New Technologies, Industry Developments and Emission Trends in Key Sectors: The Land Transportation Sector

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The Concept of Sustainable Transport

Sustainability means capable of being continued. Sustainable transport means finding ways of meeting transportation needs that are environmentally sound, socially equitable, and economically viable in the long term.

To be economically sustainable, transport must be cost-effective and continuously responsive to changing demands. Cost-effective transportation is not easily secured because travellers are not directly confronted with many of the overall social costs associated with transportation. The combination of externalities and a lack of pricing of road space often gives rise to traffic congestion, a significant problem in many of the larger cities of the advanced economies (the net social costs of traffic congestion are estimated to be between two and three per cent of GDP in the advanced economies)[1] and an acute problem in many third world megacities (notably Bangkok, where costs could be as high as 8 per cent of regional gross product, and Mexico City).[2]

Socially, sustainable transportation systems should provide safe access and livability for all sections of the community. Transportation is of vital importance for all groups in the community for accessing jobs, education and health services. Accessibility is attained through the provision of comprehensive and affordable transport services. Most major cities in the APEC region have failed to meet this objective (APEC Center for Technology Foresight, 2000). Injury and death caused by road accidents is an important social cost associated with transportation, leading to losses estimated at between two and four per cent of GDP in the advanced economies (OECD 1997a).

Environmentally sustainable transportation systems should: a) use energy resources and other natural resources at a rate not larger than rates of renewal of those resources; b) produce no more waste than can be accommodated by the planet's restorative ability; and c) make use of land in a way that has little or no impact on the integrity of ecosystems. At present, transportation systems in virtually all the major APEC cities fail to meet these criteria. Local air pollution, largely associated with the use of the motor vehicle, is one example of unsustainable transportation and could contribute as much as three per cent of GDP in terms of health costs in some cities in the advanced economies (ECMT, 1998). The range of problems associated with transport emissions is greater in the cities of emerging economies because of the greater use of high-polluting vehicles and fuels. Air pollution generated by city traffic can also have an impact on substantial regional areas. Emissions of sulphur and nitrogen compounds from transportation can lead to acidic rainfall, and contribute to acid fog and snowfall (OECD, 1996b).

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[1] OECD (1997a).

[2] Khomnamool (1999) and Pendakur (1995).

Pollution from motor vehicles produces about one-fifth of the incremental carbon dioxide in the atmosphere arising from human activity (which potentially contributes to global warming) and one–third of the chlorofluorocarbons (CFCs; these contribute to the depletion of the ozone layer). The global environmental effects of greenhouse emissions from transportation are estimated to be between 0.3 and 0.6 per cent of GDP (OECD, 1997a, ECMT, 1998).

The transport sector now accounts for more than 60 per cent of global consumption of oil products. Current high rates of oil consumption by the transport sector are inconsistent with the maintenance of secure global oil supplies in the long term(OECD, 1995).

The Drivers of Change

The threat of increasingly unsustainable transportation systems in the large cities of the world comes from the interaction between growing demand for transportation services and the environmental impact of transportation. Demand tends to grow at a geometric rate, while the environmental capacity (at given technologies) to handle such growth is fixed. Technology offers enormous possibilities for change in the longer run, but unless harnessed to the goal of sustainability, may aggravate some problems (such as traffic congestion) while in the process of fixing others (reducing emissions per road vehicle kilometre).

The demand for transportation services in the cities of the advanced economies tends to rise at a similar rate to the rise in real incomes. In the developing economies, demand for transportation rises much more rapidly for a number of reasons: the income elasticity of demand is usually well in excess of unity; per capita incomes are rising more rapidly than in the advanced economies; and urbanisation rates are rising more swiftly. In most countries, demand for travel is less responsive to prices than to incomes, and road vehicles account for an increasing proportion of total traffic (APEC Center for Technology Foresight 2000). The OECD has prepared projections which indicate that, between 1990 and 2030, there will be an increase of 79 per cent in kilometres travelled by all vehicles within the OECD countries, and a rise of 312 per cent for countries outside the OECD (OECD 1996).

The growth in urban traffic generates increasing waste outputs, assuming given technologies, which give rise to a range of environmental problems, local, regional and global. In practice, changes in vehicle technologies have led to some improvements in local air pollution, particularly in the advanced economies, and mainly with respect to emissions of carbon monoxide and lead. On current prospective trends, problems with emissions of nitrogen oxides, volatile organic compounds and suspended particulate matter will present health problems for a broad range of cities. Such emissions pose considerable health risks, ranging from respiratory ailments through to heart disease and cancer. The transport sector remains the principal area of concern with respect to global warming. CO_2 emissions from transportation continue to increase strongly as increasing vehicle-kilometres travelled more than offset improvements in energy efficiency. Finally, the transport sector is the major dynamic contributor to rising demand for crude oil, supplies of which have finite limits and can, at times, be subject to political uncertainties (APEC Center for Technology Foresight 2000).

The Impact of Technological Change

A number of key influences are driving a process of accelerating technological change in land transportation. **Traffic congestion** is encouraging new technologies to be adopted in traffic management. Concerns about **traffic safety** are leading to a consideration of new technologies, particularly road design and automated vehicle control. The **availability and price of crude oil** is encouraging research and development on fuel economy, the use of alternative fuels, and the development of fuel cell-powered engines. **Air pollution** problems in urban areas are encouraging the development of technologies to reduce harmful emissions, and concerns about **global warming** are further adding to the search for low-emission transportation. These concerns are also reflected in the adoption of new **regulatory policies** by governments in such areas as fuel standards and fuel economy standards for new motor vehicles.

The acceptance that radical new technologies will be required to achieve sustainable transportation in the coming decades is widening and deepening. Most significant has been the changing stance of the major motor vehicle producers. They are now investing heavily in research and development on alternative technologies. The public comments of the Ford Motor Company have been particularly prominent. In 1999, Ford published a specially commissioned study (Schuetzle and Glaze, 1999) which discussed future scenarios for new technologies that would meet growing transportation demand while minimising energy and environmental impacts.

Motor Vehicle Technology

Technological change impacting upon transportation can take many forms. It can change the design and operational characteristics of transport. It can impact on how vehicles are used and maintained and it can offer new possibilities for traffic management.

The potential for reformulating petrol to reduce other pollutant emissions has attracted considerable research over the past decade. The most significant potential emission reductions that can be achieved by reformulation are reducing volatility (to diminish evaporative emissions), reducing sulphur (to improve catalyst efficiency), and adding oxygenated blend stocks (thereby reducing the need for high-octane aromatic hydrocarbons).

In the future, ethanol, methanol and biogas have increased prospects for use in cars and trucks designed and built to be operable on different types of fuel. Piston engines in conventional motor vehicles can be adjusted to run on alternative fuels (such as ethanol and methanol) which reduce nitrogen-oxide emissions. A new technology known as the flexible-fuel vehicle is being developed (Volkswagen is a leader) which will detect which type of fuel its tank has been filled with and automatically adjust the engine; this would increase the flexibility of the vehicle for operational purposes.

Hydrogen is potentially an important source of energy for road vehicles. It can best be used in fuel cells, and methanol and natural gas can act as hydrogen-carriers for fuel cells. The future effective utilisation of alternative fuels will be enhanced if investments in improved distribution networks for alternative fuels are made.

Major improvements in the energy efficiency of motor vehicles can be achieved through a radical shift in technology and design. The basic features of an advanced automobile incorporating radical new technologies, some of which are already operable, include:

- new body materials (carbon-fibre or other composite materials, and also lighter metal alloys) which increase energy efficiency by reducing mass, and at the same time have a lower energy-content in their production;
- enhanced streamlining, using sophisticated body design and reduced frontal areas, aimed at reducing the vehicle's drag coefficient;
- high-pressure, low-rolling resistance tyres;
- an advanced engine;
- extensive use of aluminium and other light-weight materials in suspension and other components (such as brake fittings, sway bars, and wheels);
- major redesign of seats, bumpers and other components to reduce weight; and
- advanced transmissions.

Electronics embedded in motor vehicles is a growth area. Most of the new engine technologies imply an enhanced role for electronics, as do innovations with respect to steering, braking and throttle control. The blending of car and computer technologies is being harnessed in new and promised innovations that will help drivers find their way in unfamiliar territory, pay road tolls without stopping, avoid traffic jams, access emergency help and repair, and utilise the kind of information and entertainment features currently available only at home or in the office (APEC Center for Technology Foresight, 2000).

New Vehicle Engines

The Internal Combustion Engine

Among the new types of internal combustion engines likely to appear in the next decade or so is an advanced two-stroke engine accompanied by new electronically controlled fuel-injection techniques designed to both raise the efficiency of the combustion process and reduce emissions of unburnt fuel. Many of the two-wheeled vehicles which are prevalent in many developing countries are powered by two stroke engines. Two stroke motorcycles are a major source of white smoke and emissions of aromatic hydrocarbons and suspended particulate matter. Technological solutions to the smoke and unburned aromatic hydrocarbons associated with two stroke engines have now become available or are under development. They include catalytic exhaust conversion, direct cylinder electronic fuel injection and electronic computer control.

A second type of combustion engine with significant potential is the gas turbine. To be efficient, the gas turbine has to work at a very high temperature, high enough to melt iron and aluminium, the traditional engine block materials. New and more tractable ceramic materials, together with electronic combustion controls, would make a small powerful gas turbine engine possible for automobiles. Such an engine would emit negligible pollution and could run on a variety of fuels.

Diesel engines are typically more efficient than petrol engines because they burn less fuel, and hence produce less carbon dioxide. However, they can be noisy, smelly and they produce nitrogen oxides and particulates, the result of incomplete combustion. To overcome this latter problem, a new kind of turbo-charged direct injection engine has been developed, and is being used, or is becoming available, in cars produced by Volkswagen, Toyota, BMW, Mercedes, Alfa Romeo, Rover, Peugeot and Citroën. A further refinement, exhaust-gas recirculation, is being adopted as a way of cutting the amount of nitrogen oxide produced by diesel engines (APEC Center for Technology Foresight, 2000).

Trucks and Buses

Improving energy efficiency in the freight sector rests largely on measures related to trucks: the introduction of new, more energy-efficient trucks, retrofit technology for the existing truck fleet, changes in operations to reduce waste, increased linkages with other transport modes, and shifting to other transport modes. Opportunities exist for the introduction of improved transmissions, and increased aerodynamic efficiency associated with lighter structures and better power/load ratios through the increased use of B-double and B-triple combinations, although there are ultimate mass limits to the extent these designs can be taken, as well as impacts on road wear and tear to be taken into account. Improvements in tyre technology and truck maintenance offer further possibilities.

Diesel trucks and buses are the focus of increased attention because they are significant sources of particulate matter and NO_x, although emissions of other compounds are usually much lower than for petrol driven vehicles. The USA has adopted standards for these vehicles that will foster technological developments similar to those which have already occurred for petrol cars. The strategies for diesel emission control embrace three major categories:

- Engine modifications, including combustion chamber configuration and design, fuel injection timing and pattern, turbo charging and exhaust gas re-circulation;
- Exhaust after-treatment, including traps, trap oxidisers and catalysts;
- Fuel modifications, including control of fuel properties, fuel additives, and alternative fuels - many believe that CNG engines are the ultimate technology to use.

Electric and Hybrid Vehicles

Instead of an advanced internal combustion engine, a radically redesigned automobile might use electric motors powered by batteries or fuel cells. Alternatively, it might use a hybrid combination including batteries and a motor/generator (or one of a variety of other combinations of power sources, including flywheels). Recent significant technical advances have placed such vehicles closer to reality, with a few examples of vehicles that have actually become available for sale. The key hurdles remaining to be overcome before full competitiveness with conventional vehicles is attained include improving the manufacturing capability and reducing the cost of advanced materials, designing adequate safety systems for small vehicles, and achieving significant further improvements in fuel cell and battery technology.

Electric battery vehicles are at the most advanced stage of development. If recharged with electricity from low-emission sources (nuclear, solar, hydroelectric), they can be very efficient with respect to limiting CO_2 emissions, depending on the source of the electricity used. Their high price and restricted driving range limit their market penetration currently. They are most suitable for local or neighbourhood-oriented vehicles – urban cars in multicar households. One and two-person powered vehicles offer mobility independence for people with mobility disabilities, and could find much wider application. Electric motor scooters are now filling an important niche in the transportation system of Taipei.

The crucial element for successful mass commercialisation of a battery electric vehicle is the development of a battery that combines high energy density for range, high power density to allow competitive acceleration performance, a long life-time under relatively adverse conditions, and moderate cost. A variety of battery types are under development.

Hybrid electric vehicles combine two power sources with at least one powering an electric motor. The range of alternative power sources includes batteries, flywheels, ultracapacitors, and heat engines. Hybrid systems come in a variety of configurations. One would use a small, constant speed internal combustion engine as a generator to power high-efficiency electric motors at the wheels, with a high-power-density battery or ultracapacitor used to provide a current boost to the motors for acceleration or hill climbing. The internal combustion engine in this case could be small, efficient and clean because it runs at one design speed. Alternative systems could rely exclusively on batteries for most trips, with the engine-generator for extended range only, or they could use both electric motors and a small internal combustion engine to drive the wheels, perhaps with the electric motors providing high power only when necessary.

A fuel-cell-powered vehicle is essentially an electric car with the fuel cell and storage tank (for a hydrogen-carrying substance) substituting for the battery. If the fuel is a hydrogen carrier (methanol or natural gas), an on-board reformer is required to release the hydrogen from the carrier fuel. Fuel cells work by taking hydrogen and oxygen and putting them through a chemical reaction to produce electricity and water. Excess electricity from the fuel cell can be shunted to battery storage. The vehicle can then use a high-power-density battery (or other storage devices such as an ultracapacitor or flywheel) to provide the necessary power boost for acceleration, so that the fuel cell does not have to be sized for the vehicle's maximum power needs.

Fuel cells are particularly efficient energy converters, they generate no harmful emissions and they can be refuelled quickly, so that range constraints are less of a problem than with battery electric vehicles once sufficient refuelling infrastructure is put into place. Three types of fuel cells may be suitable for light-duty vehicles: proton-exchange membrane (PEM) fuel cells, alkaline fuel cells, and solid-oxide fuel cells. Of the three, the PEM fuel cells are closest to commercialisation. Until recently they required large quantities of expensive platinum as a catalyst to make the reaction happen. The Canadian company Ballard Power teamed up with a British specialty chemicals and metals company, Johnson Matthey, in 1993 to find ways of cutting back the platinum. Having found a suitable method, Ballard then teamed up with Daimler-Benz to commercialise the use of the technology for motor vehicles. Ballard has now shrunk the size of fuel cells to the point where they can fit into the sub-compact Mercedes-Benz A-Class. On December 15, 1997, officials from Daimler-Benz and Ford agreed to form a new partnership with Ballard. A combined investment of $US1 billion is planned, and the new consortium hopes to produce an initial 10,000-50,000 cars a year powered by fuel cells, starting commercially in 2004. Ballard does not have the field to itself - about 30 companies are actively developing fuel cells for automotive applications, including Allied Signal and International Fuel Cells (part of the United Technologies Group) in the United States, De Nora in Italy, and Siemens in Germany. Among the vehicle manufacturers, General Motors and Toyota are also developing fuel cells (APEC Center for Technology Foresight, 2000).

Other In-Vehicle Technology

Vehicle Maintenance

New technologies have an important role to play in enabling improvements in the maintenance of road vehicles. On-board diagnostic systems monitor all the emission controls on a vehicle and warn the driver, through instrument panel displays, of any faults that may occur. These systems have become mandatory for new passenger motor vehicles in the United States. Even greater opportunities for detecting malfunctioning vehicles are provided by the use of transponders to allow roadside units to monitor the condition of vehicles as they drive by. Within 20 years, these systems could be installed in sufficient numbers to render inspection and maintenance programs unnecessary.

While diesel exhaust emissions pose considerable health threats, programs to identify and rectify high polluting diesel-powered vehicles are still constrained by the lack of a simple, low cost test to identify these vehicles. There is intense interest in the United States, Australia and parts of Asia in developing appropriate testing technologies (AATSE, 1997).

Transit Vehicles

Rail has become an increasing focus of attention for intra-city transport. Technological innovations in such areas have tended to be incremental. The application of information technologies enable driverless people movers to operate on light rail systems. In Singapore, the introduction of sophisticated signalling equipment has enabled the headway of trains in the Mass Transit System to be reduced from 3 minutes to 1.5 minutes in peak periods.

While inter-city trains have been the main focus of new technological development over the past thirty years, urban people-mover systems may also benefit from new designs. Guideway-based (driverless) systems are a form of "Advanced People Mover" which has been under active development since the 1950s. These systems utilise various combinations of computer, communications and control systems technology. The basic technology of their operational systems has been available for more than 20 years, and some systems in actual operation were developed in the 1970s (APEC Center for Technology Foresight, 2000). Vehicles may be "supported" (run on guideways) or "suspended" (hung from guideways). Support for the guideways may be via conventional wheels (rubber or steel) or magnetic suspension ("maglev"). The Australian Austrans vehicle now in development uses a new type of wheel technology that enables vehicles to turn around tight corners, thereby enabling cheaper guideways to be built around winding streets (Roberts, 1998).

Urban Freight Systems

A number of new technologies for inner city urban freight systems are under development, including:

- AGV Navigation System – a prototype from Israel that uses automated guideway vehicles for moving cargo at seaports;
- Combi-Road, a new concept from the Netherlands for the surface transport of containers;
- Subtrans – an American freight system that utilises underground tubes;
- HighRail – an American system currently under development that uses a monobeam for two-way travel on one narrow guideway; and
- The Japanese Automated Freight System which proposes to use dual-mode trucks for inner-city and intercity freight movement (APEC Center for Technology Foresight, 2000).

Travel Demand and Traffic Management

Newly emerging measures are expected to contribute significantly to the improved efficiency of the management of traffic and travel demand. They are largely based on the use of advanced information technologies to provide information which greatly increases the scope for efficient traffic management (not only through advanced signalling systems but also through the use of traffic simulation systems), makes road pricing more feasible and provides advanced traveller information and driver assistance.

Electronic Road Pricing

Road pricing is increasingly seen as a precise method of impacting on traffic demand. The latest automated tolling equipment, which deducts charges from electronically tagged vehicles, travelling at speeds of up to 100 miles per hour, is being installed in more than 20 countries around the world. Electronic road pricing had its origins as a means of implementing toll charges on major motorway projects. However, its application to time-sensitive roadway charges that discourage congestion is now attracting attention.

Singapore has been the pioneer in road pricing. Direct congestion charges are now implemented by a cordon of toll points around the inner city area in Singapore. Vehicles are electronically tagged, and charges vary by time and day. Road-pricing schemes based on peak-hour charges have been successfully operating for more than six years in the Norwegian cities of Trondheim, Bergen and Oslo. Vehicles diverting away from tolled routes on minor roads are a problem for existing electronic road pricing schemes. American plans using global positioning satellites, combined with in-car receivers and digital maps, will enable vehicles to be charged wherever they are within a specific geographic area and at rates that vary according to the time of day and degree of congestion (APEC Center for Technology Foresight, 2000).

Transport Logistics

Logistics is the management of the flow and storage of raw materials, goods-in-progress and final goods from point of origin to point of final consumption; it includes the recovery and disposal of waste products. Cost, quality of service and timeliness are the key parameters of the economic efficiency of logistics, while sustainable logistics also takes into account social factors (accessibility and safety) and environmental considerations. New technologies are providing new solutions to logistical problems. Improvements in information technology are one example of this trend, but the standardisation of container sizes and the development of groupage services is another.

Logistics is only effective when there is an adequate supply of information about what is happening at each point in the supply chain, and when available alternatives are well known and understood. The improvements in information technology therefore make increasingly sophisticated logistics management possible. There is much debate about whether the availability of increased information is lengthening or shortening supply chains, acting as a substitute for transport, or enabling transport to be performed more efficiently.

The effectiveness of logistics can be enhanced if attention is given to removing certain obstacles and increasing awareness of the benefits among non-users. Among the obstacles identified in many areas is the absence of a bar-coding system suitable for tracking goods, a lack of policies on electronic commerce, and regulations against, or resistance to, night-time collection and delivery systems. With respect to raising awareness, support systems for electronic data interchange (EDI) have been identified as being important. Singapore, Hong Kong and Malaysia are leaders in this respect (Euro-CASE, 1996). High quality electronic logistics systems are increasingly being used by road freight operations in the advanced economies, as are rail freight operators.

The Internet is now beginning to be used to increase the efficiency of the road haulage industry. National Transportation Exchange (NTE) uses the Internet to connect shippers who have loads they want to move cheaply with fleet managers who have space to fill. NTE helps to create a spot market by setting daily prices based on information from several hundred fleet managers about the destinations of their vehicles and the amount of space available. It then works out the best deals. The whole process takes only a few minutes. NTE collects commission based on the value of each deal, the fleet manager gets extra revenue that he would otherwise have missed out on, and the shipper gets a bargain price, at the cost of some loss of flexibility.

When NTE was first set up four years ago, it used a proprietary network, which was expensive and limited the number of buyers and sellers who could connect through it. By moving to the web, NTE has been able to extend its reach down to the level of individual truck drivers and provide a much wider range of services. Before long, drivers will be able to connect to the NTE website on the move, using wireless Internet access devices (The Economist 1999b).

The Freight Sector

Four approaches can be taken to securing more sustainable freight transportation: improvements in the engine technology and other aspects of truck design such as aerodynamics (dealt with above); utilising options such as load aggregation and electronic commerce to shift road freight to rail and sea or to new forms of intra-urban distribution; adaptations in land use planning; and improved transport logistics. The locations of major freight generating activities, such as transport terminals, distribution centres, factories and shopping centres, will have a major effect on the pattern of urban freight transport and its impact on the urban environment, particularly through reducing the number and length of freight trips.

Unladen trucks produce emissions without any freight transport output. Greater coordination of pickups and deliveries can improve vehicle utilisation. Improved routing and scheduling of trucks, increased back-loading, driver communications and information systems and extended operating hours can all improve efficiency. The utilisation of advanced technologies for vehicle location monitoring, computer aided routing and dispatch, and data and voice communications can all yield benefits to freight efficiency. Extended warehouse operating hours enables trucks to make pickups and deliveries at times of low road congestion (APEC Center for Technology Foresight, 2000).

Intelligent Vehicle-Highway Systems

Intelligent vehicle-highway systems (IVHS) encompass several different technologies: advanced traffic management (ATM), advanced traveller information (ATI), and automated vehicle control (AVC).

ATM technologies are designed to monitor traffic by using radar and other remote traffic systems to analyse data derived from these monitoring systems, to alter traffic flows electronically by adjusting signal timing and freeway ramp controls, and by providing information on roadside bulletin boards. The Tomei Expressway, Japan's busiest motorway, has been using ATM technologies for some years on a 250 kilometre stretch leading out of Tokyo (The Economist 1992b). In Seattle (Washington State, USA), transportation authorities provide a website with an up-to-date map of motorway hotspots. The Seattle system also allows traffic signals to be adjusted to traffic flows. Turin in Italy is testing a system that turns traffic lights green for heavily loaded buses, but not for empty ones. On Toronto's Highway 401 (Canada), sensors buried in the roadway detect when traffic is slowing, and video cameras let controllers see the problem. Among other things, this system has cut the average time required to clear minor accidents from 45 minutes a decade ago to just 20 minutes today (The Economist 1998b).

ATI technologies are on-board systems that impart information about traffic conditions and alternative routes and may include electronic maps and navigational tools. ATI information may be tailored to an individual driver's travel plans. They are particularly useful for drivers with multiple route options. Such systems could also pre-book parking spaces and even hotels. For some European countries, BMW now offers a built-in electronic road map with information on the state of motorway traffic, and a similar system is available in some Avis rental cars in the United States. There are at least fourteen different navigation systems available in Japan. Oztrak, a start-up firm partly owned by the University of Ballarat in Australia, has developed a Telematic Starter Kit that is installed in a car and uses a keypad hooked to a standard mobile telephone. Drivers can use it to request such services as roadside help, travel information, and accident assistance (APEC Center for Technology Foresight, 2000).

AVC technologies are on-board technologies geared towards traffic safety. They can assist drivers with such facilities as adaptive cruise control, obstacle detection, and infrared sensing to improve safety for night driving. Other AVC technologies are designed to intervene directly in driving. They include automatic braking and manoeuvring. The rationale behind these technologies is to maintain optimal, but safe, distances between vehicles to improve driving and traffic flow. Already, some Greyhound buses in America carry microwave radar to monitor their distance from other vehicles and their closing speeds, and many American school buses use another version of this system to alert the driver to children behind or beside the bus where they cannot be seen in mirrors. Systems currently operational include speed monitors that warn drivers who go too fast, or alert drivers who stray out of lane or show signs of sleepiness, and which brake or steer automatically in certain circumstances (The Economist 1995).

The Americans believe that they will have a fully-tested prototype intelligent highway system up and running by December 2001 (The Economist 1996b). The Japanese Government, in collaboration with public agencies and the private sector, has initiated a program known as Japan's Intelligent Transport System (ITS), with a view to developing a complete system by 2010, and substantial research on IVHS is also occurring in Europe (Firth 1997).

Virtual Technologies

Technology may contribute to the extent to which non-transport alternatives can meet accessibility objectives. Examples of such alternatives include home entertainment systems, telecommuting for work, delivering services through the Internet, lean manufacturing and distribution systems that minimise transport movements, utilising transport logistics to the full, and improved urban design that minimises the need for environmentally damaging transport movements. Using advanced information technologies, a large range of travel movements could, perhaps, be displaced:

- Journeys to work could be reduced by managerial and technological changes that greatly increase working from home;
- Business travel (local and international) could be displaced by increased use of conferencing and other information technologies for communications;
- Social and entertainment needs could be displaced to a significant extent by virtual reality, especially for the young; and
- On-line and distance education could displace journey-to-school or –campus (APEC Center for Technology Foresight, 2000).

Policies for Sustainability

New policies will be needed to achieve reduced emissions of carbon dioxide from transport, to overcome problems with air pollution, to increase safety and ensure wider access to transport services. There is no single solution to these problems. However, it is generally recognised that policy actions are required on several broad fronts:

- The integration of urban planning with transport planning;
- Giving priority to transit in the development of transport infrastructure;
- The introduction of reforms to transit services;
- Strengthening transport management policies;
- Encouraging the development of sustainable new technologies over the whole range of transport service provision; and
- Utilising taxes as a means of shaping transport demand, encouraging the adoption of sustainable technologies, and providing a means of indirectly financing new transport infrastructure.

The Integration of Urban Land Planning with Transport Planning

The integration of urban land planning with transport planning is a vitally important aspect of ensuring broad accessibility to employment and services for all groups in a city. It can also reduce the amount of travel required in a community and encourage an efficient utilisation of transport infrastructure. Key aspects of the required policies are:

- Encouraging higher urban density and mixed-use development in high income cities;
- Improving the scope for walking and cycling to achieve mobility requirements;
- Integrating land use planning with the development of transit infrastructure;
- Managing parking supply; and
- Providing for efficient distribution systems in urban planning.

Singapore; Hong Kong, China; and Tokyo provide examples of successful integrated planning . Implementation of integrated urban planning in many other major cities in the advanced economies has proved to be quite difficult in practice. In the third world, economic and demographic growth has tended to produce significant problems of traffic congestion, local air pollution and poor accessibility for lower income groups in the population. Key planning priorities are to control development in the urban perimeter, the upgrading of existing informal settlements, discouraging land speculation and decentralising development. Such policies are not easy to design and are particularly difficult to administer. In economies like the Philippines and Thailand, where primate cities (Metro Manila and Bangkok) have held dominant positions during post-war economic development, it is acknowledged that decentralisation policies need to look beyond the surrounding areas to the primate cities and provide encouragement to development in other regions of the national economies (APEC Center for Technology Foresight, 2000).

Developing Transport Infrastructure

It is desirable to assess all transport infrastructure proposals on a consistent basis that takes into account their economic, social and environmental impacts. Such assessments should view transport from an intermodal perspective, taking into account the interrelationship between road traffic and infrastructure, public transport, facilities for non-motorised modes and travel demand management. An important issue is to fully recognise the net social returns from infrastructure investments. The development of transit infrastructure is especially important in the major cities of the developing world (Euro-CASE, 1996).

Singapore; Hong Kong, China; and Tokyo provide examples of successful transit infrastructure development strategies. Bangkok is in the process of planning or constructing massive transit projects. Significant developments in transit infrastructure have occurred or are planned in several major Australian cities. There has also been significant development in transit infrastructure in the major Canadian cities. There are only a relatively few examples of recently successful transit developments in the United States (APEC Center for Technology Foresight, 2000).

Public Transport Reforms

Improvements in the competitiveness and flexibility of transit services[3] can make an important contribution to the environmental sustainability of transportation and, by increasing the degree of substitutability between transit and private vehicles as a means of transportation, enhance the effectiveness of demand management and pricing strategies to contribute to sustainability. Transit services can be enhanced by the harnessing of new technologies; the extension of services coverage, capacity and frequency; improving operational flexibility; and increasing intermodality with different forms of transit and with private transport (APEC Center for Technology Foresight, 2000).

Tokyo's rail services are a model for the efficient operation of mass transit services. They provide frequency, predictability, reliability and safety to world-best standards. Mexico City has developed a many-tiered system of transit, with the mass transit Metro, intermediate carriers (light rail, electric trolley buses and suburban diesel buses), and a big range of paratransit feeder services. The development and application of new smart paratransit technologies and services offers huge scope for servicing low-density suburbs in the advanced economies, but also for servicing the otherwise less accessible areas of developing country Megacities (Sperling, 1995 and APEC Center for Technology Foresight, 2000).

Transport Management

Traffic management techniques are capable of reducing traffic congestion, increasing the effective utilisation of highway capacity, and reducing emissions. Singapore has been a leader in this area of policy. New technologies, such as advanced traffic simulators and intelligent vehicle-highway systems, offer considerable scope for improving the efficiency of traffic management. In inner-city areas, parking controls, restricted access, access tolls and traffic calming can be employed. Again, Singapore is the leader in developing such policies. Transport logistics has an important role to play in improving the efficiency of freight movements. New technologies now offer the possibility of utilising road pricing as a comprehensive technique for traffic management and rationing road space (APEC Center for Technology Foresight, 2000).

Technology Development Policies

Provided it is part of a broader menu of policies including active demand management policies, technology development policies can make a big contribution to reducing transport emissions. The OECD analysis suggests a policy of encouragement is necessary if timely contributions to transport sustainability are to be made by new technologies (OECD 1997c).

[3] Transit services include the following categories: rapid rail or mass transit; commuter or interurban rail; streetcars or tramways; buses; and paratransit (vans, jitneys, shuttles, microbuses and minibuses).

Cooperative research programs involving the public sector and companies, as occurring in the United States, will have an important role to play in developing base technologies. The potential for developing a new range of energy-efficient vehicles is high if sufficient research commitments are made. Public support may also be needed in developing an infrastructure to support energy-efficient vehicles. Inducements to secure private sector investments in new technologies may be necessary. The Californian mandatory targets for zero-emission vehicles are an example of such incentives. It is also important that encouragement is given to the swift spread of appropriate technological development to the developing economies. The scope for new technologies aimed at improving the characteristics of paratransit vehicles has big implications for transportation in the major urban centres of developing economies (APEC Center for Technology Foresight, 2000).

The Fiscal Issues

Taxes have an important role in shaping transport demand and encouraging the adoption of more sustainable technologies in transportation. Vehicle ownership and acquisition taxes have been aggressively used to control car ownership in Singapore. Fuel taxes can impact directly on transport demand and technology development. Increased fuel taxes will have a greater impact on sustainability if accompanied by improvements in transit services that increase the potential for intermodal substitution. Several countries have investigated taxing vehicles with high fuel consumption or emissions at relatively high rates compared with other vehicles and introducing rebates for purchasing vehicles with low fuel consumption or emissions.

These and other taxes aimed at transportation provide the fiscal means for funding sustainable transport infrastructure and other sustainable transportation projects. The revenues generated could be of major importance for developing sustainable transportation projects (APEC Center for Technology Foresight, 2000).

The Impact of Policies

The adoption of comprehensive sustainable transportation strategies can have a big impact on cities. The transformation of Hong Kong, China and Singapore from third-world cities some three decades ago to international benchmarks for sustainable transportation owes much to the policies pursued in those cities, particularly the integration of urban planning and transport planning, the development of transit infrastructure and the attention given to traffic management.

Research undertaken by the Transportation Research Board in the United States on the impact of various policies on carbon dioxide emissions from road vehicles indicates that, by the year 2020, the biggest impact on emissions would come from the adoption of higher fuel taxes, with improved urban planning and travel demand measures on the one hand and the introduction of new vehicle technologies on the other having smaller impacts. By the year 2040, the impacts of both higher fuel taxes and new technologies would be very considerable, leading to a marked reduction in aggregate emissions. The simulations did not allow for impacts associated with an increased development of transit services. What is important to note is that a combination of policies will have a deep impact by dealing with induced traffic associated with the adoption of single measures in isolation. Furthermore, most of the policies will take considerable time to have a major effect. Urban form can change only slowly over short periods of time, and technology development has a significant gestation period. Even taxes have a far bigger effect over a number of years than in the months following their introduction (TRB 1997; OECD 1997c).

Social impacts are expected to be positive as a result of increased traffic safety and the provision of a wider range of transport services available to lower-income groups. However, a lot depends on how the tax revenues generated by the sustainable transport policies are utilised. Higher transport charges may need to be offset by tax reductions for the lower-income groups. There is also a danger that urban restructuring integrated with improved transit services may push up the prices of housing in the restructured areas, pricing poorer people out of the most accessible sites. Hence, specific social policy interventions may be required, such as the adoption of transport concessions for poorer people (ECMT, 1998).

So far as the economic impacts of sustainable transportation policies are concerned, the important point to note is that government will collect higher taxes or use-charges for transport. This will allow increased government finance of infrastructure improvements and other sustainable projects and, possibly, reductions in other taxes. Companies will face higher charges for transportation but less traffic congestion, fewer accidents, and improved transport services. Consumers will pay more for transport, but enjoy safer, higher-quality transport services. The impact on aggregate economic activity is expected to be small, but positive. (ECMT, 1998).

The Implementation of Policies

Integrated policy-making for transport remains hampered to a large extent by fragmentation of policy responsibility both horizontally (across transport, environment, energy, finance and industry ministries) and vertically (across central, regional and local governments). Moreover, in many countries, municipal administrations are underbounded – substantial parts of the metropolitan areas are outside the boundaries of the central city jurisdiction (OECD 1997c).

The diffusion of information about sustainability to individuals within the cities is of vital importance in building support for sustainability policies. Education to broaden environmental literacy should be a key aspect of an overall strategy for sustainable transport. Finally, evaluation of policies and plans is important to test the usefulness of different approaches over time and against alternatives (APEC Center for Technology Foresight, 2000).

Transportation and Emissions: Future Scenarios

Emissions and Transportation: A Simple Model

The Core Equations

The volume of global warming emissions generated by the transportation sector, E_t, can be modelled as:

$$E_t = e_t T \qquad (1)$$

where T represents the volume of transport movements and e_t represents emissions per unit of T.

The effective demand for transportation, represented by T, can be represented as:

$$T = f_1(Y, P_t/P, tt) \qquad (2)$$

where Y is real GDP, P_t is the price index for transportation services, P a general price index, and tt represents average travel time(with the extent of traffic congestion being a major factor in travel-time). T will vary directly with Y and inversely with tt.

The emissions-intensity of transport, e_t, can be represented as:

$$e_t = f_2(tt, m, I_t) \qquad (3)$$

where m is the modal split of transport movements, and I_t represents innovation. e_t will vary directly with tt (through the costs of congestion), inversely with I_t (many prospective innovations are emissions-saving in impact). In terms of transport mode, e_t would be increased by a shift towards motor vehicles, and decreased by a shift towards transit services, bicycling and pedestrian movements.

Finally, it is useful to consider the determinants of the efficiency and effectiveness of transportation services, (T_q):

$$T_q = f_3(K_t, I_t, A) \qquad (4)$$

where K_t is the volume of capital employed in transportation (infrastructure), and I_t represents innovation, and A represents transportation service improvements unrelated to K_t and I_t.

Interrelationships

A more complex framework of analysis than that presented in the preceding section of the paper allows for interdependencies between the variables in the model.

To begin with, consider the interdependency between transportation and Y. Equation (1) considers the impact of Y on T. However, there is also a train of causation running in the other direction. It is possible to argue that T_q has an influence on Y. This relates to externalities associated with T_q. At an international level, transportation and communications, to a much greater extent than changes in trade barriers, have been the key drivers of globalisation in the past decade. Transportation improvements facilitate a greater realisation of the classic static gains of international trade, while underlying some of the impetus to increased global competition (with accompanying x-efficiency gains), and the more rapid realisation of scale economies in emerging industries (particularly with respect to learning economies). For large national economies, a similar process in relation to resource allocation, competition and scale economies, indicates a connection between transportation improvements and the growth in GDP capacity.

Secondly, let us consider the variable P_t/P. This will be influenced by:

- The relationship between transportation demand and capacity (hence the importance of increases in Kt in avoiding relative price increases associated with demand pressures);
- Innovation in transportation, which will drive transportation prices and costs down;4
- Fuel prices, which will tend to increase Pt/P because it is a fuel-intensive sector.
-

Thirdly, there is travel-time (tt). In the short-term, the degree of traffic congestion experienced will be the major factor leading to changes in tt; investment in additional transport infrastructure and innovation traffic management are two alternative approaches to dealing with the problems of congestion. In the longer term, tt will be influenced by changes in the urban form and in population density.

Utilising the Simple Model

The model will be used to analyse three scenarios.

1. Economic growth as the principle driver of the transportation sector, with no major emissions-saving innovations and no coordinated policy for sustainable transportation.
2. Substantial progress in emissions-saving innovations along with economic growth, but no major advances in sustainability policies.
3. A combination of coordinated policies for sustainable transportation, significant emissions-saving innovations and economic growth.

Innovations can, in turn, be classified into two categories:

1. Innovations that have a major emissions-saving impact;
2. Other innovations that are not aimed at directly reducing emissions.

Examples of the later group include advances in logistics, intelligent vegicel-highway systems, and improvements in transport vehicle design that are neutral in their effects on emissions.

Economic Growth and Emissions

The first term in the equation for T is income. As we have already observed, the income elasticity of demand for transportation services in the advanced economies is around one. Hence, an economy generating annual growth of 3 per cent would experience a similar rate of growth in the demand for transportation, other things being equal. However, in the developing countries the income elasticity of demand for transportation services is well in excess of unity, sometimes as high as 2. This reflects factors such as the replacement of subsistence with market economics, increasing urbanisation and urban sprawl, and rising car ownership. The high long-term growth rates being experienced in some of the largest developing economies (China and India being notable examples) implies extremely rapid growth in transportation demand.

The second term in the equation for T is the price of transportation services compared with general prices (P_t/P). Short-term price elasticities of demand are quite low because travellers can only respond to higher prices by reducing discretionary travel. However, over the longer-term travellers have greater range of transportation alternatives, Estimates of long-term price elasticities range form –0.2 to above –1.0, with an average of –0.53 (TRB, 1997). Over the longer run we shall assume for the purposes of constructing this scenario that (1) transportation capacity rises to match transportation demand, (2) there is continuing non-emissions reducing innovation in transportation, and (3) real fuel prices remain constant. In these circumstances, P_t/P can be assumed to be constant.

The third term in the equation for T is travel time (tt). Research on petrol price and on values of time suggest an overall average long-term elasticity of traffic with respect to travel time of around unity (ECMT, 1996). We assume that investment in transport infrastructure is sufficient to keep tt constant in the medium-term. With tt and P_t/P assumed constant, the demand for transportation will tend to ris eat the same rate as GDP in the medium term.

Now let us examine the emissions-intensity of transport, e_t under this scenario. We have assumes tt is constant over the medium term, and innovations in transportation is not emissions-reducing. The behaviour of m, the modal split of transportation, is of critical importance. The general in both advanced economies and rapidly developing economies has been for motor vehicles to gain an increase share of the market against rail and other modes of transport. Since the emissions-intensity of motor transport is higher that the other modes, this will lead to an increase in the emissions-intensity of transport, e_t.

So our first scenario gives rise to an increase in emissions from transportation in the advanced economies as a result of an increase in T proportional to the increase in GDP and a rise in e_t. The overall growth in emissions would exceed that of GDP. In rapidly developing economies the growth in transportation emissions would be much higher since the income elasticity of demand for transportation is well above unity and the shift in modes of transport more rapid.

This scenario, while feasible in the medium term, is not sustainable in the long term. It would lead to mounting economic and environmental costs. Continuing economic growth along with accompanying transport demand would eventually lead to an increase tin travel time (tt) as increased economic density and urban sprawl created problems for traffic management and raised the costs of the transport infrastructure required to deal with congestion problems. Moreover, continuing growth in transportation demand would sooner or later put major pressure on fuel prices and thereby increase relative transport prices. In both of these cases, the growth of transport demand would be reduced, and economic costs would lead to reduced GDP growth.

But this scenario would also give rise to significant environmental costs in terms of local air pollution and global warming emissions. For this reason, alternative scenarios need to be examined.

Innovation and Emissions

Innovations in transportation are driven by many influences. Advances in logistics enable companies to minimise their working capital while enjoying efficient transport services, but do not necessarily reduce the overall demand for transportation (they may, in fact, increase it). Other innovations are aimed at increasing consumer amenity, or improving safety. However, there are a broad group of innovations that will have the effect of reducing global warming emissions, reducing local air pollution, and decreasing the consumption of crude oil. This is particularly the case for such innovations in vehicle design as electric and hybrid vehicles, other vehicle design improvements that reduce fuel use, and new types of para-transit vehicles.

A hypothetical scenario developed by the US Transportation Research Bureau (TRB 1997) assumes that new vehicles emit only one-third as much CO_2 per mile as conventional (baseline) vehicles. Starting in 2010, the new vehicles are introduced into the fleet so that by 2020 they account for five per cent of total VMT. Their popularity quickly grows as the technologies become more mature and consumer familiarity increases. Thus, by 2030 they account for 20 per cent of VMT, rising to nearly half of all VMT by 2040. Emissions of carbon dioxide are reduced below the base projection by four per cent by the year 2020 and by 32 per cent in 2040.

The purpose of this scenario is to illustrate graphically that the development and introduction of new technologies – even with fairly aggressive assumptions about effectiveness in reducing CO_2 emissions and introduction – may require several decades to bring CO_2 emissions back to present levels. Most evident are the years of lead time required for low-emission technology development and the lags that are likely in expanding consumer acceptance and use. Although this is only one of many plausible scenarios, it portrays the importance of early research, development, and demonstration (APEC Center for Technology Foresight, 2000).

This scenario also considers only the direct effects of emissions-reducing innovations on total emissions. The indirect effects of innovation on emissions may not be quite so favourable. The strong climate for innovation in transportation should lead to a reduction in P_t/P. This, in turn, will stimulate the overall demand for transportation (T). Innovation leading to qualitative improvements in transportation could also stimulate GDP, further increasing T.

So, there are two disadvantages of a technology-only strategy for reducing emissions from transportation. The first is that the major innovations will take time to develop and time to achieve market acceptance. The second is that they could give rise to partially offsetting influences on emissions levels. But technology may also have a direct effect on T as well as e_t. Virtual technologies could reduce the demand for transportation at given levels of Y.

The Implementation of Policies for Sustainable Transportation and Emissions

In the third scenario we analyse the combined effects of comprehensive policies for sustainable transportation and an accelerating rate of emissions-reducing innovation. To begin with, we consider the impact of individual policies on emissions in isolation before examining the effects of combined policies.

The integration of urban land planning with transport planning.

The OECD argues that a comprehensive approach to land use planning along with the adoption of active traffic management policies could substantially reduce congestion and pollution. Car owners would have more attractive alternatives to travel by public transport, on foot or by bicycle. Dependence on cars would be reduced and traffic growth in urban areas might cease altogether, though overall travel levels and CO_2 emissions would continue to rise (OECD 1997c).

The US Department of Transport has constructed some projections on vehicle travel, petroleum use and carbon dioxide emissions out to the year 2040. The scenario incorporating efforts to reduce motor vehicle travel through demand management methods and land use planning reduces motor vehicle travel relative to the baseline trend on the order of 5 per cent by 2020 and 10 to 15 per cent by 2040. This still leaves situation in which petroleum use continues to grow by around 40 per cent between 2000 and 2040 (TRB, 1997).

Land use planning has three main effects on the level of emissions produced by transportation.

1. It reduces T for a given level of Y and it reduces the income elasticity of demand (the increase in T associated with a given rise in Y). More compact urban land use reduces the need for travel, enables travel by foot.
2. It reduces e_t through a shift in transport mode from car travel towards transit.
3. It reduces the price elasticity of demand for travel (the impact of P_t/P on T) by increasing the range of alternatives available to the potential traveller – foot and transit become more competitive with the car.

However, the introduction of more sustainable land use planning would take a very long time to impact on emissions. This is because of the so-called "marginality problem" (Downs, 1992). The marginality problem recognises that most development of the last 30 to 40 years has been dispersed, that new community designs emphasising transit and non-motorised travel are most likely to be adopted only in new developments at the periphery of established communities or in emerging metropolitan areas, and the new development would therefore have to be far denser to raise the average density of a metropolitan area. Here, change needs to encompass high-density rather than the more normal low-density development. Unless population growth is very rapid, it would take many decades to exercise a major impact on the overall urban form.

Fuel Taxes

The scenario put forward by the US Transportation Research Board (TRB, 1997) assumes a 3 per cent annual increase in petroleum prices and a long-run price elasticity of demand for petroleum of –0.4. The scenario demonstrates that changes in petroleum prices can have a large influence on petroleum demand. The projections developed show that the amount of petroleum used by motorists after 20 years would be about 15 per cent lower than under the baseline scenario and 35 per cent lower after 40 years.

Not considered in this simplified scenario are the means of achieving these higher prices considered (e.g., through tax policy or supply and demand forces). In the event of rising petroleum prices, motorists may switch to alternative fuels as part of their response, and these alternatives may or may not produce significantly less CO_2 than traditional petroleum motor fuels. In this regard, a graduated energy tax based on fossil carbon content or greenhouse emissions would offer more incentive for motorists to demand and suppliers to develop technologies low in fossil carbon emissions (APEC Center for Technology Foresight, 2000).

Energy taxes will tend to raise P_t/P and hence reduce T. They also encourage fuel-saving emissions and hence reduce e_t as well. In the very short run, the price elasticity of demand for travel is quite low because travellers have limited options for change, but in the medium-term, energy taxes can be quite effective in impacting on emissions.

Managing Transport Demand

Considered individually, most travel demand measures offer prospects for incremental decreases in motor vehicle travel: their collective effort, however, could be of major significance. Their aggregate impact is considered alongside that of urban planning in the previously cited TRB study (see above, TRB 1997).

Transport management policies have the capability of reducing e_t through minimising congestion. They may also raise the implicit P_t/P for some transport movements and reduce T, although positive effects on Y and congestion may partially offset these primary negative impacts on emissions. Advances in travel demand management depend, in part, on the adoption of advanced highway infrastructure, and the development of appropriate traffic simulation models. Once the appropriate infrastructure is in place, they can have a speedy impact on emissions.

Other Policies

The Development of Transit Services

The development of transit services through operational reforms and the construction of state-of-the-art infrastructure is a further avenue of sustainable transportation policies. Such policies will shift the transport mode away form car use to transit services, thereby reducing e_t.

Encouraging Emissions-Reducing Innovation

Fiscal and other incentives for emissions-reducing innovation can bring forward the timetable for major innovations, thereby reducing e_t.

Incentives for Transport Saving Through the Adoption of Virtual Technologies

The impact of such incentives remains a little uncertain, although it could reduce T at a given Y and, perhaps, also reduce the income elasticity of demand for transportation.

The Combined Effects of a Total Sustainable Policy Package

The OECD (1997c) adds to the adoption of best practice land use, demand management and transit policies a progressively increasing fuel tax to significantly reduce vehicle travel. Taking into account IPCC targets, the example considered is that of a seven per cent annual rise in real terms in the price of fuel over the next twenty years. This is estimated to reduce the amount of fuel used to about a third of the forecast level of consumption 20 years from now, i.e. to about half of today's consumption, with a corresponding reduction in CO_2 emissions.

This saving would reflect a reduction in car trip lengths of approximately a third, and much slower growth in car ownership and car travel over the next twenty years (perhaps 10 to 15 per cent instead of the forecast 50 per cent). High fuel prices should lead to more economical driving styles, smaller and less powerful vehicles and further improvements in fuel economy (perhaps as much as a third) arising from improved engine design. High fuel costs would provide a strong incentive to improve the efficiency of road freight transport and to shift freight to other modes.

This OECD analysis goes part of the way towards estimating the impact of out third scenario on emissions. The total package of sustainable transport policies, combined with accelerating emissions-reducing innovation, can be expected to have a comprehensive impact on the factors generating transport emissions. The following summary indicates how this is so.

The combined effects of a total policy package are to reduce emissions by decreasing both e_t and T.

The policy package reduces e_t through:

- Encouragement to emissions-savings innovation through a combination of incentives and energy/fuel taxes;
- The shift to transit mode as a result of transit development and land planning; and
- The reduction in congestion as a result of advances in transport management.

The policy package reduces T through:

- The direct effects of land planning reducing transport movements;
- A higher P_t/P because of fuel taxes;
- An increased price elasticity of demand as a result of land planning, transit development, innovations, increasing the impact of fuel taxes on T; and
- A reduced income elasticity of demand through land planning and, perhaps, the utilisation of virtual technologies.

The Implications for Economic Development.

An imperative for sustainable transportation is that traffic modes and flows that are socially costly are restrained, either through the pricing mechanism or by regulatory means. Such a strategy would, of itself, impose a cost penalty on countries or regions that could impact on their economic competitiveness and capacity to deliver increased employment opportunities. However, this potentially harmful impact could be offset by technological and managerial improvements that provide qualitatively improved access for individuals and major efficiency improvements in the whole freight system.

The analysis of the impact of the internalisation of external costs associated with transportation conducted by ECMT (1998) indicates benefits to government finances in the first instance. Internalisation will reduce government expenditure on infrastructure, health care and social security. Furthermore, governments will collect the higher use-charges for transport. The ECMT analysis assumes that the full financial gain to governments will be recycled in the economy through lowered tax rates.

Companies face higher transport costs resulting from higher use-charges and stricter vehicle standards, benefits from compensatory tax cuts, and reductions in costs associated with congestion and losses associated with traffic accidents. The net effect can be expected to be positive, because higher use charges are fully compensated for by lower taxes, and because of benefits from other cost reductions. However, this does not mean that every individual company benefits, but logistic and locational adjustments could offset much of the net loss.

Consumers are confronted with higher use-charges, which will reduce growth in mobility. This represents a welfare loss, at least in the short run before spatial patterns of organisation adapt. This change is compensated for by lower taxes of one kind or another. In addition, there are gains in non-financial types of welfare, less personal distress associated with fewer accidents, fewer time losses in congestion, and a safer, healthier, more pleasant environment. The net result is expected to be a small financial gain and an increase in total welfare. As a consequence, reduced mobility – and thus expenditure on transport – results in extra consumption of other goods and services (ECMT, 1998).

The ECMT analysis suggests that the competitive position of European industry is affected by internalisation policy in three ways: a) more expensive transport resulting form stricter vehicle standards and higher use-charges; b) reduced general taxation; and c) reduced costs from congestion and less loss of production from traffic accidents.

Although the net result can be expected to be positive for business as a whole, specific subsectors might face higher costs. A few general remarks can be made about this issue:

- Transport intensive industries face both higher transport costs and lower congestion related time losses, the net effect depending on specific circumstances;
- The policy measures to be selected largely determine the distribution of costs and benefits among subsectors;
- If the competitive position of an industry is harmed by internalisation, specific compensating policy measures can be considered in the total policy package;
- End-use transport prices rise by around 20-30%, but transport costs make up only a few per cent of total production costs; and
- Companies will probably adapt their logistics and spatial economic organisation a little, reducing the impact of total costs in the longer term.
-

Assuming that the competitiveness of industry is not substantially affected by internalisation policy, what are its likely impacts on economic growth and employment? The Central Planning Bureau, the economic institute of the Dutch government, has modelled the impact of measures such as very strict vehicle standards, an increase in fuel taxes, VAT on flights in Europe and speed limiting devices on trucks. A substantial reduction in growth of road and air traffic is expected. The revenues of the fuel tax are recycled through relief in labour taxes and employer contributions to social security payments.

The main conclusion of the model calculations is that the macroeconomic impact of the policy package is small, despite the substantial shift in consumption patterns. Households shift their consumption patterns away from car driving towards luxury goods (such as furniture and appliances) and tourism. A similar shift takes place in production: less transport, more services. As a consequence of these shifts, total employment increases a little, mainly because of the reduced labour costs. There is no recurring inflation effect; prices rise by a few tenths of a per cent but only in the first few years.

Other economic studies assess the impact of environmental policy in general and also integrated with economic policies. With respect to the first, there is a slight negative impact on GDP and a zero impact on employment, with a slight increase in prices. With respect to the second, there is a slightly positive impact on GDP and a marginally higher impact on employment then GDP, and an increase in prices (ECMT, 1998).

Conclusions

1. Global warming emissions arising from transportation can be minimised through the implementation of a comprehensive sustainable transportation strategy combined with major innovations in transport technologies.
2. While concerns about global warming are one reason for seeking to implement sustainable transportation strategies, such strategies are also necessary to deal with other important problems such as local air pollution and traffic congestion. In terms of the politics of change, it will be necessary to build a coalition of interests in order to achieve the political climate necessary for the implementation of sustainable transportation strategies.
3. The economic analysis of sustainable transportation suggests that economic and environmental goals can be reconciled, and an environmentally sustainable transportation system can be a positive factor in economic development. On the other hand, failure to deal with sustainability issues in the medium term can lead to the growth of new constraints on economic development.

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