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The IPTS REPORT

EDITED BY THE INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (IPTS)
AND ISSUED IN COOPERATION WITH THE EUROPEAN S&T OBSERVATORY NETWORK

SPECIAL ISSUE: QUALITY OF AIR IN EUROPEAN CITIES: URBAN TRANSPORT CHALLENGES

EUROPEAN COMMISSION
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ENGLISH VERSION

ABOUT THE IPTS REPORT

The IPTS Report is produced on a monthly basis - ten issues a year to be precise, since there are no issues in January and August - by the Institute for Prospective Technological Studies (IPTS) of the Joint Research Centre (JRC) of the European Commission. The IPTS formally collaborates in the production of the IPTS Report with a group of prestigious European institutions, forming with IPTS the European Science and Technology Observatory (ESTO). It also benefits from contributions from other colleagues in the JRC.

The Report is produced simultaneously in four languages (English, French, German and Spanish) by the IPTS. The fact that it is not only available in several languages, but also largely prepared and produced on the Internet's World Wide Web, makes it quite an uncommon undertaking.

The Report publishes articles in numerous areas, maintaining a rough balance between them, and exploiting interdisciplinarity as far as possible. Articles are deemed prospectively relevant if they attempt to explore issues not yet on the policymaker's agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda. The multi-stage drafting and redrafting process, based on a series of interactive consultations with outside experts guarantees quality control.

The first, and possibly most significant indicator, of success is that the Report is being read. The issue 00 (December 1995) had a print run of 2000 copies, in what seemed an optimistic projection at the time. Since then, readership of the paper and electronic versions has far exceeded the 10,000 mark. Feedback, requests for subscriptions, as well as contributions, have come from policymaking (but also academic and private sector) circles not only from various parts of Europe but also from the US, Japan, Australia, Latin America, N. Africa, etc.

We shall continue to endeavour to find the best way of fulfilling the expectations of our quite diverse readership, avoiding oversimplification, as well as encyclopaedic reviews and the inaccessibility of academic journals. The key is to remind ourselves, as well as the readers, that we cannot be all things to all people, that it is important to carve our niche and continue optimally exploring and exploiting it, hoping to illuminate topics under a new, revealing light for the benefit of the readers, in order to prepare them for managing the challenges ahead.

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EDITORIAL

Quality of Air in European Cities: Urban Transport Challenges

Hector Hernández and Matthias Weber, *IPTS*

The challenge of preserving the quality of the air in urban areas confronts the many obstacles raised by the intrinsic complexity of the urban system. The issues involved are highly interdependent, have intricate cause-effect relationships and depend very much on local-specific characteristics. Their impact is also crucial for phenomena at the regional and global levels. Air pollution caused by urban transport is a prime example. In spite of the significant improvement of air quality in European cities over the past decades, the present situation is still a matter of major concern. One of the main problems is the still ongoing growth of traffic that offsets the benefits of the introduction of cleaner technologies. Moreover, current social and economic trends in urban areas indicate that transport volume is likely to increase further in the future.

Policies addressing this issue have to consider technological, social, economic and environmental aspects simultaneously in order to be able to propose sustainable solutions. The recent initiatives taken by European policy to achieve further improvements in urban air quality go in this direction. A good example is the set of initiatives by DG Environment to integrate and harmonize air quality work into a single programme covering all sources of pollution. In the same vein, a benchmarking scheme has been set up for best practices in European cities concerning the management of urban problems so as to improve knowledge transfer to other cities. In transport policy, a new Green Paper is currently under preparation focusing in particular on the urban dimension. An integrated approach to urban issues is also included in the European research programmes, which include specific key actions dealing with urban issues and sustainable mobility.

One important feature is the change in focus of recent urban transport policy initiatives as compared with those in the early nineties. While it is increasingly recognized that a technological fix alone will not be able to provide a sustainable solution, the attempts to reduce the volume of local traffic by promoting alternative mobility solutions and raising citizens' consciousness of the impact of their mobility behaviour have not been very effective. In some of the Member States that over recent years have spearheaded innovative mobility solutions, investment in infrastructure, and especially in telematics systems, seems to be receiving fresh attention as a key option for coping with the ever growing demand. New infrastructures will nevertheless need to be integrated into the structural context of cities. Urban and transport planning are now recognized as the decisive tools for improving the structure of traffic demand in the *long-term.*

Taking planning measures into account at an early stage is thus imperative for sustainable city development.

Another consideration that has become increasingly important concerns the economic benefits which cleaner cities can enjoy. In fact, quality of life –of which air quality is a key element– has turned into an important factor in the attractiveness and hence competitiveness of cities. For instance, the highly qualified workforce needed in the main growth segments of our economies, i.e. in particular in high added-value services, expects a high level of quality of life to be willing to move.

However, even with the best technologies and planning measures it will be difficult to meet higher air quality standards if traffic continues to grow as it has done in the past. With the growing emphasis on quality of life in cities, awareness of the negative side-effects of urban mobility has also increased, as has the acceptance of restriction on the most polluting forms of traffic in city centres. In the end, a decoupling needs to be achieved of quality of life and economic growth in cities from growth in polluting traffic.

These arguments show that urban air quality is a problem at the intersection of many policy areas. While the European Commission's role with respect to urban policy issues may be rather limited, the exchange of experiences made, and the formulation of common targets and standards could contribute to moving further ahead towards cleaner cities. In particular, promoting better integration of different policy areas seems to be a valid area for action.

The need for better integration of policy areas is also one of the common themes addressed by the different articles in this special issue. However, this integration and coordination can only work on the basis of a sound scientific foundation and reference base, both with respect to the actual measurement and identification of emissions and their health effects, and in terms of a better understanding of causal and temporal relationships between urban transport policy measures and emissions.

A second cross-cutting issue that needs to be highlighted is the importance of technological developments from outside the transport field. In particular, information and communication technologies (ICTs) and advanced logistics offer many possibilities to improve, directly or indirectly, the efficiency of the urban transport system. However, the relation between transport and ICTs needs to be better understood to design strategies to avoid rebound effects such as additional traffic demand.

Most articles in this issue recognize the important contribution of new technology to improving urban air quality. The choices highlighted need to be seen in the context of the interests and needs of different stakeholders, ranging from the final transport user and citizen to the companies providing the technological hardware. But it is also recognised that policy intervention should be flexible enough to allow the market to self organise.

Other important contextual factors are the future evolution of urban space, and the co-evolving patterns of life and work. Their importance is recognized throughout most articles as the key long-term determinants of urban air quality, and quality of life in cities in general.

This special issue attempts to provide an integrated view of current and future issues raised by transport in the context of urban pollution. The five articles it contains address the characterization and assessment of the problem, discuss the advantages and disadvantages of potential technical and organizational solutions and analyse the socio-economic implications of urban transport and air quality policies.

The first article, by Theodoros Zachariadis, presents an overview of the air pollution problem in European cities. The author discusses the shift of priorities on air quality work, from some of the emissions that are being controlled (like the carbon monoxide and lead) to new or persistent pollutants (such as nitrogen oxides and particulate matter). The article underlines the need to bring together the control of emissions from stationary and mobile sources and outlines a number of mitigation measures.

The second article, by Arjan Heyma, attempts to explain why the currently available low and zero emissions transport technologies have not yet found widespread applications. The article describes the technical limitations and market barriers these technologies need to overcome. Recognizing the need to facilitate the uptake of more environmentally friendly technologies, it analyses past experiences of demonstration projects involving alternative propulsion systems. The lessons drawn should serve to help improve the design of new such projects, and thus the chances of success of new transport technologies.

Continuing the emphasis on technological solutions, the third article, by Jeroen Meij, argues that electric vehicles have the potential to solve the urban transport-related pollution problem. The article provides an up-to-date review of facts and developments regarding the most viable options of electrical vehicles. It includes the results of a scenario study showing the market penetration of those vehicles for the year 2020 and discusses the main elements conditioning the market penetration of electric vehicles.

The fourth article, by Panayotis Christidis, argues that the mitigation of the environmental impacts of transport can be achieved without undermining economic activity and, in addition, could enhance the attractiveness of an urban area. It is argued that the solution lies suitable differentiated policy mixes, including the internalization of the external costs of transport and the stimulation of the penetration of new transport technologies.

The last article, by José Viegas and Laura Lonza Ricci, highlights the role of innovative organizational and contractual schemes in achieving better air quality in urban areas by encouraging citizens to modify current mobility patterns.

Finally, two brief notes conclude this special issue, pointing to two fields of EU policy that influence the future air quality in urban areas. Brief note 1 provides an overview of high-profile local and EU initiatives to raise awareness and promote the transfer of best practices regarding the introduction of innovative approaches to urban mobility across Europe. The second brief note outlines the structure and breadth of expertise on air quality issues at the Joint Research Centre (JRC), which shows the JRC's increasing interest in the subject and highlights its potential to develop into a scientific reference centre in this area.

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Air Quality in European Cities: An Overview

Theodoros Zachariadis, *ATLANTIS Research Organisation and Aristotle University of Thessaloniki*, Greece

Issue: Although there have been clear improvements in air quality in many European metropolitan areas over the last two decades, air pollution is still a very serious environmental concern.

Relevance: Monitoring and estimates of emissions and air quality have improved greatly in recent years, but there is still much to be done to better assess the effects of air pollution on humans, ecosystems and monuments. This is an issue with important policy implications, as air pollution causes considerable social costs that need to be assessed and abated. It is therefore necessary to identify the most significant and cost-effective pollution control strategies.

Introduction

More than 70% of Europe's population lives in urban areas. This obviously leads to a high concentration of domestic, commercial and industrial activities in cities, which in turn gives rise to serious environmental pressures on humans, buildings and ecosystems. Air pollution is one of the major impacts of urbanization. The frequency of occurrence of high air pollution concentrations varies from city to city, depending mainly on the magnitude of emission sources, the topography of the area and the prevailing climatic conditions. As the effect of each one of these factors is variable in each area, air pollution of different types and levels is observed in various European cities.

During the last decade, air quality issues have been investigated extensively through rigorous scientific studies. Almost all the major urban areas nowadays maintain a network of air quality measuring stations, which can promptly inform about alarmingly high pollutant concentrations and thereby assist authorities in taking emergency measures. Moreover, continuous pollutant concentration data gathered by these stations are particularly useful in air quality simulations, which are now commonly used to predict pollution episodes and evaluate alternative policy options for pollution control.

This article outlines the main aspects of urban air pollution: it describes today's situation in emissions and pollutant concentrations and discusses policy options that can respond to current and future air quality problems.

Emissions

Figure 1 presents per capita emissions of two major air pollutants, sulphur dioxide (SO_2) and

The frequency of occurrence of high air pollution concentrations varies from city to city, depending mainly on the magnitude of emission sources, the topography of the area and the prevailing climatic conditions

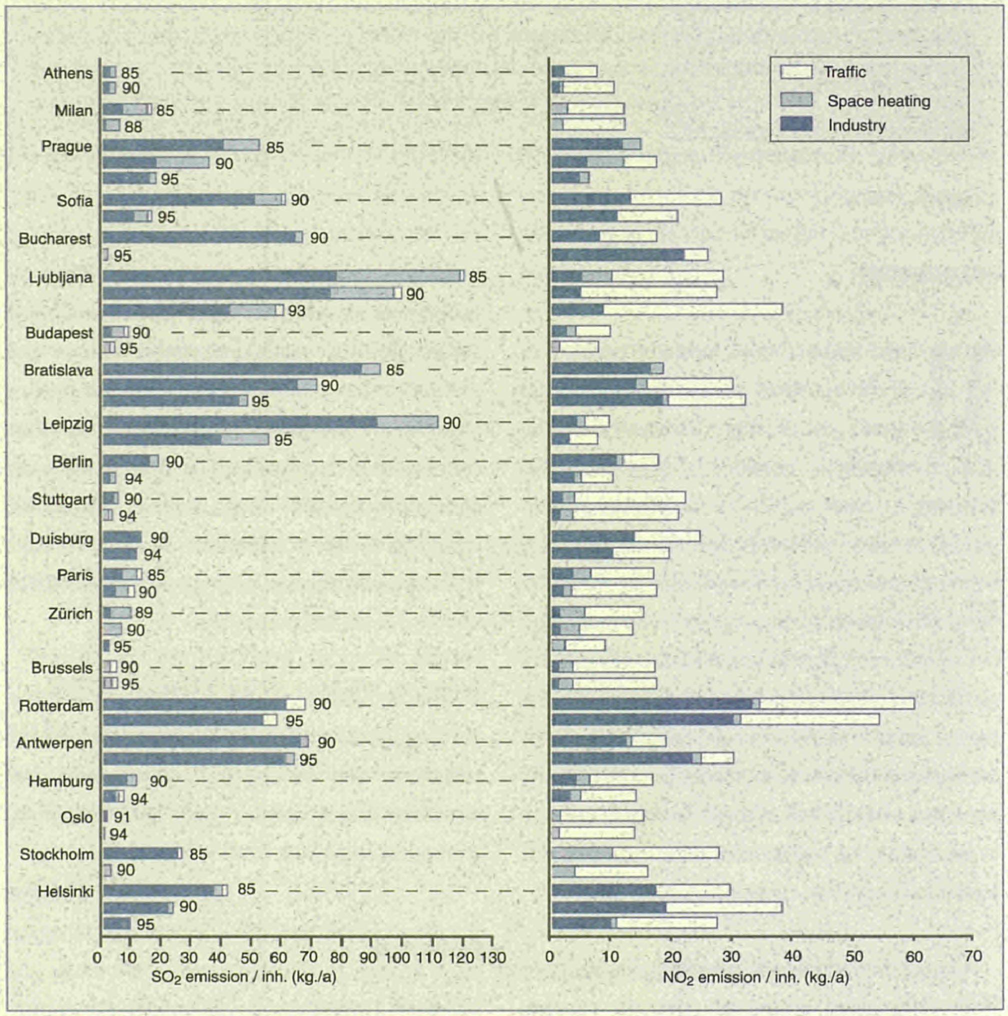
Almost all the major urban areas nowadays maintain a network of air quality measuring stations, which can promptly inform about alarmingly high pollutant concentrations and thereby assist authorities in taking emergency measures nitrogen oxides (NO_x, i.e. the sum of NO and NO_2), for a number of cities located in different regions of Europe. It is evident that SO_2 emissions, which are generally proportional to the sulphur content of the fuels consumed in a given area, vary by up to two orders of magnitude, as a result of different levels of industrialization, fuel properties and emission control technology. Industry is mainly responsible for these emissions, with space heating taking second place and road traffic contributing by less than 10%. The picture is quite different in NO_x, which are emitted in all high-temperature combustion processes, and therefore traffic is the main source in most urban areas, with industry taking the first place only in heavily industrialized conurbations like Antwerp, Bratislava, Helsinki and Rotterdam. In general, differences in NO_x emission levels per capita are much less pronounced than for SO_2.

As regards other important pollutants, about 80%–90% of anthropogenic volatile organic compounds (VOC) and 90% of carbon monoxide (CO)

SO_2 emissions, which are generally proportional to the sulphur content of the fuels consumed in a given area, vary by up to two orders of magnitude, as a result of different levels of industrialization

Emissions of CO and lead have been constantly decreasing in most EU cities during the last 5 to 10 years, thanks to the introduction of catalytic converters and unleaded petrol

Figure 1. Estimated per capita emissions of SO_2 and NO_x in European cities for various years between 1985 and 1995



Source: EEA (1998)

in cities are emitted by motor vehicles, whereas traffic and industry are both significant emitters of fine particulates (PM10). Among VOC, there are some particularly harmful carcinogenic compounds like benzene and various polycyclic aromatic hydrocarbons (PAH), which are also mainly emitted by road vehicles.

Emissions of CO and lead – a heavy metal contained in petrol with detrimental health effects – have been constantly decreasing in most EU cities during the last 5 to 10 years, thanks to the introduction of catalytic converters and unleaded petrol. Cities of Central and Eastern European countries (CEEC) generally follow the same trend, but with a considerable time lag because of older vehicle technology and faster growth of vehicle population. Compared to CO, emissions of NO_x, VOC and PM10 show a much slower decreasing rate in the EU because improvements in emission control technology in motor vehicles and stationary combustion sources are counterbalanced to a large extent by the increasing vehicle kilometres driven in cities. The situation is somewhat worse in CEEC because of the slower penetration of modern technology and the economic growth that these countries are currently experiencing after the recession of the early 90s.

Air Quality

"Winter Smog"

The oldest air quality problem in urban areas is the so called "winter smog", characterized by high concentrations of SO_2 and total suspended particulates (TSP). As a result of the attention paid to this "traditional" form of pollution, the situation has significantly improved in most European cities in the last two decades, although their population often increased and the standard of living has risen considerably (thereby leading to higher energy consumption, which tends to increase emissions). The main measures that induced the improvement were:

- the substitution of coal and heavy fuel oil by diesel oil and natural gas both in the industry and for heating purposes;
- the gradual reduction of the sulphur content of fuels used in heating and transportation and the use of unleaded petrol;
- the increasing use of high-efficiency natural gas-powered plants for electricity production;
- the penetration of three-way catalyst passenger cars as well as cleaner diesel vehicles (light and heavy duty).

These improvements have relieved – but not yet eliminated – the problem of "winter smog" pollution. Exceedances of the World Health Organization (WHO) short-term standards for SO_2 and TSP are still observed in most European cities. Figure 2 presents the estimated fraction of inhabitants exposed to exceedances of winter smog standards.

Another clear step forward that has been made is the sharp decrease of lead concentrations, since leaded petrol will be completely phased out from EU countries by the end of 2000 (2002 for Spain, Portugal and Greece).

"Summer Smog" or photochemical pollution

The formation of ozone, caused by the interaction of nitrogen compounds (coming from NO_x emissions) with oxygen and aided by substances that mainly originate from emitted VOC, is a common problem, particularly during the summer in Southern Europe. However, the phenomenon is also important in Northern and Western Europe, as a result of long-range transport of photochemical oxidants from the

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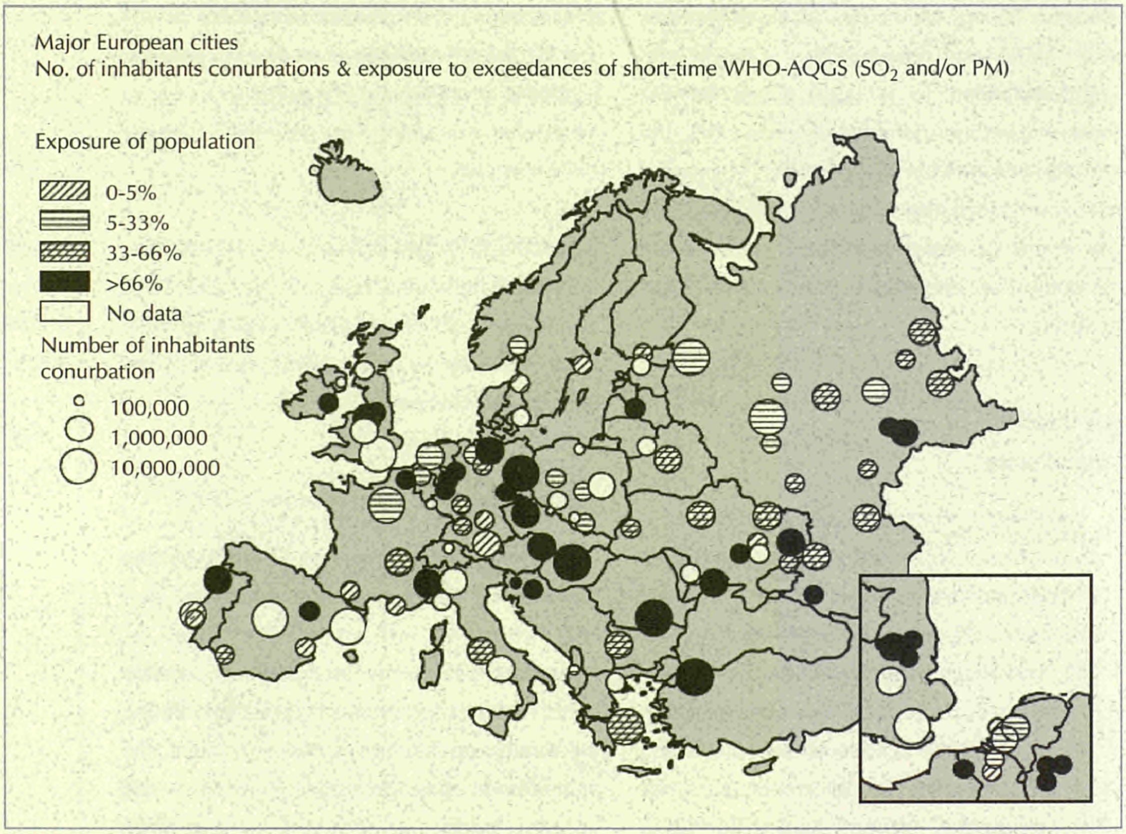
South. Hence the WHO air quality guidelines are frequently exceeded in many European cities. Urban areas of CEEC have not experienced significant "summer smog" problems yet, as ozone is consumed by the large amount of NO_x emitted in these regions.

The problem of photochemical smog has not been tackled effectively so far. Since this type of pollution depends not only on primary emissions but also on topography and local meteorological conditions, it is far more difficult to mitigate than the classical "winter smog". The evaluation of abatement strategies has to be performed with the aid of regional air quality models, which depend on a large number of variables and are therefore associated with uncertainties. It is interesting to note that the European Auto-Oil I programme has revealed that, even with the strictest realistic technical measures for motor vehicles, ozone targets in many EU cities cannot be achieved.

Other pollutants

These include fine and ultra-fine particles (PM10 and PM2.5 respectively), benzene and some PAH, most notably benzo-(a)-pyrene. As already mentioned, the main source of these pollutants is emissions from motor vehicles, both petrol and diesel. Although concentrations of total

Figure 2. Estimated percentage of citizens in urban areas of Europe that are exposed to exceedances of short-term WHO air quality guidelines of SO_2 and/or TSP



Source: EEA (1998).

suspended particulates have been decreasing, especially in the European Union, this does not happen with PM10 and PM2.5. These are carcinogenic compounds and can also cause severe damage to the human respiratory system; moreover, their contribution to transboundary air pollution is now recognized and has yet to be better understood. Therefore, these substances are now gaining in importance and are the subject of numerous studies as regards both measuring methods and health impact. As for benzene, its content is regulated and will be constantly reduced in future fuels, as legislated by the European Commission.

Pollution Abatement Strategies in a Changing Environment

As outlined in the previous section, there are a few substances that are tending to disappear from the list of today's serious air pollutants; these are primarily CO and lead – although the problems associated with these compounds may persist in some cities for yet another decade. The introduction of three-way catalysts on cars and light trucks and the phasing-out of lead from automotive petrol have been almost sufficient measures for the elimination of these two pollutants. This is good news, but the situation is quite different for most other substances, where one or two technological innovations are not enough for a substantial reduction in emissions and improvement in air quality.

Technical measures

There are three areas where technical measures are often implemented:

- *Introduction of cleaner fuels:* the sulphur content of automotive fuels has been decreasing in the last two decades in the EU, and is planned to be further reduced in the following decade from the current (year 2000) levels of 150 ppm in petrol and 350 ppm in diesel to 50 ppm in 2005, but some countries apply much lower limit values already today. The same trend applies to the oil used for space heating. Other fuel properties are also regulated: the content of benzene and aromatics in petrol as well as the content of PAH in diesel are being reduced considerably. Another fuel-related intervention is the increasing shift from coal and oil to natural gas, both for space heating and for power production and other industrial combustion processes.

- *Regulations and control options for motor vehicles:* Emission standards of "conventional" pollutants like CO, NO_x, VOC and total particulates are becoming increasingly stringent, thereby inducing technological progress in the design of engines and exhaust after-treatment devices. There are a number of technical options considered by automakers for the future, concerning both conventional and alternative propulsion systems. For petrol-driven vehicles, the options include starter catalysts, electrically heated catalysts, further improved engine management, exhaust gas recirculation, advanced on-board diagnostics. For diesel vehicles, measures include advanced systems for fuel injection, engine management, turbocharger control and exhaust gas recirculation; NO_x-reducing catalysts; and particulate traps. These measures can be enhanced through centrally controlled periodic inspection procedures, which aim at maintaining the emission levels of cars on the road close to their certification standards.

Conventional propulsion systems (mainly diesel-powered vehicles) may also operate on alternative fuels, such as compressed natural gas, alcohols (methanol and ethanol), di-methyl ether or even vegetable oils. These seem to be attractive either because of their low particulate and/or NO_x

emissions or because they may be produced from biomass, but the technical issues arising from the required modifications to existing engines still render most of these ideas too costly.

As for alternative propulsion systems, the introduction and penetration of electric vehicles, although very attractive for urban use because of their zero emissions at local level, has still to resolve problems of battery weight and capacity. Hybrid cars, which combine an electrical engine with a combustion engine, are an improved concept for several reasons, but require more complex configurations. Another concept is the fuel cell vehicle, which is effectively an electric vehicle, the electricity being generated through the separate movement of positively and negatively charged ions of hydrogen, which in turn is produced from another compound (most often from methanol). Some automobile manufacturers plan to introduce such vehicles to the car market before the end of this decade.

As existing sources of volatile organic compounds (VOCs) become cleaner, other sources, such as evaporation from fuel depots and service stations, become relatively more significant

- *Regulations for large combustion installations:* Directives 88/609/EC and 94/66/EC have set out NO_x and SO_2 emission standards for new combustion plants of installed capacity of over 50 MW in the European Union, and these standards are expected to be amended according to Directive proposal COM(98)415. Compliance with future limit values requires extensive implementation of technical measures (or a combination of several measures) such as improved methods for flue gas desulphurisation, low-NO_x burners and selective catalytic or non-catalytic NOx reduction in the flue gas.

- *Further measures:* The regulations mentioned above apply to the major emitting categories road transport, power plants and large industrial combustion units. Additionally, fuel improvements also affect the other combustion-related sectors, i.e. space heating, small industrial installations and non-road vehicles and machinery. However, as emissions from these sources tend to decrease, other sources are gaining in importance and have to be addressed with rigorous regulatory measures. Such are mainly sources of VOC emissions like organic solvents, which are used in a wide range of domestic, commercial and industrial applications, and evaporation of fuel (mainly petrol) from fuel depots and service stations. Both these sources are responsible for a high fraction of total VOC emissions in urban areas, as both involve activities that are particularly present in cities, and are partly controlled through EC Directives 99/13/EC and 94/63/EC respectively. Additional regulations will be required in the future, and the same applies to the above mentioned small combustion sources, where fuel quality alone cannot reduce their emissions adequately.

Non-technical measures

The variety of emission control options and the capabilities of modern technology make technical measures indispensable for any emission abatement policy. Despite all the regulations, however, it is still not possible to achieve compliance with ambient ozone standards, and it is highly questionable whether the improvements that will be brought about in the current decade are sufficient for the elimination of photochemical pollution in most European cities. This observation (probably more evident in the greenhouse effect issue, which is beyond the scope of this article) indicates that, apart from purely technological actions, it is imperative for urban populations to consider additional options that affect everyday life. Such options are discussed in the following paragraphs; they are related to urban traffic, although other measures might also be employed (e.g. reducing the average room temperature in the winter by 1°C or 2°C).

Traffic-related measures can be one or more of the following:

- Reduction of the overall need for mobility, through improved land use planning that could assist in decreasing the transport demand.

- Various economic measures that aim at limiting the use of private cars in favour of environmentally friendlier transport modes like buses and rail – or even cycling and walking. Such measures could include an increase in vehicle taxes (purchase tax or annual taxation), which would raise the price of vehicles, or, more importantly, increases in the costs of vehicle use such as higher fuel prices or extensive implementation of tolls in many urban and suburban roads. It seems that inverse incentives (e.g. very cheap access to public means of transport), apart from other financial problems, tend not to work well since vehicle owners need to be discouraged (in terms of high cost) to use their cars rather than encouraged to travel via other modes.

- Incentives for car sharing or car pooling (e.g. provide cars with 3 or more passengers exclusive access to particular lanes); little attention has been paid to this idea in Europe so far, in contrast to regulations of this kind in the United States.

- Traffic regulations that affect neither the transport demand nor the use of private cars, but aim at smoothing vehicle traffic because smooth driving yields lower emissions than "stop and go" driving. Such interventions include appropriate control of traffic lights in order to create "green waves", either for all transport modes or exclusively for buses or trams.

Besides the fact that the effectiveness of some of these interventions is still disputable, a basic problem with non-technical measures is the often limited public consensus. Another drawback seems to be the fact that these are mainly decentralized actions that are the responsibility of various local and regional authorities with potentially conflicting interests. As a result, such measures are usually sporadic and experience slow public response; therefore they often yield only marginal improvements in air quality.

Conclusions

In many cities of Northern and Western Europe, air quality is better today than it was 10 or 20 years ago. Other urban areas that have experienced high development rates more recently, notably some Mediterranean cities, have managed to essentially stop air quality deterioration. Conversely, it seems that most major conurbations of Central and Eastern Europe have not reached their worst pollution levels, as motorization and energy consumption are expected to rise in the coming years. Road traffic is generally the primary source of emissions and the main factor responsible for health problems in urban populations, with industry ranking second. However, although traffic volumes are expected to further increase in the future, it is foreseen that the relative significance of motor vehicles will decrease (especially as regards VOC emissions that are ozone precursors) and other sources such as small and medium-sized combustion units, solvent use and fugitive emissions from fuel depots and service stations will gain in importance. This underlines the need to adopt regulatory measures for all sources of air pollution and monitor their emissions continuously in order to respond promptly to unpredicted observations.

Problems caused by high concentrations of CO and lead are gradually disappearing, and the same

Besides the fact that the effectiveness of some of these interventions is still disputable, a basic problem with non-technical measures is the often limited public consensus for them

The fact that non-vehicle emissions could become increasingly important underlines the need to adopt regulatory measures for all sources of air pollution and monitor their emissions continuously in order to respond promptly to unpredicted observations

The EU Air Quality Framework Directive (96/62/EC) is a basic step towards an integrated approach to air quality management, which, with the aid of relevant follow-up Directives that will be gradually implemented, is hoped to achieve the desired environmental benefits

path seems to be likely for SO_2 – although about 10-15 years later than CO. Photochemical pollution (mainly ozone) is a complex problem in both Northern and Southern countries; it requires much additional research using photosmog simulations, cost considerations and analyses of the impact to humans, monuments, vegetation and ecosystems. Together with the greenhouse effect, which was out of the scope of this article, photochemical pollution demonstrates that technical measures alone are most probably insufficient for its solution; therefore, concerted action at all levels is necessary.

Carcinogenic pollutants like benzene, fine and ultra fine particles and some PAH are also a cause of serious concern. Research on the physical and chemical characteristics of particulate matter as well as epidemiological studies are under way, but our knowledge of these issues is still at an early stage. As health impact assessments are now receiving increased attention in addition to the more generic "environmental impact assessments", exposure of human populations has to be assessed with greater accuracy.

The EU Air Quality Framework Directive (96/62/EC) is a basic step towards an integrated approach to air quality management, which, with the aid of relevant follow-up Directives that will be gradually implemented, is hoped to achieve the desired environmental benefits. In this context, and apart from the regulatory steps, the coming years will provide an opportunity to evaluate the existing scientific material and eventually to revise present approaches or even develop new ideas for air pollution control. This is also the primary aim of the Clean Air for Europe (CAFE) programme, which has been initiated by the European Commission.

In short, there is still a very long way to go towards drastically improving the quality of air in Europe, and especially in its cities. A mixture of strict (but scientifically well-established) technical measures and local initiatives from people and authorities willing to really change today's environmental situation seems to be a reasonable starting poin

Keywords
urban areas, emissions, air pollutants, health effects, policy, monitoring

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Barriers and Challenges for New Urban Transport Technologies

Arjan Heyma, *TNO Inro*

Issue: Although emissions by motor vehicles have been reduced considerably in recent years they still have a significant impact on the urban environment, especially in congested areas. On the other hand, a number of low and zero emission alternative new transport technologies have been developed but have not yet found widespread applications.

Relevance: The optimization of circumstances for the successful and widespread introduction of new urban low-emission transport concepts is a prerequisite to formulating an effective solution to the apparent conflict between high quality transport and high air quality in urban areas.

Two of the main goals of public transport policy and reflected by the European Union's Common Transport Policy, are the provision of a high quality transport system and at the same time the improvement of the quality of the environment

Introduction: Why are cleaner transport technologies not in more widespread use?

Two of the main goals of public transport policy and reflected by the European Union's Common Transport Policy, are the provision of a high quality transport system and at the same time the improvement of the quality of the environment. Although emissions by motor vehicles have been reduced considerably in recent years, they still have a significant impact on the urban environment, especially in congested areas. Traffic in urban areas is responsible for around 75 percent of urban NO_2 "immissions" and 20 percent of urban PM10 "immissions"[1]. Attempts to reduce the number of trips by car to improve air quality, is in conflict with policy goals of high quality transport and ease of mobility for citizens. In addition these attempts are not effective enough to counter the autonomous growth in travel demand that results from economic and population growth. Public policy therefore has shown a rising interest in technological solutions that may help to achieve both policy goals.

A number of low and zero emission transport technologies have the potential to supply high quality transport without these negative environmental effects. The major question is why these alternative transport technologies have not yet found widespread applications. This article gives three reasons for this. Firstly, although there is a wide variety of alternative transport technologies, the applications still suffer from technical limitations. Secondly, a widespread market introduction is hampered by a number of economic, political, organizational and mobility related barriers. And thirdly, it is not always clear for which segment in the transport market these new technologies are suited. The latter issue is not further treated in this article. Instead the question is asked as to why demonstration projects, which aim to test new transport technologies to improve their (technical) quality and applicability in order to facilitate their market introduction, are not always successful.

This article elaborates on these issues in the following manner. First, an overview is given of new transport concepts based on new propulsion systems, with an indication of their main disadvantages. This shows that new technologies are widely available, but suffer from a number of technical and practical problems. Next, an overview is given of economic, political, organization and mobility related market barriers, to show why new technologies have difficulties in competing with conventional technologies. Demonstration projects are a way in which these technical and market barriers can be assessed and resolved, but they are not always successful. The most important success factors are therefore reviewed to provide a first idea for a solution to the problem raised. The paper concludes with a discussion on the feasibility of introducing new transport systems to meet the demands for both high quality transport and an improvement in urban air quality.

New transport technologies: highly promising, but still technically limited

Air quality is influenced by the emission of carbon monoxide (CO), ozone (O_3), sulphur oxides (SO_x) and hydrocarbons (HC_s). But the main emissions and most urgent in terms of local urban air quality are nitrogen oxides (NO_x) and particulates (PM_s). Conventional fuel types like diesel fuel produce high levels of these emissions and are therefore a major cause of the deterioration of urban air quality. There are however a number of alternative propulsion systems and fuels that may improve urban air quality by reducing emissions. Table 1 gives a short overview of these new technologies. The reference combination of propulsion and fuel are the internal combustion engine (ICE) with petrol or diesel. Exact figures are found in Marks et. al. (1999).

Table 1 shows that in particular the fuel cell and electric and hybrid propulsion systems show large improvements in urban air quality compared with conventional internal combustion engines using petrol as their fuel. However, these alternatives also have a number of disadvantages that need to be resolved before widespread application becomes feasible. Most of these are practical and require further technical development. But technical solutions are one part of the story, market barriers are another.

Market barriers make competition difficult

Even when all technical and practical problems are solved, the success of new technologies may be limited by economic, political, organizational and mobility related barriers. Evidence for the importance of these barriers can be found in the European Union research project UTOPIA, in which experts and demonstration project leaders have been asked about bottlenecks for the introduction of new transport technologies. Figure 1 gives an impression of the most important bottlenecks for the introduction of new propulsion systems in all-purpose cars. Economic aspects like purchase costs, market availability and operating costs are considered very important bottlenecks. Technical and practical aspects, like time to refill or recharge, range and reliability, only come in second place. This means that new and

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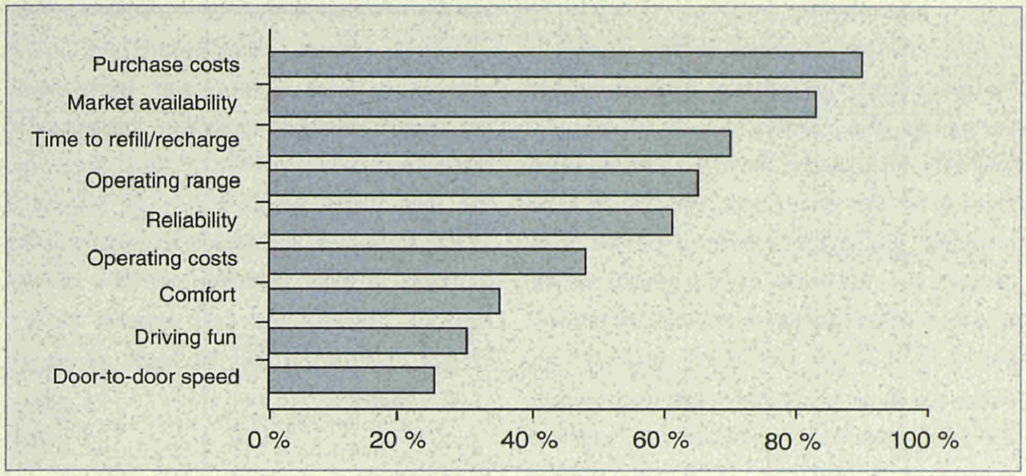
Table 1. Alternative propulsion and fuel combinations (10-100 kW), the effect on urban air quality, and disadvantages compared with traditional systems

		Improvement in air quality		
Propulsion system	*Fuel type*	*NO_x*	*PM_s*	*Disadvantages in comparison with petrol / diesel fuel*
Spark ignition ICE (compared with petrol)	Methanol	++	+	Low caloric value and therefore less efficient
	Ethanol	++	+	
	LPG	0	--	Safety problems in distribution and storage, larger fuel tank needed for same operation
	CNG	++	--	Safety problems in distribution and storage, direct influence on greenhouse effect, larger fuel tank needed for same operation
	LNG	++	--	
	Bio-fuels	+	+	Major technical modifications of existing engines needed, environmental risks (ground water) due to increased use of chemical fertilizers and pesticides, modest "energy crop", ethical problems (food for fuel versus food for hungry), possible increase in greenhouse gas emissions from fertilizers (laughing gas)
Compression ignition IC (compared with diesel)	Methanol	++	++	Low caloric value and therefore less efficient, ignition ICE must be assisted, leading to higher engine production costs and higher fuel consumption
	Ethanol	++	++	
	Synthetic diesel	+	++	Similar to CNG and LNG
	FAME / FAEE / RME	--	0	Similar to Bio-fuels
Electric (compared with petrol)	Battery	+++	+++	High costs (purchase and operation), high battery and vehicle weight, limited operating range, reduced utility (payload, seating capacity), shift of emissions to power plant in case of fossil fuels, energy loss along chain of electricity transmission, battery charging time consuming, limited recharging infrastructure
Fuel cell (compared with petrol)	Conventional petrol	+++	+++	
	Methanol	+++	+++	See methanol above
	CNG	+++	+++	See CNG above
	Hydrogen	+++	+++	Safety problems in storage and handling, larger fuel tank needed for same operation, high emissions when produced from fossil fuels, economically not viable when produced with solar energy
	Conventional diesel	+++	+++	
	DME	+++	+++	Complicated design of fuel system due to very low viscosity
Hybrid (compared with petrol)	Parallel	-	0	
	Series (with ICE)	++	+++	
	Series with fuel cell	+++	+++	
	Combined (with ICE)	+++	+++	

The air quality ratings in the table range from large deterioration (--) through small deterioration (-), no change (0), small improvement (+) and substantial improvement (+++) to a complete elimination of negative air quality effects (+++).

Figure 1. Bottlenecks for the introduction of new propulsion systems in all-purpose cars, measured by the percentage of interviewed experts that find them (very) important

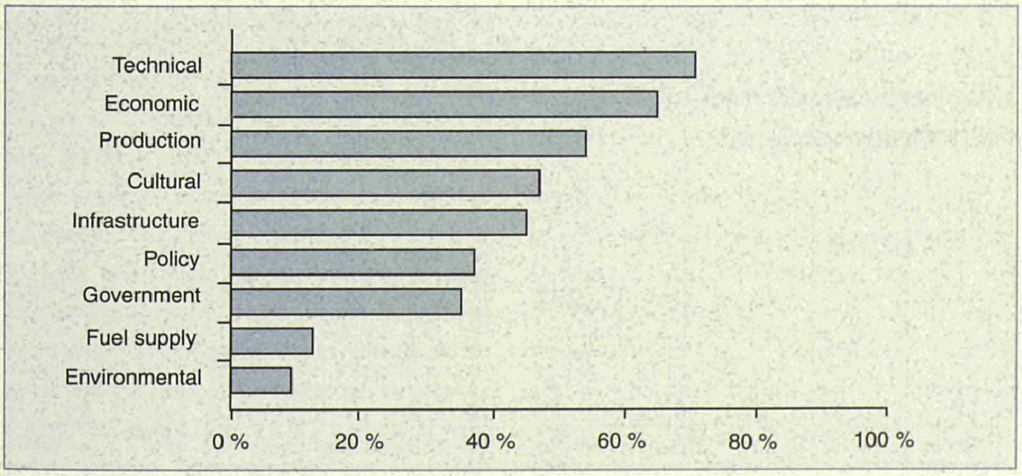


technically mature technologies must also be able to compete in costs and benefits in the transport market. Aspects like comfort or driving fun seem to be less important.

A more complete picture with regard to barriers for the market introduction of new transport technologies is obtained from participants in demonstration projects. Figure 2 shows that these participants put technical problems first and then consider problems like economic costs and the commercial production of new technologies as next highest in importance. The cultural or user-related barriers mainly concern the market price, reliability, operating range, utility and service life of new technologies, which again are mainly technical and economic aspects. Infrastructure barriers point to the lack of refuelling infrastructure for non-conventional fuels. Barriers put up by the

For participants in demonstration projects the most important barriers were technical problems, followed by economic costs and the difficulties of commercial production. Users tend to see price, reliability, range and lack of infrastructure as being the most important barriers

Figure 2. Barriers for the introduction of new transport technologies, measured by the percentage of demonstration project leaders that find them (very) important



The conditions for market acceptance can be tested and adjusted by means of demonstration projects, in which new technologies are applied in small scale real life situations. But experimentation in demonstration projects does not guarantee success for new technologies

There is evidence that success can be influenced by a number of factors, which can be selected at the start of a demonstration project or before the introduction of a new transport technology in the market

government or by policy are considered much less important for the introduction of new transport technologies.

The importance of barriers varies according to the type of propulsion system as a consequence of the specific characteristics of each. Participants from ICE projects using alternative fuels consider barriers by the government and the lack of refuelling infrastructure more important than average, since alternative fuels in general require new refuelling technologies and additional safety measures. Electric propulsion projects are threatened by policy barriers more than average and by a lack of refueling infrastructure less than average, since electricity can in principle be obtained from any standard electric outlet. Participants in projects with hybrid propulsion systems mainly worry about economic and technical barriers.

The main conclusion from the opinions on barriers, is that market acceptance of new technologies is mainly attained by practical and economic features, which are conditional on technical maturity. These conditions can be tested and adjusted by means of demonstration projects, in which new technologies are applied in small scale real life situations. But experimentation in demonstration projects does not guarantee success for new technologies.

What can be learned from demonstration projects?

Demonstration projects are a convenient way to test new technologies for introduction in the transport market. They are in general supported by public programmes initiated by national governments (e.g. the Powershift programme in the United Kingdom) or the European Commission. Table 2 gives an overview of transport concepts that apply new propulsion systems. Details of these demonstration projects can be found in Korver and Zwaneveld (1999)[2]. A number of these demonstration projects apply new transport concepts in addition to new propulsion systems. Examples are the electric vehicles in Lyon (France) and Turin (Italy), the electric scooter in Groningen (Netherlands), the electric railbus in Bristol (United Kingdom), the road based people mover in Rotterdam (Netherlands) and the electric vehicles in Skåne (Sweden). A more complete overview of new transport concepts and their assessed impacts on the environment can be found in Heyma et. al. (2000a).

The projects in table 2 not only test the technical feasibility of new technologies, but also show additional technical and practical needs for widespread application, user requirements and market potential. For the successful application of new transport technologies, much can be learned from demonstrations. By comparing the characteristics of successful European demonstration projects for new propulsion systems and transport concepts, Heyma, Zwaneveld and Korver (2000b) have derived success factors that can be used when setting up demonstration projects and introducing new transport technologies into the market. See also Zwaneveld et al. (2000).

The analysis shows that overall success is positively affected by the use of more developed technologies and transport modes that are not part of multi-modal transport chains. Applying new technologies over short distances, involving manufacturers of transport modes or propulsion systems as partner in the project and reducing governmental, political and environmental barriers for introduction of new transport technologies also increase the probability of success. Another result from the analysis is that there is a trade-off between technical and environmental success. More

Table 2. Examples of alternative propulsion systems used in European demonstration projects

Propulsion system	Fuel type	Example of demonstration project	Location
Spark ignition ICE	Methanol	• Thermie methanol bus project	Ravenna, Italy
	LPG	• LPG-driven busses in public transport • Arriva LPG bus demonstrations • LPG trucks • LPG busses (ZEUS project)	Vienna, Austria London, United Kingdom Helsinki, Finland Helsinki, Finland
	CNG	• ASTI project with CNG busses • Travel West Midlands CNG bus fleet • CNG vehicles • CNG refuse trucks	London, United Kingdom United Kingdom London Borough of Merton, United Kingdom Groningen and Velsen, Netherlands
	Bio-fuels	• Biogas busses	Linköping, Sweden
Compression ignition ICE	RME	• RME-driven vehicles in municipal services	Vienna, Austria
Electric	General	• Various electric vehicles • Elettra Park automated electric car rental • TWIP electric scooter	Lyon, France Turin, Italy Groningen, Netherlands
	Battery	• Electric Taxi project • Gulliver electric bus • Montmartrobus electric bus experiment • Electric Vehicle project • Electric Vehicles (ZEUS project) • Rivium automated people mover • Electric taxi vehicles • Electric vehicles demonstration	Graz, Austria Bristol, United Kingdom Paris, France Coventry, United Kingdom Stockholm, Sweden Rotterdam, Netherlands Rotterdam, Netherlands Hämeenlinna, Finland
	Guided	• Village underground • Electric Railbus project	Serfaus, Austria Bristol, United Kingdom
Hybrid	Parallel	• Hybrid bus fleet • Hybrid electric trucks • Electric vehicles • Hybrid busses	Genoa, Italy Göteborg, Sweden Skåne, Sweden Leiden, Netherlands
	Series	• Centaur hybrid busses project	Bologna, Italy

attention for environmental issues by the introduction of new transport technologies generally implies more technical problems, while technically mature transport concepts hardly produce environmental gains.

The main conclusion is that there is evidence that success can be influenced by a number of factors, which can be selected at the start of a demonstration project or before the introduction of a new transport technology in the market. For instance, if a very revolutionary new technology is introduced, without the direct involvement of a manufacturer, and the proposed transport concept aims at long distance trips and is in addition part of a transport chain, the likelihood of success will be low. Policy-makers and funding organizations (like for instance DG Energy and Transport and national ministries of the environment) can use these success factors as a checklist. If a proposal rates badly on a certain number of factors, it should be adjusted. Information about success factors can be used by organizations that apply for funding as a tool for setting up better projects that aim at a successful application of new transport technologies in the (urban) transport market.

Challenges for transport policy and new technologies: the road ahead

The assessment of barriers for the introduction of new transport technologies, shows that there are a number of hurdles that have to be overcome before low and zero emission transport technologies can replace conventional and proven transport concepts in urban areas. But what can be done to enable successful and widespread introduction of environmentally friendly technologies in the transport market?

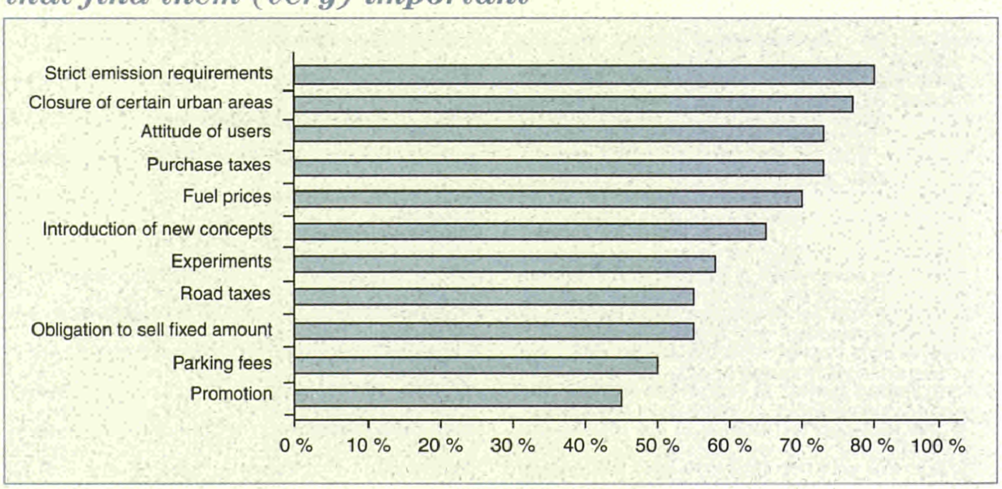
Within the UTOPIA project, experts and project managers have been asked for their opinion regarding possible measures to stimulate the introduction of new transport technologies. Figure 3 shows which factors they found most important. Much emphasis is put on regulation, like strict emission requirements and closure of urban areas for certain traffic. Financial measures or promotion activities are rated as being less crucial, but still important. Other factors mentioned by the experts include support by the (automobile) industry and changing users' behaviour.

Conventional vehicles have a monopoly as a consequence of lower investment and purchase costs, but they also have poorer environmental performance. Reaching a new market equilibrium could be achieved through government measures to make cleaner technologies cheaper relative to the existing ones

From these results, an apparent conflict arises. The main barriers that are expected for the market introduction of new transport technologies are technical and economic. Policy measures aimed at the promotion of new technologies and their economic performance are expected to be effective in enabling their market penetration. Restrictive measures are however in conflict with policy goals regarding high quality and flexible mobility for all citizens. When areas are restricted to certain vehicles or strict emission requirements impose the need for costly investments in transport services, mobility may become more available to some people than others.

The use of strict regulation and fiscal measures with regard to the use of different

Figure 3. Importance of factors that might stimulate the market introduction and use of new transport technologies, measured by the percentage of experts that find them (very) important



technologies can however be supported by economic arguments. Despite adequate development of zero and low emission propulsion systems, there is still a lack of a competitive market infrastructure for both selling and refuelling vehicles of this type. High investment requirements keep these alternative transport systems from entering the market. Conventional vehicles have a monopoly as a consequence of lower investment and purchase costs, but they also have poorer environmental performance. Government regulation and fiscal measures could be effective instruments for opening up the market for new technologies by making cleaner technologies cheaper and conventional technologies more expensive (or even prohibitively so). Once a new market equilibrium has been reached, the quality of transport services can be at least as high as in the present situation, while the environmental situation is improved. Costs that result from the suggested policy measures must however always be weighted against benefits that result from a higher level of urban air quality.

Conclusion: goals set for urban air quality well within reach

The answer to the question why cleaner transport technologies are not commonly applied, is threefold. Technical disadvantages, market barriers and unsuccessful market introductions keep a number of new zero and low emission transport systems from commercial introduction. At the same time, technological developments are such that large improvements in urban air quality are possible. Should these systems reach large scale application, the economic and production related barriers would become negligible. Emphasis must therefore be put on further technological research, on policy measures that enable new technologies to reach a competitive position with regard to conventional transport systems, and on a conscious application of demonstration projects, in which new transport technologies are applied in real life situations. Eventually, clean air technologies may co-exist with high quality transport services. Together, future goals set for the quality of urban air and urban transport come well within reach.

Keywords

new transport technologies, new propulsion systems, urban transport systems, barriers and promoting policy measures for the introduction of new transport technologies

Notes

1. Immissions are measured at street level, emissions are measured at exhaust pipe level. Percentages are taken from Metz, Potjer and Janse (2000).

2. Within UTOPIA, a database with 45 European demonstration projects has been created in which information is collected on project aims, set-up and organisation, project partners, monitoring and communication, and views of project partners with respect to success, barriers, promoting measures and market chances. In addition, a technology description is available with regard to the propulsion system and vehicle type applied in these projects, and with regard to technical performance, operating conditions, infrastructure, trip patterns and economic aspects.

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Reducing Urban Pollution through the Electrification of Road Transport

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Issue: Reducing urban pollution has become a matter of increasing importance. Although electrically powered vehicles possess several unique properties in this respect, they have long been confined to niche areas. As technology and society advance, the time has come for a reassessment.

Relevance: A short overview of recent developments in electrical vehicles offers insights into benefits, boundary conditions and possible future scenarios. This can provide anchor points for policy making and planning for urban areas.

Introduction

The future development of transport in cities will be determined to a great extent by the need for more efficient use of energy, reduced emissions of harmful substances and reduced noise levels. Using electricity as the energy to propel vehicles makes it possible to achieve a higher level of efficiency and reduced emissions of harmful substances. This applies in general, but it is particularly noticeable in an urban environment. With lower driving speeds (which apply in urban areas) it is also possible to achieve considerable reductions in noise levels. In the long term, the use of electricity from renewable sources will allow a gradual transition to sustainable transport.

Familiar forms of electric vehicles, such as trains, trams and trolleybuses, make use of special electrical infrastructure for their energy supply. Compared with vehicles powered by combustion engines, it seems that these vehicles first of all have the advantage that they are both more reliable and more durable. They are certainly quieter, and in addition, they have been demonstrated to produce fewer emissions over the energy life-cycle as a whole both because they are more efficient and because the electricity they use is mostly generated by processes which are cleaner than internal combustion (even when fossil fuels are used, techniques such as cogeneration or the purification of flue gases can mean overall emissions per unit energy produced remain lower). The urban environment benefits particularly, because what emissions there are do not take place on the streets of the city centre.

The disadvantage of trains, trams and trolley buses is that they require a permanent physical connection to the electricity supply. This means that it is impossible to travel from door to door and they lack the freedom offered by the car. Therefore

As electric vehicles are more efficient and use power from cleaner sources, they produce fewer overall emissions per unit of power used for propulsion than their internal-combustion counterparts improved technology is being developed continuously to make electric vehicles independent of the electrical infrastructure for a limited or unlimited period. This independence is based on the storage of electricity or on the generation of electricity on board the vehicle. Vehicles (powered by an electric battery) that store electricity have approximately the same environmental advantages as the train and tram. For (hybrid) vehicles that generate electricity on board, the specific advantages depend on the configuration. Both battery-powered and hybrid vehicles are also distinct from conventional vehicles in terms of the possibility of recovering the energy generated by braking. It is this distinctive characteristic that could, in the long term, swing the balance in their favour. However, innovations are necessary in transport policies to help the electric car compete with conventional cars, as the latter enjoy the advantages of a strongly developed production system (see discussion on these barriers and challenges in the previous article of this issue).

Electric vehicles also have the advantage that energy can be reabsorbed during braking rather than dissipated as heat

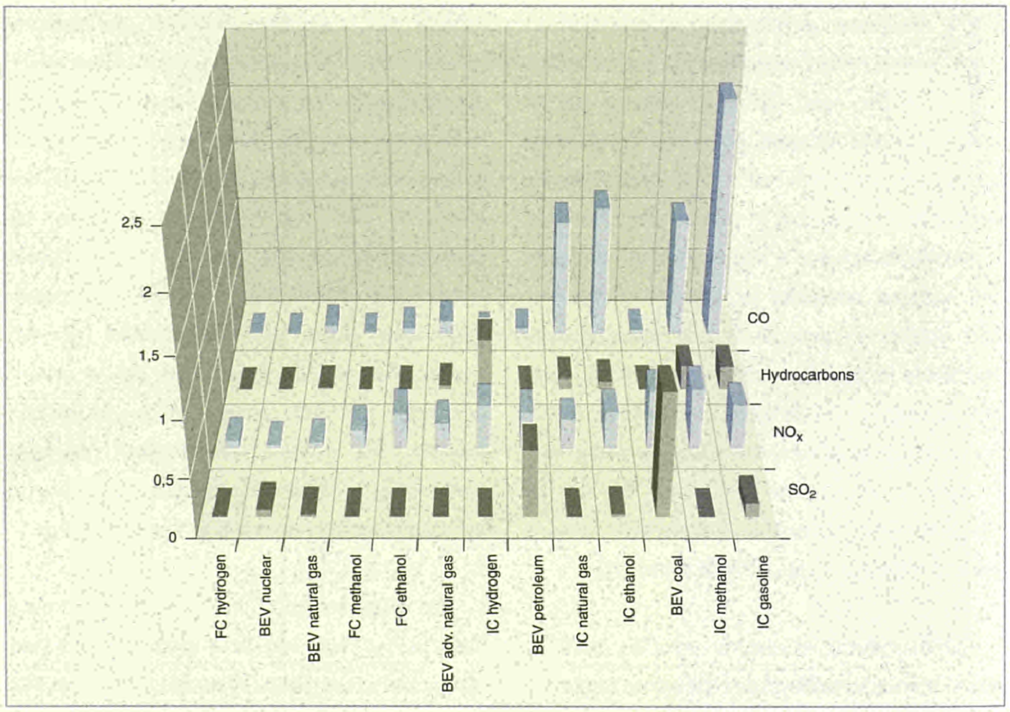
The hybrid-electric vehicle offers an attractive medium term solution with lower energy consumption, adequate range and the possibility of operating in zero-emission areas

Emissions and energy consumption

The advantage of battery powered electric or fuel cell - hybrid transport lies in the much lower levels of emissions of substances such as NO_X, SO_2 and CO and the overall lower energy consumption. This is illustrated in figure 1.

In urban areas, the emissions from battery-electric vehicles can even be reduced to zero, depending on the nature and location of electricity generation. Most hybrid vehicles can also be driven on battery power alone within a limited radius. This would allow hybrid-electric vehicles to be used in zero emission zones. As a result of the lower energy consumption (fig. 2), the emissions of CO_2 are also lower than with an internal combustion engine. This applies for both battery-electric and hybrid vehicles.

Figure 1. Emissions in g/km for a medium- sized car powered by different propulsion systems



Source: Riley (1997) and Brogan (1992). The CO values are calculated for the whole life cycle of the product, the other values at the end of the conversion processes.

Driving in a clean and sustainable way will become a possibility when sustainably generated hydrogen can be stored efficiently and safely for use in Fuel cell electric vehicles, or when battery-electric vehicles are charged with electricity from renewable sources.

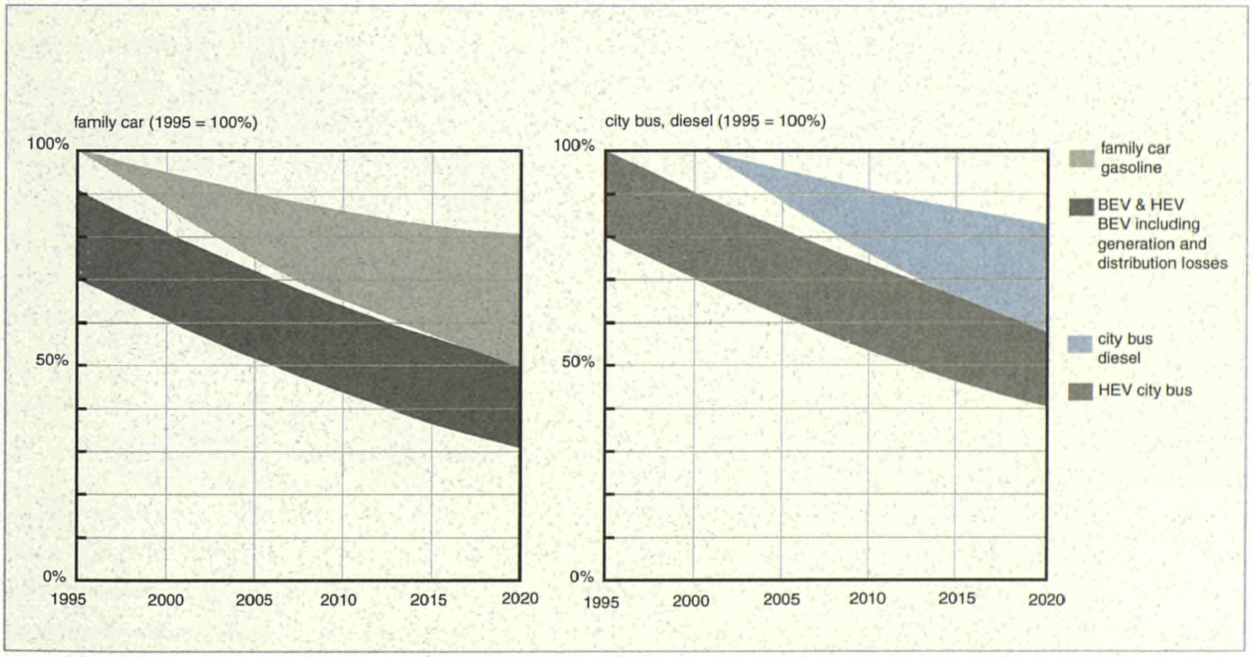
Future Scenario

Scenario studies initiated by Sep, the former Dutch electricity generating board (Gerwen, 1998, Korver, 1997a) show that road transport will increasingly make use of electric power. This study considered 4 scenarios provided by the evolution of the two main socio-economic dimensions up to the year 2020: levels of economic growth and support for sustainability targets. The "Unlimited Growth" scenario (UG) is the outcome of low levels of support for sustainability in conjunction with rapid economic growth, while the "Sustainable Growth" scenario (SG) couples a high level of support for sustainability with rapid economic growth. Low economic growth figures and low levels of support for sustainability result in the "Halt" scenario (H), while slow growth combined with a high level of support for sustainability yields a scenario called "Sustainable Balance" (SB). The types of vehicle studied were the fuel cell electric vehicle (FCEV), battery electric vehicle (BEV), hybrid electric vehicle (HEV) and internal combustion vehicle (ICV).
Figure 3 summarizes the results of the Sep scenario study.

Hybrids with a combustion engine

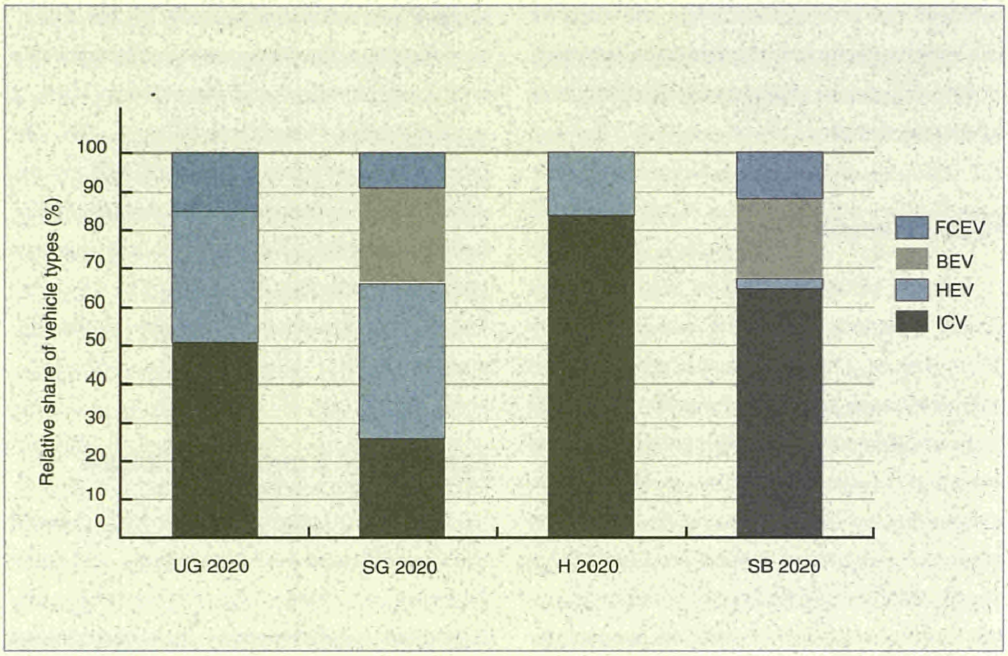
The first successful electrically powered vehicles will most likely be hybrids, and serial hybrids and some types of mechanically decoupled parallel hybrids have the greatest chance of commercial success (see the article entitled "Towards the Zero Emission Vehicle" in issue 2 of the IPTS Report). Of all the hybrids,

Figure 2. Energy consumption for a battery-electric, hybrid-electric and internal combustion engine per kilometre



Source: TNO-WT and CE (Janse, 1997)

Figure 3. Occurrence of different electric vehicles in four scenarios in 2020



Source: Korver, 1997

Scenarios studied by the Dutch organization Sep put the number of hybrid-electric cars on the road in 2020 at between 2 and 40% of the total number of private cars

Battery-electric vehicles will become attractive when battery specific energies reach 3-4 times those of current lead-acid batteries and fast-charge technology makes recharging feasible on longer trips

serial hybrids have the fewest mechanical parts and also benefit from the improved efficiency obtained by running the primary engine at constant revolutions. Hybrids can also piggy back on the developments in the field of internal combustion engines that are still taking place. Appearing in all scenarios, hybrids' projected share of the total number of private cars varied from 2 to 40%.

Battery-electric transport

The breakthrough in battery-electric transport will take place when the specific energy of the batteries is 3 or 4 times that of current lead acid batteries, and when rapid charging technology makes it possible to charge up occasionally at a service station or public charging facility. The first successful electric vehicles will be small, light and suitable for short distances making them ideal as a second car (for shopping or travelling to and from work). Such vehicles could even be two or three-wheeled. Considerable environmental advantages could be gained from replacing internal combustion engine motorbikes by electric versions (in certain suburbs this could also apply to lawnmowers). Care must be taken, however, to ensure that electric bikes do not substitute for human powered bikes. Battery-electric transport will only have a chance in the scenarios that incorporate support for sustainability targets, and in these cases might achieve a share of between 21 and 25% over the period considered.

Fuel cell hybrids

Fuel cell technology will probably first be introduced in a hybrid system (with batteries and super capacitors for storing recovered braking energy and for providing peak power) in combination with a reformer for liquid fuel. The time at which it will be introduced depends on the ability to bring down the price of fuel cells and the technical development of "on-board" reformers (used to produce hydrogen from the liquid fuel). Recent developments indicate that these reformers will become available for the application of conventional fuels within five years. In some scenarios, fuel cell (hybrid) electric cars will represent a share of between 9 and 15% of all cars.

Boundary conditions

The introduction of electric transport is closely related to a number of technological developments. In the key technology fields of batteries and power electronics, the signs are positive, and acceptable results can be expected in the relatively short term. When the technology is able to produce viable products, policy measures will be necessary to enable and stimulate their introduction. Planning and policy are required to adapt public space and infrastructure to this new type of vehicle and – if things turn out as expected – to accommodate the large scale electrification of urban transport.

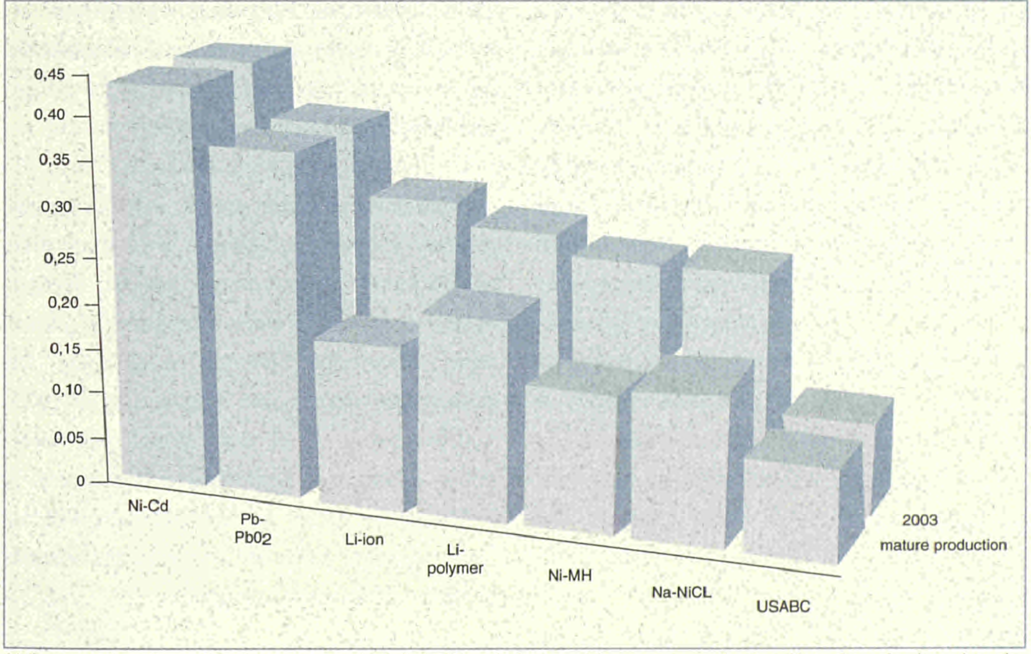
Energy storage devices

At the moment, some of the most promising types of batteries are nickel metal hybrid (NiMH) and the lithium ion batteries. It looks as though advanced lithium-polymer batteries will come close to the specific energy (relevant for driving range) required to compete with fuel combustion engines within five years. The specific power (relevant for acceleration) is still slightly below target values, but is less of a problem.

As regards the operational costs of new batteries, the projections for the price levels per kWh look fairly favourable compared with the lead-acid

Lithium-polymer batteries are expected to be able to provide specific energy levels necessary for battery-electric vehicles within the next five years or so

Figure 4. Projection of costs /kWh/charging cycle ($)



Values are given for various battery types both in 2003 and after reaching mature production. Note the value based on the USABC (United States Advanced Battery Consortium) long-term target.

battery technology. When the battery life (in charging cycles) is included in the calculation, the new types of battery will be considerably cheaper than lead-acid batteries once large-scale production is underway (see Fig. 4).

Another important storage device is the super-capacitor used to deal with peaks in voltage in hybrids and battery-electric vehicles, and produce peaks in output power, thus increasing the life-span and performance of the battery system.

The widespread use of battery-electric vehicles may make it necessary to adapt local power grids or implement demand-management strategies in order to cope with the number of chargers consuming power simultaneously

Electrical infrastructure

The availability of rapid "home" chargers of 10-11 kW could make an important contribution to the success of battery-electric vehicles with advanced batteries (these chargers would provide a full battery in 3 hours). However, if more than a small percentage of the inhabitants of a district are use chargers of this type to charge their cars simultaneously, problems could arise in the low (230V) voltage grid. In that case, "demand side management" (i.e. managing consumption) could provide a (temporary) solution. This would have to take place with more advanced methods than with time-related rates, though. Perhaps people could be encouraged to charge up slowly by linking the price of electricity to capacity demands, so that they would use the rapid charger only when it was strictly necessary. The only real solution to this problem is to increase the capacity of the distribution network to the charging points. These could also be at centralized neighbourhood parking spaces. The 120 kW rapid chargers at service stations can be connected to the medium voltage network and will not lead to any problems as regards power. With these chargers, the batteries can be fully charged in 15 minutes. This is a major improvement in charging time, but still requires a more disciplined planning of recharging stops than is the case with conventional cars.

To compete successfully, electric vehicles need to be designed in a way that takes their specific characteristics into account rather than simply being electric versions of conventional models

Power electronics

For all electrically powered vehicles, a general consideration of the chain from the source of the energy to the electronics for powering the engine, in combination with the characteristics of the vehicle, is an essential condition for achieving the best possible configurations. In this respect, a central processing unit plays an important role as an interface with the user and for intelligent power management. Rapid development of standards for the exchange of data between the components of the drive system could lead to greater flexibility and cost effectiveness.

Vehicle concepts and acceptance

If they are to compete successfully with conventional vehicles, electric vehicles need a specific design approach rather than simply fitting conventional cars with an electric motor. A properly designed battery electric vehicle does not need a gearbox, requires no oil changes, air filters, oil filters, exhaust pipe, catalytic exhaust converters, to name just a few of the differences. On the other hand, extra effort has to be put into the heating system, as conventional cars generally use the excess heat from the combustion for the interior heating.

State of the art battery electric vehicles already provide a smoother, quieter ride than their conventional counterparts, can (if desired) accelerate faster than a sports car and offer greater design flexibility. Driving range will be comparable with a Liquid Propane Gas car (200-400 km) within a few years. When price levels come down and supporting infrastructure is available, the battery electric vehicle will be an attractive alternative to a combustion-engine vehicle for the family's second car.

The hybrid vehicle will be accepted even before that, depending on its availability on the market. To date, price levels and availability have been obstacles, but when these issues are resolved, the hybrid will compete successfully for the place of the (all purpose) family car.

Conclusions

Electric transport is closely linked to electricity infrastructure and urban planning. Therefore, in the initial phase, it will require support from policy measures that accelerate the implementation of new infrastructure and provide incentives for driving electric vehicles. For example, as most people in urban areas do not have a private driveway, sufficient parking spaces will have to be converted into charging spaces. Also, the introduction of electric vehicles is linked to a greater extent to policies that stimulate new transport concepts such as the introduction of zones in which specific modes of transport are encouraged.

For the transport of goods, the construction of urban distribution centres will have a positive influence on electrification by creating a niche for vehicles travelling over a short range from a central base.

In terms of traffic congestion, the electric vehicle in itself constitutes neither a solution nor a worsening factor. Possibilities lie in combining new vehicle concepts with advanced systems for vehicle guidance, and for policies to adapt vehicle use to the transport needs and restrictions of specific areas. As mentioned above, electric vehicles are highly suitable for external guidance systems.

Electric and hybrid vehicles (the latter used in electric mode in cities) can reduce air pollution caused by road transport in urban areas. It is reasonable to expect that within a few years, electric and hybrid vehicles will be technically competitive with internal combustion-engine vehicles. These vehicles are in line with the concepts of sustainable development for transport that are proposed for the long term.

The introduction of zero emission zones would have positive results for pollution in the inner city and would stimulate the rapid take-up of electric vehicles. However, the introduction of electric transport must form part of a wider policy to adapt town and country planning and infrastructure. There are still many opportunities here with regard to the policy of councils and local governments, which could, in turn, benefit from the guidelines and incentives introduced by national governments and the European Commission.

Electric transport is closely linked to the electricity infrastructure and urban planning. Therefore, in the initial phase, it will require support from policy measures intended to accelerate the implementation of new infrastructure and provide incentives for driving using electrical power

Keywords

electric vehicles, battery electric vehicles, hybrid electric vehicles, urban transport, pollution, emissions, battery, battery cost

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Economic Growth and Reduction of Transport Emissions: A Feasible Combination

Panayotis Christidis, *IPTS*

Issue: Although the majority of transport related environmental protection measures are expected to lead to higher user costs, the combination of environmental quality and economic growth is nevertheless feasible. However, internalizing the external costs of transport is a necessary condition for the success of innovative measures and reducing transport emissions.

Relevance: The investigation of measures to minimize the environmental impacts of transport is becoming a main policy priority. The implementation of transport related policies should take into account environmental issues as well as the requirements of the economy and society in order for long-term success to be possible.

Introduction

Policy objectives in urban areas often concentrate on mitigating the environmental impacts of transport and give lower priority to the equally important economic and social issues. Consequently, measures reducing mobility may have undesirable impacts for the economy and society as a whole.

The analysis that follows concentrates on the interaction between transport and economic activities, particularly in urban areas. Alternative policy measures and their applicability are discussed taking into account both the overall policy goals and the market forces that may influence their results.

The internalization of the external costs of transport and the acceleration of the penetration of new transport technologies are two of the most important policy measures in any policy mix. Although circular causation effects will probably result in rebounding environmental pressures, the combination of a slower increase in transport demand and decreasing average pollution rates seems to offer a feasible solution for long term sustainability without halting growth.

Policy objectives in urban areas often concentrate on mitigating the environmental impacts of transport and give lower priority to the equally important economic and social issues

Decoupling growth and transport emissions

The role of transport in economic development is a well-researched subject but the available theoretical and empirical evidence is contradictory, if not insufficient. The main difficulty in identifying the relationship between

Although improving transport infrastructure at regional level can have economic benefits when part of a package of development measures, the case at local level is far from clear

The costs of the negative impacts of transport in terms of emissions, noise, congestion, accidents, etc. are not paid in full by users but borne by society as a whole

One-sided measures applied to achieve environmental objectives without taking economic or social issues into account can lead to undesirable situations. A consistent, long-term and multifaceted approach is necessary in order for sustainable solutions to be found

transport demand and growth lies in the dual nature of transport as a production factor and a derived need. As a result, a cause and effect relationship cannot be determined and most relevant work relies on empirical assumptions. At a regional level, the catalytic role of transport is generally accepted, as is the fact that transport infrastructure on its own is not sufficient to stimulate growth but, rather, has to be combined with other development policies. At the local level, and in urban areas in particular, the impact of improving transport infrastructure and services in situations where saturation has already been reached is even more questionable. And to make things even more complicated, the impact of intentionally reducing transport supply or demand –(e.g. as the result of raising transport costs directly or indirectly through environmental protection measures) is an option with consequences that are hard to predict.

In any case, transport services should be seen as economic commodities subject to certain supply and demand factors. The use of transport services has a given utility for every individual or enterprise and the intensity of use of transport services depends on the demand elasticity of each transport service. From the supply side, the capacity of the transport networks determines the amount of transport services that the system can produce. Prices play the role of a control equilibrating mechanism and affect the level of supply and demand for transport services. From society's point of view, transport services are needed in order for the required levels of mobility and accessibility to be achieved. In both the cases of the economy and society, the maintenance of current patterns of production and consumption implies that transport intensity will increase.

Unfortunately, transport activities also cause negative impacts in the form of emissions, noise, congestion, accidents, etc. that seriously affect the quality of life in most European cities. Moreover, the cost of those impacts is not perceived nor paid for in full by the users of transport services, but instead are borne by society as a whole. The fact that the cost of transport externalities is not taken into account properly encourages the inefficient use of transport services and concomitant environmental damage.

The mitigation of the environmental impacts of transport has become a main policy priority at EU, national and local levels. However, the often one-sided measures applied in order to achieve environmental objectives without taking economic or social issues into account can lead to equally undesirable situations. A consistent, long-term and multifaceted approach is necessary in order for sustainable solutions to be found. Policy interventions aimed at reducing transport intensity, i.e. the volume of transport required for a given level of economic activity, entail the danger of negative side effects for the economy and society. On the other hand, policies aimed at increasing the environmental efficiency of transport, i.e. minimizing the amount of environmental damage a certain level of transport causes, can be helped by the development of new technologies, but face high implementation costs. A combined approach is more appropriate, especially if accompanied by the internalization of the external costs of transport.

Although the necessity to meet the targets in relation to emission levels is recognized and cannot be negotiated, decoupling the growth of economic activity from the growth of transport use does not guarantee an overall solution. Such a solution could be perhaps reached in terms of emission levels, but the overall costs for the economy and society could be prohibitive. Policies aiming to lead to near-optimum, cost-effective solutions should concentrate on decoupling the growth of economic activity from the growth in emissions (including non-transport emissions).

Impact of alternative policy measures on economic activity

Mitigating the environmental impacts of transport requires a combination of technical, legislative, financial, planning and other transport demand measures. Each approach has its own potential benefits, implementation costs, side effects and time horizon; consequently, a different policy mix is suitable for each specific case, depending on the local environmental, economic and social characteristics.

- ***Technical measures*** promoting new vehicle, engine and fuel technologies would allow a significant reduction of emissions for every passenger-kilometre or tonne-kilometre (for a more detailed discussion of new technologies see also the two articles on these topics in this Special Issue). Although the cost of use has also decreased through impressive gains in fuel consumption efficiency, there is a lag in the adoption of such new technologies due to the cost of acquisition or replacement that has to be covered by users. In economic terms, even if the total social benefit of the substitution of older vehicles is higher than the total cost of implementation, the fact that users perceive only the latter acts as a counter-incentive for the renewal of the fleet. Without intervention, the full-scale adoption of current Best Available Technologies can take as much as 10-15 years, depending on the rate of vehicle renewal in each EU member state. The efficiency gains will also have a positive impact on economic growth (even if the costs of damage to the environment become a part of the bill). In addition, a faster adoption rate of new technologies will have indirect positive impacts for the sectors of the economy that are involved in their development and production. New **information and communication technologies** can improve the efficiency of the use of transport services, infrastructure and vehicles and, as a supplementary tool may enhance the success of other measures.

- ***Legislative measures*** can be successful in terms of achieving reduction goals as long as they are complemented with suitable technical or financial measures. The compulsory vehicle emissions standards and the withdrawal of leaded petrol in the EU are examples of such measures that can offer an improvement when acceptable alternatives exist. However, if applied independently, legislative measures can also have negative results, especially at local level, if adequate alternatives are not provided or if the resulting cost for the user is prohibitive. Given the need for a gradual application of the respective regulations, a legislative approach should be seen as a mid- to long-term process.

- ***Financial measures*** have the advantage of directly affecting users' choices and travel behaviour. Measures aiming to internalize the external costs of transport, in particular, can contribute significantly towards meeting environmental objectives (i.e. by also making the cost of transport reflect the cost/burden it imposes on the environment). Transport users will select more efficient alternatives if they have to pay the true cost of their actions. Not obliging users to pay the full cost of the environmental damage they cause is, from an economic point of view, equivalent to subsidizing inefficient practices. The removal of those indirect subsidies for private car use would certainly lead to lower emission levels in a short- to mid- term time horizon. As demonstrated by the AUTOOIL 1 & 2 programme, fiscal instruments tend to increase the success and lower the costs of technical measures.

- ***Planning measures*** for transport and land-use can have mixed impacts (such measures are discussed in the article "Air Quality Enhancement and Transport Management in

Policies aiming to lead to near-optimum, cost-effective solutions should concentrate on decoupling economic growth from the growth in emissions (including non-transport)

Mitigating the environmental impacts of transport requires a combination of technical, legislative, financial, planning and other transport demand measures

The high cost of transport infrastructure means that there is a long time lag before more efficient technologies are adopted

Urban Areas" in this special issue). New infrastructure that aims at reducing congestion often induces new traffic instead. Measures to promote public transport cannot easily compete with the users' preference for car travel, unless effectively combined with financial or legislative measures. Similarly, land-use policies often redistribute the problems instead of solving them. Most planning measures are in fact neutral as regards impacts on economic activity; they do, however, have an impact on the social dimension of transport and especially on transport equity issues. The impacts of such measures can often take 5-10 years to materialize and, since they are largely based on user acceptance and reaction, they are not easily predictable. Increasing **user awareness** of the true environmental costs of transport can be a useful supplementary measure but cannot solve emissions problems on its own (see brief note on initiatives included in this special issue).

As the case of unleaded petrol shows, legislative measures can be successful when acceptable alternatives exist allowing users to adapt

Not obliging users to pay the full cost of the environmental damage they cause is, from an economic point of view, equivalent to subsidizing inefficient practices

The impact of planning measures tends to be mixed and unpredictable and the effects of such measures often take 10-15 years to materialize

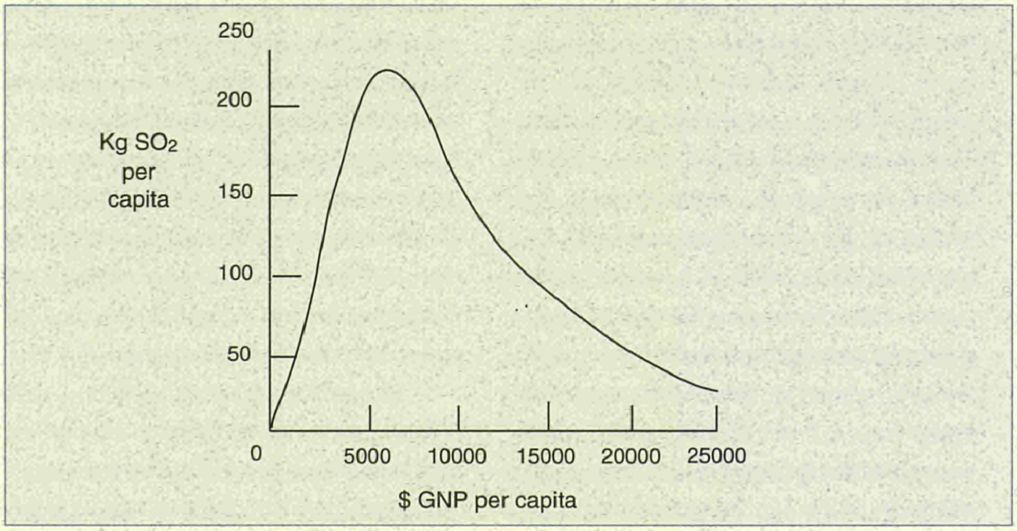
Achieving environmental goals

Transport emissions in urban areas can certainly be reduced with methods already existing today. The question is whether a reduction is feasible while maintaining desirable levels of economic growth and social acceptance. An absolute optimum solution of the problem of emissions is probably utopian, but near- optimum solutions can be found through the application of a cost-effective policy mix.

In urban areas --especially at times of congestion-- many trips by car may have a higher marginal social cost than the marginal social benefit they produce. The internalization of the external costs will allow the prices for transport services to reflect the true marginal social costs. Depending on the environmental, economic and social conditions in each urban area, a different policy mix is suitable for the minimization of transport emissions and the associated social costs. However, the need to protect economic activity and equity means that a part of the social cost of transport would need to continue to be borne by society as a whole. In practical terms, this means that a certain level of emissions will have to continue to be present.

Continuing economic growth may in fact have positive implications in terms of reducing emissions.

Figure 1. Environmental Kuznets Curves



Source: Grossman & Krueger, 1996; Panayotou, 1993

There is a large body of research showing that in some income ranges there is a positive correlation between per capita income and environmental quality. According to the "Environmental Kuznets Curves", a set of inverted U-shaped curves describing the pattern of levels of different pollutants relative to per capita income in various countries, environmental pressure increases up to a certain point as income rises. After that point, environmental quality increases as income continues to rise (figure 1). Although there are exceptions, i.e. pollutants that continue to rise at high income levels (e.g. NO_x), it is evident that income is an important parameter that determines whether a society can afford to combat pollution.

At all events, the internalization of external costs is a necessary first step. The levels at which the external costs will be internalized should depend on local conditions. Since the precise levels of external costs are not calculable, the most feasible way to internalize them seems to be the incremental increase of prices until the point when the environmental goals have been reached the "trial-and-error" approach). In the case of urban areas, the level of prices, the speed of implementation and the measures to be applied should be decided at local level. The availability of comparable, environmentally friendly alternatives should be also considered; equity issues may imply that alternatives such as public transport should be subsidized, ideally through the proceeds of car use related taxes. Equity considerations also demand that taxes or charges should be progressive, i.e. that tax rates should rise in line with incomes. In the same context, the implementation process should take into account regional differences. Specifications and limits should be applied gradually in order to allow time for the local markets to adapt.

Whatever the policy mix applied, --regardless of whether it emphasizes financial, technical or legislative measures, a large part of the cost will (and should be) paid by users. As a result the final prices paid for transport services will be higher and production costs will probably rise. At first glance such a development may seem negative for the economy but an efficient market may reach a new equilibrium at higher levels of economic activity. The improvement of environmental quality may increase the overall attractiveness of a city and the new economic activities that may be attracted as a result may offset the loss in economic activity that might result from the higher transport costs.

As already mentioned, the internalization of external costs of transport in fact transfers the costs of environmental damage to those inflicting it. The total social costs of production, also taking externalities into account, actually remain the same. If users adapt their behaviour and choose alternative transport services that pollute less, total social welfare will increase. In the long term, production patterns will change in order to avoid increased environmental costs --helped along by trends in the "new economy"-- and the increased production costs will be outweighed by the innovative production, and transport and distribution methods these higher costs induce.

The second positive implication for economic development is the enhanced attractiveness of a city where emissions have been reduced. Since environmental aspects are certainly a factor for location choice (and are increasingly gaining in importance as such), improved environmental conditions in a city can be expected to attract population and economic activity. Moreover, the new economic activities that will be attracted will normally be less transport intensive or less polluting (since otherwise their cost would be prohibitive). However, one of the main challenges for local authorities is to guarantee increased income and provide local benefits (e.g. through taxes, local consumption, etc.)

Transport emissions in urban areas can certainly be reduced with methods already existing today. The question is whether a reduction is feasible while maintaining desirable levels of economic growth and social acceptance

There is a large body of research showing that in some income ranges there is a positive correlation between per capita income and environmental quality

The improvement of environmental quality resulting from higher transport prices may increase the overall attractiveness of a city and the new economic activities that may be attracted as a result may offset the loss in economic activity that might result from the higher transport costs

It is important to reinvest the revenues generated by internalizing transport costs to ensure an effective increase in the operational efficiency of the transport system and gradual adaptation by the affected stakeholders

Conclusions

In general terms, mitigating the environmental impacts of transport in urban areas without reducing economic activity is feasible in the medium term. A combination of policy intervention and market forces can offer a solution to the problem of transport emissions. The internalization of the external costs of transport is one of the necessary conditions. Another condition is to reinvest the revenues of internalization to ensure an effective increase in the operational efficiency of the transport system and gradual adaptation by the affected stakeholders. It is also important that comparable transport alternatives are available and promoted, in order for the social aspects of transport to be safeguarded.

The problem of emissions cannot be made to disappear completely in the foreseeable future. As in most environmental issues, the problems will recur until production patterns change significantly. But if users have to pay a price that covers a large part of the marginal social cost they cause, it is reasonable to expect that the total social cost will eventually be substantially reduced.

From the point of view of the policy-maker, the subsidiarity principle limits the degree of direct intervention at EU level, which, however, is important in issues such as the targets for allowable emission levels. . The policy mix and the levels of cost internalization should be considered at all levels from European to local in order for local characteristics and priorities to be taken into account (e.g. the uptake of new technologies, and the renewal of the car fleet in particular, at state level, and city specific measures such as usage-based fees and congestion pricing at city level).

Keywords

transport, environmental impacts, economic development, decoupling principle, new transport technologies, sustainable development

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Air Quality Enhancement and Transport Management in Urban Areas

José Manuel Viegas, *University of Lisbon*, and Laura Lonza Ricci, *IPTS*

Issue: Existing transport planning and management schemes in urban areas are often hindering the process of transition towards economically attractive sustainable mobility. Planning and management of urban mobility are among the tools used to mitigate the impact of negative transport externalities, in particular, congestion and atmospheric pollution.

Relevance: Considerable attention has been —and continues to be— paid to the technological components involved in improving transport performance, such as vehicle technology and applications of ICT in the transport sector. Nonetheless, reducing congestion and air pollution is often equally a matter of finding appropriate organizational and collaboration schemes encouraging all actors in the urban transport and mobility sector to adopt new mobility patterns.

Dissuading potential drivers from using their cars in urban areas for some trips often depends on making public transport systems more attractive

Introduction

Dissuading potential drivers from using their cars in urban areas for some trips often depends on making public transport systems more attractive. This "attractiveness" comprises a number of different factors, such as safe and comfortable vehicles, convenient stops and interchanges, passenger information, reliability, flexibility and affordability. In the first part of this article we look briefly at supply-side measures aiming to achieve this. A selection of Transport Demand Management techniques are then presented, whose aim is to achieve modal shift by reducing dependency on the private car in urban areas.

The capacity to satisfy new challenges and to contribute positively to improving urban transport sustainability is closely linked to innovation leading beyond established patterns of "providing public services" and "doing business". That is, innovative organizational, regulatory and contractual measures are needed. The main body of the article looks at some promising solutions and highlights their strengths and weaknesses in the application cases.

Finally the conclusions draw upon the preceding sections and discuss the ability of the innovative organizational patterns presented to match actual users' needs. Some additional remarks are introduced on the evaluation and the perception of quality of life in urban areas.

Measures to curb car dependency

In this section we will look at supply-side measures to encourage the use of modes of transport other than the private car. The three main areas briefly covered are: land use planning; increased attractiveness of public transport via higher reliability, greater comfort and flexibility of choice of modes of transport, and tax schemes internalizing the external environmental costs of the private car.

Integrated Land-Use and Transport Planning

The functional compartmentalization of land-use has favoured segregated use of land, thereby increasing journey distances and hence the travel needs that have to be met to satisfy the prime aim of mobility, namely getting someone somewhere for some purpose. Sprawl poses a problem of equal possibilities of access for those with and without a car. Moreover, the outward spread of cities poses a threat to the viability and vitality of traditional urban centres.

The mixed use of land characterizing urban areas in Europe needs to be preserved and this represents a key aspect of urban policies. Integrated land-use and transport planning is a very important means to achieve the goal of balanced and mixed use of land in urban areas. Modelling tools have been developed to offer integrated solutions and to facilitate the task of planners in both areas of intervention[1]. On the transport planning side, providing easy modal transfer opportunities is a crucial part of giving citizens an incentive to get out of their cars and use public transport.

Alternatives to the private car via increased attractiveness of public transport

A convenient mix of land-uses allowing easy access to services needs to be backed up by the availability of alternatives to the private car. To be attractive the public transport system needs to be reliable both in terms of timing and the information given to customers. Introducing some form of compensation for excessive delays is one way of increasing users' confidence in the system[2]. Being on time is not usually a bottleneck for modes not affected by overall traffic conditions, but it is a very serious problem for bus systems, especially in areas where frequency of service is not so high as to justify a reserved lane. A promising solution in such areas is the introduction of *intermittent bus-lanes,* where bus priority is given based on time-specific traffic conditions. The best signalling technique to use for intermittent bus-lanes has yet to be decided: it could be a series of switching lights on the road surface along the lane separation (like in airports), but this is an expensive solution. A possibly feasible alternative could be a type of fibre that would change colour when it gets an electric current through it. (Viegas and Baichuan, 1999).

Waiting for the bus can be made more pleasant by putting better shelters at stops, with capacity matched to the actual demand from users. This is also an investment with an easy return if space is let for use as advertising displays. Waiting time can also be reduced by means of *bus express services* (or shuttles), whereby faster buses are run on busy routes during peak hours by reducing stops[3]. Users could also have access to *bus-alert systems* by which registered customers are informed in advance about the fact that their bus is approaching so they can reach the bus stop from the work place or home. This solution would squeeze waiting times and associated uncertainties, one of the major deterrents to shifting from the car to public transport[4]. At a later stage, seat reservation could be made possible with the same solution.

Integrated ticketing and a wider variety of ticketing schemes increase the attractiveness of public transport by expanding the range of convenient options for users, based on the

Urban sprawl threatens the viability of traditional urban centres and limits access for those without cars

To be attractive the public transport system needs to be reliable both in terms of timing and the information given to customers

Integrated ticketing and a wider variety of ticketing schemes can increase the attractiveness of public transport by expanding the range of convenient options for users, particularly in view of the fact that travel patterns are increasingly diversified and non-repetitive

Current vehicle taxation schemes tend to be based largely on a one-off purchase tax on a new vehicle and a flat-rate annual road tax, and so fail to take into account the actual usage or level of pollution caused

Transport demand management schemes have so far obtained somewhat unsatisfactory results, partly due to the "all-or-nothing" approach adopted, which fails to take into account the fact that users change their choice of optimal mode of transport depending on their immediate needs

consideration that travel patterns are increasingly diversified and non-repetitive. For instance, *frequent (but not daily) passengers* are hardly considered by current ticketing schemes which are more often tailored to the needs of daily travellers. This might be addressed by offering significant discounts for tickets valid for 20 non-consecutive days of travel (Viegas, 2000), for example. Such tickets for frequent, but intermittent, travellers could be sold as such or combined with discount tickets for complementary forms of travel such as parking in the city centre and kilometres of taxi travel. This would encourage more flexible modal choices and constitute a powerful instrument for market segmentation in urban mobility (Ampelas, 1998).

Pricing Schemes

A classification scheme could be introduced rating vehicles according to their environmental impacts[5], along the same lines as the scheme for rating the energy efficiency of refrigerators, for example. Such a classification would need to be compulsory and the rating would have to be clearly displayed on vehicles both at the time of sale and when on the road. The rating could then be checked during compulsory annual roadworthiness checks. Current vehicle taxation schemes tend to be based largely on a one-off purchase tax on a new vehicle and a flat-rate annual road tax, and so fail to take into account the actual usage or level of pollution caused. A shift away from this approach would encourage more frequent vehicle replacement and more flexibility by car-owners to the use of other modes of transport. Similarly, road-pricing schemes could be adapted to the category of emissions characterizing each vehicle.

Transport Demand Management Techniques

In this section we look at curbing car dependency in urban areas from the transport demand side. However, a comprehensive analysis of Transport Demand Management techniques is not feasible in such a short article. We have therefore limited the points covered to a number of considerations mainly regarding urban road pricing, due to the growing interest in its application throughout Europe[6].

Transport demand management schemes have so far obtained somewhat unsatisfactory results, partly due to the "all-or-nothing" approach adopted, which fails to take into account the fact that users change their choice of optimal mode of transport in view of their immediate needs. Thus, the private car may prove the ideal solution on a given day whereas public transport could be preferred (or at least accepted) on other occasions. But mixed approaches have only rarely been tried. The modal mix of integrated tickets, as outlined in the previous section provides an example of this approach.

With regard to road pricing schemes, equity considerations need to be taken into account. Where road pricing exists, it would seem reasonable to allow local taxpayers a given amount of free access to the city centre in the form of "mobility rights" they could use with a variety of modes of transport, including the private car, public transport and taxis. This would allow citizens to customize transport modes used on the basis of varying mobility needs (Viegas, 1998).

Road pricing schemes should also allow for flexible rates depending on anticipated congestion and pollution levels so as to stimulate optimal use of the transport network. Variable rates, though, typically lead to time shifts rather than modal shifts by users and therefore tend to fail to have an impact on car dependency. One underlying problem is that under current car taxation schemes adopting a variety of modes of transport implies an economic penalty for the user. As suggested above, a taxation scheme based on usage and contribution to pollution levels would change the current logic of the choice of transport mode and, therefore, facilitate multimodal travel patterns, providing that reliable information is available to users.

Innovative Regulatory Measures

In this section we will look at some of the particular issues facing European administrations responsible for urban areas. Because these institutions need to operate within the bounds of various regulatory and administrative frameworks, there can be no single approach applicable to all cases. Our aim here is rather to provide examples of innovative solutions to the problem of mobility in urban areas by presenting it from three different viewpoints: the role of local authorities, public transport regulation, and supporting market segmentation.

The most important step forward in taking an innovative approach to urban mobility management to consider the urban mobility system as a whole. Sectorial approaches to transport planning and management in urban areas have tended to cause inconsistencies and, indeed, problems mainly due to an unbalanced consideration of the transport system's components.

An integrated approach to the urban transport system is motivated not only by the consideration that common resources are shared by both public and private transport modes (for example, road space) but also by the fact that different transport modes have to be seen as complementary to each other rather than purely competitive (Reichart, 1997). In practical terms, this means that the overall competence for mobility issues should be allocated to a single unit within the local authority and that appropriate coordination schemes should permit joint action across levels of authority.

At the level of the local authority responsible for mobility, consistency has to be ensured with land-use planning (Wickham, 1999). Although transport planning and management and land-use planning are each characterized by their own specific factors, it obvious that they exert an influence upon one another. That is why closer collaborative links should be established between the administrative services responsible. In particular, it is recommended that despite the fact that merging transport and urban planning departments does not seem to provide a viable option, policy guidelines should be the same so as to provide coherent objectives and strategies to achieve them. In fact, the political responsibility for both areas should preferably be concentrated in one person (the councillor for mobility and land-use planning).

The urban system cannot be considered in isolation and the interfaces between local and regional, national and international transport networks by different modes should be planned and managed in a collaborative manner[7]. Mobility and transport-related environmental problems at the local level are partly induced by non-local traffic and this seems to be an area where technological innovations can provide the tools with which to stimulate the innovation of regulatory frameworks and collaboration patterns vertically at different levels of competence (i.e. local, regional, national, EU).

Concentrating the competence for urban mobility planning and management in one unit of the local authority is not likely to produce fruitful results unless financial responsibility is not clearly allocated to the local authorities themselves. That is, there must be clear cut responsibility for the urban mobility costs attributed to the actor in charge of regulating urban mobility, i.e. the local or metropolitan area authority. The intervention of higher levels of public authority in urban mobility

An integrated approach to the urban transport system is motivated not only by the consideration that common resources are shared by both public and private transport but also by the fact that different transport modes have to be seen as complementary to each other rather than purely competitive

Overlaps between local transport policy and urban planning, and regional, national and international transport networks, all need to be taken into account

Contracts should be used for transport services even where they are provided by public operators so as to specify clearly the aspects and parameters used to assess the quality and the overall performance levels of the service

Operators should be allowed to use their initiative to stimulate market segmentation within the urban mobility system. Closer contact with users and, hence with the market, puts them in the position of being able to identify potential needs and so launch additional services effectively

matters should be limited to participation in investments or in sharing the responsibility for the "grey areas" of urban mobility, i.e. the areas where they overlap with long-distance transport networks.

As highlighted in the previous section of this article, public transport has a fundamental role to play in providing alternatives to transport end-users and curbing car-dependency in urban areas. Therefore, the relationship between the body with overall competence for urban mobility matters and public transport operators should be defined precisely. Contracts should be used even if operators are publicly owned, so as to specify clearly the aspects and parameters used to assess the quality and the overall performance levels of the public transport service. Concrete consequences for the application of the assessment criteria for the service should also be foreseen in terms of incentives and penalties.

Competitive pressure should be applied to all public transport operators, either directly through tendering the concessions for certain lines based on clear quality and performance requirements, or indirectly through benchmarking (for instance between publicly owned and managed operators and private operators managing tendered bits of the public transport network). In cases where indirect competitive pressure has negative results, concrete actions should be taken, such as tendering new sections of the network so as to bring in direct competition.

Interfaces between transport modes are of the utmost importance, as briefly mentioned above when referring to local and long-distance transport networks. The same holds true at the local level for modal shifts. The public transport network has to be planned in a way that is consistent with the other modes and, once again, this suggests the need for a single body or agency in charge of urban mobility.

The considerations expressed above regarding the desirability of bringing the competence for urban mobility – and land-use planning although with somewhat looser links - to a coherent unity and the value of having the local authority define in detail the service characteristics and performance requirements to be provided by operators, should not lead to the conclusion that operators' hands should be tied.

Operators should be allowed to use their initiative to stimulate market segmentation within the urban mobility system. Closer contact with users and, hence with the market, puts operators in the position of being able to identify needs and launch additional services (either in public transport only or in combination with private transport) at their own risk (and for their own gain) and subject only to the verification that they do not represent a threat to overall mobility policy, the integrated approach to mobility management, or the performance of other operators. Such a position by the local authority should ensure that citizens' needs are met optimally.

Since the launch of new initiatives not included in the contractual clauses of agreement with the public authority implies costs and risks, successful innovations introduced by operators should receive incentives going beyond the additional revenues generated. For instance, it could be possible to foresee some kind of "patent rights" for a limited time period (3 to 5 years), which could be traded for an extension of the basic contract of the innovative operator, should the public authority consider it worthwhile to apply the innovation to the whole public transport network.

Conclusions

When looking at urban mobility patterns, negative externalities of high car dependency both in terms of time wasted (congestion) and quality of life (poor air quality and noise, among other things, but also limited access for non-drivers) stand out. Technical improvements are partially helping to improve the picture but are more often than not rapidly offset by a reinforcement of the trend towards even more car-dependency and increased sprawl.

Non-technical measures have been identified as the cornerstone of the problem and a number of considerations have been formulated looking at both supply-side measures and demand-side management techniques. Most of the solutions proposed are being applied or are under preparation. Additionally, new approaches to vehicle taxation could be looked at.

Nonetheless, specific measures do not provide the overall solution to improved urban mobility management. Institutional frameworks need to be rethought carefully, but without imposing solutions which are foreign to the culture and the tradition of the specific place considered. That is why suggestions made in the second section of the article cannot be generalized easily. However, what can be generalized is the fact that the fragmented allocation of competence to different departments of the public authority concerning mobility does not provide satisfactory answers to mobility problems.

The ideas and schemes presented here are not intended to constitute a recipe for guaranteed success in improving quality of life in any urban area in particular, but it is hoped they may provide some useful ideas for local actors seeking to put together their own policy mix. If studied and implemented carefully, such mixes should at least help reverse the trend for ever increasing use of the car in our cities, and ever deteriorating quality of life for urban dwellers (DETR, 2000).

Keywords

urban mobility management, public transport, innovative organizational solutions

Notes

1. MEPLAN model and the SPARTACUS project (ENV 4960201, 4th RTD Framework Programme); TRANUS model (more information available at: **http://www.modelistica.com)** and the PROPOLIS project (5th RTD Framework Programme).

2. In Oslo, the public transport company offers its customers the possibility of claiming a refund, either using a form available on the web or by contacting one of the AS Oslo Sporveier's customer service centres (see: **http:www.sporveien.oslo.no**).

3. This is a fairly common practice. In Bristol, for example, a number of express buses are operated by the local bus company (see: **http:www.pti.org.uk/bristol/bus.html**).

4. The Public Transport Company in Lisbon is currently studying such an option, which requires that buses - possibly the whole fleet - are equipped with fleet location devices (e.g. GPS).

5. The UK Government has introduced a graduated charge for road tax, to reflect the importance of fuel consumption to the environment. From 1 June 1999, cars with an engine size smaller than 1100cc only have to pay £100 per year, instead of £155. This scheme is being extended in 2000 to charge road tax for new vehicles on the basis of their carbon dioxide emissions. A clear label with information on carbon dioxide emissions could show purchasers how much road tax they would have to pay each year. More information is available at: **http://www.roads.detr.gov.uk/cvtf/driving/1.html**

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6. Several European cities have introduced road-pricing schemes or are in the process of doing so. Norwegian cities, namely Oslo and Trondheim, have been among the forerunners. A number of recently started EC-funded projects such as PROGRESS aim at integrating road pricing, public transport ticketing and parking management schemes.

7. For additional information on non-technical institutional co-ordination issues the reader can refer to the results of the CARISMA-Transport Concerted Action, funded by DG TREN in the 4th RTD Framework Programme.

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Laura Lonza Ricci holds a university degree in International and Diplomatic Sciences, specialising in International Economics from Trieste University (Italy) and an MSc in Environmental Management and Land Use Planning from Université Libre de Bruxelles. She has gained international working experience with the POLIS association of European cities and regions for transport innovation, which enabled her to become familiar with local and regional policy and technological issues in the mobility sector. Her main field of activity as a Grantholder at the IPTS includes the analysis of institutional co-ordination mechanisms to achieve integrated urban mobility.

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BRIEF NOTE

European Networks for Air Quality and Sustainable Mobility

Laura Lonza Ricci, *IPTS*

EU policies are dedicating increasing attention to the urban dimension of mobility in the context of sustainable development. The European Commission has been supporting local initiatives to exchange information and expertise, raise awareness as well as to benchmark experiences across Europe.

A non-exhaustive overview of some of the most relevant actions focussing on urban mobility is briefly presented below.

Car Free Cities is a local authority network bringing together over 65 European cities from both EU and non-EU countries and aiming to promote a new mobility culture. The network's main priority is to improve the quality of urban life for all citizens by advocating the sensible use of the private car, raising awareness amongst decision makers and citizens of the negative effects of urban traffic on the environment, health and society, while changing mobility behaviour and encouraging the implementation of sustainable mobility policies and measures at the local level.

Politically, Car Free Cities' members are committed to transforming the network into an operational mechanism, a process geared towards improving the quality of life in cities. The Copenhagen Declaration adopted during the Annual General Meeting in Copenhagen (1996) represents this political commitment.

The network pursues these objectives by acting as a forum for influencing EU policy-making; facilitating the exchange of ideas and experience, as well as the transfer of know-how; pooling experience and disseminating good practice; helping cities to identify practical solutions and implement specific projects.

The technical work of the network is undertaken by 6 working groups which deal with the most important issues concerning urban mobility: Cycling & Walking; Commercial Traffic; Commuting; Public Transport; Practical Alternatives to the Car; Use of Less Polluting Urban Vehicles.

Launched in 1994 in the context of the Fifth Environmental Action Programme "Towards Sustainability", the network is a joint initiative of the European Commission and Eurocities.

The **European Car-Free Day** follows the "in town without my car" day inaugurated by France in 1998 and observed successfully in 66 French and 92 Italian towns (plus six Swiss towns) with the financial support of the Life-Environment programme. Of the 22 million individuals who participated in this campaign, 80% expressed the wish to see it repeated regularly in the future.

The funding by the European Commission's LIFE programme (1 million euros), 50% of the cost, is being given to five partners: the Energy Agencies of France and Italy, the Car Free Cities network of local authorities, to Energie-Cités (Besançon) and the German NGO Klimabündnis.

Cities such as Strasbourg, Ferrara, Bremen, Graz and Edinburgh along with their Nordic and Dutch counterparts have demonstrated that it is possible to have town planning and transport systems which stabilize or even reduce the use of individual cars without threatening economic growth.

The "European Car-Free Day" operation, scheduled for 22 September 2000, was kicked off on Friday 4 February in Brussels by the European Commission and the nine Member States already involved in the initiative. The operation has a threefold objective: to raise the awareness about the urgency of changing urban mobility patterns and the advantages of a car-free environment for the quality of life and the environment; to create a platform for dialogue and information on the development of transport plans; to enable local communities to test new measures in situ (gas-powered buses, pedestrian zones, cycle paths, electric cars, etc.).

At the kick-off conference, Margot Wallström, European Commissioner responsible for the environment, and Ministers José Socrates (Portugal), Dominique Voynet (France), Edo Ronchi (Italy) and Isabelle Durant (Belgium), signed a "European Car-Free Day Pact" in which they undertook to facilitate organization of the event by local authorities and invited fellow Ministers from other Member States to join them in this initiative.

The **European Sustainable Cities & Towns Campaign** was launched at the end of the First European Conference on Sustainable Cities & Towns, held in Aalborg, Denmark in 1994. To date, more than 700 European local and regional authorities from 34 European countries have signed up to the Aalborg Charter. With this number of participants, the Campaign is the biggest European initiative for local sustainable development and the Local Agenda 21.

The Lisbon Action Plan, adopted at the Second European Conference on Sustainable Cities & Towns (Lisbon, October 1996), provides a basic framework to support local and regional authorities striving for sustainable development. In 1998/99, a series of four regional conferences held in Turku (Finland), Sofia (Bulgaria), Seville (Spain), and The Hague (Netherlands) addressed specific issues and made an important contribution to the promotion of Local Agenda 21 and sustainable development across Europe.

At the Third Pan-European Conference on Sustainable Cities & Towns, held in Hanover in February 2000, a strong political message was given through the Mayors' Convention and its final document, the *Hanover Call of European Municipal Leaders at the Turn of the 21st Century*. The EU Environment Commissioner Margot Wallström presented a draft proposal for a *Community Framework for Co-operation to promote sustainable urban development* (COM(99)557).

Moreover, the initiative **"Towards a Local Sustainability Profile – European Common Indicators"** was launched based on a list of indicators developed by the European Commission's Expert Group on the Urban Environment. The work will continue at a workshop organized in Seville on 5-6 October 2000. Monitoring transport behaviour and air quality in urban areas is an important part of integrated management using indicators to identify trends and assess policy performance. It is important that public authorities participate in European-wide indicator initiatives so that they can identify strengths and weaknesses based on comparison with other authorities and best practice can be disseminated in urban areas across Europe.

Urban environment has been the theme for the informal meeting of the EU environment Ministers held in Oporto in April 2000. A document entitled *"Towards an urban environment policy"* acted as a basis for the debate that the Presidency wants to dedicate to a subject of interest and major preoccupation for the quality of life of European citizens.

Noise, air quality, the enjoyment of public spaces, the promotion of alternative solution to conventional transport, the active participation of citizens and local authorities in urban planning and management occupied a place of choice. Through the debate, the Presidency hopes to bring a useful contribution to the preparation of the 6th Action Programme for the Environment and Sustainable Development that should grant particular importance to the promotion of the sustainable urban environment and the monitoring of policies through "urban sustainability" environmental indicators.

The reflection document advocates a strategic approach for sustainable urban development, steered by guidelines and clearly defined objectives that take into account the interdependence of the multiple factors at stake and enable politicians to effectively take on ten challenges, among which the promotion of sustainable transport represents a priority.

ELTIS and the Citizens Network Benchmarking Initiative recently launched by DG TREN as an expansion of the European Local Transport Information Service (ELTIS) aims at offering support to European local authorities providing them with a support tool for comparing their performance with that of other urban areas across Europe. The goal is that of helping local authorities identify their strong and weak points

The aim of ELTIS, launched by DG TREN in 1997 as part of the follow-up to the Citizens' Network Green Paper, is to support a practical transfer of knowledge and exchange of experience in the field of urban and regional transport in Europe and so help create a more sustainable living environment, by ensuring greater accessibility and mobility to its inhabitants. ELTIS provides facts and illustrations on urban and regional transport activities in Europe. The ELTIS database incorporates an ever-growing number of transport case studies, concepts and documentation. ELTIS allows users to add information to publicize and disseminate the results of local transport measures and projects implemented in their city or region. The ELTIS Forum provides a platform to participate in the debate on the latest European transport policies and tools.

The **European Platform for Mobility Management (EPOMM),** founded in 1999 under the auspices of DG TREN of the European Commission, aims to promote and further develop mobility management in Europe and seeks to fine-tune its implementation in European countries by providing a forum for EU member governments, local and regional authorities, researchers, major employers, transport operators and other user groups. The establishment of a "European vision" of mobility management needs permanent interaction with the local level to ensure a dynamic approach and to stimulate evolution, which is done via the activities of EPOMM National Focal Points (NFP) as its decentralized operational arms. The NFP ensure an optimal information flow from the European Platform to the national/ local level and vice versa.

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BRIEF NOTE

Clean Air: Emissions and Health Effects A Cluster of projects at the JRC

Giovanni de Santi, *JRC*

The growing complexity of issues involved in the air quality policy-making requires advanced expertise on a number of scientific fields. It is required to assess the quality of air; to characterize emissions from a variety of sources and to understand their complex interactions; to evaluate emissions effects on human health; and to identify the most cost-effective reduction measures. Furthermore, an integrated approach is necessary to take balanced policy decisions and to prevent mitigation measures shifting pollutants from one media to another or producing contradictory or rebound effects.

In this context, there is a clear role for a scientific institution such as the Joint Research Centre (JRC), in supporting European policy-making in this area. The JRC has recently launched the concept of Clusters to group various projects targeting similar policy issues in order to achieve synergies, critical mass and efficiency. Thus, a Cluster concerned with emissions and health effects has been created, bringing together the JRC expertise in this field across its various institutes (see table A1).

Scope of the Emissions Cluster

The Emissions Cluster is in line with the Commission's new policy to provide a comprehensive strategy for the management of air quality and control of emissions from mobile and stationary sources (forthcoming CAFE programme; "Clean Air for Europe"). The aim of this group of projects is to contribute to this multidisciplinary issue by targeting problems related to emissions through close inter-institutes collaboration. This will result in a recognized position in relevant areas of formation, reduction, dispersion, measurement and impact of emissions.

The Cluster's research in this area will back-up European legislation, national research organizations and industry by utilizing advanced facilities and a combination of competencies. This will make a significant contribution to the development and validation of emission reduction technologies, emission measuring methods, standardized tests, modelling and the evaluation of health effects.

In addition the long-standing experience in the field of setting up, managing and operating European networks allows it to interact closely with industrial players as well as with research centres in the member states. This allows a more effective and efficient European approach to the issue by coordinating dispersed efforts, ensuring dissemination of information, transfer of knowledge and allowing for easier implementation of policies.

Furthermore, because of JRC's independent position as the corporate research centre of the EC,

Table A1. Policy needs and JRC expertise regarding emissions, air quality and health effects

AIR QUALITY POLICY NEEDS	JRC EXPERTISE
Characterization (off-line) • emissions • sources • health effects	**Environment Institute** • European Reference Laboratories on Emissions (ERLIVE) • Integrated Air Quality Assessment (IAQA) • Environmental Integrity and Human Health
Monitoring & control (on-line) • direct & indirect measurement • source identification • modelling & indicators	**Institute for Health and Consumer Protection** • Chemical Products, Risk Assessment (ECB) **Institute for Systems, Informatics and Safety** • Modelling and decision support systems
Reduction measures • technical • non technical	**Institute for Advanced Materials** • Technologies for emissions abatement in transport (projects TEMAT, & ECRIT) • Clean technologies
Cost-effectiveness of reduction measures • economic impact - implementation costs - competitiveness • social impact - accessibility & quality of life - equity	**Institute for Prospective Technological Studies** • Best available techniques as support to the IPPC directive (host of EIPPCB) • Transport and mobility: Integrated analysis of sustainability issues

the Cluster can provide unbiased advice in the interest of European citizens and European industry.

Issues covered by the Emissions Cluster

The JRC has already demonstrated expertise in emission related areas such as measurement of emissions and air quality, its impact on health, testing and assessment of emission abatement technologies and techno-economic analysis. The scientific background is therefore in place to provide a scientific basis for sounder and more dependable policy-making.

The Emission Cluster covers nearly all important aspects in this field. Starting from the emission sources, projects work on the evaluation and assessment of abatement technologies. The project on Technologies for Emission Abatement in Transport (TEMAT) focuses on critical engine components and the influence of materials in the transport sector. The EPG, Efficient Power Generation - Power Plants and Gas Turbines as well as the Safety and Reliability of High Temperature Systems (SAFTS) study the influence of corrosion in incinerators and power plants.

A new European Reference Laboratory on Vehicle and Waste Incineration Emissions (ERLIVE) has been set up for the physical and chemical characterization of emissions from vehicles and waste incinerators and the study of their impact on human health. It includes a full-scale vehicle test facility and a pilot scale incinerator for the harmonization and standardisation of emission measurements and test cycles.

Air quality measurement and modelling have a long tradition at the JRC. The European Reference Laboratory for Air Pollution (ERLAP) was already set up in 1994. Within the Integrated Air Quality Assessment (IAQA) project it supports the formulation, implementation and monitoring of environmental legislation dealing with air pollution. Particular attention is given to the assessment of air-pollution levels and the validation of air-monitoring techniques. Modelling of pollutants, their transport and transformation is performed on a European basis supporting the Auto-Oil-I/II programmes and the new CAFE programme.

The experience in risk assessment, health effects and toxicology are concentrated in two projects on Chemical Products, Risk Assessment and Environmental Integrity and Human Health. Their contribution will focus on the comparative toxicological evaluation of particulate emissions from stationary and mobile sources.

Two projects particularly address the sustainability aspects of mobile and stationary emission sources. The Transport and Mobility project carries out simultaneous analysis of social, economic and environmental issues raised by transport. The European Integrated Pollution and Control Bureau (EIPPCB) project specifically supports the Environment DG in the implementation of Directive 96/61/EC concerning integrated pollution prevention and control, which lays down a framework requiring Member States to issue operating permits for certain stationary industrial installations. The Directive requires that conditions within these permits are based on Best Available Techniques (BAT) to protect the environment as a whole taking account of costs and advantages.

Future Research Activities at the JRC

Future work at the JRC will continue considering emissions from transport, from industry and from waste incineration. In each case the issue of reference methods, harmonization of procedures, sampling, automatic monitoring and impacts will be considered in direct support to existing and future directives. In the transport sector new air quality criteria will be developed taking into consideration results of air pollution research. The potential for emission reduction from a wide range of sources will be assessed. Work will be conducted on the emission reduction potential of various fuels and engine types. In the waste sector, JRC work will focus on the development, assessment and modelling of advanced emission control and reduction methodologies. The JRC will expand its work on the use of biomarkers to support epidemiological studies and in view of developing a unified European approach.

About the author

Giovanni de Santi obtained a Mechanical engineering degree at the University of Pisa (UNI-Degree). Ph.D in fluid dynamics at Technical University of Munich. Over 20 years experience in chemical engineering, heat-transfer and aerosol physics. Responsible at JRC-Environment Institute of the Clean Technology Sector. Manager of the ERLIVE Project, the European Reference Laboratory on Vehicle Emissions for the physico-chemical characterisation of pollutants emissions from stationary and mobile sources, with the evaluation of related health effects.

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- ADIT - Agence pour la Diffusion de l'Information Technologique - F
- ARCS - Austrian Research Center Seibersdorf - AT
- CEST - Centre for Exploitation of Science and Technology - UK
- COTEC - Fundación para la Innovación Tecnológica - E
- DTU - University of Denmark, Unit of Technology Assessment - DK
- ENEA - Directorate Studies and Strategies - I
- INETI - Instituto Nacional de Engenharia e Technologia Industrial - P
- ITAS - Institut für Technikfolgenabschätzung und Systemanalyse - D
- MERIT - Maastricht Economic Research Institute on Innovation and Technology - NL
- NUTEK - Department of Technology Policy Studies - S
- OST - Observatoire des Sciences et des Techniques - F
- PREST - Policy Research in Engineering, Science & Technology - UK
- SPRU - Science Policy Research Unit - UK
- TNO - Centre for Technology and Policy Studies - NL
- VDI-TZ - Technology Centre Future Technologies Division - D
- VITO - Flemish Institute for Technology Research - B
- VTT - Group for Technology Studies - FIN