned is that the market signals are fluctuating and do not provide enough certainty for the suppliers to invest continuously in better energy efficiency.

Presently, there is high interest of the automobile manufacturers to invest in E-mobility, i.e., in new battery technology, electric propulsion, or fuel cells. In some countries, this tendency is massively supported by the state, for instance in China. Also European countries give financial support and organize pilot projects for an accelerated propagation of E-technology. This industrial and political trend is only consistent with the climate goals if a number of conditions can be met:

1. Energy efficiency of E-mobility has to be increased, i.e., presently an electric car consumes more (primary) energy compared with an efficient diesel-driven car.
2. Electrical energy has to be produced by a high share of regenerative power.
3. The charging of vehicles has to be controlled that the peak of electricity demand in the evening hours are smoothened.

4. The driving range of battery-driven cars has to be extended and the loading or exchanging of batteries organized more convenient.
5. Hydrogen-based technology (if applied) would need a new infrastructure for the supply of energy and a much more efficient production method.
6. The costs for the battery can still not cope with the conventional technology – a price decline would be necessary.

As a consequence, one cannot expect that under the current conditions E-mobility will gain a big market share in the next decade. A decrease in battery-prices, a more volatile electricity price, might however foster a considerable market share in the near future. There is still a big potential for improving the efficiency of diesel and gas-driven cars, which will make the main contribution for energy saving in a foreseeable future. Furthermore, one should not neglect the other possibility for energy savings, as there are better aerodynamics, lower weight, better tyres, automatic switch-off of engines, gear mechanism, and other technological improvements, which bring considerable efficiency gains in combination, and especially if paired with better energy consciousness of the drivers. A trend to smaller cars cannot, however, be beaten by these measurements – at least when costs are included in the considerations. Furthermore, traffic management in form of traffic information, guidance, recommendations, and obligatory route choices can help the drivers to make the best choices with respect to travel time, route and mode choice or the choice of destination, e.g., for leisure or shopping.

To conclude: A change of the technology from the supplier side can only be expected if the demand side is changing to more energy-efficient products, and the latter will only happen in a regime, which offers benefits to the customers if they change demand patterns. With respect to the latter conditions, it is not enough to hope for the market signals to develop to the right directions rather than it is necessary that the state sets the regulations and prices in a way that energy-efficient behavior pays for the agents.

13.4.2 Regulations

Economists usually argue that regulations constrain unduly personal freedom of market agents and leads to a failing of the welfare optimum. But in the long run, when decisions for future generations are made, it is inevitable to include the incapable future generation by a long-term reliable regulatory framework to guide the market forces into the sustainable direction. The European Commission, when reacting on the failure with the self-commitment of the automobile industry, took the second position and introduced a strict regulatory regime for the CO_2 emissions of newly licensed cars.

Following Directive 2009/33 EC, the European Commission introduces weak regulations on fuel consumption of the vehicle fleet of manufacturers in 2012, which are followed by rigid rules in the year 2015, limiting CO_2 emissions to 120 g/vkm in 2015 and reducing this limit to 95 g/vkm in 2020. The penalties foreseen can reach a magnitude of 95 Euros per gram of CO_2 emission per vkm exceeding the reference curve per vehicle sold. The reference curve allows the producers of bigger cars (e.g., vans) to deviate from the target, but less than proportional. Under status quo conditions, the producers of big premium cars would have to pay between 3,500 and 15,000 Euros per car in the future, which might influence purchase decisions substantially, even in the market segments of premium cars.

A crucial problem with regulatory policy of this type is the dynamic adjustment of regulatory standards over time, as the US example with the CAFE standards demonstrates. In the USA, the Corporate Average Fuel Economy (CAFE) standard has been enacted in 1975, as a response to the oil embargo from the organization of the Petroleum Exporting Countries (OPEC) in 1973. The limit values were set dynamically and in a way that producers could adjust without major frictions, e.g.,: 20 mpg (274 g/vkm) in 1980 and 27.5 mpg (199 g/vkm) from 1990 to 2010. The regulation has been successful until the nineties, but lost its incentive power because it was no longer adjusted dynamically after 1990. Furthermore, particular trucks and sport utility vehicles (SUVs) were exempted or treated more softly, such that vehicle types with high fuel consumption – as for instance the famous Hummer SUV – were not penalized.

In 2007, the CAFE standards received their first update after about three decades. Future fuel efficiency should be increased substantially by setting the performance of 35 mpg (156 g/vkm) until 2020, without exemptions for light trucks and SUVs. Furthermore, a credit trading flexibility was introduced, such that producers of high fuel consumption cars can trade with producers of low fuel consumption cars. The new requirements mark a first fixed standard for the emission of GHGs by car traffic in the USA and cover the years 2012–2016. The standards foreseen for 2016 are 39 mpg (141 g/vkm) for cars and 25 mpg (219 g/vkm) for trucks.

13.4.3 Taxes and Charges

Taxes and charges are the classical "Pigou-instruments" for internalizing external costs. According to the textbook paradigm, there would be one Pigou tax appropriate to internalize all externalities of different types. This would presuppose that all types of external effects can be aggregated consistently by one (concave) welfare function. More sophisticated approaches follow the Koopmans (1975) theorem according to which every type of externality represents a particular objective and optimizing a set of objectives needs a set of instruments. With respect to climate change, one can follow that fuel or carbon taxes are compatible instruments and also a differentiation of vehicle excise taxes might generate right incentives. Kilometer-based charges, however, are not appropriate because a vehicle km travelled does not indicate exactly how much CO_2 is produced. This is the reason that the European Commission includes only three types of externalities into an internalization strategy based on time and/or spacial sensitive charges: noise, air pollution, and congestion. Climate change effects are excluded with the well-founded argument that fuel or carbon taxation or trading CO_2 certificates are better instruments.

Although fuel or carbon taxes are appropriate instrument to internalize external climate effects, it is rather difficult to implement an harmonized worldwide carbon taxation scheme even this would be desirable form an economic point of view. Taxes usually have a long national history, and they are an element of the overall public finance. Within the EU, a unification of fuel taxes or the introduction of a unified carbon tax would presuppose a unanimous decision of the EU Council. The different budget situation and tax structures of different countries make it difficult to come to a harmonized tax solution for the internalization of climate effects. It furthermore has to be considered that the sectors of international aviation and maritime shipping are governed by international agreements such that isolated national or EU taxation interventions are not possible.

13.4.4 Trading of Emission Certificates

Emission trading is the favorite instrument of the Kyoto Protocol, and it seems that also the international agreements for the post-Kyoto phase (after 2012) might be based on this instrument. Emission trading schemes can be mainly characterized in two dimensions:

1. Open or closed emission trading schemes
2. The obliged party within the energy flow chain (upstream, downstream or midstream emission trading schemes)

In open schemes, all (applicable) parties emitting CO_2 are allowed to trade, regardless which sector or region they belong to. Closed schemes are restricted to particular sectors or spatial entities. The second dimension is from an ecological perspective unproblematic as a liter of fuel emits the same amount of CO_2 – this allows a regulation at each node within the energy flow chain. However, from an economic point of view the associated transaction costs may differ strongly. An upstream scheme means that the producers or traders of fossil energy – which is burned in engines and transformed to CO_2 – are the trading agents. International organizations and the states set the targets, which are introduced as yearly caps to reduce emissions over time. The advantage is that the number of traders is limited and the transaction costs are low. For the demand side of the market, this scheme works like a carbon tax.

In downstream schemes, the consumers of fossil energy are the trading parties, such that there will be millions of traders. CO_2 allowances in such a system function like an additional currency and high transaction costs are necessary to make such a market functioning.

Midstream schemes usually are closed and regulate the vehicle manufacturers even though other agents could be considered. Producers of small and fuel-efficient cars would be able to sell allowances, while producers of premium cars and SUVs would have to buy. In this case, every producer would be free to produce an optimal mix of passenger cars under consideration of the purchase/sales of CO_2 allowances.

However, as the number of cars as well as the concrete driving behavior is unrestricted, this scheme does not guarantee the achievement of the desired emission reduction aim.

The allocation of certificates is of minor interest in this context.

According to the simulations with a multiagent model by Jochem (2009), the decision to close or to open an emission trading scheme for the transport sector has a significant influence on the CO_2 price. In an open scheme (upper part of Fig. 13.5), the transport sector benefit from other sectors, which have lower mitigation costs such that the price of CO_2 emission allowances will be kept low. As soon as the trading system is closed for the transport sector and a particular reduction target has been set (e.g.,: 10% until 2020), the price for a ton of CO_2 will strongly increase from a current point of view (lower part of Fig. 13.5). This is mainly driven by the willingness to pay for big and prestigious vehicles of many households.

As it is hard to integrate international aviation into a fuel or carbon taxation scheme, the European Commission has tried to include this sector into the existing European CO_2 emission trading scheme (EU-ETS), which has been introduced in 2005 and was restricted to industrial sectors and electricity production until 2012.

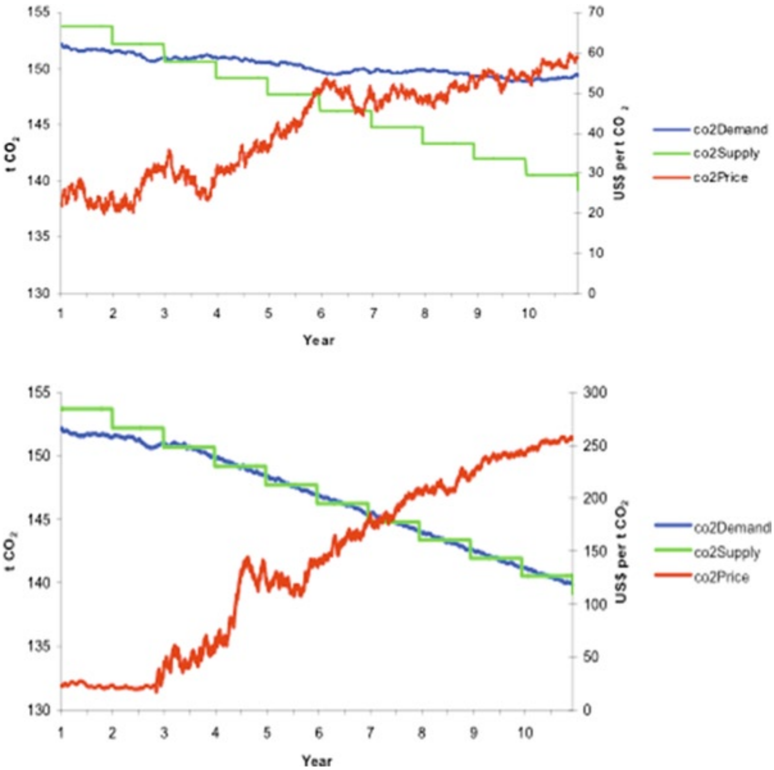

Fig. 13.5 Example of CO_2 prices in an open (*above*) or a closed (*below*) trading scheme (*Source*: Jochem 2009)

Directive 2008/101 states – among other clauses – the following essential arrangements for the aviation sector:

1. All flights are included which arrive/depart at EU aerodromes, beginning with Jan. 1, 2012.
2. From January 1, 2013, 15% of allowances will be auctioned. This percentage may be increased as part of the general review of this Directive.
3. At least 15 months before the start of each period, the Commission shall calculate and adopt a decision setting out:
   – The total number of allowances
   – The number of allowances to be auctioned
   – The special reserve
   – The number of allowances allocated free of charge
   – The benchmarks to be used to allocate allowances free of charge to aircraft operators (in principle dependent on the fuel consumption of the operated aircraft fleet).

This system can be regarded as an international "top runner"-model for including international transport sectors into a CO_2 trading scheme. From the logical point of view, it can easily be extended to the maritime sector, while the practical implementation problems might be bigger in the latter sector.

13.5 Conclusions

Looking at the upcoming challenges in the climate change concern, it is inevitable that the transport sector contributes considerably to CO_2 emission reduction. Notwithstanding, the growth in the global passenger car fleet and the increasing volumes in freight transport will lead to very ambitious efforts.

From an economic point of view, CO_2 emissions are external effects, which should be internalized to increase social welfare. In the neoclassical theory, this is straightforward. However, in its empirical implementation the approach is very sophisticated and the "first-best"-rules such as marginal cost pricing collapse for most external effects. In the real world, it is the major issue of economic advice, to consider the dynamic incentive patterns, the acceptability and the institutional consequences of a pricing scheme. Hence, the public objectives can only be achieved by a variety of instruments.

These instruments include the support of voluntary commitment, of setting regulations and standards, of introducing taxes and charges as well as establishing trading schemes for CO_2 emissions. With respect to the externalities of climate change, general taxes such as fuel or carbon taxes or CO_2 trading schemes are appropriate measures. However, the quantification of unpredictable future damages as well as the stock feature of GHG makes a valuation of external costs of GHG very demanding. With respect to the political implementation, the considerable difficulties to implement harmonized taxation schemes in an international context make a concentration on an agreement for an international open CO_2 certificates trading scheme most reasonable. The specific problems of developing and transition countries could be solved by allocating the CO_2 allowances on a per capita basis. Additional instruments such as a change in allocation rules of the clean development mechanism (CDM) within the Kyoto Protocol framework and of the 1991 initiated Global Environment Facility (GEF) could help to increase the interest of these countries in effective reduction policies.

References

Anable J (2008) The cost-effectiveness of carbon abatement in the transport sector. Project report, London

Baumol WJ, Oates WE (1988) The theory of environmental policy. Cambridge University Press, Cambridge

Bickel P, Schmid S (2002) Marginal costs case study 9D: urban road and rail case studies Germany. Project report of UNITE (UNIfication of accounts and marginal costs for Transport Efficiency), Stuttgart

BMU (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety) (2006) Nationaler Allokationsplan 2008–2012 für die Bundesrepublik Deutschland, Berlin

CfIT (Commission for Integrated Transport UK) (2007) Transport and climate change, London

Coase RH (1960) The problem of social cost. J Law Econ 3:1–44

DeCicco J, Ross M (1996) Recent advances in automotive technology and the cost-effectiveness of fuel economy improvement. Transp Res D 1(2):79–96

EC (European Commission) (1998) Implementing the community strategy to reduce CO2 emissions from cars: an environmental agreement with the European automobile industry, Communication from the Commission to the Council and the European Parliament. COM (98) 495 final, Brussels, 29.07.1998

EC (European Commission) (2006) Mid-term review of the Transport White Paper: keep Europe moving – sustainable mobility for our continent, Brussels

EC (European Commission) (2009) EU energy and transport in figures, Statistical pocketbook, DG Energy and Transport, Brussels

Edenhofer O, Luderer G, Flachsland Ch, Füssel H-M (2008) A global contract on climate change, Background Paper for the Conference on "A Global Contract Based on Climate Justice: The Need for a New Approach Concerning International Relations", Brussels

Erdmann G (2009) CO2-Emissionen von Batterie-Elektrofahrzeugen. Energiewirtschaftliche Tagesfragen 59(10):66–71

Eurostat (2008) Energy and transport in figures, Luxemburg

Eurostat (2010) Eurostat database. www.ec.europa.eu/eurostat

Farber M, Proops J, Speck S (1999) Capital and time in ecological economics. Edward Elgar cheetham

INFRAS and IWW (Institute of Economic Policy Research) (2004) External costs of transport. Project report, Karlsruhe

IPCC (Intergovernemmental Panel on Climate Change) (1999) Aviation and the global atmosphere. Special report of IPCC working group I and III and the scientific assessment panel of montreal protocol on substances that deplete the ozone layer, Cambridge

IPCC (Intergovernemmental Panel on Climate Change) (2007) The Physical Science Basis, Summary for Policy makers, Geneve

JAMA (Japan Automobile Manufacturers Association) (2008) Reducing CO2 emissions in the global road transport sector, Tokyo

Jochem P (2009) A CO2 emission trading scheme for German road transport: assessing the impacts using a meso economic model with multi-agent attributes. Nomos, Baden-Baden

Jochem P, Gerbracht H, Ihrig J, Fichtner W (2010) Integrating battery electric vehicles into the German electricity market. Presentation at the 12th WCTR, Lisbon

Koopman TC (1975) Concepts of optimality and their uses. Math Program 11(1):212–228

LeBlanc LJ, Rothengatter W (1982) Gleichgewicht in Verkehrsnetzen. Das Basismodell und einige Erweiterungen für integrierte Verkehrsplanungen. Jahrbuch für Regionalwissenschaft 3:28–115

Maibach M, Schreyer C, Sutter D, van Essen HP, Boon BH, Smokers R, Schroten A, Doll C, Pawlowska B, Bak M (2008) Handbook on estimation of external costs in the transport sector, Delft

Meade JE (1952) External economies and diseconomies in a competitive situation. Econ J 62(245):54–67

Nordhaus W (2007) The Stern review on the economics of climate change. Yale, New Haven

Papandreou AA (1994) Externality and institutions. Oxford University Press, Oxford

Pigou AC (1920) The economics of welfare, edn 1952. Macmillan and Co, New Brunswick

Rothengatter W (2000) External costs of transport. In: Polak JB, Heertje A (eds) Analytical transport economics: an international perspective. Edward Elgar, Northhampton, pp 79–116

Rothengatter W (2003a) Environmental concepts. In: Hensher DA, Button KJ (eds) Handbook of transport and the environment. Elsevier, Amsterdam, pp 9–36

Rothengatter W (2003b) How good is first best? Marginal cost and other pricing principles for user charging in transport. Transp Policy 10(2):121–130

Schafer A (2000) Carbon dioxide emissions from world passenger transport. Transp Res Rec 1738:20–29

Stern N (2006) Stern review on the economics of climate change. HMSO, London

T&E (Transport and the Environment) (2008) MEPs capitulate on deadlines, targets and penalties on fuel efficiency deal, T&E Press Release, 10.12.08

TNO, IEEP (Institute for European Environmental Policy), and LAT (Laboratory of Applied Thermodynamics) (2006) Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2 emissions from passenger cars. Project report, Delft

WBCSD (World Business Council for Sustainable Development) (2004) Mobility 2030, Geneve

WHO (World Health Organization) (2003) Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide. World Health Organization, Bonn

Chapter 14
Downstream Emissions Trading for Transport

Charles Raux

14.1 Introduction

Transport generated approximately 25% of emissions of CO_2 in the world in 2003, and this share amounted to 30% in OECD countries. Among these emissions of one of the main greenhouse gases (GHGs), 18% come from road transport; 3% from air and 2% from maritime transport (OECD 2007). Moreover, emissions from transport have increased by 31% in the world between 1990 and 2003. Given recent evidence on the need for deep GHG reduction in the next few decades (Stern 2006), several industrialised countries have set ambitious targets, e.g. a reduction by four of their emissions by 2050. Regarding transport, the policies will have to be more determined: they should aim at reducing total consumption which means reducing vehicle-kilometres travelled, not just vehicle-specific consumption.

Among the measures identified to reduce transport intensity, carbon taxes and vehicle taxes seem to be the most cost-effective (OECD 2007; Parry et al. 2007). However, the "fuel tax protests" of September 2000 in several European countries have shown that public opinion is very resistant to fuel tax increases (Lyons and Chatterjee 2002). This resistance can also be explained by concerns about fairness, since many households depend on the car for day-to-day living and for getting to work. Moreover, fuel tax increases would require the international harmonisation of fuel taxation in different countries, which, in Europe, appears to be extremely difficult.

In the light of these difficulties, another instrument which combines economic incentives and quantity control, namely marketable or tradable permits (TPs), might be of interest. This category of instruments is part of a wider one, namely transferable permits. According to a general definition given by Olivier Godard (OECD 2001), transferable permits cover a variety of instruments that range from the introduction

C. Raux (✉)
LET (Laboratoire d'Economie des Transports), CNRS and University of Lyon,
ISH, 14 Avenue Berthelot, 69007, Lyon, France
e-mail: charles.raux@let.ish-lyon.cnrs.fr

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of flexibility into traditional regulation to the organisation of competitive markets for permits. These instruments have in common: the setting of quantified physical constraints in the form of obligations, permits, credits or rights allocated to target groups of agents consuming scarce resources; and the permission granted to agents to transfer these quotas between activities, products or places (offsetting), periods of time (banking) or to other agents (trading, hence "tradable permits").

We will show that there are several directions of theoretical relevance for the use of emission trading in transportation, especially "cap-and-trade" schemes, and that hybrid instruments combining tradable permits with taxation may be particularly efficient. Moreover, we will also show that there is no sound reason to dismiss in principle downstream trading on the basis of their potentially high transaction costs, because of the large number of mobile sources to deal with. Downstream schemes will be presented, which are feasible both on technical and institutional grounds, thanks to available electronic technology. Regarding the need to coordinate transport emissions reduction at the international level, and especially regarding international transport, we will also argue that emission trading in transport could be quickly implemented contrary to the harmonisation of fuel taxation.

This chapter is structured as follows. First, starting from the theory about tradable permits, their relevance in transport emissions is analysed. Second, the case for downstream approach is discussed, and two proposals of tradable rights for fuel consumption for private vehicles and for freight transportation are presented. Third, international aspects regarding border effects and international coordination in the European Union and with other regions in the world are analysed. In the next two sections, some evidences regarding behavioural effectiveness and acceptability issues are presented.

14.2 The Theoretical Case for Economic Efficiency

The economic theory of pollution permit markets is well established now. It started from the seminal work of Coase (1960) on external costs, showing that with low transaction costs and well-defined property rights an efficient distribution of resources (including externalities) could be achieved. This was followed by the work of Dales (1968) on regulating water use, and the formalisation of pollution permit markets by Montgomery (1972).

In a "cap-and-trade" scheme, the regulating authority determines the total amount of pollution acceptable (i.e. the "cap") and distributes the permits (or quotas or rights[1]) among the agents, who are liable to return these permits to the authority in proportion of their emissions. The agents are authorised to trade the unused permits.

The theory may be summed up as follows (Baumol and Oates 1988). A system of tradable permits (TPs) equalises the marginal costs of reduction between all emission sources. Under some assumptions, this is a sufficient condition for minimising

[1] The terms "quota", "permit" or "right" will be used interchangeably thereafter.

the total cost of achieving a given emissions reduction objective. This result is obtained independently of the initial allocation of rights: it should be stressed that this makes it possible to separate the issues of efficiency and equity. Moreover, opposite to conventional taxation, the public authority needs no information about damage and abatement cost functions to fix the optimal level of intervention: with permit markets the authority needs only to fix the total amount of pollution.

Indeed, regarding the quantitative objective of emissions reduction, the essential difference between taxes and permits lies in the fact that in practice the public authorities do not possess full information on the reduction costs for the different agents. With a permit-based approach, achieving the quantitative objective of emissions reduction is guaranteed, but there is no guarantee with regard to the actual level of the marginal costs of reduction. On the contrary, in the case of the tax, the marginal cost of reduction for each agent is fixed, but there is no guarantee with regard to the amount of emissions reduction.

This uncertainty makes it difficult for the regulator to make a choice as errors regarding reduction costs for agents may be very costly to the community, particularly regarding the distribution of efforts over time and between agents. Nevertheless, a number of criteria may be relevant when making this choice (Baumol and Oates 1988).

A first criterion for the appropriateness of a quantity-based approach (i.e. quotas) is whether the damage to the environment is increasing very rapidly or becoming irreversible when certain emission thresholds are reached or exceeded. In this case, TPs provide a relative advantage over a tax approach since quotas control reduces the cost of errors (Weitzman 1974).

However, there is a controversy regarding the pace of damage cost function of GHG emissions, between those who argue it is rather steep relative to the abatement cost function (Stern 2006) and those who argue the opposite (see, for instance, Nordhaus 2006). In order to overcome this uncertainty about the costs of (in)action, a hybrid approach combining permits and a “safety valve” for price would provide a pragmatic solution (Roberts and Spence 1976; Baumol and Oates 1988, pp. 74–76). It involves setting a payment in full discharge (i.e. a “safety valve”): this way, the emitter could be discharged of his or her obligation to return permits by paying the payment in full discharge for each unit of emission exceeding the rights he or she holds. This payment in full discharge would then set the upper bound of the permit price. This hybrid solution is to be applied when the regulator must make decisions either with regard to the temporal distribution of efforts (e.g. annual objectives) or with regard to the distribution of this effort between the different actors or sectors.

A second criterion is whether agents are more sensitive to quantitative than to price signals, particularly if the price-elasticity of demand is low in the short or medium term as is the case in transportation. Here again a permit system is more appropriate.

For example, emissions from travel may be reduced by various means: by changing driving style; by reducing vehicle-kilometres travelled (by increasing the number of passengers in vehicles, reorganising trips or changing the locations of activities); and by changing one’s vehicle or changing transport mode in favour of one which consumes less energy. Some of these actions may be implemented in the short term, while others such as changing one's vehicle, changing one's place of work or residence may take much longer. Thus, price-elasticities of fuel consumption are generally low in the short term and considerably higher in the long term. For example, for fuel consumption, the price-elasticity values are between −0.2 and −0.3 in the short term[2] and −0.6 and −0.8 in the long term (Goodwin 1988; Graham and Glaister 2002; Brons et al. 2006).

Furthermore, a third criterion that is an important factor for the effectiveness of TPs is the heterogeneity of the agents involved in the system. This means that the marginal costs of abatement must be sufficiently different between agents to allow benefits from trading permits, thereby making the market function effectively.

For instance, if one considers the use of private car, the marginal abatement cost curves are highly varied and, in particular, rise as one moves from urban to suburban and then to rural settings. Changes in the locations of activities to reduce the distances between different activities are much easier to make in urban areas than in suburban or rural locations, as a result of the density of available activities. Reducing commuting distances is easier in a conurbation which provides a high density of job and housing opportunities. Likewise, public transport which provides an alternative to the private car is more frequently available in urban areas.

To sum up, there are several directions of relevance for TPs in the transport sector. Moreover, the controversy about efficiency opposing pure taxation to pure tradable permits looks now old-fashioned: the design of practical schemes should be based on hybrid solution combining TPs with the "safety valve" referred to above.

There are now a lot of experiences in implementation with TPs, for instance in the fisheries, and in the fields of construction rights and water pollution, some with success other with failures. The US "Acid Rain" scheme is a good example of a large-scale system of tradable sulphur dioxide emission permits between power plants (Godard 2000). These experiences make it possible to identify some general criteria of success (OECD 1997, 1998) which include among others: the simplicity and the clearness of the system; the possibility of effective market operation; the credibility of emissions monitoring and sanctions; and the long-term validity of permits.

14.3 Towards Practical Implementation: The Case for Downstream Approach

The main arguments against the use of permits in the transport system are the cost of administering and monitoring permits over a large number of mobile sources, i.e. the transaction costs. This is why trading is generally considered only at the upstream level, i.e. fuel producers and refiners: however, some limits of upstream trading can be identified. Since transport in Europe is already partly concerned by the current Emission Trading Scheme (ETS), schemes regulating emissions of

[2] That is, a 10% increase in price would lead to a 3% reduction in fuel demand.

ground transportation need to be modulated in addition to this one. Two proposals are recalled, one regarding a domestic tradable fuel rights scheme for private vehicles, the other regarding a tradable fuel rights scheme for freight transportation. Final sections address the phasing in of these schemes and the issue of administrative costs.

14.3.1 The Crucial Issue of Transaction Costs

Stavins (1995) has shown that when transaction costs are involved, the initial allocation of rights affects the final balance and the total cost of reducing emissions. Thus, reducing these transaction costs is a crucial issue: this should be done by avoiding finicky regulations or by facilitating the activity of intermediaries – like brokers – between vendors and purchasers (Hahn and Hester 1989; Foster and Hahn 1995).

Crals and Vereeck (2005) offer a definition and an in-depth comparison of transaction costs between taxes and tradable permits. Transaction costs include legislative, information, search, set-up, operational, negotiation, contract, monitoring and enforcement, and compliance costs. Their conclusion is that the overall costs depend on the details of the scheme design, whether tax-based or permits-based.

For instance, permits distributed for free on a large scale incur almost no information costs when compared with taxation. An upstream system with a few participants may incur high costs of negotiation (or lobbying) when compared with a large-scale downstream system with a fixed allocation. Combined with modern technology and brokerage without regulatory interference for trading, permits operational costs can be set at their minimum.

Last but not least, with corrective (e.g. personalised) taxation there is a trade-off between transaction costs and environmental effectiveness. This has to do with the issue of acceptability (see below). On the opposite, the permits allocation scheme needs no trade-off with its environmental effectiveness since permits are by design used in their most efficient way.

14.3.2 Some Limits of Upstream Trading

This issue of administrative costs is the main argument against the use of permit systems within the transport sector which, by definition, involves a large number of mobile sources. This explains why propositions in the literature have been initially confined to targeting vehicle unit emissions through auto makers (Albrecht 2000; Wang 1994; and the California's ZEV programme in Raux 2004). The main advantage of these proposals is that the permit systems would involve a small number of participants thus allowing lower transaction costs. Permits on household car ownership are another indirect way of controlling car travel (Walton 1997) but the linkage with actual fuel consumption is very crude. These systems have the disadvantage of ignoring the other component of total emissions, fuel consumption through actual vehicle use by drivers.

Transport supply might be another area of TPs implementation. For instance, local governments, which plan land use and define transport policy and hence provide transport infrastructure and services, could be involved in ETSs (following the idea of "city carbon budget" by Salon and Sperling 2008). However, the basic difficulty is to monitor mobile sources which can be fuelled somewhere in a specific administrative area and can travel through other administrative areas: to which local governments should the liability of emissions be attributed?

Regarding fuel consumption by transport vehicle users, to reduce the administrative costs, it seems relevant to set up the system of permits at the very upstream, at a level where the actors are very few: it could be the fuel refiners or distributors, which already transmit the current excise duty to the ultimate consumer and return the product of the excises to the government. By imposing to the producers and the importers of oil, natural gas and coal to return the quotas, the system would cover the whole CO_2 emissions resulting from the combustion of the hydrocarbon fuels by the end-users (Winkelman et al. 2000).

In a study on the design of a GHG emissions trading system for the USA, Nordhaus and Danish (2003) argue the case for a hybrid approach which would combine an upstream procedure for fuel producers with a downstream procedure for automobile manufacturers. However, as German (2006) points out, there are a number of difficulties with such a scheme: one of the main problems is the risk of double counting both in terms of credits to automobile manufacturers for fuel efficiency improvements and in terms of allowances for fuel producers: credits for vehicle manufacturers are based on the entire lifetime of the vehicle, while allowances for fuel producers are for emissions in the current year. Furthermore, this type of programme does not cover the existing vehicle fleet, which is known to have a lifespan of around 15–20 years on average. In short, such a programme would be highly complex.

Moreover, an upstream system is prone to two disadvantages. First, there is a risk of diluting the incentive effect of permits on the final emitter, so that they implement the complete panoply of behavioural adaptations which are available to them. Indeed, whether the permits are acquired by auction or distributed free to the fuel suppliers, these suppliers would pass opportunity costs[3] relating to these permits to their customers as a simple additional fee. In this case, the advantage vis-à-vis the current system of fuel taxation is null.

The second disadvantage appears in the event of free allocation of quotas to the fuel suppliers. The fuel suppliers could transmit the opportunity costs relating to these permits: this would not call into question the economic efficiency of the system but certainly its acceptability, since those supporting the effort of reduction would not benefit from the revenue created by the free allocation. An upstream permits system thus seems, for reasons of political acceptability, incompatible with a free allocation.[4]

[3] As the permits will have a value on the market, the opportunity cost for a fuel supplier would consist in not selling on the market the permits which they received for free, or not recovering their value in the form of extra costs to their consumers.

[4] Unless this revenue is taxed, from which arises a new complexity.

14.3.3 Transport in Europe Is Already Concerned by an ETS

The advantage of complete coverage by an upstream permit system has lost its strength today in the European Union, with the operation of the CO_2 ETS since 2005 (see Box 14.1). Since electricity production is already included in the ETS, ground transportation in Europe is impacted through rail operation and the future potential large-scale use of electric plug-in vehicles.

Box 14.1 The European Emission Trading Scheme

The ETS is in force since 2005 and has been set to help the European Union to reach the Kyoto Protocol targets of its member states. It covers currently more than 12,000 energy intensive fixed industrial facilities and power plants and till now concerns only CO_2 emissions. After the first phases of the scheme which have seen an over-allocation of free allowances by member states to their industries and a subsequent collapse of carbon price, the scheme will be modified by 2013.

Following the EU commitment to reduce its emissions by 20% compared to 1990 levels, total EU industrial emissions will be capped at 21% below 2005 levels by 2020. New industrial sectors will be included along with two new GHGs (nitrous oxide and perfluorocarbons). It is expected that 50% of all EU emissions will be covered. In order to avoid over-allocation by member states to their domestic industries, national allocation plans of the ETS first phases will be replaced by an EU-designed allocation method based on benchmarking vis-à-vis the most efficient techniques and processes.

Moreover, from 2013 auctioning of emission allowances will be introduced and increased with the aim to have 100% auctioning in 2027. Sectors not included and which use fossil fuel, such as ground transport or buildings for instance, are expected to achieve a 10% reduction of emissions by 2020: national caps have been established for these sectors.

Regarding the articulation with world international freight transport, the inclusion of air transport in the European ETS is already on tracks by 2012 (see Box 14.2).

When it comes to maritime transport, the same approach might be adopted by the European Commission as stated in the “climate package” adopted in December 2008. If no agreement is reached with the International Maritime Organisation by 2011, the Commission should make a proposal to include international maritime emissions with the aim of its entry into force by 2013. These initiatives are first steps towards the inclusion of international transport in a worldwide ETS.

Since aviation is already included in the ETS – and maritime transportation will potentially in the near future – a scheme regulating emissions from ground transportation should now be modulated as a complement to the ETS.

Box 14.2 The Inclusion of Aviation in the European Emission Trading Scheme by 2012

Given the slow progress of negotiations regarding international air transport emissions at the International Civil Aviation Organisation (ICAO), the European Commission decided in 2005 to take unilateral action and proposed to bring aircraft operators into the EU ETS for all flights arriving or departing from the European Union. According to the directive 2008/101/EC issued in November 2008, the scheme will include all the flights, starting in 2012. The scheme will initially concern only CO_2 emissions and not nitrogen oxides and water vapour with its condensation trails.

The total quantity of allowances will be calculated on the basis of average CO_2 emissions for the aviation sector over the period 2004–2006: it will amount at 97% of this quantity in 2012 and set to decrease gradually after the starting of the scheme. A fixed percentage of this total will be allocated free of cost (85% in 2012) and the remainder will be auctioned.

Each aircraft operator will then apply for a free allowance based on its historical activity (tonne-kilometres) and a benchmark ratio of total quantity allowances to the tonnes-kilometres achieved by the operators. In addition, operators will be able to buy allowances from other sectors covered by the ETS.

Indeed, end-users are an important target for emissions reduction since vehicle use represents about 75–80% (tank to wheel) of whole emissions from the point of view of vehicle life-cycle analysis (from cradle to grave). End-users as the final decision makers can modify, albeit with more or less constraints, their travel choices, activity locations, or choice of vehicle or transport mode. Moreover, according to Baumol and Oates (1988), the incentive to reduce CO_2 emissions should be put as close as possible to the pollution source, to maximise the policy efficiency. This pleads for targeting the fossil fuel consumption of end-users.

In the next two sections, schemes of fully downstream permit markets within the transportation sector are proposed. This is undertaken separately for private vehicles and for the freight industry, due to significant differences in economic behaviour between these two sectors.

14.3.4 Proposal for a Domestic Tradable Fuel Rights Scheme for Private Vehicles

Here is summarised a proposal of "tradable fuel consumption rights" for motorists (for a detailed description and discussion, see Raux and Marlot 2005; Raux 2010). This idea has some connections with the more general one of "domestic tradable quotas"[5] which would encompass all fossil fuel consumption of households, thus including, e.g. home heating.

According to this scheme, motorists as consumers of fuel and hence emitters of CO_2 would be liable for the obligation to return the corresponding fuel rights to the regulating authority. The right corresponds to an authorisation to emit the CO_2 equivalent of a litre of fuel.[6] These rights may be held initially by the agent or purchased in the permit market.

Different options are available for allocation of fuel rights and these refer to different views of equity. One option would be to allocate free fuel rights on a per capita basis. The rate by which rights allocations would be reduced each year would be announced several decades ahead and periodically adjusted by a regulatory authority independent of the government in office.

In order to consume more fuel than his or her free allocation, a consumer would have to purchase additional rights on the market. On the other hand, a consumer who does not use all his or her allocated rights could sell them. Practically, participants would buy and sell rights through intermediates like their usual bank operator or buy them at the petrol pump.

In order to reduce administrative costs and enforce a reliable monitoring, fuel rights debit would be validated when the motorist buys fuel at the pump. The rights, awarded annually, would be held on a chipcard. This could be either a smart card compatible with the automatic teller machines (ATM) that are already installed at petrol stations or a modification of credit smartcards currently used in these ATM. It would also be possible to purchase or resell permits in banks, using ATM bank distributors or over the Internet.

Other options in design include the choice of limited or unlimited validity of permits, and a face CO_2-equivalent value decreasing year-to-year to limit speculation.

For acceptability reasons, the management of fuel rights would not be left entirely to the market: rights would be sold and bought back at a price fixed by the authority. This implies that the authority would adjust this price on a yearly basis.

It would be socially unacceptable to apply suddenly the fuel rights system to all motorists. Hence, the implementation of the fuel rights market should be progressive and would coexist with a CO_2 taxation system. Moreover, taking part in the fuel rights system should be voluntary.

A solution is to set up the "safety valve" referred to above, which would be paid both by fuel consumers who wish to stay outside the rights market, and those who are taking part in it but have used up their allocation and are either unable or unwilling

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[5] This idea was first developed by David Fleming (http://www.dtqs.org/ Accessed Dec 2008).

[6] Currently in France, 2.4 kg CO_2 for a litre of gasoline and 2.6 kg CO_2 for a litre of diesel. Strictly speaking, this value should vary according to the type of fuel: diesel fuel contains more carbon than gasoline, gasoline with ETBE can have different emissions than gasoline without ETBE. A conversion factor would apply for each kind of fuel. For the purpose of simplicity of exposition, we have assumed that one right unit corresponds to 1 L of any fuel.

to purchase permits. That would play the role of a conventional “CO_2 tax” and constitute a price ceiling of permits on the market. It would have to be adjusted with reference to the country’s international commitments to reduce emissions.

To sum up, the current fuel excise taxation system will be supplemented by the coexistence of two schemes: the rights market on a voluntary basis on the one hand, the extension of fuel taxation with a “CO_2 tax” for those not wishing to take part in the rights market on the other hand. These two systems will be the alternative proposed to motorists: the incentive to adopt the fuel rights system will be effective if the price of fuel right stays lower than the CO_2 tax.

14.3.5 Proposal for a Tradable Fuel Rights Scheme for Freight Transportation in Europe

Fuel rights for freight transportation would also be based on quotas of CO_2 calculated from the carbon contained in the fuel (mainly diesel oil for trucks) consumed by any freight vehicle user, i.e. a for-hire carrier or a shipper performing its own transport (Raux 2010). Obligation would be made to the user to return to the regulating authority the corresponding rights, which would then be cancelled.

In principle, there should be no free allocation to shippers. In case of full integration in the ETS, shippers holding ETS quotas could use them for transport. A free allocation could be devised for transport operators to improve the acceptability of the scheme. Given the European scale of freight ground transportation, the principle of a free allocation or not and, if a free allocation is adopted, the choice of the method of allocation and the calculation of the allocations would be decided at the level of the European Union.

The for-hire carrier (or the transport organiser) would negotiate with the shipper to get (or be paid for) fuel rights in view of the achievement of transport operation. Carriers holding unused rights (after having transferred the required quantity to the regulating authority) could sell them.

All freight transport modes would be covered, i.e. road, rail, river, maritime and air modes. This is already the case for aviation by 2012 (see above). The geographical coverage would be at the level of the European Union at least.

Transfer of quotas to the regulating authority would be monitored at the time of fuel purchase, either at the pump or when filling a tank on the carrier’s site.

The entrance into the fuel rights trading system would be on a voluntary basis. A “CO_2 tax” would apply to the fuel consumers not wishing to take part in the fuel rights market. Participants to the rights market who have exhausted their initial allocation could buy additional rights on the market or pay the CO_2 tax as a “full discharge” payment. Other transport sectors or agents not included in the fuel rights market (eventually the private cars, depending on the extension of fuel rights market to them, see above) would be covered at least by a CO_2 tax.

14.3.6 Phasing In

Fuel rights markets in the transport sector could be phased in. The fact that a new market is implemented does not mean that it will gain the support of all of the stakeholders overnight. Operations on rights transfer – for instance, debiting procedures at the pump – will require technical and institutional modifications which inevitably take time. This said, the necessary modifications might well happen quickly as fuel distributors will wish to attract customers who want to participate in the rights market.

If stakeholders are free to enter the market, the incentive for them to do so will implicitly be the existence of the "CO_2 tax", provided that the latter, driven by governments, remains higher than the price of fuel rights on the market. The other role of the "CO_2 tax" is to ensure fair treatment by avoiding ways out of emission reduction requirements.

For political and practical reasons, the different fuel rights markets could be introduced separately, i.e. on different dates for the freight transport and private car sectors. Of course, for a complete coverage, public transport operators should be included in the scheme for passenger transportation, along with private car owners.

The crucial point is that as soon as at least one of the markets is implemented, a general "CO_2 tax" is established for all of the agents not yet concerned. To ensure the acceptability of these measures, the tax should be reasonably low to begin with, with increases to be phased in over several years announced in advance. This means that the different markets will have to be established within a limited timeframe.

14.3.7 How Administrative Costs Are Reduced?

ETS operation has revealed that the costs of administering and reporting emissions is high for small emitters, i.e. structures managing only a few stationary installations affected (e.g. a boiler in a hospital). This is a good example of how a scheme design influences its operation costs. On the opposite, the above proposals on fuel rights are aimed at avoiding these pitfalls.

In the case of fuel rights for drivers, the principle of a fixed free allocation is proposed. It avoids the need for complicated calculations that are costly to administer on an individualised basis. The simplicity of the allocation principle proposed and the transparency of the calculation as well as the fact that it applies to the entire population reduces any risk of government decision-making being captured by private interest groups.

For freight transport, it is proposed that there be no free allocation to shippers, which eliminates any reason to lobby for allocations and the adverse consequences that might occur. This is in line with the developments agreed regarding the ETS, which will introduce progressive auctioning of permits by 2013. However, regarding road freight vehicles, in view of increasing the scheme acceptability fuel rights could be allocated as a fixed allowance free of charge per vehicle. In order to reduce the risks of escalating allocations if member states pursue a "free rider" policy, the flat-rate allocation method should be defined at the European Union level.

As a general rule, the principle of fixed, cost-free allocations, which avoid complicated calculations, sharply reduces the administrative costs of these schemes. There would still be the costs of monitoring emissions and managing fuel rights transactions, which the proposals above have sought to keep as low as possible.

14.4 Border Effects and International Coordination

14.4.1 Border Effects and the Issue of "Tank Tourism"

Overall, the above scheme of fuel rights for private vehicles is designed in a way that allows a domestic implementation, that is to say a state regulating private cars fuel consumption to comply with its own commitments regarding CO_2 emissions.[7] In this scheme, foreign drivers would not benefit from the fuel rights free allocation of the country they visit and would have to buy rights or more probably pay the "CO_2 tax" on automotive fuel.

However, a domestic implementation raises the issue of coordination with neighbouring countries, because of the potential of cross border fuelling (i.e. "tank tourism" by a driver residing in one country and travelling to another one to fuel the vehicle): the driver behaviour results from a trade-off of the price difference between the two countries and the distance travelled (Rietveld et al. 2001; Banfi et al. 2005). In case of no coordination between neighbouring countries, an obvious limit would be put on a government trying to control more strongly fuel consumption. Yet it should be underlined that this problem is not specific to quotas approach but also concerns the tax approach.

When it comes to the scheme of fuel rights for freight transportation, which is designed at the scale of the European Union, a legitimate interrogation remains that of the possible competition of carriers external to the European Union. In fact, the carriage of goods is less prone to economic distortions than the other branches of industry: freight will always have to be loaded in locations within the EU to be distributed for use in other locations within the EU, whether processing industries or final goods delivery locations. The only notable incidence would come from carriers being able to load fuel outside the European Union, thus potentially not subjected to any CO_2 taxation or fuel rights scheme, and then carry out a transport within the EU. This competition could be significant in the border countries, since trucks can have a cruising range of 1,500–3,000 km on a single tank (CEC 2002). This issue would require some kind of coordination with neighbouring countries.

[7] In order to attribute national responsibilities, UNFCCC greenhouse gases inventories per country are based on fuel sales within the country, excluding fuels used in ships or aircrafts for international transport.

14.4.2 International Coordination Within the European Union and with Other Regions

Within the European Union, national caps have been established regarding sectors not included in the ETS like ground transportation. While in principle the economic incentive of the ETS guarantees the future reach of the target for the sectors covered, there is no such guarantee regarding transport: there is no economic sanction preventing potential "free rider" behaviour by any member state. That is why the issue of carbon taxation in Europe is set again in discussion.

This is a critical issue especially in the European Union where the proposals for an EU-wide tax based on both carbon and energy date back to the 1990s. Currently, the Energy Taxation Directive imposes only minimum rates of tax on energy products to reduce distortions of competition between member states.

Indeed, taxation is an area in the EU legislation where unanimity is required from member states (which are 27 today). While some countries support the idea of a carbon tax (some of them like Sweden or Finland have already implemented such a tax), others are fiercely opposed to any greater cooperation on energy taxation issue, which they see an interference in their own domestic taxation policy.

On the contrary, in the EU legislation procedures, emissions trading comes under environmental matter, and there is no need for unanimity but rather for "qualified majority" voting, that is to say a majority of countries suffices to impose such a legislation.

Recently, in June 2010 a new proposal for a European carbon tax was dismissed again by the European Commission. These 20 years of political discussion about carbon taxation in Europe without any step forward are to be opposed to the speed of ETS implementation: the Green Paper on GHG emissions trading within the European Union was issued in 2000 and the Directive on ETS in 2003 with an entry in force in 2005.

From a European – and a political economy – point of view, ETS looks like an obvious and particularly attractive scheme around which to organise the regulation of transport emissions, especially when considering the international nature of this activity. This should be the frame upon which to coordinate transport emissions policy with other regions in the world, of which some are currently discussing their own ETSs.

14.5 Behavioural Effectiveness

Due to the novelty of the instrument, empirical knowledge regarding this topic is limited.

According to their design, TPs should have an obvious effect on emissions: fuel consumers should at least comply with their allowances or buy supplementary emission permits (for instance if they want to maintain their current behaviour). Moreover, there is another effect in case of free allocation, due to the possibility to sell unused permits: this is an incentive to make further abatement efforts. This last effect is expected to yield supplementary positive outcomes when compared with taxation.[8]

Moreover, due to the specific nature of tradable permits applied to personal consumption of fuel, potentially supplementary outcomes are expected on psychological grounds rather than economic ones (Fawcett 2010). First, fuel rationing through a carbon allowance is a radical policy and seen in this way may induce radical behaviour change. A second effect might come from making carbon visible at the end-user level, with a carbon account delivering frequent feedback on travel behaviour. A third effect could come from the social norm associated with a personal allowance fixed within the frame of a public policy: sticking to this personal target would be rewarded by the respect of others. However, one should be cautious since fiscal or monetary incentives may "crowd out" intrinsic motivation to pro-environmental behaviour (Frey 1997; Frey and Stutzer 2008).

Some empirical studies indicate that personal carbon trading may induce additional emissions reduction when compared to carbon taxation (Bristow et al. 2010; Harwatt 2008). However, these studies remain largely exploratory due to the size of the samples.

Bristow et al. (2010) have identified only five studies of behavioural response to personal carbon trading in the UK whether restricted to transport or not. More research is obviously needed on the interaction between economic mechanisms and psychological ones in the process of individual behaviour when facing cap-and-trade schemes. Lee-Gosselin (2010) offers empirical and methodological lessons from research on consumer behaviour following oil shortages in the 70's. A study of stated choices of individuals ($N \sim 300$) facing tradable permits or taxation in transport, undertaken by the author in France, will soon provide additional insights.

14.6 Acceptability

If one considers the development of stringent objectives of emissions reduction in the future, a fuel rationing seems unavoidable: this rationing can basically take the form of either price rationing (tax) or quantities rationing (permits). From this point of view, the acceptance of rationing is an identical precondition for the two instruments and needs at least an information campaign and a political willpower to introduce any measure of emission control. This is the first step which needs to be achieved. It is in this context of "accepted rationing" that the relative acceptability of tradable permits can be evaluated.

The "tax rebellion" that took place in several European countries during the high rise of oil price in September 2000 shows how sensitive the public opinion is to fuel taxation (Lyons and Chatterjee 2002). Central government is a focus for opposition

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[8] It is argued that a tax combined with a direct fixed compensation would achieve the same objective. However, such a scheme would be subject to the same set-up and administrative costs as tradable permits.

as it benefits from the tax, although it has little control over oil prices. Proposing a "CO_2 tax" in view of emissions reduction is likely to start again the debates on the use of the fiscal revenues from the excises, which currently in the majority of countries are not earmarked and play an essential part in the balance of public finances.

A first step to avoid raising too much revenue from voters who could successfully oppose the scheme would be to implement a tax with a threshold under which the fuel consumption would remain uncharged (Pezzey 2003). A similar scheme was proposed by the French government in 2009 but cancelled in 2010 because of a massive rejection by the public opinion, despite the planned threshold (in fact a direct compensation) was taking into account the size of families and the consumption needs through the household residential location (urban or not).

Like for behavioural response to tradable permits scheme, studies about acceptability of these schemes are rather limited and often combined with the studies about behavioural responses previously evoked. However, a detailed study of how the design of schemes – whether personal carbon trading or carbon tax – influences their acceptability has been performed by Bristow et al. (2008) in the UK with a stated preferences survey ($N \sim 300$). Their key result is that personal carbon trading or carbon tax may be both acceptable depending on the design of the schemes. In particular permits allocation is considered fairer when it includes children and takes into account the extra needs (e.g. remote home locations). Carbon tax with threshold may be nearly as acceptable, accompanied with revenue hypothecation. Other features of permits scheme include authorised use of excess permits, permit life, scope of the scheme, management of carbon accounts and market operation with government setting annually the price: the results are broadly consistent with the features of the scheme for private vehicles proposed above.

Another recent in-depth study in France (Lejoux and Raux 2010), with a much smaller sample ($N \sim 38$), is in line with some of the previous results regarding acceptability. According to the preferences expressed by the majority, the allowances should not be allocated only to motorists and should apply to both car and plane trips. Allowances should take into account the household size and residential location. However, the people surveyed were equally divided regarding their preferences towards permits or carbon tax scheme.

14.7 Conclusion

There are several directions of theoretical relevance for the use of emission trading in transportation. The controversy between pure taxation and pure tradable permits is no more topical: policymakers should consider hybrid instruments combining tradable permits, partly distributed for free and partly auctioned, with a ceiling price as a "safety valve".

There is no sound reason to dismiss downstream trading in principle on the basis of potentially high transaction costs. These costs depend on the actual design of the schemes to be implemented, including their needed features regarding behavioural effectiveness and acceptability. From this point of view, the full range of instruments should be considered, including taxes, permits and their hybrids, tax thresholds or compensations, free permits and so on.

According to the theory, the policy efficiency would be maximised when the incentive to reduce emissions is put as close as possible to the decision-maker. Given the electronic technology available nowadays for monitoring end-user fuel purchase, schemes that are technically feasible have been presented. A parallel can be made with the case of electronic road pricing which has made road user charging feasible in urban areas.

There is a need to achieve the integration of transport emissions with existing schemes, especially the ETS in the European Union. Opposite to harmonised taxation, emission trading in the transport sector can be quickly implemented, in coordination with other regions in the world. Due to its international nature, the implementation process could start with freight transportation.

The urgency now is to design fine-tuned practical schemes and to devise the optimal mix of economic and psychological incentives that may maximise the behavioural efficacy and the acceptability of a policy which could be actually implemented.

References

Albrecht J (2000) The diffusion of cleaner vehicles in CO_2 emission trading designs. Transp Res D 5:385–401

Banfi S, Filippini M, Hunt LC (2005) Fuel tourism in border regions: the case of Switzerland. Energy Econ 27(5):689–707

Baumol W, Oates W (1988) The theory of environmental policy. Cambridge University Press, Cambridge, 299

Bristow AL, Wardman M, Zanni AM, Chintakayala PK (2008) Public acceptability of personal carbon trading and carbon tax. Ecol Econ 69:1824–1837

Bristow AL, Zanni AM, Wardman M, Chintakayala PK (2010) Exploring innovative policy frames for achieving behavioural change to low carbon transport. Paper presented at the 12th world conference on transport research, Lisbon, Portugal, 11–15 July 2010

Brons M, Nijkamp P, Pels E, Rietveld P (2006) A meta-analysis of the price elasticity of gasoline demand. A system of equations approach, Tinbergen Institute Discussion Paper, TI 2006-106/3

CEC (2002) Proposal for a Council Directive amending Directive 92/81/EEC and Directive 92/82/EEC to introduce special tax arrangements for diesel fuel used for commercial purposes and to align the excise duties on petrol and diesel fuel. COM(2002) 410 final, Brussels, Commission of the European Communities, November 2002

Coase R (1960) The problem of social cost. J Law Econ 3:1–44

Crals E, Vereeck L (2005) Taxes, tradable rights and transaction costs. Eur J Law Econ 20:199–223

Dales JH (1968) Land, water and ownership. Can J Econ 1:797–804

Fawcett T (2010) Personal carbon trading: a policy ahead of its time? Energy Policy. doi:10.1016/j.enpol.2010.07.001

Foster V, Hahn R (1995) Designing more efficient markets: lessons from Los Angeles Smog Control. J Law Econ 38:19–48

Frey B (1997) Not just for the money: an economic theory of personal motivation. Edward Elgar, Cheltenham

Frey B, Stutzer A (2008) Environmental morale and motivation. In: Lewis A (ed) Psychology and economic behaviour. Cambridge University Press, Cambridge, pp 406–428

German J (2006) Reducing vehicle emissions through cap-and-trade schemes. In: Sperling D, Cannon JS (eds) Driving climate change: cutting carbon from transportation. Elsevier, Burlington, pp 89–105

Godard O (2000) L'expérience américaine des permis négociables. Économie Int 82:13–43

Goodwin PB (1988) Evidence on car and public transport demand elasticities 1980-1988, TSU Ref 427, Oxford, June 1988

Graham DJ, Glaister S (2002) The demand for automobile fuel. A survey of elasticities. J Transp Econ Policy 36:1–26

Hahn R, Hester G (1989) Marketable permits: lessons for theory and practice. Ecol Law Q 16:361–406

Harwatt H (2008) Tradable carbon permits: their potential to reduce CO_2 emissions from the transport sector. PhD Thesis, ITS, University of Leeds

Lee-Gosselin MEH (2010) What can we learn from North American transport energy demand restraint policies of the 1970s and 1980s and public reactions to them? Energ Effic 3:167–175

Lejoux P, Raux C (2010) Exploring travellers' reactions and attitudes towards a carbon tax or fuel quotas: results of an interactive survey in France. Paper presented at the 12th World Conference on Transport Research, Lisbon, Portugal, 11–15 July 2010

Lyons A, Chatterjee K (eds) (2002) Transport lessons from the fuel tax protests of 2000. Ashgate, Aldershot

Montgomery WD (1972) Markets and licenses and efficient pollution control programs. J Econ Theory 5:395–418

Nordhaus WD (2006) After Kyoto: alternative mechanisms to control global warming. Am Econ Rev 96, no. 2 (May):31–34

Nordhaus RR, Danish KW (2003) Designing a mandatory greenhouse gas reduction program for the U.S. Pew Centre on Global Climate Change. Arlington, May 2003, 66 p

OECD (1997) Putting markets to work. The design and use of marketable permits and obligations. Organisation for Economic Cooperation and Development, Public Management Occasional Paper 19. OECD, Paris

OECD (1998) Lessons from existing trading systems for international greenhouse gas emissions trading. Organisation for Economic Cooperation and Development, Environment Directorate. OECD, Paris

OECD (2001) Domestic transferable permits for environmental management. Design and implementation. Organisation for Economic Cooperation and Development, Paris

OECD (2007) Cutting transport CO_2 emissions. What progress? OECD-ECMT, Paris

Parry IWH, Walls M, Harrington W (2007) Automobile externalities and policies. Discussion paper 06-26. Resources for the future, Washington, 37 p

Pezzey JCV (2003) Emission taxes and tradeable permits. A comparison of views on long-run efficiency. Environ Resour Econ 26:329–342

Raux C (2004) The use of transferable permits in transport policy. Transp Res D 9(3):185–197

Raux C (2010) The Potential for CO_2 emissions trading in transport: the case of personal vehicles and freight. Energ Effic 3:133–148

Raux C, Marlot G (2005) A system of tradable CO_2 permits applied to fuel consumption by motorists. Transp Policy 12:255–265

Rietveld P, Bruinsma FR, van Vuuren DJ (2001) Spatial graduation of fuel taxes; consequences for cross-border and domestic fuelling. Transp Res A Policy Pract 35(5):433–457

Roberts MJ, Spence M (1976) Effluent charges and licenses under uncertainty. J Public Econ 5(3–4):193–208

Salon D, Sperling D (2008) City carbon budgets: a policy mechanism to reduce vehicle travel and greenhouse gas emission. OECD/ITF, Paris, 17 p

Stavins R (1995) Transaction costs and tradable permits. J Environ Econ Manage 29:133–148
Stern N (2006) Stern review on economics of climate change. Executive summary. http://www.hm-treasury.gov.uk/media/4/3/Executive_Summary.pdf. (Accessed February 2011)
Walton W (1997) The potential scope for the application of pollution permits to reducing car ownership in the UK. Transp Policy 4(2):115–122
Wang MQ (1994) Cost savings of using a marketable permit system for regulating light duty vehicle emissions. Transp Policy 1:221–232
Weitzman ML (1974) Price vs. quantities. Rev Econ Stud 41(4):477–491
Winkelman S, Hargrave T, Vanderlan C (2000) Transportation and domestic greenhouse gas emission trading. Center for Clean Air Policy, Washington, p 32

Chapter 15
Passenger Mobility and Climate Constraints: Planning for Adaptive Mitigation Strategies

Hector G. Lopez-Ruiz and Yves Crozet

15.1 Introduction

Today, numerous works conclude that transport seems to be completely coupled to economic growth. Therefore, as a direct consequence of economic development, transport sits today as one of the major final energy consumers and one of the most important sources of greenhouse gas (GHG) emissions. What is more, in the absence of major technological change, this unsustainable situation will most undoubtedly get worse in the future.

Furthermore, recent scientific insight has shown that to reduce the climate change risk (overshooting a 2°C increase in global temperatures), global emissions should be cut by at least 50% in the next 40 years. Consequently, for developing and developed economies to be able to attain the 50% mark, industrialized countries must reduce their emissions by at least 75%. This is not an easy task; to plan for these drastic reductions, numerous studies (Banister et al. 2008; Kato et al. 2010; Lopez-Ruiz and Crozet 2010; Schade et al.; Schipper et al. 2010; Schäfer 2009; Sperling and Lutsey 2009) have looked into different options on how to get to this desired future. These studies concur on the fact that new technologies and their widespread use will be necessary to attain considerable GHG reductions, but they also agree that these new technologies will not be enough for industrialized countries to get to their objectives. Indeed, most works conclude that it would also be necessary to increase the match between new technology supply and consumer demand through the use of incentive economic instruments.

In this manner, GHG mitigation strategies imply the need to set up a certain number of public policies ranging from inciting technological progress, to tolls, to intermodal development or even rationing (tradable emission permits). Currently, an

H.G. Lopez-Ruiz (✉)
Laboratory of Transport Economics (LET), LET-ISH,
14, Avenue Berthelot, 69363 Lyon, France
e-mail: hector.lopez-ruiz@let.ish-lyon.cnrs.fr

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increasing number of countries have started to set up different types of programs to try to influence behavior in passenger mobility (especially personal vehicle mobility) and curb emissions from the transport sector, but are these initiatives enough?

This chapter has three aims: first, we explore – on the basis of long-term scenarios for the French economy – how a continued trend in the vehicle market (although promising concerning GHG reductions because of lower consumption factors) is not viable in the long-term future from an infrastructure point of view. Second, we offer insight on how requiring changes in behavior through public policies can offer more viable solutions for mitigation of GHG emissions in developed economies. Finally, we will explore how policies aiming at mitigation of emissions can cause imbalances on a microeconomic level which lead to envisaging adaptive strategies to increase policy acceptability.

In order to better explain how we have carried out our analysis, we will present the reader with a brief description of the overall inner workings of the model used for this chapter [Transport Issues in the Long Term (TILT)] while focusing particularly on the microeconomic module (TILT-micro) which will be used extensively throughout the chapter.

15.2 The TILT Model

The TILT model has been designed to be a long-term equilibrium model by combining a macroeconomic and a microeconomic structure in a backcasting approach that takes into account new motor technologies and facilitates sensitivity and impact assessments through five modules that work on three different geographical scales (urban, regional, and interregional):

- A macroeconomic model based on a refoundation of the energy-environment modeling structures to properly assess long-term modifications of demographic variables and their impact on economic productivity and time use. This module was adapted from the BASES module in the VLEEM model (Consortium VLEEM 2002).
- A microeconomic model based on discrete choice modeling – adapted from ant algorithms – (Lopez-Ruiz 2009) that takes into account transport cost, infrastructure capacity, and quality of service.
- A vehicle fleet dynamic model that analyses technological impact based on market penetration probabilities for new motor technologies and vehicles' survival rates.
- A public policy model that joins a sensitivity analysis and a multicriteria analysis to offer a detailed assessment of the effects of different public policies on oil consumption and GHG.
- An impact assessment model based on an input–output equilibrium analysis that details impacts on employment and production by sector.

The TILT model is centered on the simple idea of defined behavior types – in which speed/GDP elasticities play a key role – to determine macroeconomic transport demand estimations. The TILT model supposes that modal split in transport is directly linked to the idea that modal speed, transport times, transport management, and household/firm locations determine modal shares. In this manner, the model's main hypothesis is that transport modal saturation rhythms can be varied – in the model – through public policies that have an effect on household/firm location and speed/GDP elasticities (LET-ENERDATA 2008; Lopez-Ruiz 2009).

Furthermore, the model is also able to asses the system's sensitivity to public policies, investment needs in infrastructure, and economic impact of different public policies while taking into account microeconomic choices. In this manner, the TILT model structure enables the user to calculate energy consumption and pollutants emitted by transport activity (freight and passengers) on different geographical scales based on behavior patterns that can be influenced by public policies. In sum, the model has three main functions:

- Modeling passenger-kilometers and ton-kilometers coherent with a micro/macro-equilibrium structure according to motor technology used for journeys and area of service
- Modeling the vehicle park according to: age, motor technology, and year of production (for freight and passengers)
- Modeling and assessing public policy impacts on CO_2 emissions, infrastructure investment needs, as well as overall impact on the economy

By joining these three functions of the different TILT modules, it is possible to build scenarios that:

- Quantify the consequences of transport on the environment while detailing the systems' structure according to behavior and organizational changes and motor technology
- Give a precise view of traffic by motor technology, gas consumption, and emission levels for each type of transport according to service distances, type of vehicle, and transport cost
- Assess impacts of different policy pathways according to different scenario configurations

These results, coupled with the model's structure, make TILT a powerful tool for building and exploring scenarios. The utility of the TILT model lays not only in its capacity to be flexible concerning different transport policies, changes in demography, behavioral differences, as well as changes in transport structure and cost, but also in its capacity to integrate a microeconomic insight module, on which this chapter will be focused.

The TILT microeconomic submodel lets us understand how, according to past tendencies (characterized by the coupling between growth and mobility), future public policies will impact demand for transport services as well as tradeoffs linked to behavioral change and infrastructure use on different geographical scales.

TILT-micro is largely inspired by developments done on ant algorithms (Dorigo et al. 1999) and their application to freight and passenger transport (Lopez-Ruiz 2009). This model relies on the idea of a representative agent that optimizes its transport decisions by taking into account opportunity (defined as the sum of goods and services that can be consumed in a period of time, Linder 1970) and cost in respect to a certain level of service on infrastructure – measured through a lateness index (Lomax et al. 1997).

TILT-micro considers that the lateness index is defined by the difference existing between normal transit time and real transit time. This last indicator is useful in factoring in speed, distance, and time into the calculation of the choice model and has the convenience of being comparable between modes.

In this manner, the proposed framework lets us asses the representative agent's choices that are coherent with the transport structure and its level of service. In the model, the value assigned to each choice [$a_{ij}(t)$ – which refers to the choice of mode used to move from point i to point j] is calculated using the following equations:

$$a_{ij}(t) = \frac{[\tau(t)]^{\alpha}[\eta]^{\beta}}{\sum_{1 \in Ni}[\tau(t)]^{\alpha}[\eta]^{\beta}} \qquad \forall j \in N_i, \tag{15.1}$$

where:

$$\eta = \frac{\sum goods\ and\ services}{(time + access\ time) * \cos t} \tag{15.2}$$

and

$$\tau(t) = Lateness\ index(t). \tag{15.3}$$

The inherent logic of the microeconomic module is particularly useful in technico-organizational public policy assessments, as it enables an analysis based on the idea that public policies are implemented as increasing/decreasing constraints on the system, in view of getting to a certain objective. Consequently, this facilitates the building of scenarios where a wide variety of social effects on different levels and aspects are comprised. In this manner, the TILT model is capable of giving insight on how changes in the transport structure linked to environmentally oriented public policies might influence passenger behavior in the future.

The following paragraphs will show how the theoretical framework of the TILT-micro model can assess social effects on a public level for new behavior patterns that will undoubtedly need to be accompanied by clearly defined adaptive mitigation strategies.

15.3 BAU Scenario Overview, Car Market Trends, and Infrastructure Investment Assessment

In 2008, the TILT model was used to develop three technico-organizational scenarios to quantify the effects of climate-oriented policies in the transport sector (LET-ENERDATA 2008). The original version of the report is in French; a detailed description in English can be found in Lopez-Ruiz and Crozet (2010). The main aim of these scenarios was to test the efficiency of public policies (modeled as growing constraints – ranging from promoting new motor technologies to public policies aiming at multimodality and decoupling transport activities from GDP) on GHG emissions.

In this study, the underlying principle of incremental constraints on the system allowed to present three different scenarios that allow a quick comprehension of the GHG reductions that can be obtained through policy mixes. Consequently, the scenarios offer a good representation of the general policy pathways usually accepted as being efficient and viable options for long-term oil consumption reductions. On this basis, we will develop how the presented microeconomic framework can help in the analysis for each scenario and can give insight on adaptive strategies for sustainable planning.

The 2008 LET-ENERDATA report assessed sustainable transport scenarios for the French economy with a specified objective of −75% in GHG by 2050 through the identification of the different equilibriums possible that allow the attainment of the specified future. From these possible equilibriums, the three that best depict the range of solutions available – through public policy – were chosen:

- Promoting strict technology standards – business as usual (BAU)
- Green multimodality
- Decoupling transport activities from economic growth (GDP)

The results for each scenario were obtained by modeling a mix of different policies aiming at sensible changes in transport behavior and new motor technologies. Each of these scenarios imply different characteristics (a list of the main hypothesis can be found in annex) that are tightly linked to modal shares and demographic dynamics.

In sum, the first scenario is a BAU situation with strict technology standards. This scenario depicts a 48% reduction in emissions, whereas the other two scenarios (multimodality and decoupling) represent a reduction of a little over 75%. In the following paragraphs, we will first present the details of the BAU scenario and then we will go over the two alternative scenarios.

15.3.1 Promoting Strict Technology Standards (BAU)

The BAU scenario represents a situation where the speed/GDP elasticity for passengers is of 0.33 and where transport times are stable (1 h per person per day). This scenario lets us appreciate:

- Mobility in a situation where there is no major public policy affecting behavior and/or the system's regular performance (continued infrastructure investments and optimization is supposed)
- The effects of new motorization technologies on total CO_2 emissions

In this manner, the BAU scenario lets us evaluate the contribution of strict and realistic technology standards that – according to our calculations – would lead to half of the reductions of the CO_2 target (Fig. 15.1).

As we can see in Fig. 15.2, if we suppose that hybrid vehicles go into the market in 2010 and electric vehicles are marketed by 2015, the modeled vehicle fleet, for this scenario, would be mainly composed of hybrid vehicles in 2040. This change in

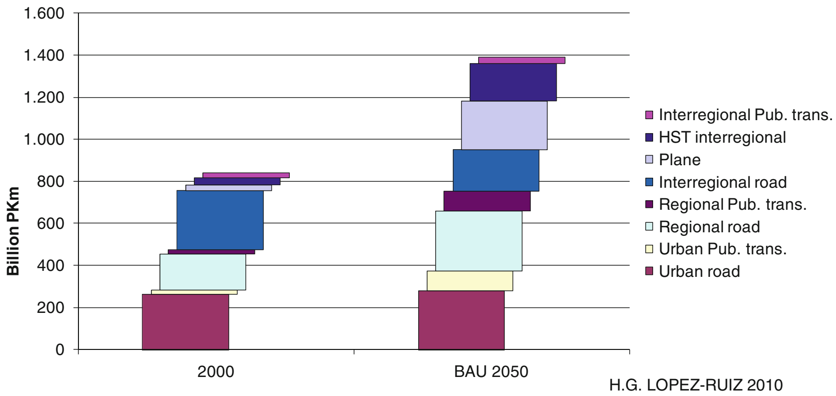

Fig. 15.1 Passenger mobility BAU

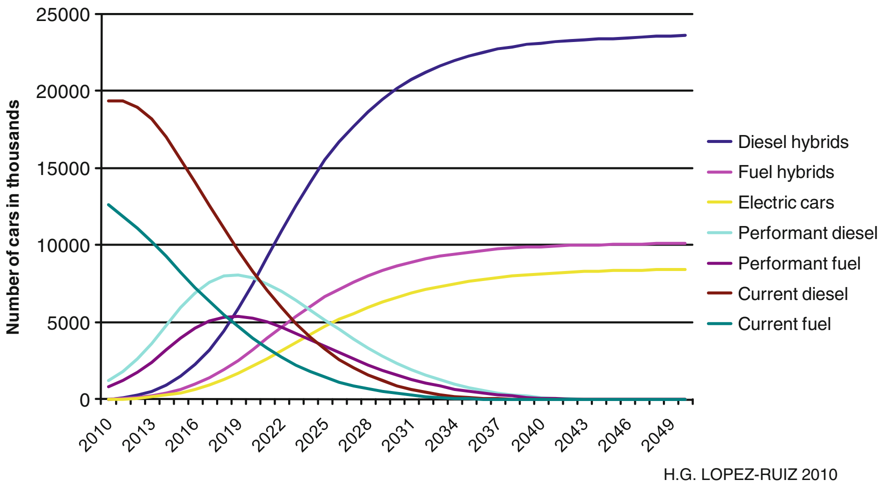

Fig. 15.2 Total number of cars per type of motor technology

Table 15.1 Investments in new infrastructure

Billions of €	Mode	2050 Pegasus	Per annum	% of GDP	Year 2007	% of GDP
Investments	Road	1,043	21	0.7	12	0.9
	Rail	747	15	0.5	2	0.2
	Public transport	137	3	0.1	2	0.2
	Others	–	–	–	1	–
	Total	1,927	39	1.4	18	1.4

Lopez-Ruiz (2009)
Note: means not applicable – values are in 2,000€

technology (coupled to the fact that electricity in France is mainly produced by nuclear reactors) would ensure in a BAU case almost a 50% reduction in CO_2 emissions.

If we take a more detailed look into the details of this scenario, we observe that it is a scenario based on an inelastic market structure largely dependent on private vehicles with high oil prices and a very good offer in public transport. This translates into a scenario that is very dependent on road transport and, thus, dependent on road infrastructures. Therefore, if we suppose that market trends in cars continue to follow current practices, it is more than likely that spatial demand for car use – thus infrastructure needs – will grow accordingly. In order to carry out this assessment, we calculated the investments (see Table 15.1) that would be required throughout the 40-year period, to 2050, for new infrastructures in a BAU scenario (operation costs are not included). In sum, spending on infrastructure would remain at a 1.4% of GDP level (which is roughly the same as in 2007) with most of it going to road infrastructures.

Although it would seem like an ideal situation, because we would not be spending more money than we are today, the dilemma behind these results is linked to the fact that it might be a loss of money to have continued high investments on road infrastructure when it can be spent on something else. A BAU scenario with continued investments in road infrastructure would mean a reduction of almost 55 million tons of CO_2 (Mt CO_2), thus a ratio of 35€ invested in infrastructure per mitigated tCO_2. Although this ratio is highly speculative and narrow sighted, it is very self-illustrative, especially when it will be compared to its value in other scenarios in the following section.

15.4 Exploring Alternative Scenarios

Although the BAU scenario results in almost a 50% reduction in GHG emissions, this result is far from the desired 75%. Consequently, the LET-ENERDATA report analyzed two alterative scenarios that look into the effects of public policies aiming at changing behavior. These two scenarios offer a great basis for exploring how sustainable scenarios would shape future investment needs in the transport sector. In the original report, these scenarios are presented as different possibilities to attain important GHG reductions through multimodality and/or decoupling from GDP.

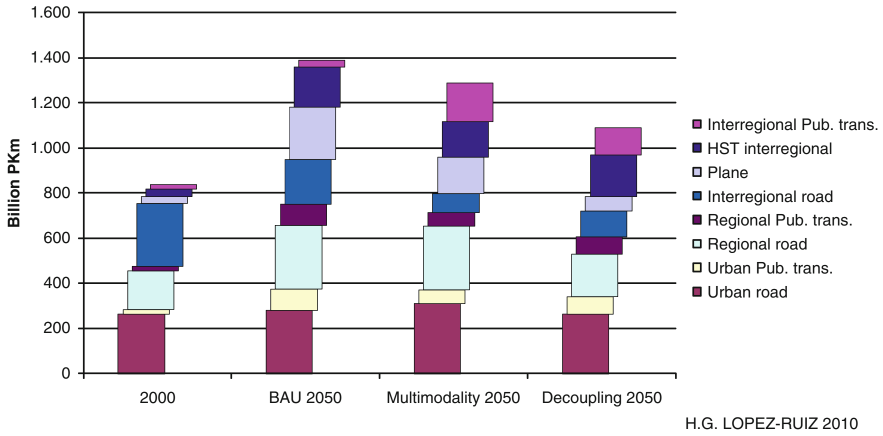

Fig. 15.3 Passenger mobility for all scenarios

The differences between each scenario are linked to the transport structure where: speed/GDP elasticities, modal speeds, and transport times differ accordingly to public policy aims. Therefore, each scenario implies different characteristics and thus different types of results that are tightly linked to modal shares and demographic dynamics. Before going into the details of each scenario, the reader can review the mobility results in Fig. 15.3.

15.4.1 *Promoting Green Multimodality*

In this scenario, market-oriented policies constrain the use of high carbon footprint modes which lead to an increase in the use of slower transport options that have smaller carbon footprints. In this scenario, the 75% reduction objective is nearly attained by favoring greener modes through an increase in transport costs according to their speed and associated emissions. As a result, the multimodal scenario shows a change in behavior patterns where the main effects are as follows:

- A tradeoff between the system's need for speed (coupled to growth)
- An increase in transport times, consequence of an important modal shift (especially towards public transport)

Indeed, since the characteristics of this scenario imply a speed/GDP elasticity equal to zero, this translates into an increase in transport times (roughly 1 h 20 min per person per day). Thus, this scenario is based on market-oriented public policies in an infrastructure intensive situation (because transport distances and public transport traffic increase sharply). In this manner, it lets us appreciate that a mix of technology and policy can get us to the wished reduction target but at the cost of slower transports speeds, higher transport times, and continued investment needs in infrastructure (see Table 15.2).

Table 15.2 Investments in infrastructure for all scenarios

Billions of €	Mode	2050 Pegasus	Per annum	% of GDP	2050 Chronos	Per annum	% of GDP	2050 Hestia	Per annum	% of GDP	Year 2007	% of GDP
Investments	Road	1,043	21	0.7	384	8	0.3	140	3	0.1	12	0.9
	Rail	747	15	0.5	1,529	31	1.1	992	20	0.7	2	0.2
	Public transport	137	3	0.1	74	1	0.1	77	2	0.1	2	0.2
	Others	–	–	–	–	–	–	–	–	–	1	–
	Total	1,927	39	1.4	1,987	40	1.4	1,209	24	0.9	18	1.4

Lopez-Ruiz (2009)
Note: means not applicable – values are in 2,000€

15.4.2 Promoting Decoupling Between Transport Activities and GDP

The main issue in this scenario is a tradeoff between an elevated transport cost and average transport distances. Indeed, transport costs (both in time and in money) are considered to be higher than in the multimodal scenario. This results in economic agents choosing to modify their household/firm locations and develop a proximity intensive way of life.

This scenario implies a speed/GDP elasticity equal to zero but, since transport distances increase less rapidly than in the BAU and the multimodal cases, transport times are reestablished around 1 h per person per day. In this manner, the decoupling scenario leads the way to reductions in GHG emissions that go over the 75% objective through market mechanisms, regulation, and spatial planning.

This new equilibrium based on proximity gives the system a better opportunity for the implementation of low range zero emission vehicle technologies and also requires lower investments on transport infrastructure.

As we can see in Table 15.2, a decoupling scenario lets us appreciate a situation where mobility increases from the 2000 level (and less than in a BAU or multimodal scenarios) but where infrastructure needs are not as overwhelming as in the two previous scenarios. Nevertheless, we need to take into account that as transport distances get shorter, cities get denser, and this implies high costs in urbanism investments (which are not calculated in Table 15.2).

In sum, these three scenarios and their assessment give us a clear view of how the allocation of funds in planning for CO_2 reductions will be a crucial factor. Indeed, the value of CO_2 reductions per euro invested, in a BAU scenario (35€), is a bit higher than that of the multimodality scenario (33€) and higher than the decoupling scenario (20€). In our view, this ratio is important in the sense that the two alternative scenarios present a situation where, even though investments needs are high (maybe even higher than the BAU if we add urban planning costs in the decoupling scenario), the choice of infrastructure in which the community would be investing would seem more sensible.

Furthermore, investment calculations for the scenarios clearly illustrate that the implementation of different long-term policy mixes entails a (re-)optimization of agents' (passengers and firms) choices based on transport cost, infrastructure availability, and the opportunities offered by transport services. Therefore, these sustainable scenarios imply private social effects linked to welfare variations associated with tradeoffs between transport expenditure, house/firm location, accessibility, transport monetary budgets, and *in fine* consumption of goods/services. These variations are important to understand to define how acceptability of these different public policies can be increased through adaptive mitigation strategies.

15.5 Adapting to Change

In order to assess how change in behavior will influence adaptive strategies in the long term, it is necessary to take into account how changes in passenger behavior – as a result of public policy – will undoubtedly have an effect on the system. For this, TILT-micro can offer some insight into how the (re-)optimization linked to public action in different scenarios can lead to household budget (money and time) reallocation effects that will have an important impact on other sectors (which will have a loopback effect on transport).

As long as the inherent principle of transport policies will be based on rendering high carbon footprint transport less attractive (through cost, speeds, level of service, etc.) than low carbon footprint transport, the results stemming from the policy's macroeconomic changes will most certainly influence microeconomic choices in other domains. These effects will be different for each country, network, and set of public policies.

In this manner, if we assess the TILT-micro results for the French multimodality scenario, we see that as constraints on speed and emissions come into play as a signal aiming at changing behavior patterns, there is a sharp increase in the use of rail and public transport. This, in turn, implies that average speed in the system should invariably go down and transport times should go up (more or less depending on the evolution of car use elasticity).

This situation seems particularly difficult because it translates into: paying more (for car users) for lower transport speeds (an all modes) and thus loosing potential value added time (VAT) that could be spent increasing revenue. In this setting, we can easily deduct that increasing the sum of goods and services (opportunities) linked to transport activities might help to counterbalance the situation of lost VAT [in other words increasing the numerator in equation (15.2)]

If we follow the same line of reasoning, the logic behind a decoupling scenario is very much influenced by proximity services, and public policies at play are largely related to spatial planning and infrastructure investment. In a decoupling logic, the main tradeoff at play is directly linked to location strategies, and production organization aimed at decoupling transport distances from GDP growth. This entails a densification of main cities and production sites which would, in turn, translate into a sharp increase in the use of urban and regional road networks.

Unlike the multimodality scenario, transport cost characteristics in a decoupling logic lead to more stable transport money budgets because transport distances grow at a slower pace. Nevertheless, if a decoupling scenario is not accompanied by an adaptive strategy based on a fast increase in the supply of proximity solutions as consumer behavior is modified, an important loss of welfare could be observed.

In sum, a multimodality scenario implies paying more for the same opportunities with higher transport times, and, in consequence, a microeconomic equilibrium requires adaptive strategies looking to counterbalance lost welfare by increasing opportunities. In a decoupling scenario, due to the fact that constraints are even higher than in a multimodality scenario, opportunities must increase even more (becoming proximity opportunities) to counterbalance overall distance reductions and stay within an equilibrium.

Moreover, the need for adapting to mitigation is reinforced by the fact that as constraints on oil consumption grow, more and more passengers will turn to public transport services. Consequently, a second underlying factor (the first being the before-mentioned microeconomic equilibrium hypothesis) that explains the need for planning adaptive mitigation strategies is market power. Indeed, as private vehicle costs rise, public transport use will also rise and, in consequence, this will imply a decrease in price elasticity of demand in public transportation and thus cause a shift in market power. This change in market power will most undoubtedly profit users instead of transport operators. Consequently, the system would be pushed toward a change in how opportunities are conceived by operators and planners.

Indeed, as market power shifts, the need for a change in the way that opportunities are assessed, planned, and evaluated would become more and more pressing at the risk of welfare loss. As a result, assessment methods would have to start taking into account the time it takes to access opportunities [c.f. the denominator of equation (15.2)].

Currently, certain dense networks are already starting to carry out this type of analysis: for example, the Access To Opportunities and Services (ATOS) index (Cooper et al. 2009) proposed by Transport for London to improve planning measures.

Indeed, just as the UK's planners have begun changing their metrics to take into account these new behavior patterns in transport activities, ITS specialist and planners will have to evolve to seize the opportunity to offer new services and explore new markets that will be based on a choice model taking into account adaptive mitigation strategies that conceive the utility of the representative agent as not only being a function of opportunities but also of the goods and services that are accessible to him in a reasonable lapse of time.

Accordingly, this change in how the utility function of users is integrated into the planning process will imply a differentiation within transport time budgets and how it is perceived by the agent's choice model [c.f. (15.2)]. In this sense, the choice model would change to take into account the effects that access time would have in a situation where we differentiate the time needed to consume and also the time it takes to get to that consumption.

As public policy evolves, changes in the transport system will suppose behavioral modifications. This situation will face planners and industry deciders with a new challenge: to plan according to a utility function that will depend not only on the opportunities an agent has but also on the possibility of actually being able to consume them. In this manner, all changes linked to public policies affecting time use should be accompanied by adaptive mitigation strategies.

15.6 Closing Remarks

On the basis of the three scenarios, different ways of attaining planned CO_2 reductions were analyzed and discussed. In sum, realistic technological hypothesis show that a 50% reduction in emissions is a clear possibility, and that going further based on new technologies would require very big advances in zero emission vehicles.

Nevertheless, in the absence of these new technologies, the remaining reductions in emissions are possible through different types of policy mixes that come down to:

- Encouraging important modal shifts that would translate into a decrease in total average speed which would in turn make transport times go up.
- Encouraging modal shift accompanied by a decoupling of transport distances. Consecutively, this would help to maintain stable transport times.

In this setting, this chapter offered a brief view of current developments concerning organizational solutions that could lead to a reduction in oil consumption and emissions through important changes in the transport structure and behavior patterns and proposes a quantitative analysis of investment needs for different policy mixes.

On this basis, this chapter gives insight on how policies aiming at modifying passenger behavior could heighten the pressure put on infrastructure demand (road, rail, etc., depending on the scenario), and will be an important issue in long-term planning for mitigation.

In addition, we would like to identify the following three main points on the relationship between policy and adaptive mitigation strategies.

15.6.1 Mitigation Leads to Systemic Changes

On a regional and interregional level "low-emission high speed transport" for passengers is something that already exists and that will most certainly keep on being promoted as a solution to GHG emissions. Nevertheless, planning for mitigation will most certainly bring about big changes on how public transport is conceived, by planners as well as users, and how it might be better utilized.

15.6.2 Change Needs Flexibility

Integrating the user into the planning process will bring about important changes in time use and consumption behaviors accompanied by the continued development of proximity services. All of this implies the need for innovative transport solutions and new consumer services. In this manner, associating freight policy strategy and passenger policy strategy with urban and transport planning will be important to gain flexibility while continuing to open new markets for new types of behaviors and consumption patterns. These integrated policies for mitigation will undoubtedly require careful planning.

15.6.3 Flexible Cities Adapt Over Time

Although, the actual lack of quick answers to the climate risk problem will most certainly continue to be an important subject in future studies and even though innovative ideas will help overcome this problem, it will most certainly take time to seriously address all problems involved with transport activities. However, adaptation-based planning should not to be underestimated as it offers great opportunities for mitigation acceptability.

15.7 Annex

Scenario characteristics		2000	Pegasus 2050	Chronos 2050	Hestia 2050
Urban					
Freight	Km/h				
	Road urban	50	60	52	52
Passengers	Km/h				
	Private car urban	23	30	25	25
	Public transport urban	20	24	20	22
Regional					
Freight	Km/h				
	Road regional	50	60	52	52
Passengers	Km/h				
	Private car regional	58	67	58	55
	Public transport regional	58	68	57	54
Interregional					
Freight	Km/h				
	Rail + plane national	40	63	45	45
	Rail + plane international	–	70	70	70
Passengers	Km/h				
	Private car interregional	110	115	90	90
	Public transport interregional	80	90	80	80
	High speed rail interregional	250	250	250	250
	Plane	500	500	500	500
Total					
Freight (nat/inter)	Km/h	43	54/52	43/52	43/52
Passengers	Km/h	45	50	37	37

(continued)

(continued)

Scenario characteristics	2000	Pegasus 2050	Chronos 2050	Hestia 2050
Elasticities				
Speed/GDP	–	0.33	0	0
T.Km/GDP	–	0.6	0.6	0.3
T.Km/international trade	–	1.6	1.6	0.25
Macroeconomics				
Population	64	67	67	67
Average yearly GDP growth		1.5	1.5	1.5
Child per household	2.19	2.15	2.15	2.15
Productivity rate	100	225	225	225
Transport time budget	1	1	1.2	1

Note: means not applicable
Lopez-Ruiz (2009)

References

Banister D, Stead D, Hickman R (2008) Looking over the horizon - visioning and backcasting. Perrels, A., Himanen, V. and Lee-Gosselin, M. (eds.) Building Blocks for Sustainable Transport. Helsinki: VATT and Emerald

Consortium VLEEM (2002) "VLEEM 2." Final report, EC/DG Research. http://www.enerdata.net/VLEEM/PDF/30-05-05/final%20report.pdf

Cooper S, Wright P, Ball R (2009) Measuring the accessibility of opportunities and services in dense urban environments: Experiences from London. Paper from The Association for European Transport Conference held in Leeuwenhorst, The Netherlands on 5–7 October, 2009

LET-ENERDATA (Crozet Y, Lopez-Ruiz HG, Chateau B, Bagard V) (2008) Comment satisfaire les objectifs internationaux de la France en termes d'émissions de gaz à effet de serre et de pollution transfrontières? Programme de recherche consacré à la construction de scénarios de mobilité durable. Rapport final. PREDIT, Paris. http://halshs.archives-ouvertes.fr/docs/00/29/37/25/PDF/Mobilite_durable_rapport_final_Avril_2008.pdf. Consulted on: 15/02/2011

Dorigo M, Di Caro G, Gambardella LM (1999) Ant algorithms for discrete optimization. Artif Life 5(3):137–172

Kato H, Ito K, Shibahara N, Hayashi Y (2010) Estimating the amount of additional mass transit needed to reduce CO_2 emissions from regional passenger transport in Japan. WCTRS, Lisbon

Linder S (1970) The harried class of leisure. Columbia University Press, New York

Lomax T, Turner S, et al. (1997) NCHRP Report 398. "Quantifying Congestion Final Report." Washington, DC: National Cooperative Highway Research Program

Lopez-Ruiz HG (2009) Environnement & Mobilité 2050: des scenarios pour le facteur 4 (-75% de GHG en 2050). PhD Thesis, University of Lyon, October

Lopez-Ruiz HG, Crozet Y (2010) Sustainable transport In France: is a 75% reduction in GHG emissions attainable? Transportation Research Record: Journal of the Transportation Research Board. Transportation Research Board of the National Academies. Volume 2163 / 2010. pp 124–132

Schade W, Helfrich N, Peters AA. Transport scenario for Europe until 2050 in a 2-degree world. Paper from WCTRS Conference held in Lisbon, Portugal on 11–15 July, 2010

Schäfer A (2009) Transportation in a climate-constrained world. MIT Press, Cambridge

Schipper L, NG, W-S, Gould, B, Deakin E (2010). Carbon in motion 2050 for North America and Latin America. University of California at Berkeley. Global Metropolitan Studies. http://metrostudies.berkeley.edu/pubs/reports/Carbon%20in%20Motion-UC-Final.pdf. Consulted on: 15/02/2011

Sperling D, Lutsey N (2009) Energy efficiency in passenger transportation. Bridge Summer:20

Chapter 16
Potential of Biofuels to Reduce Greenhouse Gas Emissions of the European Transport Sector

Burkhard Schade*, Tobias Wiesenthal*, Stephan Hubertus Gay*, and Guillaume Leduc*

16.1 Introduction

Many countries have introduced policies to support the use of biomass-based transport fuels (see, e.g. Searchinger 2009; Wiesenthal et al. 2009). EU Member States have agreed to achieve a share of energy from renewable sources in all forms of transport of at least 10% by 2020 (EU 2009a), with biofuels being likely to constitute a considerable part of those. In 2009, biofuel consumption reached 12 Mtoe, representing a 4% share of the total road transport fuel consumption in the EU (EurObserv'ER 2010).

Substituting fossil-based transport fuels with biomass-based fuels has gained momentum as a techno-economic option in the context of climate change mitigation policies. Depending on the primary feedstock used and the conversion process, many types of biofuels emit less greenhouse gas (GHG) emissions on a well-to-wheel basis than conventional fuels and have therefore the potential to reduce the GHG intensity of transport energy demand. The net GHG savings can nevertheless be altered to a significant degree when direct and indirect land use change effects that occur increasingly with higher biofuel production are accounted for.

Other drivers behind public support to biofuel production and consumption include the creation of an alternative outlet for farm produce and development of rural areas,[1] and the aim to reduce the oil dependence of the transport sector and hence increase supply security. While historically, support to the agricultural sector

*The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

[1]According to EmployRES study (Ragwitz et al. 2009) and quoted in the European Commission's Renewable Energy Progress report 2009 (COM 2009) agricultural activity related to the renewable energy sector generates a gross value added of over bn 9 € per year.

B. Schade (✉)
European Commission, Joint Research Centre – Institute for Prospective Technological Studies, Economics of Climate Change, Energy and Transport Unit,
Edificio Expo – c/Inca Garcilaso, 341092 Seville, Spain
e-mail: Burkhard.SCHADE@ec.europa.eu

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(e.g. France, Czech Republic) and especially energy security were the main drivers (e.g. the Brazilian Proálcool support programme), combating GHG emissions has become an at least equally important goal for biofuel support.

In this chapter, we will assess the potential of biofuels in reducing the GHG emissions of the European transport sector. After a brief review of key characteristics of the main biofuel conversion routes and the related fuels in Sect. 16.2, we will approach the assessment of the biofuel potential from three different angles. To this end, Sect. 16.3 starts with an appraisal of the available primary bioenergy potential and then focuses on the technical and realisable potential of biofuels in distinct transport modes in the EU, which is determined by blending limits, the vehicle stock and introduction of new dedicated vehicles and constraints in the growth rates of production capacities. This is complemented by an estimation of the economic potential for a given trend of energy and carbon prices. Sect. 16.4 discusses the results before we draw conclusions in Sect. 16.5.

16.2 Biofuel Characteristics

16.2.1 Biofuel Conversion Routes

There are three main routes for producing biofuels: esterification, biochemical conversion and thermo-chemical processes (Fig. 16.1).

Esterification is an established way for producing (first generation) biodiesel (fatty acid methyl ester, FAME) from vegetable oils such as rapeseed, soybean, palm or sunflower. Oil seeds are crushed to produce vegetable oil and oil cake, a byproduct used for animal feed. The oil is combined with alcohol (methanol or ethanol) and transformed into biodiesel, with glycerine as a byproduct. During the production process, bioethanol can be used to replace methanol. Biodiesel is currently the main biofuel type used in the EU, representing 9.6 Mtoe of the total biofuel consumption volumes of 12.1 Mtoe in 2009 (EurObserv'ER 2010).

The biochemical route is used for producing ethanol of first or second generation. Conventional (or: first generation) bioethanol is produced by fermentation from biological feedstock that contains sugar or material that can be converted into sugar such as starch. To date, the most widely used raw materials for bioethanol are sugarcane (Brazil), corn (USA), sugarbeet and cereals such as wheat, barley and rye (European Union), which are then processed by traditional fermentation. As a byproduct, dried distillers grains with solubles (DDGS) and pulp for animal feed are produced. The production of ligno-cellulosic ethanol (or second generation ethanol) does not depend on a sugar- or starch-based feedstock but can use a much broader variety of feedstock, such as straw, maize stalks and woody residues. In order to extract sugar glucose for ethanol production, it is necessary to break down the ligno-cellulosic raw material (i.e. made of cellulose, hemicellulose and lignin). This takes place in a pre-treatment phase followed by cellulose hydrolysis on which enzymes are needed. This enzyme-based breakdown of complex sugars is still a process in R&D and demonstration phase.

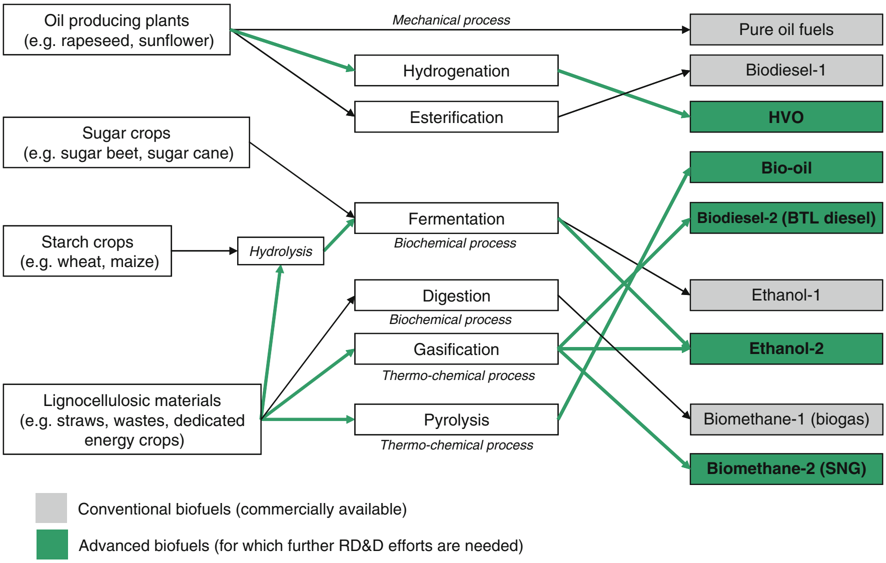

Fig. 16.1 Overview of biofuel production routes (simplified). *Source*: own elaboration

The thermo-chemical route can use a wide range of feedstocks to produce synthetic fuels such as second generation biodiesel (biomass-to-liquids, BtLs), synthetic natural gas (SNG), and bio-oil. For this purpose, and after being treated, the feedstock can undertake either a gasification or pyrolysis process, depending on the biofuel required (e.g. gasification for BtL diesel, pyrolysis for bio-oil).

Other types of biofuels can be obtained via mechanical processes (pure vegetable oil), hydrogenation of vegetable oils (hydrogenated vegetable oil, HVO) or digestion (biogas). HVO biodiesel is based on the hydrogenation of vegetable oils or animal fats. In terms of the primary feedstock, it is therefore similar to biodiesel. Nevertheless, within the process the oils are hydrogenated, obtaining a high quality synthetic diesel that does not have any restrictions in use. Biogas is obtained from various types of biomass (dedicated energy crops as well as byproducts such as manure, green tops of crops and from landfill gas or sewage treatment) anaerobic fermentation. It is usually further treated to obtain a gas with a high methane content. Besides the described pathways, R&D efforts are currently undertaken on the fermentation of sugar crops to produce biodiesel (BP 2009; Shell 2010).

While production of first generation biofuels is a mature technology, the so-called second generation biofuel processes are not yet being commercialised in significant quantities. Uncertainty remains as to which pathway will become competitive and market-ready and by when.

The bio-refineries concept is based on a selection of the above. Its advantage is that it can use a wide variety of feedstock and can produce not only different final products, including biofuel, heat and electricity, but also materials or food, in various proportions. Due to this, it achieves a higher utilisation of the entire primary biomass (IEA Bioenergy 2009). The basic biofuel conversion processes nevertheless remain the ones described above, yet with an improved use of “byproducts”.

In addition to significant RD&D efforts undertaken on advanced biofuel conversion processes, a wide variety of crops is being assessed with regard to their suitability as future bioenergy feedstock (see for an overview, Connor and Hernandez 2009; IEA 2010; WBGU 2010; Sect. 7.1). One of the most promising new bioenergy feedstocks that is currently being researched are microalgae due to their elevated yields and the fact that they do not compete for land or for other biomass uses. In addition to the high yields, algae consume much less water; besides, due to their CO_2 consumption characteristics they may also be used to clean flue gas from coal power plants; and their nutrient needs can help in cleaning wastewater. However, the GHG emission saving potential of large-scale algae cultivation needs to be further assessed. All in all, McGill (2008) and Accenture (2009) come to the conclusion that the barriers to the commercial use of algae-based biofuels will take many years to overcome.

The various biofuel pathways do not only differ in the types of feedstock used and the conversion processes and its maturity, but also in the quality of the obtained biofuel. This affects the level of blending that can be used in transport vehicles. The limitations in the use of the distinct types of biofuels largely determine their technical potential and will therefore be discussed further in Sect. 16.3.2.

16.2.2 GHG Savings

As a result of the distinct types of feedstock and of conversion processes, the specific GHG emissions per unit of biofuel differ largely between the various fuel types and production pathways. They crucially depend on the crops used and the way in which they have been cultivated, the conversion process and here in particular the carbon content of the energy used. Also the way in which byproducts are used, and the carbon credits associated with the distinct forms of their usage and the products they substitute, influence the GHG emissions of biofuels.

Table 16.1 provides an indication of the well-to-wheel emission savings when replacing one energy unit of fossil fuels with biofuels. First generation biofuels turn out to reduce GHG emission in the range of 20–70%, while GHG emission reductions of second generation biofuels are higher (80–95%).

It is very important to note that the specific emission reductions as shown in Table 16.1 do not consider the recently published communication on sustainability criteria, in which the Commission set out a detailed way of calculating default values and counting rules for biofuels (COM 2010a, b; Biograce 2010). Furthermore, Table 16.1 does not take into account GHG emissions from land use change (see Sect. 16.2.3 for further discussion). Moreover, Crutzen et al. (2008) pointed out that the N_2O emissions caused by fertiliser use should be well above the default values of the IPCC approach. Applying a higher conversion factor from N to N_2O could lead to higher specific emissions of biofuels. At the same time, there is discussion

Table 16.1 Range of GHG savings when replacing fossil fuel without land use change in final use

GHG emission savings (%)		Howarth et al. (2009)[a]	FAO (2008)[a]	Gallagher Review (2008)[a]	IEA (2008a,b)[b]	Schade and Wiesenthal (2011)[c]	Directive 2009/30/EC (EU 2009b) typical value [default value]
Biodiesel	Rapeseed	20–85%	38–59%	28–47%	ca. 15–85%	25–67%	45% [38%]
	Sunflower	35–110%				54–81%	58% [51%]
	Palmoil	8–84%	49–84%	25–65%	ca. 25–80%		36% [19%]
	Soybean	−17 to 110%		8–66%			40% [31%]
Ethanol	Wheat	18–90%	12–34%	12.5–41%	ca. −10 to 90%	24–47%	32–53%[d] [16–47%]
	Sugar beet	35–65%	38–59%		ca. 25–70%	31–67%	61% [52%]
	Corn	−5 to 35%		−28 to 32%	ca. −20 to 60%		56% [49%]
	Sugar cane	70–100%	68–89%	−32 to 71%	ca. 70–110%	53–89%	71% [71%]
Ligno-cellulosic	Wheat straw			79–90%	60–120%	72–92%	87% [85%]
	Switchgrass						
	Waste-wood						80% [74%]
	Farmed wood						76% [70%]
BtL	Various ligno-cellulose	28–200%			60–120%	84–94%	93% [93%]
	Residual wood	80–96%		92–96%			95% [95%]
HVO	Rape seed						51% [47%]
	Sunflower						65% [62%]
	Palm oil						40% [26%](68% [68%][e])
Biogas[f]				34–174% (manure) of diesel emissions			80–86% (depending on feedstock)[73–82%]

[a] Studies as quoted in Mandil and Shihab-Eldin (2010)
[b] Values of ethanol and biodiesel are read on chart
[c] Values are building on the assessment of JEC (2007) and JEC (2008)
[d] Depending on the fuel type in the conversion plant; if straw-fired combined heat and power plants were considered, the typical WTW emission savings would rise to 69%
[e] Process with methane capture at oil mill
[f] According to Ramesohl and Stucki (2007), BIO-SNG based on waste-wood reduces 65% compared to gasoline

on whether the reference emissions of fossil fuels may need to be revised upwards considering that the marginal environmental costs of fossil fuels are increasing as more energy-intensive oil drilling techniques are needed and unconventional resources are progressively entering the market (Pieprzyk et al. 2009).

16.2.3 Effect of Land Use Change

One of the most critical issues in the biofuels debate involves the GHG emissions arising from land use changes, when land is converted from non-arable (e.g. forest or grassland) to arable use (Searchinger et al. 2008). One can distinguish two categories of land use change that are triggered by the expansion of biofuel production: direct and indirect. A direct land use change occurs when a producer allocates more of his land to growing crops to be used as feedstock for biofuels at the expense of the previous use of the reallocated land. Direct land use changes thus alter the supplies of other outputs, which may affect relative prices across a wide range of commodities, thereby causing a further round of land use changes, so-called indirect land use changes. Direct and indirect land use changes potentially alter the GHG emitted by agriculture and therefore the net emissions of biofuels (see, e.g. WBGU 2010; Al-Riffai et al. 2010; Croezen et al. 2010) because of changes in the type of vegetation covering the land and/or changes in the degree of intensity of cultivation of an existing crop.

A generalised calculation of the impact of land use changes on GHG emission levels remains nevertheless difficult due to the large number of uncertainties involved when moving beyond the level of single case studies. Uncertainties arise in the determination of (1) the equilibrium level of below and above ground carbon storage of a specific land use, (2) the net annual carbon sequestration and release of a specific land use, (3) the land use before and after, and (4) the land use change expected due to biofuels.

Starting from both ends, methodologies to reduce these uncertainties are currently being researched. In order to tackle the first two uncertainties, approaches based on IPCC (2003) and complemented with land cover surveys can provide a detailed starting point. The assessment of the third uncertainty regarding the actual land use before and after the introduction of a change is the most difficult to approach and is in an infant status.

A large uncertainty lies in the quantification of the overall level of land use change created by biofuels (point 4 above). Biofuels create an additional demand on agricultural resources on top of those already present, making agricultural resources in general scarcer in relation to demand. Thus, the associated indirect land use changes are not in response simply to changes in relative prices to meet a fixed aggregate demand. Rather, they are the combined effect of changed relative prices and an overall increase in the prices of agricultural (land-using) outputs generally stimulated by higher aggregate demand. This general rise in commodity prices has several effects. First, it causes land already in agricultural use to be used more intensively (e.g. by adopting higher-yielding varieties and techniques). A result of switching lower-grade land to more demanding land uses is that production becomes less sustainable in the longer term. Increases in intensity of land use are modelled to the extent that yields are allowed to be price-sensitive. Second, however, and of greater concern, are land use changes at the so-called extensive margin. Because of the extra pressure generated by higher prices on the total land area in commercial use, there are strong incentives for land that was previously not used for agriculture (commercial forest, rainforest, peat land, rangeland, savannah) to be cleared and switched to agricultural use. This very often involves reducing the carbon-storage role played by the land that is switched, resulting in a loss of sequestered carbon that will take many years to cancel out by the use of bioenergy. Moreover, this previously virgin land often performed other important ecological functions as well, such as providing unique habitat for wildlife and helping to regulate complex climate patterns.

Considerable efforts are undertaken to assess biofuel-induced land use changes and several approaches are currently being developed. In the studies by Hertel et al. (2008) and Taheripour et al. (2008), substitution between agricultural land and commercial forestry is allowed, but not the clearing of virgin land for commercial use. A study by Banse et al. (2008) tries to solve the problem by incorporating land supply functions that are driven by land prices, while acknowledging that this solution presents calibration problems for countries where land price data are lacking. Nonetheless, in their conclusions, Banse et al. (2008) stress the importance of land supply endogeneity, and relative degrees of land scarcity in different countries and regions, for their results. Blanco Fonseca et al. (2010) assess the land use implication of the EU biofuel policy on a global scale.

Overall and despite all ongoing efforts, a full albeit simplified accounting of GHG emission changes including land use changes is not available in a consistent manner so far. Nevertheless, it would most likely result in a reduction of the overall potential of biofuels to reduce GHG emissions. A first approach (Al-Riffai et al. 2010) modelled the changes in world land use due to the EU biofuel policy and in addition calculated general estimates based on change in carbon stock due to the overall land use change, assuming average values of carbon stock for different land uses in agro-ecological zones. It finds that direct emission savings from a 5.6% share of (first generation) biofuels in the European road transport mix by 2020 could achieve direct emission savings of some 18 Mt CO_2, while indirect land use changes would cause additional emissions of 5.3 Mt CO_2, thus reducing the net balance to 13 Mt CO_2 (Al-Riffai et al. 2010). The study further concludes that higher shares of biofuels could lead to substantially larger emissions from land use changes, hence substantially reducing the net emission savings.

Due to the large uncertainties regarding the GHG emission changes due to land use changes (direct and indirect), these are not considered in the calculations presented in the reminder of this chapter.

16.2.4 Biofuel Production Costs

As for the specific emissions of GHG, the biofuel production costs also depend on a wide variety of factors: First, the costs of conventional first generation biofuels are largely determined by the (highly volatile) feedstock prices. Second, production costs depend on the oil price. Eventually, the costs are also largely influenced using the byproducts and the prices paid for them.

Overall, there is no central figure on the production cost of the different biofuel types but a broad range rather, which is shown in Table 16.2.

As second generation biofuel production has not yet reached a large-scale commercial state, it is difficult to determine what would be the standard production costs of the mature process. Most studies expect substantial improvements in the process and feedstock production for the future. Together with economies of scale, an important drop in the costs due to learning effects can be anticipated. Cost reductions will depend on a number of factors that according to IEA (2008a) include a continuous strong public and private support to R&D; demonstration and pre-commercial testing; the development of measures of environmental performance; and a better understanding of relevant biomass resources and geographical availability.

Despite the remaining uncertainties, most studies expect significant cost decrease for second generation technologies for 2020 and thereafter, assuming sufficient investment and scale of production. For BtL, production cost reductions are assumed to be around 35–50% below 2010 values by 2030 (see Table 16.2; values in brackets). On an annualised basis, this is equivalent to a learning rate of 3.1% p.a. for capital cost. In the case of ligno-cellulosic ethanol, production costs are estimated to be in the order of magnitude of some 35–55% below 2010 values (see Table 16.2; values in brackets). On an annualised basis, this is equivalent to a learning rate of 3.8% p.a. for capital cost.

16.3 Potential of Biofuels

Various ways exist to determine the potential of biofuels (see, e.g. Resch et al. 2008), three of which will be described in detail in this section. First, one can aim to derive the *theoretical production potential* for biofuels on the basis of the available amounts of primary biomass that is largely limited by land available for the cultivation of bioenergy crops and residues (Sect. 16.3.1). Second, the *realisable technical potential of biofuel demand* can be estimated for a given year on the basis of blending restrictions imposed by engines, taking into consideration the dynamic changes in the car fleet and limits to the annual growth of biofuel production capacities (Sect. 16.3.2). Finally, the *economic potential* can be calculated for a given point in time and a specific scenario that provides consistent energy and carbon prices (Sect. 16.3.3). The economic potential forms a subset of the realisable technical potential. In contrast to this, the realisable technical potential cannot be

Table 16.2 Biofuel production costs of different biofuel pathways

Biofuel production cost (Euro/GJ)		Schade and Wiesenthal (2011)[a] (2030 values)	Central value Schade and Wiesenthal (2011)[a]	IEA (2008a) (2030 values)	FNR (2009) (2020 values)	OECD (2006)[b]	FAO (2008)[b]	Other studies[c]
Biodiesel	Rapeseed	14.1–35.5	19.1		24 (23)	38.9	38.9	15.8–30.6
	Sunflower	17.2–22.7	17.9					
Ethanol	Wheat	12.4–28.6	19.1		26 (23.6)	21.7	31.2	10.2–23.7
	Sugar beet	15.5–28.6	17.9		25 (22)	21.2	12.5	
	Corn				16 (16)	10.9	18.8	
	Sugar cane	5.7–13.6	7.2		9.5 (9.5)	8.3	7.3	
Ligno-cellulosic		17.5–27.6 (9.8–14.4)	21.6	20–22.5 (13.8–16.3)	30–32 (18–24)			20.6–30.9
BtL		21.6–28.8 (12.2–15.8)	24.0	25–30 (15–17.5)	31 (26)			
Biogas					21 (27)			15–47
Bio-SNG								12–34
HVO					23 (23)			

[a] Values are building on JEC (2007), OECD (2008), DEFRA (2008), DFT (2006), The Energy Charter Secretariat (2007), Hamelinck and Faaij (2006), Toro et al. (2006)

[b] Studies as quoted in Mandil and Shihab-Eldin (2010); conversion from US$/litre gasoline equivalent to €/GJ assuming an energy content for gasoline of 32 MJ/l and an US$/€ exchange rate of 1.25

[c] Values for biodiesel, bioethanol, ligno-cellulosic and biogas/bio-SNG are building on Ecofys (2003), Smokers et al. (2006), Worldwatch Institute (2006; quoted in Mandil and Shihab-Eldin 2010) and Müller-Langer and Oehmichen (2009; read on chart), respectively

directly derived from the theoretical primary production potential; nevertheless, a comparison of the former with the latter allows concluding on whether there is sufficient primary biomass available for fully exploiting the realisable technical potential.

16.3.1 Theoretical Biomass Potential

Even though available biomass resources have been assessed by many different studies, the differences in the approaches and the assumptions made[2] imply that there is not one consolidated figure for the European or global potential. The ongoing FP7 project Biomass Energy Europe (BEE) therefore aims at harmonising biomass resource assessments, focusing on the EU and neighbouring countries. In the "Status of biomass resource assessments" (BEE 2008) available studies are assessed and compared, broken down by the different main biomass sources, namely agriculture, forestry and waste. Most relevant for first generation biofuels are the resources available on agricultural land due to the need for dedicated energy crops. The biomass resource assessments reviewed in BEE (2008) all find an increase in the potential from energy crops over time, but widely differ in the absolute amounts. (Fig. 16.2). Some explanation of the difference are given by the scenario assumptions, others stem from the crops (and the related energy yields) assumed to be grown on the available land area. Nevertheless, for the year 2020, the majority of the studies find a potential in the 2–5 EJ/year range.

When looking into the potential of second generation biofuels, also other bioenergy streams are of interest as these pathways can make use of a wide range of cellulosic biomass. To this end, the overview of resource assessments from forestry and residues is also included in the figure shown below.

A recent overview of major studies on the global bioenergy potential is provided in German Advisory Council on Global Change (WBGU 2010). It analysed the bioenergy potential in a geographically explicit manner for four scenarios that differ in assumptions on food production and nature conservation. Depending on the scenario, the global bioenergy potential from the cultivation of energy crops could reach 30–120 EJ/year by 2050. On top of this, agricultural and forestry residues could add around 50 EJ/year. The German Advisory Council on Global Change (WBGU 2010) notes that this potential can be further limited by socio-economic considerations and competition with existing traditional biomass uses. In order to further determine which part of the bioenergy potential would be available for biofuels, and which others for the competing uses as electricity, heat or materials, further assumptions would need to be made which is beyond the scope of thepresent analysis. These assumptions

[2]Some studies focus on the theoretical, others into the technical or economic potential. A number of studies introduce further framework conditions such as environmental guidelines that shall ensure that the potential does not create additional environmental pressures (e.g. Thrän et al. 2006; EEA 2006).

would need to consider economics as well as non-market considerations (equity issues, etc.). Moreover, it is likely to assume that substantial parts of the European biofuel demand will be imported either directly as biofuel or in the form of feedstock. This potential depends on the relation between the prices of domestically produced biofuels and imported ones, the latter of which being influenced by the way in which biofuel demand develops in other world regions as well as by domestic and foreign trade policy (import/export tariffs).

A recent overview of the global bioenergy potentials by 2050 undertaken by the IEA (2010) comes to a similarly wide span of results. IEA also further analyses the available potential from dedicated energy crops grown on arable land and the potential for second generation biofuels production from agricultural and forestry residues. It finds that some 10% of the global forestry and agricultural residues would be sufficient to produce some 4.2–6.0% of current transport demand from second generation biofuels. Twenty-five percent of the residues could provide as much as 10.5% of BtL or ligno-cellulosic ethanol, and 14.9% if converted into Bio-SNG.

Another way of cross-checking the potential availability of primary biomass for producing certain amounts of transport biofuels is to calculate the corresponding requirements of arable lands. UNEP (2009) estimates that about 118–508 Mha would be required for providing 10% of the global transport fuel with biofuels by 2030, depending on assumptions on crops, yields, etc. This corresponds to between 8% and 36% of current world cropland.

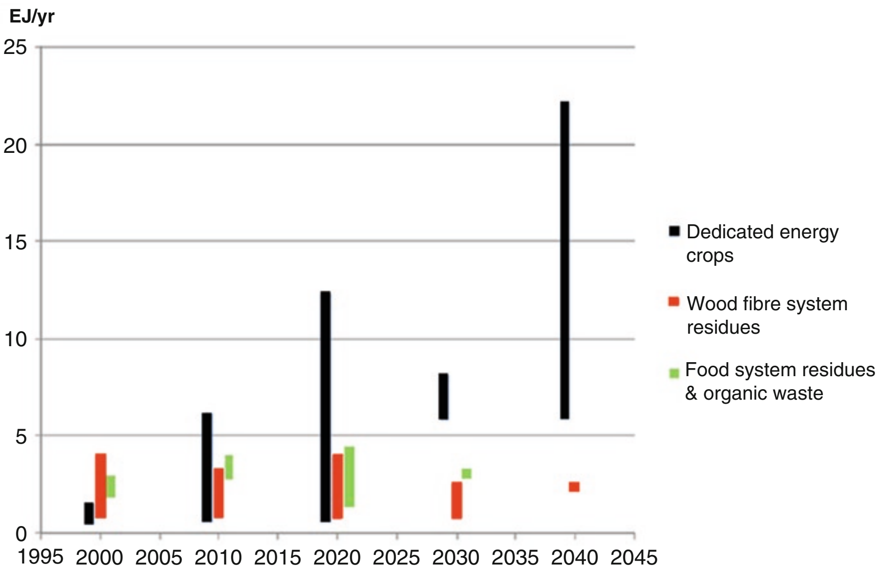

Fig. 16.2 Annual potential of bioenergy from different sectors in the EU27; synthesis of various sectoral resource assessments (EJ/year). *Source*: BEE (2008)

All in all, the competition for resources at various levels – e.g. over land with food and fodder production, infrastructure and nature protection requirements; over the primary bioenergy potential with the material use, bio-heat and bio-electricity generation – makes it difficult to determine a theoretical biofuel production potential on the basis of the raw material without introducing major assumptions on development of the agricultural sector, energy and carbon prices, the availability of substitutes and policy choices which directly or indirectly favour one use to another.

16.3.2 Realisable Technical Potential

Rather than estimating the potential of biofuels in road transport from the primary bioenergy potential, we will assess the biofuel demand on the basis of considerations of fuel quality and blending limits prescribed by current EU legislation as well as maximum blends determined by engine technologies, and the vehicle stock in road transport and similar considerations for other transport modes.

Furthermore, for second generation biofuels dynamic constraints in the available production capacities are included. They are based on the BtL production capacity projection under optimistic assumptions such as a technological breakthrough and successful demonstration made by Vogel et al. (2008). This growth rate has also been used as proxy for the HVO capacity development. Hence, both production capacity developments can be considered as a maximum technical potential.

16.3.2.1 Realisable Technical Potential per Transport Mode

Road Transport

Bioethanol can be used in different ways to replace fossil-based fuels: as low blends in the car fleet or high blends in dedicated flexi-fuel vehicles, or as ethyl-tertiary-butyl-ether (ETBE) to replace methyl-tertiary-butyl-ether (MTBE) in the fuel production processes. Tests are also being performed to mix some bioethanol into fossil diesel. The use of low blends of ethanol to gasoline is limited by its higher oxygen content and the increase of fuel vapour pressure at low blends of ethanol. The amendment of the EU fuel quality directive 2009/30/EC currently allows a blending of up to 10% in volume terms, corresponding to a 6.6% share in energy terms. This is accepted by all car, engine and fuel injection system manufacturers. Considering the renewal of the car stock, we have assumed that by 2020 all gasoline-fuelled cars can run on E10. We assume that the blending of gasoline will increase to 20% (E20) until 2030 due to adaptations of the vehicle technology.

In high concentrations, ethanol is typically used as a blend of 85% ethanol and 15% petrol, known as E85. High blends of ethanol are mainly used in flexible-fuel-vehicles (FFVs) that can operate on any blend of ethanol and petrol. A large number of FFVs is already available on the market at limited extra-costs; in a number of countries like Brazil, the USA and Sweden, FFVs have already entered the market in considerable quantities. In Brazil, the number of FFVs increased from around 30,000 in 2003 to more than nine million vehicles in 2009. In the USA, FFVs reached seven million vehicles in 2008 starting from around 170,000 vehicles in 1998. Based on the annual growth in these countries, we assume that the annually purchased amount of FFVs in Europe could increase by 500,000 vehicles each year. This would result in a realisable technical potential of 27.5 million vehicles in EU27 in 2020 which equals some 20% of all gasoline cars in the vehicle stock. Until 2030, FFV could increase further to 50 million vehicles in EU27 in 2030.

Ethanol can also be used for the production of ETBE, which is produced by etherification of ethanol (47%) and isobutylene or natural gas. ETBE is an additive to enhance the octane rating of petrol as a replacement of the fossil MTBE and to reduce emissions. In Europe, the maximum limit for the ETBE content in gasoline is set at 15% in volume terms.

First generation biodiesel replaces fossil diesel and can be blended in different shares. Compared to fossil diesel, it is sulphur-free and contains about 8% less energy per volume. Low blends can be used in diesel engines without any adjustment to the engine or fuel system. Current EU legislation (standard EN 590:2009 and EU fuel quality directive) limits the maximum blend of biodiesel in fossil diesel to 7% in volume terms, equalling 6.4% in energy. ACEA (2008) points out that for passenger cars the blending of diesel should not exceed 7%, which has been assumed here to be valid also by 2020. Nevertheless, several studies point to the possibility of higher blends for the use in heavy duty vehicles (ADFC 2010; MAN 2010); hence a B20 blend has been assumed for diesel consumption by HDVs in 2020.

Synthetic fuels (e.g. BtL and HVO) can be used in all levels of blends in conventional diesel engines without any modifications of the engine. They are usually sulphur-free and have a very low aromatic content. Moreover, they have a high cetane number, which indicate good auto-ignition qualities. They can be blended with fossil fuels at any level or be used pure without any modifications to the engine; their technical potential is therefore only limited by the available production capacities and the primary feedstock (see above). Biomethane is considered to be used in vehicles that would otherwise be powered from natural gas.

Aviation

The use of alternative fuels in jet aircrafts is seen as key option for the medium term.[3] The International Air transport Association (IATA) has set a target for its member airlines to have 10% of airline fuel needs from alternative fuel sources by 2017 (IATA 2008). As shown in Fig. 16.3, there are several alternative jet fuels that are being developed.

[3] For a more detailed analysis of the developments of alternative fuels in the aviation sector, see e.g. IATA (2009), Kinder and Rahmes (2009) and SWAFEA (2010).

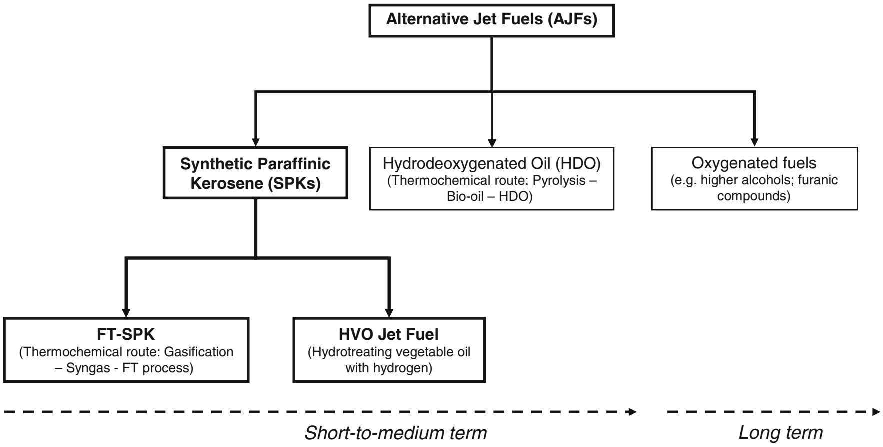

Fig. 16.3 Overview of potential alternative jet fuels. *Source*: Based on IATA (2009)

In the short to medium term, two alternative "drop-in" fuels are expected to be used as replacement for conventional jet fuel. There are synthetic fuels obtained via the Fischer Tropsch process from fossil fuels or biomass (xTL) and hydrotreated vegetable oils (HVOs), both are synthetic paraffinic kerosenes (SPKs). Even if these two fuels have common points, they are produced by means of different processes (see Sect. 16.2.1) and present several differences in terms of maturity level, environmental and economical aspects. They both meet the specific technical/operational requirements for aviation, which is far from being the case for the commercially available biofuels (e.g. in terms of energy density, viscosity, flash point, freezing point; IFP 2009).

FT-SPK[4] is an SPK obtained via the Fischer Tropsch process derived from fossil fuels or biomass (BtL). FT-SPK has already achieved certification for commercial use at 50% blend under the International specification ASTM D7566 (American Society for Testing and Materials) that was created in 2009.

HVO jet fuel or Bio-SPK is also an SPK produced from a wide range of vegetable oils or fats (see above). In the last years, HVO was successfully tested in real conditions throughout the world by different aviation motorists, airline companies, fuel suppliers and airframe manufacturers (IATA 2009). During these tests, engines were running successfully on HVO up to a 50% blend ratio in volume terms. In their conclusions, Boeing reported that "The Bio-SPK fuel blends used in the test flights have all either met or exceeded the performance specifications for jet fuel" (Kinder and Rahmes 2009). Hence, the certification ASTM D7566 of the 50% HVO blend is ongoing and scheduled for the end of 2010 (100% blend is expected to be approved by 2013).

[4] Also called synthetic fuel (xTL) or simply FT-fuel.

Apart from the above-mentioned SPK fuels, medium-to-long-term options for the aviation sector might be the use of naphtenic fuels (coal or biomass liquefaction) and oxygenated fuels (higher alcohols and furanic compounds) that are at early development stage. They will be analysed in detail in the EU FP7 project Alpha-Bird (Alpha-Bird 2010).

Shipping

In general, it is considered that bio-based fuels may replace the use of diesel in shipping rather than that of fuel oil (Hill et al. 2009), even though some considerations have been given to, e.g., pure plant oil. An additional advantage of biodiesel for the use in shipping is the fact that it is biodegradable, hence being less harmful in case of spillages. Furthermore, some blends can reduce the CO and PM emissions, while at the same time emissions of NOx would slightly increase (Hill et al. 2009).

Rail

In the rail mode, the most important use of biofuels is again to replace diesel by biodiesel. It is generally used in blends of less than 30%. Moreover, replacing fossil by biodiesel can also reduce gaseous and particulate emissions (Silver 2006). Presently, biofuel consumption in the rail sector is very limited due to economic reasons. There are, however, some countries that aim to increase its use in rail (see Hill et al. 2009).

16.3.2.2 Total Realisable Technical Potential

The total realisable technical biofuel potential is obtained by summing up the technical potential in the distinct modes as assessed above, taking into account that limitations in the production capacities restrict the aggregated consumption of second generation fuels of all modes. For each mode, the technically realisable potential is derived by applying the maximum blend of biofuels to the total energy consumption of the mode. The total energy consumption per transport mode and the vehicle fleet composition are taken from the iTREN 2030 reference scenario (Fiorello et al. 2009).

The realisable technical biofuel potentials in the various transport modes can be up to 111 Mtoe by 2020 as shown in Table 16.3, representing 26% of the transport energy consumption by then. It would rise rapidly thereafter to almost double by 2030, reaching a level of 250 Mtoe by then.

By 2020, much of the technical potential of biofuels would be realised in road transport (63 Mtoe) and aviation (46 Mtoe). The potentials for the use of biofuels

Table 16.3 Technical potential of transport modes in the EU-27 in 2020

Technical potential of transport modes in 2020 (Mtoe)		Fuels (engine)	Projected energy consumption	Bioethanol and Ligno-ethanol	Biodiesel	BtL	Bio-SPK	Bio-methane	Biofuels total	Biofuels %[a]
Road	Pass. Cars	Gasoline (ICE)	97.9	6.6					6.6	6.7
		Gasoline (FFV)	23.8	18.7					18.7	78.6
		Gas	1.8					1.8	1.8	100.0
		Others	4.9						0.0	0.0
		Diesel (ICE)	101.4		6.6	2.6			9.1	9.0
	Trucks	Diesel (ICE)	124.9		23.6	3.2			26.6	21.3
Rail		Diesel	2.7		0.7	0.1			0.8	28.1
		Electricity	8.0						0.0	0.0
Maritime[b]		Diesel	5.4		1.4	0.1			1.5	28.1
Aviation[b]		Kerosene	56.1			6.0	40.0		46.0	82.0
Total energy cons. (Mtoe)			426.8	25.2	32.0	12.0	40.0	1.8	111	26.0
GHG emiss. red. (Mt CO_2-equivalent)				42–84[c]	59	40	67	2	231	

[a]In energy terms

[b]Maritime transport refers to inland navigation only. Energy consumption of aviation refers to the fuel consumption of airplanes. It is not considered in which geographical area flights actually take place

[c]The actual GHG emissions reduction from ethanol consumption depends on the mix of first and second generation ethanol. We assume for the following that second generation ethanol contributes up to 50%

in maritime and rail transport are limited. Using a blend of 30% biodiesel in maritime transport could lead to a technical potential of around 2 Mtoe. In rail transport, a blend of 30% biodiesel could lead to a technical potential of around 1 Mtoe.

The technical potential of first and second generation ethanol, for both of which apply the same limitations in terms of maximum blending, has been estimated to be around 25 Mtoe in 2020. Until 2030, it could increase further to some 45 Mtoe due to the assumed replacement of E10 by E20 in road transport until 2030. The realisable technical potential of first generation biodiesel use would be around 30 Mtoe by 2020 due to the assumptions of B20 used in trucks, with only limited increases thereafter.

The technical potential of BtL and HVO has been estimated to be in the order of 12 and 40 Mtoe, respectively, by 2020. It could rise steeply thereafter to reach 76 and 100 Mtoe, respectively, by 2030 as constraints in the expansion of production capacities become less important.

Multiplying the biofuel potentials with the specific emission factors taken from Table 16.1 gives an indication of the realisable technical GHG emission potential without land use change that may be achieved through the use of transport biofuels in the EU.[5] Biofuels may avoid GHG emissions in the order of 230 Mt CO_2 by the year 2020. First generation bioethanol and biodiesel contribute with about 70 Mt CO_2, while second generation biofuels already have a higher GHG emission reduction potential.

While in energy terms, the realisable technical biofuel potential almost doubles between 2020 and 2030, the rise in the GHG emission reduction potential is even more pronounced. It might triple from around 250 Mt CO_2-equivalent by 2020 to more than 750 Mt CO_2-equivalent by 2030, when neglecting emissions from land use changes. The main reason behind this is the shift toward second generation biofuels with higher relative GHG emission reduction potentials (see Table 16.1).

16.3.3 Economic Potential

In order to address the market-driven response to the technically available opportunities assessed by the technical potential analysis, an approximation of the economic potential by biofuel type was carried for a scenario that assumes an oil price of 80 €/bbl and a CO_2 price of 50 €/t CO_2 by 2020. No further biofuel support policies are assumed in the determination of the economic potential.

To derive the economic potential, abatement cost-resource curves of the various biofuel types and pathways have been generated using the BioPOL model, which will therefore be briefly described in the following. The model uses the biofuel

[5] As described above, this does not account for emissions from indirect land use change that will lower the net emissions avoided.

production costs and specific emission factors shown in Tables 16.1 and 16.2 above ("central value Schade and Wiesenthal").

The BioPOL model is a recursive dynamic model that is constructed in the VENSIM modelling platform (for details, see Schade and Wiesenthal 2011). It is based on a year-by-year simulation of biofuel production, production cost and biofuel demand until 2030. The model delivers detailed outcomes for the types of biofuels considered[6] with regard to production capacity and produced volumes, costs and well-to-wheel emissions of GHGs.

For each set of exogenously given parameters, the biofuel consumption level is determined so that the market prices of biofuels equal those of the fossil alternative they substitute, taking into account the feedstock prices coming from the agricultural market conditions. An increase in the biofuel consumption and the related production capacities imply a higher demand for feedstock. This in return means rising feedstock prices, and therefore increasing production costs, resulting in higher market prices of biofuel. The latter are then compared with the market prices of fossil fuels to determine the biofuel demand which triggers biofuel capacity and biofuel production. The model also takes into account additional costs – reflecting technical adaptations – related to certain levels of biofuel consumption, which reflect well the different blends described above. The abatement cost curve linking the biofuel production cost per pathway with the avoided GHG emissions was generated by applying the BioPOL with different oil prices (60, 80, 100 €/bbl in constant prices) and varying the level of biofuel shares.

To derive one value for the economic potential from the abatement cost curve, certain economic framework conditions were defined based on the iTREN-2030 reference scenario. The oil price was assumed to rise from 80 €/bbl in 2020 to 100 €/bbl in 2050, and the carbon value would be of 50 €/t CO_2-equivalent in 2020 and 2030. The level of the carbon value could rise further to 100 €/t CO_2-equivalent in 2050.

The resulting economic potential is in general significantly lower than the technical potential (see Table 16.4). Overall, it reaches only 31 Mtoe compared to 111 Mtoe of the technical potential. Due to improvements in biofuel cost production, the economic potential increases to about 50 and 130 Mtoe in 2030 and 2050, respectively.

Bioethanol both from first and second generation would take the highest share, as well as Bio-SPK. The use of biomethane might avoid some 2 Mt CO_2-equivalent by 2020 in an economic manner, if sufficient gas-powered vehicles were on the market. In aviation, some 6 Mtoe could be replaced by biofuels mainly by HVO. Second generation biofuels gain more importance over time. For example, the economic potential of BtL would reach 3 Mtoe by 2020, avoiding some 11 Mt CO_2-equivalent. Including technical improvements the economic potential could reach 37 Mtoe, avoiding some 125 Mt CO_2-equivalent in 2050.

[6]The model considers conventional biodiesel based on the two feedstocks of rapeseed and sunflower, and conventional ethanol based on cereals and sugar beet. It also includes advanced second generation pathways from ligno-cellulosic feedstock (i.e. ethanol and synthetic diesel BtL).

Table 16.4 Economic potential in the EU-27 in 2020, 2030 and 2050

Economic potential in 2020, 2030 and 2050	Energy (Mtoe)			GHG emission reduction (Mt CO_2-equivalent)		
	2020	2030	2050	2020	2030	2050
Gasoline by first generation bioethanol	10	10	22	16	16	36
Gasoline by ligno-cellulosic bioethanol[a]	5	8	27 (17)	18	25	90 (55)
Diesel by biodiesel	5	5	9	9	10	16
Diesel by BtL[a,b]	2	7	30 (19)	8	25	100 (65)
Kerosene by BtL[a,b]	3	9	37 (24)	11	31	125 (81)
Kerosene by bio-SPK	6	13	29	10	40	85
Gas by biomethane	2	2	2	2	2	2
Sum[b]	31	47	126	66	124	355

[a] Figures in *brackets* indicate economic potential if no further technological improvements after 2030 are assumed

[b] The economic potential provided for BtL is either the one shown in the row "Diesel by BtL" or the one shown for "Kerosene by BtL". These must not be added

Table 16.5 GHG emission reduction at different oil prices and carbon value in EU-27 in 2020

GHG emission reduction (Mt CO_2-equivalent)			
Carbon value (€/t CO_2)	Oil price (€/bbl)		
	60	80	100
25	17	36	99
50	32	66	139
75	51	99	170

Note that the economic potential does not imply that there are no other measures that are cheaper for reducing GHG emissions in the transport sector; neither that the use of the available raw feedstock as transport biofuel is preferable to its use in heat and/or electricity production. The analysis of those topics goes beyond the scope of the present work

Based on the economic potential, around 70 Mt CO_2-equivalent could be avoided by biofuels at a carbon value of 50 €/t CO_2-equivalent in 2020. The GHG emission reduction might double until 2030 and reach 350 Mt CO_2-equivalent in 2050. While in the short run, the GHG emission reduction potentials of first and second generation are very similar; second generation biofuels contributes with 215 Mt CO_2-equivalent much more to overall GHG emission reduction in the long run (excl. emissions from land use change).

Given that biofuels directly compete with the fossil fuels they substitute, the economic potential heavily depends on the trends in oil and CO_2 prices as well as in feedstock prices (Schade and Wiesenthal 2011). This relation is illustrated in Table 16.5.

16.4 Discussion Results

16.4.1 Comparison with Other Studies

The "economic potentials" estimated above can broadly be compared to the penetration of biofuels found in other scenario exercises.

According to the IEA Energy Technology Perspective (IEA 2008a), second generation biofuels could globally save up to 2.2 Gt CO_2-equivalent by 2050 in the ambitious "Blue Map scenario". Some 13% of this (286 Mt CO_2) might be realised in OECD Europe. This confirms the economic mitigation potential of second generation biofuels (i.e. ligno-cellulosic ethanol, BTL, HVO; see Table 16.4) that has been calculated in this chapter and was found to be in the order of 300 Mt CO_2. Possible biofuel implementation scenarios for achieving the EU renewable targets were assessed within the JEC Biofuels programme (JEC 2010). The work is mainly based on the development of the European vehicle fleet and the type of blending. In the reference scenario biofuel demand could reach 20 Mtoe. Varying the blending biofuel demand could be more than 30 Mtoe, which is close to the economic potential (31 Mtoe) derived in this chapter, although some assumptions and applied methods differ significantly.

McKinsey (2009) calculates that by 2030, globally 380 Mt CO_2 could be avoided at relatively low cost through a 25% blend of biofuels in the gasoline supply of road transport and an increase in biodiesel, stemming from conventional and advanced biofuels. In Europe, this potential would be around 57 Mt CO_2. Additional potential is considered to be available, but at higher costs. This compares to the biofuel mitigation potential in road transport of 76 Mt CO_2 calculated here for 2030.

The climate mitigation scenario of the IEA World Energy Outlook, which is more in line with the energy framework used here than their reference scenario, projects a European biofuel consumption of around 25 Mtoe by 2020, rising to 42 Mtoe in 2030 (IEA 2009). This is well in line with the findings of the present work, according to which the economic biofuel potential could reach 31 Mtoe and 47 Mtoe by 2020 and 2030, respectively.

16.4.2 Consistency Between the Approaches

As the economic potential forms a subset of the technically feasible potential, it is consistent by construction. It remains to be seen whether the economic and/or technical potentials are well below the available primary bioenergy potential, and are therefore theoretically possible to realise from a resource point of view without significant harm to the global environment.

Converted to primary bioenergy, the technical potential by 2030 would equal some 600 Mtoe (25 EJ) of primary biomass in total. Of this, around 350 Mtoe (15 EJ) would to come from dedicated sugar/starch and oily energy crops, while the remainder would serve the production of BtL or ligno-cellulosic ethanol and could thus draw on a wider range of feedstock including residues. Exploiting the economic potential would imply a need for primary feedstock in the order of 90 Mtoe (3.6 EJ) by 2030 and around 225 Mtoe (9.4 EJ) by 2050 to satisfy the EU demand.

The comparison with studies on the primary biomass potential (see Sect. 16.3.1; Thrän et al. 2006; EEA 2006; BEE 2008) shows that these potentials in the EU alone would most likely not be sufficient to fully exploit the technical or economic potential. This implies that the EU will to some extent depend on imports of biofuels and/or biofuel feedstock and could then draw on the sufficiently large global potentials. But also on the global level competition for various (energy) uses prevails over the primary potential; hence only part of it would be accessible as feedstock for biofuels, depending on market and policy choices made both in the EU and abroad.

16.4.3 Limitations of the Methodology

The consideration of the technical biofuel potential largely relies on assumptions of biofuel blends and the market uptake of advanced biofuel technologies. The former considers the maximum levels set by European legislation; it also considers some potential revisions to these in the future. As for the development of second generation production capacities, we have relied on published material. Nevertheless, all these considerations remain assumptions that may well turn out to develop differently over time than foreseen here. Some studies even conclude that on the basis of today's knowledge, no reliable assessments can be made for the GHG-abatement potential of second generation biofuels for the time horizon 2020/2030 (UBA 2010). Modifications to the assumptions on technological learning of advanced biofuels not only influences the realisable technical potential, but also the economic potential, considering that this is one of the key determinants of biofuel market penetration besides the prices of oil of CO_2, and primary feedstock (Schade and Wiesenthal 2011).

There is also the possibility of novel technologies – such as the fermentation of sugar crops into biodiesel or the exploitation of algae – to achieve an unforeseen and unforeseeable breakthrough.

The potential of biofuels in avoiding GHG emission of the European transport sector is also largely influenced by the specific emission reductions assumed for every biofuel pathway. In the present analysis, these do not account for the emissions of land use change (direct and indirect), and therefore overestimate the GHG emission reduction potential (see Sect. 16.2.3).

At the same time, Pieprzyk et al. (2009) claims that the reference emissions for fossil fuels may be set too low as the exploitation of conventional oil resources become increasingly difficult and energy-intensive and unconventional resources with elevated GHG emissions are entering the market. This would imply that the GHG savings from biofuels as sketched out above may be underestimated.

Also the sustainability criteria for biofuels that are being set out in Directive 2009/28/EC are not taken into account here (EU 2009a, COM 2010a, b; Biograce 2010), which may limit the use of biofuels produced from some emission-intensive pathways. The Directive prescribes minimum GHG emission requirements for biofuels that are taken into account in the targets set by the Directive. Biofuels shall save at least 35% of GHG emissions, rising to at least 50% by 2017. Biofuels produced in installations that started production on or after 1 January 2017 shall save at least 60%. Furthermore, biofuels shall not be made from raw material obtained from land with high biodiversity value.

16.5 Conclusions

This chapter sketches out the potential of biofuels in avoiding GHG emissions of the European transport sector. To this end, it reviews the available primary bioenergy potential, calculates the realisable technical potential and finally estimates the economic potential.

The realisable technical biofuel potential has been estimated on the basis of the vehicle stock, blending and market deployment of novel technologies. It could reach a level of around 110 Mtoe in 2020, representing 26% of the sector's energy consumption by then. It increases thereafter to make up as much as 55% of transport energy demand in 2030, facilitated by the assumed use of higher blends and the faster higher deployment of second generation biofuels. Most of this potential is considered to be found in the road sector – and for first generation biodiesel in road freight – and aviation once synthetic biofuels (SPK-like) become available. This indicates the high influence of legislation setting maximum levels of blends, and of a successful market introduction of advanced biofuels that can overcome blending limits and can also be used in aviation.

The economic potential reaches 7% of the transport energy demand by 2020 – less than one third of the technical potential despite assuming an oil price of 80 €/bbl and a carbon value of 50 €/t CO_2. Depending on the assumptions made for prices of oil and CO_2, the economic potential could nevertheless adopt very distinct values. Due to technical improvements, the economic potential would increase further to reach some 50 Mtoe in 2030.

A comparison of these potentials with assessments of the available primary biomass potential suggests that sufficient biomass could theoretically be made available for biofuel production when also considering imports to the EU. Ultimately, the amount of primary bioenergy that can be used for production of transport biofuels will depend on relative prices and policy choices between their competing uses. As the EU is likely to be a net importer of biofuels, it will depend on these policy choices made abroad. At the same time, considering that the European biofuel market currently represents about one fourth of the global biofuel market, the EU can set biofuel sustainability criteria that may factually have an influence beyond its borders.

The elevated substitution potentials of fossil-based fuels with biofuels indicate the theoretically high GHG mitigation potential. Yet, the extent to which the biofuels uptake can materialise in emission savings heavily depends on which biofuels are used, and therefore point to the need of quantifying the emissions caused by land use changes (direct and indirect). As the present study does not consider emissions from land use change, the "economic" GHG mitigation potentials of 66 Mt CO_2-equivalent in 2020 and almost twice this value by 2030 can be seen as optimistic results. The doubling of the emission reduction potentials between 2020 and 2030 compared with the 50% increase in energy terms results from the increasing share of second generation biofuels with their significantly lower specific emissions in the biofuel mix and points to the importance of these advanced technologies in exploiting the role of biofuels as GHG mitigation measure.

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Glossary

ACEA	European Automobile Manufacturers' Association
BEE	Biomass Energy Europe
BtL	Biomass-to-liquid
DDGS	Dried distillers grains with solubles
ETBE	Ethyl-tertiary-butyl-ether
FAME	Fatty acid methyl ester
FFVs	Flexible-fuel-vehicles
GHG	Greenhouse gas
HVO	Hydrogenated vegetable oil
IATA	International Air Transport Association
ICE	Internal combustion engine
IPCC	International panel on climate change
iTREN-2030	Integrated transport and energy baseline 2030
MTBE	Methyl-tertiary-butyl-ether
R&D	Research and development
RD&D	Research development and deployment
SNG	Synthetic natural gas
SPK	Synthetic paraffinic kerosene
xTL	Coal, gas or biomass-to-liquid

References

Accenture (2009) Betting on science. Disruptive technologies in transport fuels

ACEA (2008) EU Legislators must ensure consumers have access to the right fuel. Press release of ACEA from 18 December 2008

ADFC (2010) B20 and B100: alternative fuels. Alternative Vehicles Data Center (ADFC) sponsored by the US Department of Energy. http://www.afdc.energy.gov/afdc/fuels/biodiesel_alternative.html. Accessed 22 July 2010

Alpha-Bird (2010) Alternative fuels and biofuels for aircraft development. Project co-funded by the EU in the 7th framework programme for research and technological development. http://www.alfa-bird.eu-vri.eu/. Accessed 30 July 2010
Al-Riffai P, Dimaranan B, Laborde D (2010) Global trade and environmental impact study of the EU biofuels mandate. IFPRI, Washington, DC
Banse M, Van Meijl H, Tabeau A, Woltjer G (2008) Will EU biofuel policies affect global agricultural markets? Eur Rev Agric Econ 35(2):117–141
Blanco Fonseca M, Burrell A, Gay SH, Henseler M, Kavallari A, M'barek R, Pérez Domínguez I, Tonini A (2010) Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment. European Commission, Brussels, Belgium. JRC Scientific and Technical Report, EUR24449 EN. http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3439
Biograce (2010) Condensed list of standard values – version 3. Agentschap, Utrecht
BP (2009) Sugar to diesel fact sheet. Download under http://www.bp.com/liveassets/bp_internet/alternative_energy/alternative_energy_english_new/STAGING/local_assets/downloads_pdfs/b/biofuels_Sugar_to_Diesel_Factsheet_FINAL_090909.pdf. Accessed 05 July 2010
COM (2009) The Renewable Energy Progress Report
COM (2010a) Communication from the Commission on voluntary schemes and default values in the EU biofuels and bioliquids sustainability scheme
COM (2010b) Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels
Connor DJ, Hernandez CG (2009) Crops for biofuel: current status and prospects for the future. In: Howarth et al (2009) Rapid assessment on biofuels and environment. Biofuels: environmental consequences and interactions with changing land use, pp. 65–80
Croezen HJ, Bergsma GC, Otten MBJ, van Valkengoed MPJ (2010) Biofuels: indirect land use change and climate impact. CE Delft, Delft
Crutzen PJ, Mosier AR, Smith KA, Winiwarter W (2008) N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Atmos Chem Phys 8:389–395
DEFRA (UK Department for Environment, Food and Rural Affairs) (2008) Estimating the cost-effectiveness of biofuels. DEFRA, London
DFT (UK Department for Transport) (2006) International resource costs of biodiesel and bioethanol. DFT, London
EC (2009) The renewable energy progress report. Communication COM (2009) 192 final
Ecofys (2003) Biofuels in the Dutch market. A fact-finding study. Ecofys, Utrecht
Energy Charter Secretariat (2007) Driving without petroleum? A comparative guide to biofuels, gas-to-liquids and coal-to-liquids as fuels for transportation
BEE (Biomass Energy Europe) (2008) Status of biomass resource assessments, Version 1. IFEU, Heidelberg, Germany
EEA (European Environment Agency) (2006) How much bioenergy can Europe produce without harming the environment? EEA report 7/2006
EU (2009a) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
EU (2009b) Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EC
EurObserv'ER (2010) Biofuels barometer July 2010
FAO (Food and Agriculture Organization of the United Nations) (2008) The state of food and agriculture. Biofuels: prospects, risks and opportunities. FAO, Rome
Fiorello D, De Stasio C, Köhler J, Kraft M, Newton S, Purwanto J, Schade B, Schade W, Szimba E (2009) The iTREN-2030 reference scenario until 2030. Deliverable 4 of iTREN-2030 (Integrated transport and energy baseline until 2030). Project co-funded by European Commission 6th RTD Programme. Milan, Italy

Gallagher E (2008) The Gallagher review of the indirect effects of biofuels productions. Renewable Fuels Agency, St Leonards-on-Sea, England
WBGU (German Advisory Council on Global Change) (2010) Future bioenergy and sustainable land use. WBGU, Berlin
Hamelinck CN, Faaij APC (2006) Outlook for advanced biofuels. Energy Policy 34(17):3268–3283
Hertel T, Tyner W, Birur D (2008) Biofuels for all? Understanding the global impacts of multinational mandates. In: GTAP working paper No. 51. Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University
Hill N, Hazeldine T, von Einem J, Pridmore A, Wynn D (2009) Alternative Energy Carriers and Powertrains to Reduce GHG from Transport (Paper 2), EU transport GHG: routes to 2050? AEA, London
Howarth RW, Bringezu S, Bekunda M, de Fraiture C, Maene L, Martinelli L, Sala O (2009) Rapid assessment on biofuels and environment. Biofuels: environmental consequences and interactions with changing land use. In: Proceedings of the Scientific Committee on problems of the environment (SCOPE) international biofuels project rapid assessment. Ithaca, NY, USA. Cornell University. http://cip.cornell.edu/biofuels/
IATA (2008) Building a greener future, 3rd edn. IATA, Montreal
IATA (2009) Report on alternative fuels. IATA, Montreal
IEA (2008a) Energy technology perspectives. Scenarios and strategies to 2050. IEA, Paris
IEA (2008b) From 1st-to-2nd generation biofuel technologies. An overview of cur-rent industry and RD&D activities. IEA, Paris
IEA (2009) World energy outlook 2009. IEA, Paris
IEA (2010) Sustainable production of second-generation biofuels. IEA, Paris
IEA Bioenergy (2009) IEA bioenergy task 42 biorefinery. IEA, Paris
IFP (2009) Aviation and alternative fuels. Panorama. IFP, Ruell-Malmalson
IPCC (Intergovernmental Panel on Climate Change) (2003) Good practice guidance for land Use, land-Use change and forestry. In: Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F (eds) IPCC/OECD/IEA/IGES, Hayama, Japan
JEC (JRC/EUCAR/CONCAWE) (2007) Well-to-wheels analysis of future automotive fuels and powertrains in the European context WELL-TO-WHEELS Report Version 2c. JEC, Brussels
JEC (JRC/EUCAR/CONCAWE) (2008) Well-to-wheels analysis of future automotive fuels and powertrains in the European context. WELL-TO-TANK report version 3.0 November 2009. WTT App.2 – description and detailed energy and GHG balance of individual pathways. JEC, Brussels
JEC (JRC/EUCAR/CONCAWE) (2010) JEC biofuels programme. Overview of Results. JEC, Brussels
Kinder JD, Rahmes T (2009) Evaluation of bio-derived synthetic paraffinic kerosenes (Bio-SPK). Boeing Company
Man (2010) MAN Latin America introduces dual fuel-Truck with pure biodiesel. Press release from 02 June 2010
Mandil C, Shihab-Eldin A (2010) Assessment of biofuels potential and limitations. A report commissioned by the International Energy Forum
McGill R (2008) Algae as a feedstock for transportation fuels – the future of biofuels? A white paper prepared for the IEA advanced motor fuels implementing agreement. Presented to the 35th Executive Committee Meeting, May 2008, Vienna, Austria
McKinsey (2009) Roads toward a low-carbon future: reducing CO_2 emissions from passenger vehicles in the global road transportation system
Müller-Langer F, Oehmichen K (2009) Biomethane as a fuel, presentation at the biofuel research – a transatlantic dialogue conference. German Biomass Research Centre, Berlin
FNR (Fachagentur Nachwachsende Rohstoffe) (2009) Biokraftstoffe – Eine vergleichende Analyse (Biofuels – a comparative study). FNR, Gülzow
OECD (2006) Directorate for Food, Agriculture and Fisheries. Agricultural market impacts of future growth in the production of biofuels. OECD, Paris

OECD (2008) Biofuel support policies: an economic assessment (biofuel performance with respect to environmental and other criteria). OECD, Paris

Pieprzyk B, Kortlüke N, Rojas Hilje P (2009) The impact of fossil fuels. Green-house gas emissions, environmental consequences and socio-economic effects. ERA-Energy Research Architecture, San José

Ragwitz M, Schade W, Breitschopf B, Walz R, Helfrich N, Rathmann M, Resch G, Panzer C, Faber T, Haas R, Nathani C, Holzhey M, Konstantinaviciute I, Zagamé P, Fougeyrollas A, Le Hir B (2009) EmployRES. The impact of renewable energy policy on economic growth and employment in the European Union. Fraunhofer ISI, Karlsruhe

Ramesohl S, Stucki S (2007): Biomethane as a transportation fuel – substitution potential of conventional and second generation biogas. Presentation at the JRC international conference transport and environment: a global challenge, techno-logical and policy solutions, Milan, March 2007

Resch G, Held A, Faber T, Panzer C, Toro F, Haas R (2008) Potentials and prospects for renewable energies at global scale. Energy Policy, 36(11):4048–4056

Schade B, Wiesenthal T (2011) Biofuels: a model based assessment under un-certainty applying the Monte Carlo method. J Policy Model 33(1):92–126

Searchinger T (2009) Government policies and drivers of world biofuels, sustainability criteria, certification proposals and their limitations. In: Howarth et al (2009) Rapid assessment on biofuels and environment. Biofuels: environmental consequences and interactions with changing land use, pp 37–52

Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J, Tokgoz S, Hayes D, Yu TH (2008) Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319(5867):1238–1240

Shell (2010) Shell and virent expand their collaboration on advanced biofuels. Download under http://www.shell.com/home/content/media/news_and_library/press_releases/2010/shell_virent_advanced_biofuels_07062010.html. Accessed 06 July 2010

Silver I (2006) An examination of biodiesel fuel and the implications of its potential use on UK railways

Smokers R, Vermeulen R, van Mieghem R, Gense R, Skinner I, Fergusson M, MacKay E, ten Brink P, Fontaras G, Samaras Z (2006) Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2 emissions from passenger cars

SWAFEA (2010) State of the art on alternative fuels in aviation, SWAFEA project (FP7). http://www.swafea.eu/

Taheripour F, Hertel T, Tyner W, Beckman J, Dileep K (2008) Biofuels and their by-products: global economic and environmental implications. Presented at the 11th GTAP Conference, June 12–14 2008, Helsinki, Finland and at the 2008 American Agricultural Economics Association meeting in Orlando, Florida

Thrän D, Weber M, Scheuermann A, Froehlich N, Thoroe C, Schweinle J, Zeddies J, Henze A, Fritsche UR, Jenseit W, Rausch W, Schmidt K (2006) Sustainable strategies for biomass use in the European context – analysis in the charged debate on national guidelines and the competition between solid, liquid and gaseous biofuels. IE, Leipzig

Toro FA, Hasenauer U, Schade W, Wietsche M (2006) Biofuels technology database. Deliverable of the TRIAS project: sustainability impact assessment of strategies integrating transport, technology and energy scenarios. Fraunhofer ISI, Karlsruhe

UBA (Umweltbundesamt) (2010) CO_2 Emissions reduction in the transport sector in Germany. Possible measures and their reduction potential. Federal Environment Agency, Dessau-Roßlau

UNEP (2009) Towards sustainable production and use of resources: assessing biofuels. UNEP, Nairobi

Vogel A, Mueller-Langer F, Kaltschmitt M (2008) Analysis and evaluation of technical and economic potentials of BtL-fuels. Chem Eng Technol 31(5):755–764

Wiesenthal T, Leduc G, Christidis P, Schade B, Pelkmans L, Govaerts L, Georgopoulos P (2009) Biofuel support measures in Europe: lessons learnt for the long way ahead. Renew Sustain Energy Rev 13(4):789–800

Worldwatch Institute (2006) Biofuels for transportation: global potential and implications for sustainable agriculture and energy in 21st century. Prepared for the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), Germany in cooperation with GTZ and FNR. Worldwatch Institute, Washington, DC

Chapter 17
Technological Potential for CO_2 Emission Reductions of Passenger Cars

Michael Krail and Wolfgang Schade

17.1 Introduction

Today, road transport activities are the major source for CO_2 emissions from transportation in Europe. According to the DG-TREN Statistical Pocketbook 2009, freight and passenger road transports were responsible for 93% of all transport-related CO_2 emissions within EU27 in 2006. About two third of this road CO_2 emissions can be allocated to passenger transport activities. Since 1990, passenger road CO_2 emissions have been steadily increasing.

In order to meet the CO_2 emission reduction targets of the EU until 2020 (–20% compared to 1990 levels) and long-term targets to remain on the 2-degree pathway according to the IPCC, significant changes in today's passenger road transport sector have to happen. One way to achieve prospective CO_2 emission limits for transport is the reduction of transport demand by changing mobility behaviour. Pricing mechanisms and other incentives are powerful instruments to induce these changes in combination with the awareness of transport burdens for the climate. Policy makers are reluctant to implement incentives that oblige the population with additional financial burdens on passenger transport as mobility is still an essential need for a functioning and growing economy. Hence, instruments leading towards less transport demand, modal shift towards rail and decreasing average trip lengths have to be accompanied by innovations reducing the energy consumption of the rolling stock.

Climate policy impacts on transport, economy and society have been assessed in several studies like ADAM (Jochem et al. 2009) or iTREN-2030 (Schade et al. 2010). This chapter focuses on the technological CO_2 emission reduction potentials of passenger cars. This includes technologies aiming at improving the fuel efficiency of conventional cars with internal combustion engines as well as

M. Krail (✉)
Fraunhofer Institute for Systems and Innovation Research (ISI), Sustainability and Infrastructure Systems, Breslauer Strasse 48, 76139, Karlsruhe, Germany
e-mail: m.krail@isi.fraunhofer.de

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alternative fuel technologies such as CNG, LPG and battery electric vehicles (BEVs). The technological potentials have been elaborated in the GHG-TransPoRD project (Akkermans et al. 2010) on behalf of the European Commission (DG-RTD). Another project that deals with technological potentials is EU Transport GHG: Routes to 2050.

In the following sections, the methodology to analyse the reduction potentials is described in detail. Based on a long list of technologies, the most efficient and compatible technologies are clustered into eleven measure groups. A zoom into these groups is as follows. It should explain the technologies considered, their functioning and where in the car they can be applied. Additionally, the technical feasibility and the maturity of the technologies are elaborated. Finally, relative CO_2 emission reduction potentials as well as absolute CO_2 savings are derived for all measure groups.

17.2 Study Approach

The approach applied has been developed for the GHG-TransPoRD (upcoming in 2010: Akkermans et al. 2010) project on behalf of the European Commission. It foresees two lines of activity. The first line starts from a literature research, technology journal review, expert and stakeholder interviews. A long list of potential technologies to reduce CO_2 emissions of road passenger transport is the result. As most studies offer ranges of potential CO_2 emission reductions from a minimum to a maximum value, both values are extracted. The final choice of a technically feasible CO_2 reduction potential for each technology is carried out by comparing outcomes of different studies, assessing the underlying assumptions and if available expert judgment in technology journals and forums. Additionally, the technical feasibility, the maturity, the applicability and the compatibility with other technologies are elaborated.

The next step consists of an allocation of all technologies to the respective subsystem in a car (e.g. engine, car body, drive, etc.). Non-compatible technologies are excluded in this clustering process such that those combinations of technologies are chosen which bear the highest CO_2 emission reduction potentials. Reduction potentials of a combination of technologies are estimated by multiplying the single reduction factors.

The second line starts from existing projects analysing energy demand and CO_2 emissions from transport until 2030 (iTREN-2030 project, Fiorello et al. 2009) and 2050 (ADAM project, Schade et al. 2009). Based on these studies and particular extensions based on the TREMOVE model (version 2.7c) and the EXTREMIS database, the so-called common energy framework is developed. The common energy framework constitutes an aggregate summary of fuel use in energy units by type of fuel and by mode.

Projections of energy demand for each car type and the CO_2 emission reduction potentials of the different measure groups are the basis for estimating the absolute reduction potentials in the years 2020 and 2050. They provide an indication on the importance of each measure group to contribute to transport CO_2 reductions. This approach supports to identify effective measures, since we are speaking about reductions of CO_2 emissions of transport of more than 60% until 2050, which will not be feasible applying marginal measures. Broadly this approach for the second line of activity comes from the German study preparing the annual UNFCCC reporting of Germany (Öko-Institut et al. 2008).

Absolute CO_2 emission savings of the considered technologies in 2020 and 2050 do not only depend on the energy framework but also on the technical feasibility, the maturity and the applicability to only certain engine types. Even for technologies that have entered the market in 2010, a complete diffusion into the whole car fleet until 2020 is due to the average lifetime (13–14 years in EU27) of passenger cars not feasible. Therefore, many technology groups have significantly lower impacts on CO_2 emission savings in 2020 compared to 2050.

17.3 Energy Framework

The baseline for the assessment of CO_2 emission saving potentials is the projection of the energy demand from passenger car transport between 2010 and 2050. The so-called common energy framework is derived from the iTREN-2030 Reference Scenario (Fiorello et al. 2009). As iTREN-2030 only provides forecasts until 2030, the iTREN-2030 energy demand pathway is prolonged by results from the TREMOVE model and from the Reference Scenario of the ADAM project in which the ASTRA model has been applied.

Figure 17.1 shows the estimated development of energy demand from car fuel consumption between 2010 and 2050. Car fuel consumption is projected to increase until 2030, stagnate in the following decade and slightly consolidate in the last 10 years until 2050 in EU27. The share of alternative fuel cars in this reference case is supposed to be only marginal.

BEVs and hydrogen fuel cell cars do not diffuse into car fleets in EU27, which can be considered as a pessimistic case. Transferring the energy demand into CO_2 emissions shows that passenger cars are projected to emit about 12% more CO_2 in 2020 and 24% more in 2050 compared to 2010.

17.4 Long List of Technologies

The outcome of literature and technology journal review, expert and stakeholder interviews is consolidated in a long list of car technologies improving fuel efficiency. Table 17.1 demonstrates the 46 most promising technologies and the estimated contribution of each technology to the reduction of CO_2 emissions of cars in a range from minimum to maximum potentials. For some technologies, upper

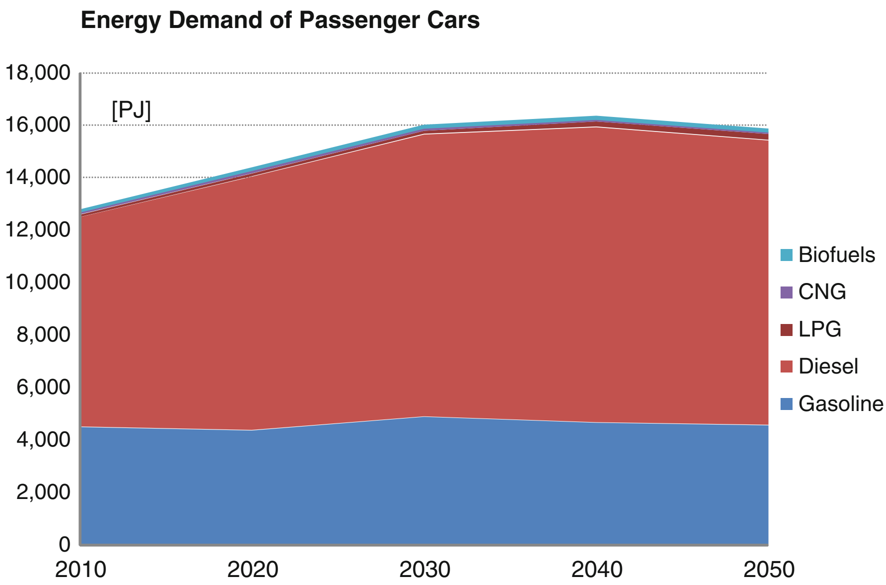

Fig. 17.1 Energy demand of passenger cars in EU27 (reference case). *Source*: GHG-TransPoRD

and lower potentials differ significantly as they were extracted from different studies with varying degree of implementation and underlying assumptions. As an example, the measure "utilization of lightweight materials" covers a whole range of possibilities. It starts from a simple substitution of smaller steal by plastic parts and ends with a complete substitution of steal by lightweight materials such as carbon fibres, aluminium and magnesium. In this case, the technical feasibility was taken into account, such that only the lower CO_2 reduction potential is estimated to be realized until 2020.

In the next step, all 46 technologies are allocated into the following 11 technology clusters. lightweight construction, engine control system, heat and cooling management, electrical system – energy supply, injection technology, aerodynamics and resistance, electrical system – energy demand, BEVs, hybrid vehicles, drive and transmission and CNG and LPG vehicles, respectively.

Additionally, the compatibility of all technologies is elaborated to avoid double counting of CO_2 reduction potentials. Total CO_2 emission reduction potentials of a combination of compatible technologies in a cluster are then estimated by (17.1). Finally, the technology combination with the highest potential is chosen.

$$\mathrm{POT}(i) = 1 - \prod_{j=1}^{n} (1 - \mathrm{POT}_j(i)), \tag{17.1}$$

where POT = relative CO_2 emission reduction, i = eleven technology clusters, j = technologies 1 to n in a cluster.

Table 17.1 Long list of car technologies

Nr.	Measures/technologies	CO_2 reduction Min	CO_2 reduction Max
1	Reduced mechanical friction components	0.4%	5.0%
2	Low viscosity lubricants	0.5%	4.0%
3	Low rolling resistance tyres	2.0%	2.0%
4	Improved aerodynamics	1.5%	1.8%
5	Tyre-pressure monitoring system	1.0%	1.0%
6	Substitution of fossil fuel by battery electric vehicles	7.8%	7.8%
7	Control mechanism for servo-steering	3.1%	5.0%
8	Electric power steering (EPS)	2.0%	3.0%
9	LED headlights		2.5%
10	Pneumatic brake booster	1.6%	2.5%
11	Intelligent fuel pumps	0.3%	0.3%
12	Solar panels on roofs	17.0%	29.0%
13	High efficiency alternators	0.5%	2.0%
14	Intelligent battery sensor	1.5%	1.5%
15	CNG	16.7%	16.7%
16	LPG		9.0%
17	Electrohydraulic valve gear		10.0%
18	Variable compression ratio	5.0%	10.0%
19	Cylinder deactivation	2.1%	8.0%
20	Variable valve actuation	3.0%	7.0%
21	Start–stop system	3.0%	4.0%
22	Variable valve timing	1.0%	3.0%
23	Fuel quality sensor	1.2%	1.2%
24	Latent-heat storage	8.1%	8.1%
25	Intercooling	2.5%	2.5%
26	Dual cooling circuits	0.5%	2.0%
27	Exhaust heat recuperation	1.5%	1.5%
28	Cooling fluid shutdown system	1.0%	1.0%
29	Hybrid-type: full	18.0%	22.0%
30	Hybrid-type: mild	10.0%	11.0%
31	Brake energy recuperation	3.0%	3.0%
32	Hybrid-type: plug-in		
33	Homogeneous Charge Compression Ignition	11.0%	25.0%
34	GDI with stratified charge (stoichiometric)	8.0%	14.0%
35	GDI with stratified charge (lean burn)	4.3%	6.4%
36	GDI with homogenous charge (stoichiometric)	0.7%	5.0%
37	Piezo injectors	3.0%	3.0%
38	Further penetration of gasoline direct injection		
39	Utilization of lightweight design and materials	0.9%	20.0%
40	Weight reduction by minimizing convenience features	4.9%	4.9%
41	Smaller capacity fuel tanks	2.0%	3.0%
42	Continuous variable transmission	2.1%	9.0%
43	6-speed manual/automatic gearbox	2.5%	5.0%
44	Dual clutch transmission	4.0%	5.0%
45	Piloted gearbox	4.0%	4.0%
46	Optimization of gear boxes	1.0%	2.0%

Source: GHG-TransPoRD

17.5 Technology Packages

The chosen technology clusters respectively measure groups to reduce CO_2 emissions from car transport are described in this chapter. Table 17.2 provides an overview in terms of relative and absolute CO_2 emission reductions on the technical potential of the eleven clusters. All savings refer to the CO_2 emissions in EU27 in 2020 respectively 2050 in the reference scenario described by the common energy framework. It is assumed that all technologies will be implemented in all new cars in EU27. Due to the average lifetime of a car in EU27, not all cars will be equipped with the new technologies until 2020. Additionally, the savings consider that some technologies are only applicable for a certain car technology (e.g. only for diesel cars).

Injection technologies bear the highest CO_2 reduction potential in 2020 with about 92 Mt of CO_2 abated. In the long term, the substitution of fossil fuel cars by BEVs could contribute by 77% less CO_2 significantly to the achievement of GHG reduction targets. All numbers consider only technical issues and hurdles. They do not take into account lower potentials due to lacking acceptance, currently too high costs or internal constraints in the automotive industries like long-term linkages between OEMs and certain suppliers.

Following the approach for estimating the potential of a combination of technologies, one could also assess the CO_2 emission reduction potential of the best combination of all compatible technology packages. Technically, a reduction of CO_2 emissions of about 40–45% from passenger cars in EU27 in 2020 is projected to be feasible. In the long term, the underlying assumptions on different technology packages make such a calculation more difficult. Most packages foresee a complete diffusion of a technology bundle into the EU27 car fleet until 2050. As many technology bundles can be applied only to fossil fuel cars with an ICE, the strong potentials of hybrid vehicles and BEVs can only hardly be accounted. Considering only fossil fuel technologies, about 60–68% CO_2 can be saved in 2050 compared to the reference case.

The following sections describe the technologies allocated to the respective measure group, their CO_2 emission reduction potential, the technical feasibility and the maturity.

Table 17.2 Technical CO_2 reduction potentials

	2020		2050	
Measure/technology group	rel.	abs (Mt)	rel.	abs (Mt)
Injection technology	10%	92	24%	211
Electrical system – energy supply	10%	89	20%	178
Heat/cooling management	10%	89	14%	122
Lightweight construction	8%	72	17%	152
Engine control system	7%	65	12%	112
Hybrid vehicles	7%	61	18%	159
Aerodynamics/resistance	7%	60	9%	83
CNG/LPG	6%	54	8%	75
Battery electric vehicles	6%	54	77%	689
Electrical system – energy demand	5%	47	7%	64
Drive and transmission	3%	29	6%	50

Source: GHG-TransPoRD

17.5.1 Injection Technology

The technology cluster with the largest technical CO_2 reduction potential is called injection technology. It is assumed to contribute by 10% less CO_2 emissions in 2020 and even 24% less CO_2 emissions in 2050. Several promising injection technologies have been developed in the past to reduce CO_2 emissions of ICE. This measure group focuses on the most promising technology in terms of its potential: Homogeneous Charge Compression Ignition (HCCI). HCCI combines homogeneous charge spark ignition (gasoline engines) and stratified charge compression ignition (diesel engines) such that well-mixed fuel and oxidizer are compressed to the point of auto-ignition.

Several automobile companies are currently experimenting on the potential of HCCI engines. Overall, controlling HCCI engines is the major hurdle to more widespread commercialization. HCCI is more difficult to control than other popular modern combustion engines. Another technical problem is currently the limited power of engines operating completely in HCCI mode. Current HCCI engines run only in HCCI mode at part load conditions.

HCCI engines are still being researched on test beds and very early prototype vehicles. HCCI technology is expected to be ready to diffuse into the market in 2018 (EPA 2008).

17.5.2 Electrical System: Energy Supply

This technology cluster focuses on three technical measures aiming at improving the efficiency of the energy supply side of electrical systems in passenger cars. The most promising technology in terms of reducing CO_2 emissions from passenger cars in this group is the measure solar panels on vehicle roofs (SEV 2010). High efficiency mono-crystalline photovoltaic cells are installed on vehicle roofs to generate electricity for electronic on-board applications in all passenger cars or to upload the batteries in hybrid and BEVs.

The second measure analysed in this group of measures is the implementation of high efficiency alternators. Most passenger cars are currently equipped with low cost alternators which have an efficiency of only 50–60% (IEA 2005). Due to the rising number of electronic on-board applications, the importance of the efficiency of alternators is increasing.

The last measure to be considered in this group is the application of intelligent battery sensors. Batteries in vehicles did not advance that much compared to the significantly growing number of electronic equipment in passenger cars. Intelligent battery sensors should balance the electric energy requested by the numbers of consumers with the energy supplied by the alternator and the battery. This balance optimizes the energy flow and supports the improvement of fuel efficiency.

The CO_2 reduction potential of this technology cluster in EU27 is with about 10% in 2020 and 20% in 2050 slightly lower than the projected HCCI potentials. About 89 Mt of CO_2 can be saved in 2020 by implementing the combination of these technologies consequently starting in 2011. In combination with hybrid respectively battery technology, this cluster even bears higher CO_2 saving potentials. Assuming that all fossil fuel based cars in 2050 will have hybrid systems about 178 Mt of CO_2 could be reduced in 2050.

Solar panels are already offered in 2010 on the US market. High efficiency alternators and intelligent battery sensors are as well already available, but not yet implemented in most current passenger cars.

17.5.3 Heat and Cooling Management

The technologies and measures allocated to the group "heat and cooling management" contain solutions to reduce CO_2 emissions from passenger cars by recycling originally wasted heat energy or by optimizing cooling processes in internal combustion engines. Two approaches are considered to transform the heat energy of ICE into useful energy. Latent-heat storage is a technology that is proposed by Greenpeace (2008). The waste heat generated in combustion engines is stored in the battery and recycled by fostering the warm-up phase in following cold starts. Hence, the engine operates earlier in an efficient stage which bears a CO_2 emission reduction potential. The second technology is called exhaust heat recuperation or exhaust gas recirculation (EGR). It is already applied in turbocharged engines and transfers waste heat of exhaust gases to compressed air to preheat the air before entering the engine.

Additionally, three technologies optimizing cooling management processes are included in this group of measures. The first approach is implemented in turbocharged respectively supercharged gasoline and diesel engines and acts as an air-to-air heat exchange device. The so-called intercoolers aim at improving the volumetric efficiency of ICE by increasing the intake air charge density. This is realized by nearly pressure constant (isobaric cooling). Another technical solution to reduce CO_2 emissions via improving fuel efficiency is the implementation of dual cooling circuits. The concept of this technology aims at reducing engine warm-up times by installing two separate cooling circuits for cylinder heads on the one hand and cylinder walls on the other hand. The last technical measure included in this package is called cooling fluid shutdown system. According to the automotive supplier Hella (2010), this system prevents the car from circulating cooling fluids during engine warm-up phases to save energy.

Available studies do not indicate the compatibility of all five measures within one car. At least no study has been reviewed that doubts about the efficiency of such a combination. Therefore, the resulting maximum potential is computed by multiplying all single maximum reduction potentials. Therefore, the group of measures has a CO_2 reduction potential of 14.3% over all passenger cars.

Assuming a vehicle fleet composition in EU27 as in the Reference Scenario of the iTREN-2030 project (Fiorello et al. 2009), the implementation of all five measures would save about 10% CO_2 (89 Mt) in 2020 and 14% CO_2 (122 Mt) in 2050.

All technologies in this group can be implemented in all fossil fuel driven cars. The only limitation consists for the intercooling technology which can only be applied for turbocharged or supercharged gasoline or diesel engines. Technically, all five measures are feasible and partially already implemented like intercooling or exhaust heat recuperation.

17.5.4 Lightweight Construction

There is a direct correlation between the weight of passenger cars and its fuel consumption. Therefore, each unit of weight saved in cars reduces CO_2 emissions. The first option in this set of measures and the most effective in terms of the CO_2 emission reduction potential is the utilization of advanced lightweight design and materials. AEA (2009) estimates the CO_2 reduction potential of this option by about 20% compared to an average conventional passenger car. TNO (2006) assumes lower reduction potentials of up to 6.3%. As the implementation of advanced lightweight materials will only be partly diffuse into car fleets until 2020, only 10.5% CO_2 reduction is assumed until 2020.

The automotive industry already tried to reduce weight using higher share of plastics in cars or aluminium in car bodies. This option foresees an advanced use of materials such as reinforced composites, aluminium or magnesium.

The second component foresees the further reduction of weight by minimizing or eliminating unnecessary convenience features like seat heating or electrical devices. Greenpeace (2008) estimates about 4.9% improvement of fuel efficiency by abandoning unnecessary luxury features in passenger cars. As this measure automatically decreases the investment costs, the real abatement costs per tonne of CO_2 would even be significantly lower than assumed here.

The third measure among this group proposes the reduction of fuel tank capacities to avoid additional weight. Between 2% and 3% fuel efficiency improvement can be achieved without additional financial burdens on users.

Overall the combination of these measures could save about 8% of all CO_2 emissions from passenger cars in 2020 and 17% in 2050 in EU27. This represents about 72 Mt of CO_2 in 2020 and 152 Mt of CO_2 in 2050.

Materials such as magnesium, aluminium or carbon fibres are already applied on the luxury segment to reduce weight and improve fuel efficiency. High costs of lightweight materials prevented most manufacturers to apply those in lower cost segments until now. In future cars magnesium is expected to be applied for reducing the weight of engines. Aluminium and carbon fibres are implemented in oder to decrease the weight of car bodies.

17.5.5 Engine Control System

Engine control system is a set of five technical measures to reduce CO_2 emissions by optimizing the control of ICE. According to CARB (2004), variable compression ratio (VCR) technology is the measure with the highest reduction potential in this group. The compression ratio in current internal combustion engines is fixed. An optimal engine operation requires VCRs. VCR enables higher compression ratios with lower loads and lower compression ratios with higher loads to reduce CO_2 emissions. CARB (2004) estimates 5% up to 7% CO_2 reduction potential for VCR, while AEA (2009) considers even 10% maximum potential of this technology.

Another fuel economy technology works via deactivation of cylinders. Depending on the load, cylinders are switched off or half of cylinders are deactivated to reduce pumping losses. Cylinder deactivation is projected to improve fuel efficiency in a range between 2.1% and 14% (CARB 2004; IEA 2005; IEEP 2004).

Start–stop systems are also assigned to this measure group, even if they are applied also in most hybrid vehicles. Start–stop systems automatically shut down and restart a vehicles ICE to reduce the amount of time the engine spends idling. The technology behind has already been implemented in the 1970s by Audi but due to lacking interest of costumers not considered any more since then. The potential of start–stop systems differs between 3% and 4% (TNO 2006) and 3% and 6% (IEEP 2004)

Variable valve timing is an additional technical feature to improve fuel efficiency in gasoline engines. This measure allows gasoline engines to operate more efficient by managing precisely on optimal opening and closing of valves depending on the current vehicle load demand. Variable valve timing is assumed to reduce CO_2 emission by 1.5% up to 3% (TNO 2006; CARB 2004; IEA 2005).

The last measure considered in this group is the application of fuel quality sensors to control the injection of the optimum amount of gasoline or diesel at engine start processes. This technology is assumed to contribute by about 1.2% to less fuel consumption.

Taking the average between minimum and maximum potentials, about 7% less CO_2 emissions (65 Mt) by combining these five measures are expected in 2020 and 12% (112 Mt) in 2050.

Despite VCR all measures of the engine control system group are already implemented in cars. Start–stop systems are common at least in the upper car segments. VCR is the only technology that only started to diffuse into vehicle fleets in EU27. According to CARB (2004), the technology was too expensive at its state in 2004.

17.5.6 Hybrid Vehicles

The group "hybrid vehicles" focuses on the CO_2 emission reduction potential that can be achieved according to literature review by replacing new registered conventional vehicles with mild hybrid vehicles in a first step until 2020 and with full hybrid or plug-in hybrid vehicles until 2050.

Generally, hybrid electric vehicles (HEVs) are differentiated by the degree of hybridization. Mild hybrids are vehicles that cannot be driven by its electric motor as this motor is not designed for that purpose and does not have enough power.

They have an oversize starter motor enabling the ICE to be turned off during coasting, braking and stopping. Furthermore, the motor is used for regenerative braking to recapture energy. Full hybrid vehicles can run on both, an ICE and on electric engines provided with energy from batteries with high capacities.

The CO_2 emission reduction potential of HEVs depends strongly on the driving situation. As regenerative braking is a major issue in HEVs, the operation in urban stop and go situations is more efficient than long distance travel with constant speed on motorways. Two studies quantified the fuel efficiency gains by HEVs compared with conventional cars (diesel and gasoline): AEA (2009) and IEA (2005). IEA (2005) estimates a CO_2 emission reduction potential for mild hybrids between 5% and 7% compared with average gasoline cars, while AEA (2009) indicates between 10% and 11% better fuel efficiency. The reduction potential difference between the studies for full hybrids is significant. The IEA (2005) study assesses about 30% up to 50% less fuel consumption compared to gasoline cars, while AEA (2009) ranges only between 18% and 22%. Obviously, the difference emerges due to varying baseline assumptions about the driving situation. AEA (2009) considers a realistic mixture of driving on motorways, interurban roads and in urban areas which differs from the assumptions of IEA (2005).

Substituting fossil fuel cars by HEVs has a CO_2 emissions reduction potential of about 7% in 2020 and 18% in 2050. In total numbers, the substitution of conventional cars by HEVs can save about 61 Mt of CO_2 yearly in EU27 in 2020 and about 159 Mt in EU27 in 2050.

Technically, the development of HEV depends strongly on the battery development, as the batteries constitute a major cost and weight factor. Nevertheless, hybrid components are currently implemented in many upper segment car types. As most OEMs have to reduce average fleet emissions due to the CO_2 emission legislation, equipping cars with hybrid components to improve fuel consumption is a widely used measure.

17.5.7 Aerodynamics and Resistance

The group of measures named aerodynamics and resistance aims at reducing the opposing resistance or frictional forces that act against the motion of a car. The technical measures considered try to optimize aerodynamic drag, rolling resistance and mechanical friction of internal combustion engines in passenger cars.

The measure to improve aerodynamics covers solutions to reduce frontal areas and to optimize car body shapes with skirts, air dams or underbody covers. TNO (2006) and CARB (2004) estimate about 1.4% up to 1.8% less CO_2 emission due to improvements in aerodynamics.

Reduced engine friction losses can be realized by different approaches. One consists of outlining of the crank with the cylinder to lower the friction of the piston. Other concepts foresee coatings in the cylinder or electrification of auxiliaries. Furthermore, engine manufacturers try to reduce friction losses at rolling element bearings, rolling contacts, block deformation and ring tension. The estimated CO_2 reduction potential ranges between 0.4% and 5% (CARB 2004; IEA 2005; AEA 2009).

Low resistance tyres and tyre-pressure monitoring systems are measures to improve fuel efficiency by reducing rolling resistance of passenger cars. The design and material of tyres are relevant for the rolling resistance of cars. Tyre tread patterns, tyre belts or the traction surface are areas to improve rolling resistance of tyres. According to AEA (2009) and IEA (2005) low resistance tyres bear a potential between 1% and 2% less CO_2.

Additionally, tyre-pressure monitoring systems should help to operate the car with optimal tyre pressure. Tyre-pressure monitoring systems are assumed to improve fuel efficiency by further 1% (TNO 2006; IEA 2005).

The last measure in this group is the application of low viscosity lubricants in fossil fuel driven engines to reduce mechanical friction and improve fuel efficiency. CO_2 emission reduction potentials of low viscosity lubricants differ among the available studies between 0.5% and 4% (TNO 2006; IEA 2005).

The combination of all technologies in this group results in a CO_2 emission reduction potential of 7% (60 Mt) in 2020 and 9% (83 Mt) in 2050. Despite low viscosity lubricants, all technologies can be applied to all types of passenger cars. Low viscosity lubricants are limited for the application in cars with ICE.

All technologies in this group are at least partially implemented in several new passenger cars. Tyre-pressure monitoring systems are offered in the luxury segment or in other segments as extra equipment. Several OEMs already offer more fuel efficient alternatives for nearly all car products. Optimized aerodynamics is part of these products as well as low resistance tyres. Nevertheless the tyre companies are still experimenting with different material mixtures and low resistance full-cushion tyres are still not on the market. According to AEA (2009), approaches to reduce engine friction losses in an optimal way are still being researched by engine manufacturers.

17.5.8 CNG and LPG

The objective of the measure "CNG and LPG vehicles" is to reduce CO_2 emissions from passenger cars by replacing conventional gasoline and diesel cars by CNG cars. LPG technology is not considered, as the CO_2 emission reduction potential of CNG vehicles is higher. According to TNO (2003), LPG technology provides a benefit in CO_2 emissions only compared with gasoline cars. The report indicates that average diesel cars emit even less CO_2 than LPG cars.

Current CNG cars are usually equipped with an internal combustion engine which resembles a classical gasoline engine. Instead of combusting a gasoline air mixture, CNG cars combust a CNG air mixture. Due to the characteristics, CNG cars can also operate as conventional cars with gasoline. In order to extend the range of CNG cars, nearly all currently available CNG cars are equipped with both, a CNG tank and a gasoline tank. Due to the high compression ratio of CNG, the tanks bring additional weight which influences the environmental benefit negatively.

The CO_2 emission reduction potential of CNG cars is analysed in the following studies: TNO (2003) and CONCAWE (2006). As opposed to TNO (2003) study, CONCAWE (2006) considers in the estimation of average CO_2 emission reduction potentials Well-to-Wheel emissions. The study assumes that CNG is imported mainly over an average distance of 4,000 km. Taking into account the additional emissions, the reduction potential ranges between 4.1% compared with average diesel cars and 16.7% compared with gasoline cars.

Transforming these potentials into a total reduction potential, about 6% in 2020 and 8% CO_2 emissions could be abated by replacing conventional with CNG cars. In total numbers, this means a reduction of 54 Mt of CO_2 in 2020 and about 75 Mt of CO_2 in 2050 compared to the reference case.

The highest technical hurdle for stronger diffusion of CNG cars is the at least in some EU27 countries small number of filling stations offering CNG and the limited range that can be achieved by operating the car only with gas. Nevertheless, the number of filling stations is increasing steadily, and the range could also be improved by OEMs in the last years, such that 300 km on average are possible with a full tank. Compared with conventional cars, the potential for fuel efficiency improvements of CNG technology is still large.

17.5.9 Battery Electric Vehicles

The substitution of fossil fuel cars by pure BEVs is subject to this group. BEVs use electric motors instead of internal combustion engines for propulsion. The required energy is stored in rechargeable battery packs in terms of chemical energy. Plug-in hybrids or other forms of hybrid vehicles are not considered in this group.

The CO_2 emission reduction potential of substituting fossil fuel cars by BEVs is estimated in several steps. As opposed to technologies in other groups of measures, the assumption of a complete and immediate substitution of all new registered fossil fuel cars by BEVs from 2010 on is supposed to be not realistic. Problems with only small ranges, high costs of batteries and uncertainties about the durability of battery packs are still significant. Furthermore, the envisaged average purchase costs of BEVs are still high by more than 34,000 €. Hence, a challenging but realistic projection on the diffusion of BEV in EU27 until 2020 has been extracted from the 2-degree Scenario of the ADAM project (Schade et al. 2009). The study estimates an optimistic market diffusion of about 19.3 million BEVs in EU27 until 2020. In order to estimate the maximum reduction potential until 2050, a complete replacement of fossil fuel cars by BEVs is assumed. Based on the Reference Scenario of the iTREN-2030 project, about 285 million BEVs will be registered in EU27.

Based on average yearly mileages and the assumed development of energy efficiency of average BEVs, the energy consumption of all BEVs in 2020 and 2050 is assessed. Average carbon intensities of electricity production in EU27 from the POLES model (Fiorello et al. 2009) is then taken to transfer the energy consumption into CO_2 emissions. Finally, abated CO_2 emissions by replaced fossil fuel cars are accounted with additional emissions from electricity generation induced by higher numbers of BEV to estimate the CO_2 emission reduction potential of this measure in 2020 and 2050.

The absolute CO_2 emission reduction potential of this measure is projected to be about 54 Mt of CO_2 in 2020. The maximum potential will be achieved under the prerequisite that all cars will be BEV which will be in 2050. Hence, a maximum of 689 Mt of CO_2 emissions from road passenger transport can be saved by this measure in EU27 in 2050. In relative terms, this means a reduction potential of about 6% in 2020 and about 77% in 2050.

The limited range and the high costs for batteries are still the major disadvantages of BEVs compared with conventional cars. Some countries in the EU try to promote BEVs by giving purchase incentives. Nevertheless, the low range allowing only something about 130 km maximum without recharging is a hurdle.

17.5.10 Electrical System: Energy Demand

The group of measures called "electrical system – energy demand" combines technologies that aim at reducing energy demand of on-board energy consumers. The first technology in this group covers the replacement of classical halogen head, rear and brake lamps by LED lamps. The application of LED lams bears several advantages besides lower energy demand leading towards lower CO_2 emissions. They are characterized by longer economic lifetimes and higher robustness. Furthermore, they require less space in the car body and can be switched on faster than classical halogen lamps, which is essential for brake lights. LED lights can contribute to about 2.5% less CO_2 as they require only 80 W compared to halogen lights with about 200 W.

The second technology called electric power steering (EPS) optimizes the energy demand caused by steering assist systems (IEA 2005). EPS is designed to use an electric motor to reduce effort by providing steering assist to the driver of a vehicle. The idea behind this intelligent version is to provide assist only in case of steering activities such that in all other driving situations, the assist will be kept switched off. IEA (2005) assesses the impact of EPS on fuel efficiency between 2% and 3% less CO_2 compared to an average fossil fuel driven car.

The third technical measure covered in this group foresees the substitution of inefficient motor driven by electrical vacuum pumps for example applied for brake boosting (Hella 2010). The electronic pump helps improving fuel efficiency as it provides the brake booster with additional vacuum only when it is required. Usually, this is only the case during warm-up phases. Electric vacuum pumps are assumed to improve fuel efficiency by 1.6% up to 2.5%.

The last technical measure consists of an implementation of intelligent fuel pumps. Currently, cars are equipped with fuel pumps providing continuously the amount of fuel required during full load situations. The application of a controlling advice limiting the power of the fuel pump according to current load situation can reduce the energy consumption of the fuel pump by 0.3%.

Overall, the implementation of all technologies is projected to save about 5% CO_2 (47 Mt) in 2020 and about 7% CO_2 (64 Mt) in 2050.

Technically, the implementation of all four technologies has no constraints. All technologies are already offered by automotive suppliers like Hella. In the past, OEMs tried to save money by integrating low cost components accepting losses in fuel efficiency. The growing importance of fuel efficiency due to changing consumer behaviour, increasing political pressure on OEMs and higher fossil fuel prices will foster the optimization of energy demanding parts in vehicles.

17.5.11 Drive and Transmission

The measure "drive and transmission" consists of a technical innovation which aims at improving fuel efficiency by optimizing the gear and transmission process. The so-called continuous variable transmission (CVT) is a type of transmission, which can change through a nearly infinite number of gear ratios between minimum and maximum values without any steps in between. Other conventional transmission technologies allow only the selection of few different distinct ratios. CVT is the most flexible transmission technique and allows the driving shaft to maintain a constant angular velocity over a whole range of output velocities. Thus, the engine can operate at its most efficient revolutions per minute for a range of vehicle speeds which makes driving significantly more fuel efficient.

Compared with other drive and transmission technologies, CVT bears the highest CO_2 emission reduction potential. IEEP (2004) estimate between 2.1% and 9% improvement in fuel economy by implementing CVT in fossil fuel cars. Fuel consumption reductions achieved by implementing other technologies like dual clutch transmission, piloted or optimized gear boxes are significantly lower.

The relative CO_2 emission reduction potential for road passenger transport in 2020 is about 3% or 29 Mt of CO_2. This value results from the assumption that all new registered fossil fuel driven passenger cars will be equipped with CVT. As the average lifetime of cars is higher than 10 years (between 12 and 14 years), CVT will only diffuse partly into the car fleet until 2020. The potential increases until 2050 with about 6% less CO_2 or 50 Mt of CO_2 less.

The principle of CVT has been implemented already in 1987 by Subaru and Ford. As opposed to the early applications, CVT generation of today is controlled electronically such that the engine can operate always in the most fuel efficient RPM. Due to the high costs, most OEMs offer CVT only as an optional extra equipment.

17.6 Conclusions

The objective of this chapter was to review innovative and prospective technologies to reduce CO_2 emissions from passenger car transport. Therefore, a comprehensive literature review in combination with stakeholder interviews and expert judgments has been carried out. The major outcome of this research was a list of technologies clustered into 11 topics. Technically feasible CO_2 emission reduction potentials as well as information about the feasibility, maturity and compatibility with other technologies were studied. Technically, a CO_2 emission reduction from passenger cars of 40% up to 45% in the EU27 until 2020 seems to be achievable. Until 2050, even 60% up to 68% are realistic. All these potentials refer to the common energy framework which acts as a reference case. At first sight the reduction potentials seem not astonishing. Considering that these potentials can be reached even without strong diffusion of alternative fuel cars like BEVs or hydrogen fuel cell cars increase the importance of the feasible reduction potentials. Nevertheless, the potentials have to be treated carefully, as they do not take into account costs or organizational constraints. Some of the considered technologies have currently high prices, such that a widespread implementation in all price categories of cars seems to be at least questionable. This has definitely an impact on the estimated potentials until 2020 as this will influence the speed of diffusion. The remaining 40 years until 2050 seem to be long enough to even take these hurdles.

Having a closer look at the technology bundles, injection technology (HCCI), electrical system – energy supply and heat and cooling management are projected to have the highest CO_2 emission reduction potential in 2020 each by about 10%. Until 2050, the picture changes. BEVs as a single technology bundle can contribute by about 77% less CO_2 emissions to the transport GHG reduction targets in EU27.

References

AEA (2009) Assessment with respect to long term CO2 emission targets for passenger cars and vans. Deliverable D2 of the Framework contract No. ENV/C.5/FRA/2006/0071. European Commission, Brussels

Akkermans L, Vanherle K, Moizo A, Raganato P, Schade B, Leduc G, Wiesenthal T, Shepherd S, Krail M, Schade W (2010) Ranking of measures to reduce GHG emissions of transport: reduction potentials and qualification of feasibility. Deliverable D2.1 of GHG-TransPoRD: Project co-funded by European Commission 7th RTD Programme. Transport & Mobility Leuven, Belgium

CARB (2004) Staff proposal regarding the maximum feasible and cost-effective reduction of greenhouse gas emissions from passenger cars. California Environmental Protection Agency and Air Resources Board, Sacramento

CONCAWE (2006) Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. Concawe/Eucar/JRC, Brussels, update of the 2003 study

EPA (2008) A Study of potential effectiveness of carbon dioxide reducing vehicle technologies. United States Environmental Protection Agency.

Fiorello D, De Stasio C, Köhler J, Kraft M, Newton S, Purwanto J, Schade B, Schade W, Szimba E (2009) The iTREN-2030 reference scenario until 2030. Deliverable 4 of iTREN-2030 (Integrated transport and energy baseline until 2030). Project co-funded by European Commission 6th RTD Programme. Milan, Italy

Greenpeace (2008) 10 easy steps to cut car emissions: climate control manual. Greenpeace, Amsterdam

Hella (2010) http://www.hella.com/hella-de-de/308.html

IEA (2005) Making cars more fuel efficient – technology for real improvements on road. IEA, Paris

IEEP (2004) Service contract on a business impact assessment of measures to reduce CO2 emissions from passenger cars. Carried out by IEEP, TNO and the Centre for Automotive Industry Research (CAIR) at the University of Cardiff (UK) on behalf of DG Environment (contract nr. B4-3040/2003/366487/MAR/C2) in 2003–4

Jochem E, Barker T, Catenazzi G, Eichhammer W, Held A, Helfrich N, Jakob M, Criqui P, Mima S, Quandt L, Reiter U, Reitze F, Schade W, Schelhaas M, Turton H (2009) Report of the reference and 2°C scenario for Europe. Deliverable D-M1.2 of ADAM (adaptation and mitigation strategies: supporting European climate policy). Project co-funded by European Commission 6th RTD Programme. Karlsruhe, Germany

Öko-Institut, Forschungszentrum Jülich, DIW, Fraunhofer-ISI (2008) Politikszenarien für den Klimaschutz IV - Szenarien bis 2030. UBA-Bericht 01/08, Berlin, Karlsruhe

Schade W, Jochem E, Barker T, Catenazzi G, Eichhammer W, Fleiter T, Held A, Helfrich N, Jakob M, Criqui P, Mima S, Quandt L, Peters A, Ragwitz M, Reiter U, Reitze F, Schelhaas M, Scrieciu S, Turton H (2009) ADAM 2-degree scenario for Europe – policies and impacts. Deliverable D-M1.3 of ADAM (adaptation and mitigation strategies: supporting European climate policy). Project co-funded by European Commission 6th RTD Programme. Karlsruhe, Germany.

Schade W, Krail M, Fiorello D, Helfrich N, Köhler J, Kraft M, Maurer H, Meijeren J, Newton S, Purwanto J, Schade B, Szimba E (2010) The iTREN-2030 Integrated scenario until 2030. deliverable 5 of iTREN-2030 (Integrated transport and energy baseline until 2030). Project cofunded by European Commission 6th RTD Programme. Fraunhofer-ISI, Karlsruhe, Germany.

SEV (2010) http://www.solarelectricalvehicles.com

TNO (2003) Evaluation of the environmental performance of modern passenger cars running on petrol, diesel, automotive LPG and CNG. TNO-report 03.OR.VM.055.1/ PHE, TNO Automotive, Delft.

TNO (2006) Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2-emissions from passenger cars. TNO, Delft

Part VI
Policy Conclusions

Chapter 18
Transport, Environment, and Institutions: Why Good Science, Engineering, and Economics Fail?

Louis S. Thompson

18.1 Introduction

In evaluating the effect of changes in transport operations and technology on the GHG emissions from transport carriers, it is critical to emphasize that transport is a "derived demand." That is, neither people nor goods typically consume transport merely to sit on a train or truck; instead, transport is primarily a means for moving people and goods from one point to another. Thus, transport actually exists to serve more fundamental needs that are driven by decisions related to broader economic or social activity.[1] Choices about transport are generally made on the basis of economic benefit to the user; to the extent that noneconomic benefits or costs influence modal choice, they must be introduced through forces outside transport markets, per se.

18.2 Economic Benefits

In meeting underlying economic requirements, each mode of transport has a specific set of characteristics that are usually summarized by: trip or shipment time from origin to destination; perceived total cost of the trip or movement, including fares or tariffs and insurance and allowing for public subsidy; the frequency and convenience of departures; on-time reliability and safety of the trip or movement; and access and egress times for the trip or movement. To these general characteristics might be added a number of more detailed influences such as perceived comfort, minimum shipment size, personal security, etc., depending on the person or commodity involved.

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[1]Some travelers do enjoy the "view out the window," and certain kinds of Dutch Gin (Oude Genever) are put on ships for purposes of aging, but these exceptions serve to prove the rule.

L.S. Thompson (✉)
Thompson, Galenson and Associates, LLC, 14684 Stoneridge Drive, Saratoga, CA, USA
e-mail: lthompson@alum.mit.edu

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All forms of transport are subject to market-based tradeoffs among these characteristics. Railway freight transport is always cheap, but is usually slow and requires large minimum shipment size. Rail freight is also relatively unreliable and often infrequent. Airlines are usually the fastest way to travel long distances but are increasingly subject to slow airport access, unpredictable security delays, and unreliable takeoff and departure times. Discount airlines offer very basic transport, but often do not serve convenient airports, and frequently impose high charges for all but the most basic services. The airline "majors" may offer higher frequency from large airports, but charge more and are increasingly adding annoying "extras" that jack up the total cost. Urban passengers often use slightly different modes (bus and rail transit), but the fundamental choice determinants are the same.

These modal choice tradeoffs never involve CO_2 (or other GHGs) directly: that is, neither shippers nor travelers consider CO_2 or other emissions explicitly in making modal choices. There is never an entry on the ticket or shipping document that includes kilos of CO_2 emitted,[2] nor is there a direct way that emissions can be traded against other qualities such as cost and frequency.

The most direct way in which CO_2 emissions enter the transport market calculation is through the cost of the energy consumed.[3] In practice, though, energy costs may not be a significant factor in total cost and thus changes in energy cost may not have much of an effect on tariffs or fares. Table 18.1 shows that energy (fuel) costs as a percent of total operating costs range between 7% and 30%. Other costs, especially labor and depreciation, loom much larger.

Table 18.1 The percent of total cost that energy use represents

Freight	
Truck (YRC worldwide)	13
Rail	20
Passenger	
Auto[a]	11–20
Rail (Amtrak)	19
Bus	9
Commuter rail	9
Heavy rail	7
Air (SWA)	30

Source: Author's calculations, based on APTA (2009), STB various years, 2008 annual reports of YRC Worldwide and Southwest Airlines

[a] Ownership costs only

[2] It is an interesting speculation whether a requirement that each transport ticket or document contain an estimate of the GHGs emitted by the trip or shipment – similar to statements of nutritional content (or absence thereof) in restaurants – would have any impact.

[3] As discussed later, this assumes that the transport provider actually faces the market cost of energy – an assumption that is generally invalid. See Fig. 18.1.

In one sense, this table shows that carriers might well decide to increase energy costs (and GHG emissions) to reduce other operating costs: vehicle operating speed might be a good example. In another sense, the table underlines the fact that measures aimed at reducing CO_2 emissions though (for example) taxes on fuel might not have the full effect expected: taxes might have to be quite high before causing any significant change in fuel use. In summary, market forces acting through transport fuel costs (even as affected by taxes or emissions permit costs) alone might not have a significant impact on transport demand or modal choice.

18.3 Nonmarket Aspects of Transport

Transport has many nonmarket attributes that we recognize, but find hard to quantify. Consumption of fossil fuel or other hydrocarbon energy, aside from its direct costs, emits CO_2. Transport operations also generate air “pollutants,” including carbon monoxide (CO), oxides of sulfur (SO_x), oxides of nitrogen (NO_x), unburned hydrocarbons (HC), and particulate matter (PM). Many parts of transport networks are congested during peak usage times, imposing trip time costs on all users. Transport systems emit noise and are often unsightly. Transport can improve access to jobs, with particular import for the poor who would otherwise have fewer employment options. Urban form and density (and productivity) are governed by the transport options available: some countries may lose as much as 3% of national GDP as a result of congestion in major cities. Highway accidents are one of the major national public health problems in many countries. The difficulty is that when market forces are not available to influence behavior directly, then they must be incorporated through the political and policy processes – and that has proven difficult, especially in the case of GHGs.

There are a number of reasons why the political process finds the complex, nonmarket benefits difficult to manage. The result is that experts often have a very different and more detailed understanding of complex issues – an understanding that is usually not shared by politicians or the public at large.

To some extent, this is caused by the sheer problem of availability and complexity of the information involved. Even interested laypersons find it difficult to get access to the large databases on which much of the modern understanding of global warming is based. In addition, many databases are either not open to the public or only usable by professionals with specialized expertise in the hardware and software involved. It is encouraging that the web is rapidly expanding information availability and access, but large gaps will always remain between what experts know and the public does not.

This is compounded by the fact that science becomes ever more specialized. It is in fact unlikely that any one scientific discipline qualifies a professional to understand all of the sources of information or analysis involved in analyzing the GHG problem. The public and politicians are inevitably left far behind.

In fact, the real problem may be deeper than a gap in expertise or information; instead, it deals with the way in which problems and facts are understood. "The public perception of scientific ideas depends largely on two factors: people's ability to grasp factual information and the *cultural lens through which that information is filtered*."[4] [emphasis added].

The seriousness of this issue can be seen by one example – the degree to which the public rejects the Theory of Evolution, one of the most thoroughly researched and "proven" sets of knowledge that science has to offer. Table 18.2 shows the percentage of people in different countries that share the belief that humans evolved (over any time frame) from an earlier life form. For example, Table 18.2 shows that 45% of the US population believes that evolution did NOT occur – that is, they believe in creationism, which is the religious dogma that the earth and all its inhabitants were created in a relatively recent time frame (thousands of years). Although the USA appears to be extreme in this regard (only Turkey has a higher percentage of creationists on the chart), the 20–25% creationist range typical of many EU countries points to a significant percentage of the population that must, by this measure, be unreachable by scientific reasoning and evidence. Polling on this topic has not been done in other countries, but it seems likely that similar (or higher) results would emerge since the sample in Table 18.2 contains many of the wealthier and better-educated people in the world. In democracies where a committed minority can slow or even halt legislation on a contested measure, 20–35% can be a major roadblock.

One could validly question whether the theory of evolution is an atypical flash point on the boundary between faith and reason. Perhaps global warming, not having historical associations with the religious aversion to Charles Darwin, would be different. Table 18.3 shows that it is not distinct. About 30% of US White Evangelical Protestants reject the idea that global warming is happening *at all* (for whatever reason, anthropogenic or otherwise), in stark contrast to the beliefs of those with no religious affiliation. Perhaps more significant, less than half of religiously affiliated people in the USA believe that *anthropogenic* warming is happening. The effect of the "cultural lens" of religion (US Christianity, at least) could hardly be clearer, and it is not promoting a response to global warming.

This is not, of course, to suggest that religion is the only lens that is filtering perceptions. There are significant gaps in perception as a function of degree of education and income level, with concern for global warming growing with increasing income and education, although the correlation clearly suffers from multicolinearity among education, religion, and economic status.

A good example is the fact that agreement with the statement that "[t]here is solid evidence that the earth is warming" actually *fell* in the USA between April 2008 and October 2009. While the scientific evidence actually grew stronger during this period, the economic crisis and the presidential election focused the attention of the electorate on economic and partisan political issues. Sadly, the issue of global warming has become a partisan political issue in the USA, with Republicans

[4] *Nature*, p. 1173, 29 October 2009.

Table 18.2 Belief that humans evolved from earlier species (over any time frame)

	Yes	No	No opinion
US scientists	95	5	0
Iceland	85	7	8
Australia	72	11	17
France	80	12	8
Denmark	83	13	4
Sweden	82	13	5
Britain	79	13	8
Spain	73	16	11
Norway[a]	74	18	8
Estonia	64	19	17
Italy	69	20	11
Belgium	74	21	5
Ireland	67	21	12
Hungary	67	21	12
Portugal	64	21	15
Bulgaria	50	21	29
Canada	58	22	20
Germany	69	23	8
Luxembourg	68	23	9
The Netherlands	68	23	9
Slovenia	67	25	8
Malta	63	25	12
Romania	55	25	20
Finland	66	27	7
Czech Republic	66	27	7
Poland	59	27	14
Latvia	49	27	24
Switzerland	62	28	10
Croatia	58	28	14
Austria	57	28	15
Slovakia	60	29	11
Lithuania	49	30	21
Greece	55	32	13
Cyprus	46	36	18
US ALL	41	45	14
Turkey	27	51	22

Source: Eurobarometer (2005)
[a]Separate website source

generally arguing either that warming is not happening or that doing anything about it would be too costly. The recent, overblown scandal of stolen email correspondence at The Climatic Research Unit at the University of East Anglia[5] gives further evidence of cultural (and political) lenses at work.

[5]*Nature*, p. 545, 3 December 2009.

Table 18.3 Linkage between religious belief and perception of global warming in the US 2009

	Anthropogenic warming exists	No opinion, or warming exists but not anthropogenic
Religiously unaffiliated	58	24
White mainline protestants	48	33
White non-Hispanic Catholics	44	35
Black protestants	39	47
White evangelical protestants	33	37
US total	47	33

Source: Pew Research, April 16, 2009

Another example of an issue where the cultural lens is critical is the gap in attitudes between developing and developed countries. However productive (or not) it might be to frame the issue in "fault" terms and to argue that the only "fair" solution is to aim for equal emissions per capita, it is also clear that the largest single emitter is now a developing country (China), and India may not be far behind in absolute terms. In this case, even if global warming is accepted, cultural perceptions as to the cause and "fair" solutions will hinder a resolution.

Whatever the perceptual lenses, there are three critical points that scientists, engineers, and economists need to focus on: (1) the consensus that is needed to bring about effective policies in the major democracies to deal with GHGs simply does not yet exist, especially in the largest economy and second largest emitter (the USA), but probably elsewhere as well; (2) reaching consensus in a wide variety of developing and developed countries will probably take place on grounds that are only partially scientific or engineering or economic; and (3) the challenge for the academic community is more effective communication of quantitative information and conclusions that will inform politics, notably when a large (usually a majority) of the audience is neither qualified nor necessarily inclined to accept a merely fact-based argument.

18.4 The Challenge of Implementation

Effective management of the threat of global warming will clearly involve reasonably proficient implementation of the largest, most sophisticated, and most expensive set of coordinated policies and investment projects ever undertaken on a worldwide scale. Given the policy "noise" that currently exists, and the incentives for poor execution that actually exist, is it reasonable to plan for success; or, in the alternative, is there a way to frame our programs to minimize the predictable problems?

18.4.1 Policy Noise

Economists often argue (on impeccable theoretical grounds) that price signals are the answer to efficient implementation of carbon emission management programs.

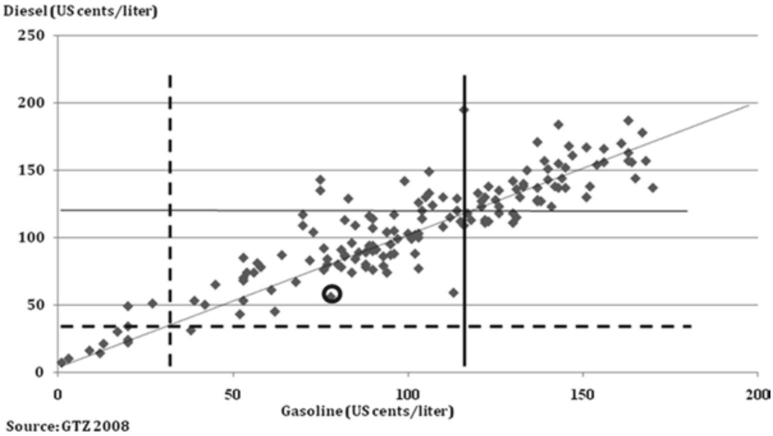

Fig. 18.1 Fuel price variations: the impact of tax policy (November 2008)

The problem, at least in the transport arena, is that nations have such widely varying tax regimes for transport fuels that any reasonable price signal will be lost in the fiscal noise. Figure 18.1 shows the range of policies in force for setting domestic prices (US cents/liter) of gasoline and diesel fuels. This figure plots the November 2008 diesel price (vertical axis) against the gasoline price (horizontal axis) in 152 countries for which the German Technical Cooperation Agency (GTZ) collects fuel prices.[6] Each point thus reflects a paired set of diesel and gasoline prices in a particular country as of November 2008.

The price for crude oil on the world markets at the time of the data collection was roughly the equivalent of 30 US cents/liter for diesel and for gasoline. Any gasoline price to the left of the vertical dashed line, or below the horizontal dashed line is below the related world price and is therefore defined as "highly subsidized" by GTZ. There are seven countries, mostly oil producers (including Iran and Venezuela) in which the price of *both* diesel and gasoline is below the world price. Any gasoline prices to the right of the solid vertical line or diesel prices above the horizontal solid line are considered by GTZ to be "highly taxed." There are 39 countries in which *both* gasoline and diesel fuel are highly taxed (most of the EU countries fall in this category).

Fuel prices in the USA (56 cents/liter for gasoline and 78 cents/liter for diesel – the point is circled in Fig. 18.1) are considered by GTZ to be "the international minimum benchmark for a nonsubsidized road transport policy." That is, in broad terms, US prices reflect the world price plus a normal industry margin and taxes adequate to pay for the road system in total. By this GTZ definition (which can of course be debated), transport fuel prices begin to be subsidized when the price falls

[6]GTZ (2008).

below that in the USA, and they begin to be more and more highly taxed (above transport system costs) when they rise above the US levels.

As Fig. 18.1 shows, gasoline prices range from 7 US cents/liter to 195 US cents/liter, and diesel prices range from 1 US cent/liter to over 170 US cents/liter. The ratio of the price of gasoline to the price of diesel (in the same country) ranges from 50% to 700%. If we accept that the absolute price of gasoline should be in the range of 56 cents/liter and diesel should be 78 cents/liter, then the impact of national tax policies having nothing to do with transport costs or social impacts becomes rather stark. In addition, if we accept that the ratio of the price of gasoline to the price of diesel should be in rough proportion to their energy content (about 90%), then the impact of different tax policies for gasoline as compared with diesel (i.e., assigning the burden on autos as compared with trucks or vice versa) also becomes clear.

Most important, a US $10.00 tax per ton of carbon content would yield a tax per liter of fuel of slightly less than 10 US cents/liter. Even a carbon tax of US $40.00/ton (~40 US cents/liter of fuel), which has been discussed as a place to start with carbon taxes, would be lost in the noise caused by national revenue policies having little to do with GHGs or even transport costs. In other words, many countries have effectively already imposed a carbon tax that is well above the level needed to create appropriate GHG incentives. Put another way, a carbon tax in the range of US $40/ton so far proposed will not have as significant an impact on transport as it will have in other sectors, such as coal-fired electric power generation.

18.4.2 Management Capacity and Incentives

As suggested above, implementation of all of the required carbon reduction measures will involve a coordinated effort that, in many ways, will be larger and more difficult than the world has seen before. The term "mega-project" has been used to define an effort which, because of a combination of sheer size, location and identity of its management, and impact on social objectives, assumes a character far broader than the normal engineering project.[7] Given the character of the GHG control effort, perhaps we even need to invent a new term, "giga-project," to describe what lies ahead.

The question this poses is whether we have any right to expect (or hope) that the investment, management, and policy coordination challenges involved will be met at anything like the cost and timing that is currently planned. Will "everything go right," or might there be bumps along the road?

There is, unfortunately, little reason to be optimistic. Large public sector initiatives seem inherently to be subject to over-optimism on cost, schedule, and performance. Whether this is due to normal political exuberance or something a little

[7] See, e.g., Thompson (1982) and Flyvbjerg et al. (2003).

Table 18.4 Cost and performance experience for mega-projects

Project	Construction cost overrun	Initial traffic as % of forecast
Humber Bridge, UK	175	25
Channel Tunnel, UK/FR	80	18
Baltimore Metro, USA	60	40
Tyne & Wear Metro, UK	55	50
Portland Metro, USA	55	45
Buffalo Metro, USA	50	30
Miami Metro, USA	35	15
Paris Nord TGV, FR	25	25

Source: Flyvbjerg et al. (2003)

darker, the typical unfavorable experience with large public transport projects is shown in Table 18.4.[8] It deserves emphasis also that, by comparison with transport, planned GHG projects are often based on less proven technology and on more limited operating experience. In addition, most of the transport projects in Table 18.4 were in a single country where multi-jurisdictional coordination was, in principle, not as serious as a multi-country context.[9] While many of the individual investments in GHG control will be in a single country, international policy development, coordination, and implementation will almost always include a large number of countries, which will inevitably complicate the task. The projects in Table 18.4 were also conducted in developed countries where human and financial resources were adequate to the task: this is not often going to be the case with GHG control programs in developing countries (where much of the work will eventually be done).

18.4.3 Corruption

Developers of large, multinational programs and drafters of treaties often make the comforting assumption that the governments of the countries involved have two characteristics: (1) they are actually motivated to act in the interest of their citizens; and (2) they are capable of implementing the measures they are committed to by agreement or treaty. Pervasively corrupt governments will not meet either test very well.

Is this a serious concern? Corruption is a very uncomfortable subject that international institutions have long found difficult to discuss. Unfortunately, it will be difficult to ignore the issue in looking ahead to the implementation of a many-year

[8]Flyvbjerg et al. (2003) contains a detailed analysis of the performance of transport mega-projects and the reasons why expectations are not usually met.

[9]The policy and financial coordination problems on the Channel Tunnel project illustrate how multiple jurisdictional disputes can further complicate a mega-project.

program, especially if there is a transfer of wealth from developed to developing countries or if, as is planned, carbon offsets paid by developed countries are to be implemented and enforced in developing countries, especially when implemented by government agencies or state-owned enterprises.

Transparency International compiles annually a corruption perception index based on interviews and responses from individuals and companies doing business in 177 countries.[10] The corruption index could range from 1.0 (utterly corrupt – government officials essentially use their office wholly for private gain) to 10.0 (totally honest – officials carry out their duties entirely in accord with rules and laws and do not attempt to benefit personally from the exercise of public authority). Table 18.5 shows the corruption indices for a sample of countries.

Table 18.5 confirms some expectations. The Scandinavian countries enjoy exceptionally honest and effective governments, as do Canada, Austria, Australia, The Netherlands, Switzerland, and New Zealand: we would have confidence that these countries would act in the interest of their citizens and that they would be able to implement their obligations. Iraq and Afghanistan suffer from the most corrupt regimes, and we would realistically have to discount expectations as to their willingness and ability to live up to obligations where any significant economic sacrifice or program complexity is involved.

Obviously the measurement of the corruption index has a significant qualitative component and the reported value of each index is subject to a range of error. Moreover, the shadings are gradual. It would be difficult to say exactly when the obvious confidence that a 9.3 rating inspires must be replaced with the pessimism that a rating of 1.3 or 1.5 would require. For example, by experience one would expect countries with the 6.9 to 7.3 indices of France, Belgium, Japan, and the USA to be within the range of acceptable performance. Similarly, experience might suggest as well that ratings below 5.0 would justify caution, and ratings below 4.0 could indicate a real question about the motivation and/or capabilities of governments, their officials, and public enterprise managers in the countries involved.

Figure 18.2 looks at the issue from a more global point of view. Figure 18.2 shows the cumulative percentage of four variables [Gross National Income (GNI)] at official exchange rates, GNI adjusted for Purchasing Power Parity, tons of CO_2 emitted, and population that are found at or below various corruption indices. For example, around 80% of the world's population lives in countries with corruption indices of 4.0 or below. More significant, about half of the world's CO_2 is emitted by countries (notably Russia, India, and China) where the corruption index is 4.0 or below.

Yes, the question is serious and is likely to pose serious challenges as soon as GHG programs move beyond treaty signing and into actual implementation.

[10]The entire data set is available at Transparency International (2008).

Table 18.5 Sample corruption indices

Country	Index
Iraq	1.3
Afghanistan	1.5
Russian Federation	2.1
Iran, Islamic Rep.	2.3
Pakistan	2.5
Ukraine	2.5
Egypt	2.9
India	3.4
China	3.6
Bulgaria	3.6
Romania	3.8
Poland	4.6
Turkey	4.6
Greece	4.7
Italy	4.8
South Africa	4.9
Hungary	5.1
Czech Republic	5.2
Korea, Rep.	5.6
Israel	6.0
Spain	6.5
Estonia	6.6
France	6.9
Belgium	7.3
Japan	7.3
USA	7.3
UK	7.7
Germany	7.9
Norway	7.9
Austria	8.1
Australia	8.7
Canada	8.7
The Netherlands	8.9
Switzerland	9.0
Denmark	9.3
New Zealand	9.3
Sweden	9.3

Source: Transparency International (2008)

18.4.4 How to Respond?

To some extent, this chapter is an unavoidable counsel of despair. Many years of personal experience with governments and public enterprises in developed and developing countries lead me to the conclusion that "optimism in objectives, pessimism in plans" would be a good idea. It seems clear that the easier (but still difficult

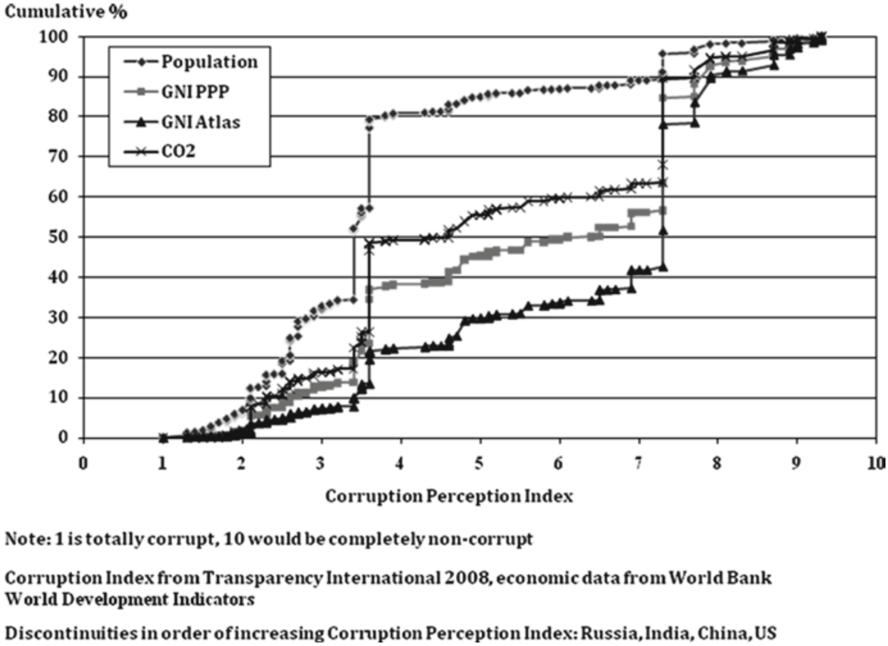

Fig. 18.2 Cumulative percent of population, PPP GNI, Atlas method GNI, and CO_2 emissions versus corruption perception index

and not yet achieved) part of GHG control will be the development of appropriate policies and technology and getting reasonable international agreement on them. The really hard part will be implementation. With this said, there do seem to be a number of points that scientists, engineers, and economists should be considering:

- Shape the message to the real audience and repeat it consistently. The scientific community simply can no longer talk down to those who, by different faith or culture, look at life differently. The scientific message must be shaped to transcend the critical cultural and educational barriers to understanding. A 2009 study by the Center for Research on Environmental Decisions contains an excellent discussion of the psychology of understanding and communicating a better understanding of climate change issues.[11]
- Align science and engineering with economics or, at least, ensure that economic incentives do not undermine science and engineering objectives. This will be particularly true with regulations that, for whatever reasons, are in conflict with clear price signals (e.g., regulations requiring better fuel economy in combination with politically imposed cheap fuels – see Fig. 18.1).
- Keep solutions, programs, and investments simple, especially in corrupt environments. Complexity is the enemy, and that which is not transparent

[11] Center for Research on Environmental Decisions (2009).

usually evaporates. This would, for example, argue strongly for carbon taxes and against trading regimes or carbon offsets where the additionality or implementation of the offset is questionable, or where enforcement is critical.

References

American Public Transit Association (2009) Public transportation fact book. American Public Transit Association, Washington, DC. http://www.apta.com/gap/policyresearch/Documents/APTA_2009_Fact_Book.pdf

Center for Research on Environmental Decisions (2009) The psychology of climate change communication: a guide for scientists, journalists, political aides and the interested public. Center for Research on Environmental Decisions, New York

Eurobarometer (2005) Data on responses to the proposition that "human beings, as we know them today, developed from earlier species of animals." US data taken from http://www.religioustolerance.org/ev_publi.htm

Flyvbjerg B, Bruzelius N, Rothengatter W (2003) Megaprojects and risk: an anatomy of ambition. Cambridge University Press, Cambridge

Gesellschaft für Technische Zusammenarbeiten (GTZ) (2008) GTZ international fuel prices, 6th edn. Data Preview. http://www.gtz.de/de/dokumente/en-int-fuel-prices-6th-edition-gtz2009-corrected.pdf

Pew Forum on Religion and Public Life (2009) Just what is it with evangelical Christians and global warming? Quoted in Manchester Guardian. http://www.guardian.co.uk/environment/blog/2009/apr/17/climate-change-religioSouthwestAirlines. Annual report 2008. http://www.southwest.com/investor_relations/annual_reports.html

Thompson L (1982) The Northeast Corridor Project. Henry M. Shaw Lecture in civil engineering, School of Civil Engineering, North Carolina State University

Transparency International (2008) Global corruption perception index. http://www.transparency.org/policy_research/surveys_indices/cpi/2008/cpi_2008_table

U.S. Surface Transportation Board (various years) Statistics of class I railroads. U.S. Surface Transportation Board, Washington, DC

YRC Trucking, 10K Annual report to US Securities and Exchange Commission. http://investors.yrcw.com/sec.cfm?DocType=&DocTypeExclude=&SortOrder=FilingDate%20Descending&Year=&Pagenum=9

Chapter 19
Converting the Unconverted and Establishing Financial Incentives

Werner Rothengatter, Yoshitsugu Hayashi, and Wolfgang Schade

1. Climate change is the biggest challenge for the world economy since the industrial revolution. Climate change is partly man-made and can be influenced. As it seems to be inevitable that the world temperature will increase by about 2°C until the end of this century, it will be important to consider adaptation measures to be prepared for the long-term impacts. But it is an even more essential issue to start with effective mitigation actions as soon as possible to avoid temperature increases which might be substantially above this limit and might lead to a catastrophic change of the worldwide ecosystems.
2. The economic crisis gives the chance to change the structures of economic activities toward a more sustainable trajectory. Old routines may be replaced and the long-term challenges of energy saving and CO_2 reduction might be boosted through the market mechanism. Logistics and freight transport have a big potential to adjust through technological and organizational changes, while passenger transport could be directed to a more sustainable path, induced by behavior and technology.
3. Industrialized countries have caused the problem of increased CO_2 concentration in the atmosphere since the industrial revolution. Therefore, it is their major responsibility to take the lead in the next decades to come in achieving substantial reductions of greenhouse gas emissions in an order of magnitude of 20–30% until 2020 and 50–60% until 2050, compared with 1990. Compared with the trend development, the transport sector would have to achieve about 80–90% to be in line with this requirement.
4. Developing and transition countries will change from followers to leaders with respect to climate policy. The reason is first that they will be hit most by the long-term impacts of global warming. Second, there will be a change of economic and political power in favor of transition countries like China, India, Brazil, Russia, or Indonesia. Third, there will be a growing market for climate technology, and the transition countries will develop from the workbenches of production today to growth poles of new technology in the future.

W. Rothengatter (✉)
Institute for Economic Policy Research, Karlsruhe Institute of Technology,
Waldhornstrasse 27, 76131 Karlsruhe, Germany
e-mail: rothengatter@kit.edu

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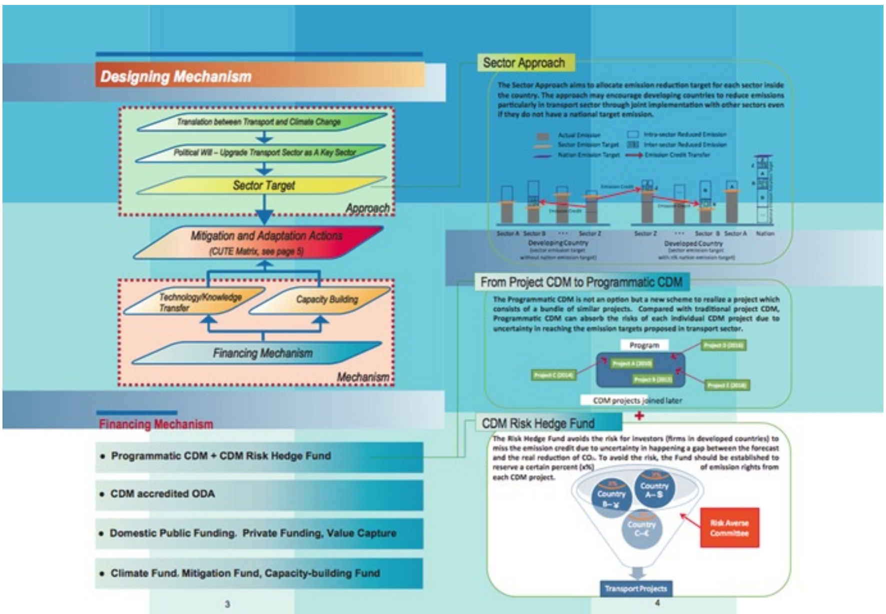
5. There are a number of instruments to accelerate the market mechanism such that the necessary reduction of emissions is achieved earlier than under a regime of free market decisions. Global instruments such as carbon taxes or emission trading are favored, but they will not be sufficient in the next decades. They have to be complemented by national taxation, regulation, and standard setting, and it is the role of industrialized countries to start with effective packages of instruments to show developing/transition countries the way to proceed.
6. The cornerstones of a successful international policy scheme are threefold: first, the industrialized countries have to take the role of top runners, to demonstrate that reduction policy is possible without economic disadvantages. Second, the unconverted countries have to be converted, which works best by removing possible regulation leakages and stopping climate arbitrage. Third, the developing and transition countries have to be motivated much more by financial instruments. Some very efficient instruments have been created under the Kyoto Protocol and the UN initiatives, such as the Clean Development Mechanism (CDM) or the Global Environmental Facility (GEF) scheme. These instruments have not been successfuly applied in the transport sector for particular reasons (e.g., project-related measurement of CO_2 reduction) and have to be developed further in the future, eventually under a Post-Kyoto Regime. The following figure exhibits the diagnosis and the suggestions of the Special Interest Group on Transport and the Environment (SIG11) of the World Conference on Transport Research Society (WCTRS), as they have been submitted to the Copenhagen World Climate Conference. Following the suggested path would increase the motivation of developing and transition countries much more to participate in the common actions to control the climate change.



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