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Group on Pollution Prevention and Control
Task Force on Transport

Eco-Efficiency in Transport

Workshop Report and Background Paper

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OECD Environment Directorate Project on

ECO-EFFICIENCY IN TRANSPORT

Workshop Report and
Background Paper

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Foreword

At their 1996 Ministerial, OECD Environment Ministers recognised a need for more effective longer-term strategies to address pollution reduction. Building on the conclusions of the OECD “Rosendal Workshop” (“*Sustainable Consumption and Production: Clarifying the Concepts*”, Rosendal, Norway, July 1995), one concept in particular, that of *eco-efficiency*, was seen as a promising pathway for reconciling environmental and economic objectives. In response, the Environment Directorate’s Pollution Prevention and Control Division and Sustainable Consumption and Production Programme organised an Experts Workshop on “Eco-Efficiency in Transport” that was held on July 7-8, 1997, at the German Federal Environmental Agency in Berlin. The first part of this document is the report of that meeting. The workshop was jointly chaired by Dr. Axel Friedrich, Head of the Transport and Environment Division of the German Federal Environmental Agency, and Jeremy Eppel, Counsellor to the Director, OECD Environment Directorate. This report has been written by Philippe Crist, Consultant to the OECD Environment Directorate. It is published on the responsibility of the Secretary-General of the OECD.

The second part of this document is a report which was written by Tim Young of the UK-based consulting firm Environmental Resources Management. This report served as a background document for the Berlin workshop.

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OECD Environment Directorate

I. Report of the Workshop on

ECO-EFFICIENCY IN TRANSPORT

7-8 July, 1997 Berlin

1 INTRODUCTION

OECD economies have made significant progress in reducing pollution in many industrial sectors while maintaining fairly high levels of economic growth over the past fifty years. Many of these environmental improvements were made possible through use of “end-of-pipe” technologies (e.g. wastewater treatment, smokestack scrubbers, engine exhaust catalysts, etc.). Since the first energy crises of the early 1970’s, these initiatives have also been accompanied by efforts to increase the energy efficiency of both processes and products. Government regulation and “command and control” legislation have been the hallmark of these policies whose efficacy in recent years has sometimes been questioned due to the high cost of achieving marginal improvements. At their 1996 Ministerial, OECD Environment Ministers recognised a need for more effective longer-term strategies to address pollution reduction. Building on the conclusions of the OECD “Rosendal Workshop” (*“Sustainable Consumption and Production: Clarifying the Concepts”*, Rosendal, Norway, July 1995), one concept in particular, that of *eco-efficiency*, was seen as a promising pathway for reconciling environmental and economic objectives. While eco-efficiency is principally a business concept, the Ministers noted that it may equally apply to broader sectors of society, including public policy-making. They asked the OECD Secretariat to evaluate the potential contribution of eco-efficiency and report back at the 1998 OECD Environment Ministerial.

In response, the Environment Directorate’s Pollution Prevention and Control Division and Sustainable Consumption and Production Programme jointly undertook an investigation of eco-efficiency in the transport sector. A first study – “Eco-efficiency in the Transport Sector: Applying the Concept to Public Policy and Individual Travel”, commissioned from Environmental Resources Management Ltd. (ERM) -- was completed in 1996 (see attached executive summary). This study served as a background document to an Experts Workshop on “Eco Efficiency in Transport” that was held from July 7-8, 1997, at the German Federal Environmental Agency in Berlin.

The workshop had three objectives:

- To explore the use of the concept of eco-efficiency as a public policy tool in the transport sector.
- To address the role of national and local governments in facilitating transport-related eco-efficiency initiatives.
- To provide input to the forthcoming report to Ministers on the usefulness of the concept of eco-efficiency as a framework for environmental policy-making.

Workshop Structure¹

The workshop was organised into the following series of plenary sessions:

- Session 1: Eco-Efficiency in Transport (with a discussion of environmental impacts/limits)
- Session 2: Business Perspectives on Transport Sector “Value Creation”
- Session 3: Government Perspectives on Transport Sector “Value Creation”
- Session 4: Indicators and Measures of Eco-Efficiency in Transport
- Session 5: Frameworks for Promoting Eco-Efficiency

These sessions were punctuated by two smaller breakout discussions on the operational challenges of applying and promoting eco-efficiency in both freight and passenger transport. This workshop report synthesises the broad range of issues raised and discussed in Berlin.

¹ See also attached programme (Annex A)


2 ECO-EFFICIENCY: THE CONCEPT AND ITS CONTEXT

Two opening presentations on lifecycle eco-balances and factor ten reductions in material intensity stressed the importance of understanding both the breadth of transport-related environmental impacts as well as the absolute limits of the environment's capacity to absorb human-generated waste streams. Transport-related environmental impacts are principally generated by the operation of motorised road vehicles and result from the emissions of major air pollutants and the production of air and water-contaminating road dust. Transport-related land-use and, to a lesser extent, noise also have an impact on the environment. Much of past and current work on mitigating the impacts of transport activity has focused on vehicle operation by, for example, seeking to shift modal shares, improve vehicle technology and develop new fuel sources. Despite the relative importance of vehicle use impacts in disrupting the environment, participants were cautioned not to ignore impacts related to infrastructure construction, vehicle production and disposal and fuel/energy production. These can be significant and ought to be taken into consideration by policy-makers (see figure 1).

DESPITE THE RELATIVE IMPORTANCE OF VEHICLE USE IMPACTS IN DISRUPTING THE ENVIRONMENT, PARTICIPANTS WERE CAUTIONED NOT TO IGNORE IMPACTS RELATED TO INFRASTRUCTURE CONSTRUCTION, VEHICLE PRODUCTION AND DISPOSAL AND FUEL & ENERGY PRODUCTION

PASSENGER TRANSPORT				FREIGHT TRANSPORT			
	Rail vs. Road Operation Only	Rail vs. Road Operation & Energy Generation	Rail vs. Road Total Effect (incl. rolling stock & infrastructure)		Rail vs. Road Operation Only	Rail vs. Road Operation & Energy Generation	Rail vs. Road Total Effect (incl. rolling stock & infrastructure)
Energy	1 : 7	1 : 5	1 : 1.7	Energy	1 : 8	1 : 5	1 : 2.5
CO ₂		1 : 70	1 : 4	CO ₂	1 : 78	1 : 40	1 : 5
NO _x		1 : 140	1 : 4	NO _x	1 : 50	1 : 44	1 : 15
Noise	1 : 0.4	1 : 0.4	1 : 0.4	Noise	1 : 1	1 : 1	1 : 1
Land-use		1 : 45	1 : 0.7	Land-use		1 : 32	1 : 2
Accidents	1 : 10			Accidents	1 : 6		

One opening speaker also underscored the importance of establishing commonly agreed-upon strategic objectives for improving environmental performance. Extrapolating current resource use trends, speakers emphasised that in order to avoid massive and/or permanent disruption to the environment, societies would have to drastically reduce pollution and increase energy and resource productivity over the next 30 to 50 years. These changes ought not necessarily come at the expense of economic and social development but rather, development, and in particular economic development, ought to become de-coupled from the material and energy intensity of human activities. Speakers suggested that, accounting for growth in less developed countries, the industrialised world will have to increase resource productivity by a factor of 4 in the short-run and, ultimately, by a factor of 10 to 20 over the longer term (see box on page 14).

 **Figure 1: Transport-Related Life-Cycle Impacts**
Source: INFRAS, 1996

REDUCING MATERIAL INTENSITY: FACTOR TEN / FACTOR FOUR

Industrialised countries' relatively high levels of economic growth have been enabled by the use of massive amounts of the earth's geological and biological resources. The use of these resources has typically not been constrained by scarcity but rather, by the availability of capital, labour and knowledge. This has led to a "through-put" economy that wastes energy and materials at alarming rates. In Germany, for example, each citizen's annual consumption entails the movement of 70 tonnes of materials and 500 tonnes of water. Globally, more materials are moved by the action of humans than are moved by geological forces. Less than 20% of these materials ultimately end up in products; the rest are returned to the environment as wastes (ultimately, many of the materials incorporated into goods also are returned to the environment as waste at the end of products' life cycles). This inefficient use of materials threatens the environment in three ways:

1. Extracting resources from the environment disturbs local dynamic ecosystem equilibria. These disturbances can negatively alter the development of eco-systems.
2. Concentrating and releasing polluting substances can adversely impact ecosystem and human health
3. Returning materials to the environment in the form of waste can also disturb dynamic ecosystem equilibria.

Much of the world's use of materials and energy is linked to consumption in the wealthier industrialised countries. These countries account for approximately 20% of the world's population and consume approximately 80% of the world's resources. Many researchers have pointed out that these levels of consumption are incompatible with the long-term health of the environment -- especially if adopted by less- and non-industrialised nations¹. Furthermore, many experts have pointed out that the Earth's capacity to sustain these levels of resource extraction and their resulting impacts may have already been surpassed.

In 1992, Friedrich Schmidt-Bleek of the Wuppertal Institute estimated that the *wealthier nations* of the world would have to, at a minimum, reduce their use of energy and materials by half, in order to not surpass these limits. He pointed out that this reduction did not necessarily translate into a net loss of welfare since great improvements were possible in resource and energy productivity. However, a factor two increase in the resource and energy productivity of the more industrialised nations would not be sufficient if less industrialised countries increased their use of materials and energy as they develop. Allowing for these countries to double their current rates of resource and energy use, industrialised countries would have to "dematerialise" --that is, increase the resource and energy productivity -- their economies by at least a factor of ten (and to a factor of 20 to 50 when population growth is taken into account) over the next fifty years.

Some have pointed out that the practical difficulties of accomplishing such drastic changes in resource productivity may discourage many firms and governments from adopting the factor ten goal as a guide for decision-making. Ulrich von Wieszäker and Amory Lovins have pointed out that the intermediate target of a factor four increase in resource productivity is not only possible by combining existing technology and process changes, but that it is already taking place in a number of innovative firms. They assume that the implementation of a factor four increase in resource productivity by less industrialised countries would allow these to bypass a phase of unsustainable resource and energy use as they seek to develop. This assumption may not hold true and some have suggested that a factor four increase in resource productivity in *industrialised nations* can only be considered as an intermediate stage towards the goal of a factor ten improvement if the rest of the world is to have "room" to develop.

¹ For example, one participant estimated that if China were to reach current levels of car ownership in Europe, the world's total iron ore production would have to double -- along with the intending effects linked to habitat degradation, pollution, energy use and greenhouse gas emissions.

Participants generally agreed that a factor 10 increase in resource productivity seemed to be a helpful, general goal for transport policy-making although they pointed out that it need not necessarily be a universal objective as some products and processes are more efficient than others.

THE CONCEPT OF ECO-EFFICIENCY

Since the late 1980's, some members of the business community have sought to develop a framework for reconciling economic goals with the challenge of significantly dematerialising industrialised economies. In the early 1990's, the Business Council for Sustainable Development (now the *World Business Council for Sustainable Development*) proposed that the concept of *eco-efficiency* allowed such a reconciliation. While not necessarily developed with public policy in mind, some have pointed to the potential usefulness of the concept for environmental decision-making.

Eco-efficiency is a concept that focuses on value creation rather than physical output in the design and delivery of products, in order to reduce overall environmental impacts. It entails a major shift in business thinking, emphasising service, rather than material intensity, and might have the potential for leading to a significant dematerialisation of both consumption and production. Promoters of the concept assume that consumers value the *services* rendered by products rather than the specific products themselves. Implicit in this view is the notion that real wealth and value can be generated through the use of less material and energy inputs and the creation of less environmentally harmful outputs

ECO-EFFICIENCY IS A CONCEPT THAT FOCUSES ON VALUE CREATION RATHER THAN PHYSICAL OUTPUT IN THE DESIGN AND DELIVERY OF PRODUCTS, IN ORDER TO REDUCE OVERALL ENVIRONMENTAL IMPACTS

Used alternatively as an overall aim ("eco-efficiency is reached when..."), a business philosophy ("we aim to implement eco-efficiency...") and as a measure ("product x's eco-efficiency has been increased by..."), the concept's definition has been ambiguous. A quick overview of self-described "eco-efficient" initiatives reveals a broad range of understanding of the term. In most cases, business views eco-efficiency as little more than "business as usual" in which firms seek to increase resource productivity in order to lower production costs. Relatively limited process changes and/or incremental product improvements characterise these approaches. In a small but growing number of firms, however, eco-efficiency is understood to imply major process changes and completely new product/service development. Many participants at the Berlin Workshop underscored the shifting understanding of eco-efficiency as a source of confusion during discussions. Some even suggested that the only value in promoting the concept was in order to find some commonly-agreed-upon definition!

The World Business Council for Sustainable Development (WBCSD) emphasises that eco-efficiency is a process and/or way of thinking

rather than a strict input/output mechanism for guiding firms' behaviour. The WBCSD has defined the concept as follows--

“Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality to life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth’s estimated carrying capacity.” [WBCSD 1995]

The discussions at the Berlin workshop focused on the following three key features of eco-efficiency :

I. VALUE CREATION

BY FOCUSING ON THE SERVICES PROVIDED BY THEIR PRODUCTS, BUSINESSES CAN EXPLORE ALTERNATIVE STRATEGIES FOR DELIVERING THE SAME, IF NOT GREATER, VALUE TO CUSTOMERS WITH LESS ENVIRONMENTAL IMPACT

Eco-efficiency encourages firms to re-examine how their products and/or services create value for customers. By focusing on the services provided by their products, businesses can explore alternative strategies for delivering the same, if not greater, value to customers with less environmental impact. For example, are consumers interested in *travelling between destinations* or *carrying out activities* at a specific location? Are people interested in owning cars or having access to quick and spontaneous mobility? By linking such broader definitions of value creation to environmental concerns, advocates of eco-efficiency argue that considerable reductions in environmental impacts can be achieved with greater overall value to consumers, shareholders and society (see box on page 17).

II. DEMATERIALISATION/INCREASING SERVICE INTENSITY

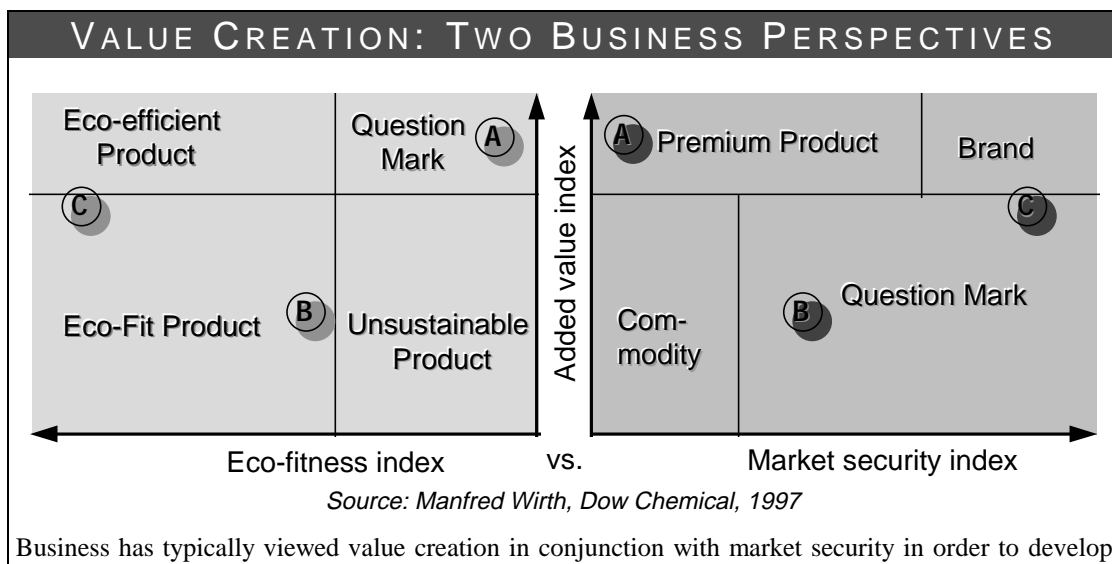
IN MANY CASES, INCREASING THE SERVICE INTENSITY OF THE ECONOMY IMPLIES DE-COUPLING OWNERSHIP AND USE OF PRODUCTS.

Closely linked to the notion of value creation is that of selling services to consumers rather than specific goods. This focus on long-term relationships with customers implies increasing inputs of knowledge and skills to make up for decreased material intensity. In extreme cases, firms assume ownership of their products throughout the life-cycle and derive profit from leasing products' functionality to customers. Firms, by designing closed loop systems where materials and components are re-used and/or recycled into new products, can greatly increase the resource productivity of meeting consumers' needs. Examples include leasing the cleaning power of solvents for industrial production and, in the transport sector, the freight capacity of trucks. In many cases, increasing the service intensity of the economy implies de-coupling ownership and use of products.

III. DECREASING LIFE CYCLE IMPACTS

In seeking to improve their environmental performance, firms have generally concentrated on reducing the impacts of internal production processes. Business has typically viewed its environmental responsibility as ending once their product is in the customer's hands. Eco-efficiency recognises that companies can do much more to reduce the environmental impacts associated with the use and disposal of their goods and calls for these impacts to be accounted for within the firm. Reducing life cycle impacts is seen by advocates of eco-efficiency as a net gain since it reduces future environmental liability, increases competitiveness in an environment characterised by more stringent environmental legislation and enhances the firm's public image. However, while many firms have developed specific indicators of life-cycle impacts, these mostly remain relative and do not necessarily provide a frame of reference from which to reduce overall impacts on the environment.

REDUCING LIFE CYCLE IMPACTS IS SEEN BY ADVOCATES OF ECO-EFFICIENCY AS A NET GAIN SINCE IT REDUCES FUTURE ENVIRONMENTAL LIABILITY, INCREASES COMPETITIVENESS ... AND ENHANCES THE FIRM'S PUBLIC IMAGE.



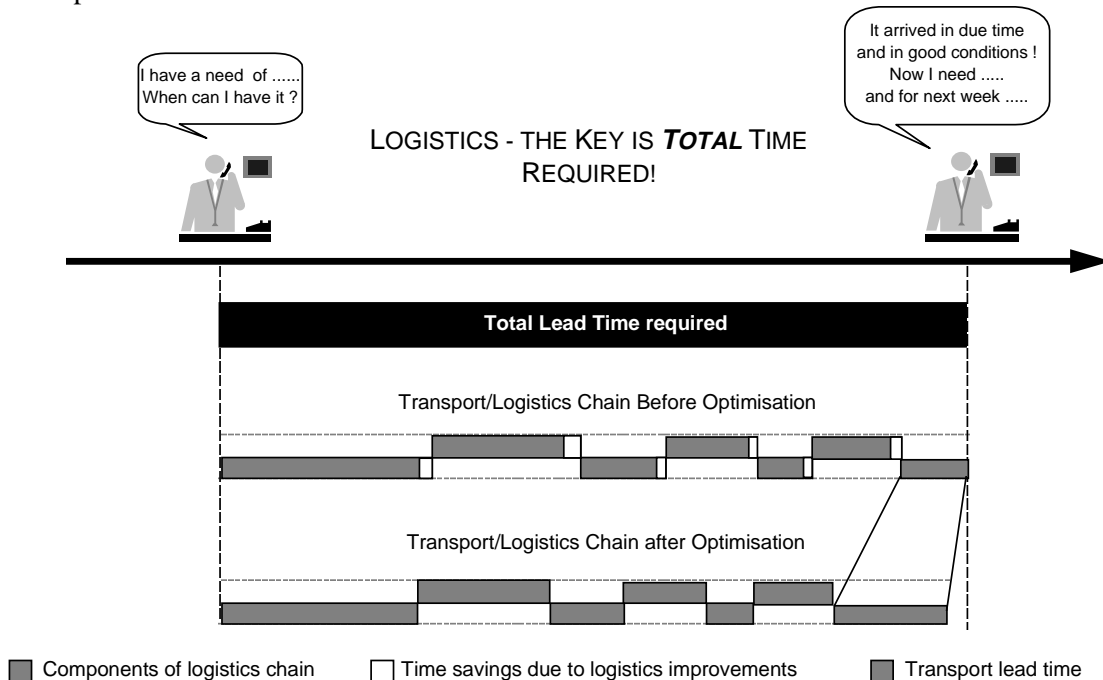
Business has typically viewed value creation in conjunction with market security in order to develop product strategies. This approach is illustrated by the right-hand side of the above figure. According to this matrix, companies will invest in products that receive higher value-added and market security ratings (e.g. fewer competitors have the capability of producing the same product). In this example, product A has an extremely high value added rating, product B has median ratings and product C has a fairly high value added rating and a high market security index. Companies might be hard pressed to choose between products A and C, although the temptation might be to select product A for its quick return on investment.

Some leading-edge companies, however, are beginning to see the environmental impacts of products as an important factor to account for when developing new strategies. They view eco-fitness as a proxy for long-term market security and have, accordingly, modified their product selection matrices. The left-hand side of the figure displays the same three products viewed according to value-added and eco-fitness. Product C is clearly the preferred option as it rates very highly for eco-fitness and relatively highly for value-added. Product A, while still a high value added product, loses much of its appeal as its production might entail a higher level of environmental liability.

3 VALUE CREATION IN TRANSPORT

Some participants stressed that transport is mostly a derived activity that generally does not in itself create value. Rather, value is generated through the *access* to people, goods and services that transport facilitates by linking spatially separated activities and locations. Responding to access needs might involve improving the quality of physical movement necessary to link destinations (e.g. travel speed, duration of travel, etc.), reducing the spatial separation between destinations and/or eliminating the need for physical movement altogether. Most efforts aimed at improving the quality of access have focused on the first of these strategies -- e.g. improving mobility. This tendency has, in part, been fuelled by relatively low-cost access to energy and materials necessary to build and operate both vehicles and infrastructure.

(TRANSPORT) VALUE IS GENERATED THROUGH THE ACCESS TO PEOPLE, GOODS AND SERVICES THAT TRANSPORT FACILITATES BY LINKING SPATIALLY SEPARATED ACTIVITIES AND LOCATIONS



Many of the presentations at the workshop incorporated wider interpretation of transport value. For example, the Swedish paper pulp manufacturer, Stora, has interpreted the value of its transport operations as getting its products to customers “*when they need them*” or “*at the right time*” rather than “*just in time*” or “*as quickly as possible*”. This slight re-formulation of its transport policy objectives has allowed Stora to concentrate on the entire logistical chain leading from raw material extraction to final delivery. “Good housekeeping” and efficiency improvements at various stages along the way have opened the possibility of using slower and less environmentally harmful modes while still guaranteeing high value for customers by meeting their delivery deadlines (see figure 2). Questions remained as

▲ **Figure 2:**
Transport Time Savings from Logistics
Source: Stora Purchasing and Transport

to whether, in the long term, decreasing the total production time might not be coupled with fast (and more environmentally harmful) transport modes to deliver more value to customers in the form of even faster order fulfilment.

Another example of innovative “value creation” can be seen in various efforts to sell the services that cars provide rather than cars themselves. While cars are very good at responding to the spontaneous travel needs of individuals, they remain a highly inefficient travel mode. For example, of the fuel energy potential from the pump, only 19% goes towards moving the car and only 2% towards actually moving the car’s occupants (see figure 3). Cars are also relatively inefficient considering their cost per hour of actual travel. Such inefficiencies have led individuals and firms to question whether the functionality (e.g. spontaneous and flexible mobility) of cars might be better provided via different means. Some participants even suggested that current demand for multi-use vehicles, including sport utility vehicles, reflects a hidden demand for multi-functionality that might be satisfied equally through non-ownership access to several types of vehicles.

CONSUMERS MIGHT BE WILLING TO OWN SMALLER AND MORE EFFICIENT VEHICLES SUITED TO THEIR MOST COMMON MOBILITY NEEDS IF THEY COULD RETAIN ACCESS TO LARGER VEHICLES FOR SHOPPING, OUT-OF TOWN TRAVEL AND OTHER SPECIAL OCCASIONS

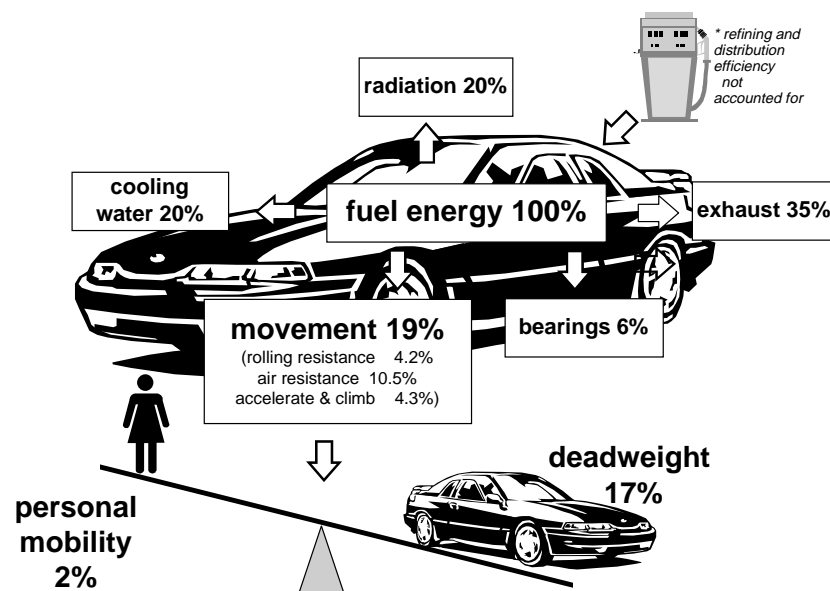


Figure 3:
Break-down of car fuel use
Source: Fussler, 1997

Consumers might be willing to own smaller and more efficient vehicles suited to their most common mobility needs (1-2 passengers, short/medium range urban driving at low/medium speeds) if they could retain access to larger vehicles for shopping, out-of town travel and other special occasions. A growing number of firms and entrepreneurs are developing transport services based on this interpretation of the value provided by cars. One speaker alluded to Mercedes’ plans to market (through its subsidiary Micro Compact Car GmbH) the SMART car as a package comprised of a yearly lease of a small efficient urban vehicle combined with 30 days use of a normal size vehicle for longer trips and/or when more carrying capacity is needed. In France, PSA

Peugeot is also developing a small urban vehicle (the TULIP) available for use at neighbourhood stations to subscription customers.

The concept of car sharing was felt by many of the workshop participants as being a particularly interesting application of transport eco-efficiency (see box on page 22). Car sharing initiatives seek to provide a practical alternative to car ownership by offering flexible car hire from neighbourhood locations. By avoiding car ownership and the accompanying need to amortise one's investment by using a car for all trips, car sharing allows people to better rationalise their car use and use less costly alternatives such as public transport and cycling. Car sharing, however, is not without its problems – not least of which are the cultural barriers to giving up car ownership. Discussions of car sharing also highlighted two other issues:

- Car sharing, if widely adopted, has the potential to remove a significant number of cars from the road. If past experience is a guide, this road space is likely to attract new drivers and generate new trips unless accompanied by measures aiming to attenuate this “rebound effect”
- Members of car sharing initiatives stand to incur financial savings from their everyday travel. If these savings are used for increasing environmentally harmful consumption (e.g. airline travel to remote vacation destinations), then the overall environmental impact may be negative.

These issues highlight the problem of addressing absolute levels of environmental impact through use of the eco-efficiency concept. While switching from owning cars to purchasing mobility certainly can be seen to reduce the environmental impacts of daily travel, overall transport-related environmental impacts are not, nor can they be, addressed at the level of the car sharing firm. That said, however, car sharing serves as a good example of the type of behavioural and resource productivity changes necessary for more sustainable transport.

Many other innovative interpretations of value creation from transport were presented at the workshop, including notably, the city of Heidelberg's efforts to reduce the average distance of trips made within the city by providing access via *proximity* rather than through *mobility*, and efforts underway in the United Kingdom and the Netherlands to reassess transport objectives in order to provide access via the least-costly options. One interesting feature of the British and Dutch transport policies is their focus on solving transport problems by demand- rather than supply- side management. Participants underscored eco-efficiency's potential to help firms and governments better supply appropriate products and services by more precisely articulating real consumer demand and transport service value. In this sense, eco-efficiency was seen as a powerful framework for promoting innovation since the concept allows transport decision-makers to focus on end-goals rather than the specific means to reach those goals.

PARTICIPANTS UNDERSCORED ECO-EFFICIENCY'S POTENTIAL TO HELP FIRMS AND GOVERNMENTS BETTER SUPPLY APPROPRIATE PRODUCTS AND SERVICES BY MORE PRECISELY ARTICULATING REAL CONSUMER DEMAND AND TRANSPORT SERVICE VALUE. IN THIS SENSE, ECO-EFFICIENCY WAS SEEN AS A POWERFUL FRAMEWORK FOR PROMOTING INNOVATION SINCE THE CONCEPT ALLOWS TRANSPORT DECISION-MAKERS TO FOCUS ON END-GOALS RATHER THAN THE SPECIFIC MEANS TO REACH THOSE GOALS.

Car -Sharing

Much as apartment dwellers in many countries have become used to sharing clothes washing machines and dryers with their neighbours, many Europeans are discovering the advantages of shared car use. Car sharing is an innovative alternative to car ownership for urban dwellers in which individuals pay for the functionality of the car, e.g. quick and flexible mobility, rather than own the car itself. In principle, car sharing is not such a new concept as friends and family have always shared cars on an informal basis. However, since 1988, a growing number of entrepreneurs have developed businesses around the idea of selling car mobility. Members typically pay a security deposit and a modest up-front yearly fee to help cover the company's capital costs. Thereafter, members are charged per kilometre and per hour of use according to the vehicle type. In return, car-sharers have access to a fleet of vehicles (ranging from sub-compact city cars to small passenger vans) that typically are made available at a number of strategically placed neighbourhood stations. Reservations can be made by telephone -- in some cases 24 hours a day -- and with relatively little advance notice. One of the principal selling points of car-sharing is the cost savings incurred by members. Rather than paying for their car to sit unused for most of the day, car-sharers pay only for their actual use which, for those that drive less than ~12000 kilometres a year, is usually less than the cost of owning and operating a car. These savings have made car sharing an attractive option for an estimated 50,000 people sharing 3,000 cars in 700 locations throughout Europe.

Essentially targeted at urban inhabitants with relatively low yearly driving (e.g. less than 12,000 km/year) car sharing has sometimes been criticised because of its potential to lead to more overall driving rather than less. Some have questioned whether decreasing the cost of car use might not serve as an incentive to drive more. This seems not to be the case. Whereas car owners typically account only for the marginal costs of operating a car (essentially the fuel costs), and treat all other fixed or indirect costs (such as parking, maintenance, insurance, tolls, traffic fines, depreciation, etc.) as being paid out of a separate "account", car sharers pay these costs per kilometre driven and per hour of use. This provides a strong incentive to rationalise car use and substitute other modes of transport whenever appropriate. Car-sharers typically drive cars *less* (both their own and shared cars) after joining and use more alternative means of transport. Many car-sharers give up their car entirely.

Car-sharing does allow for people who previously did not own a car to drive. However, non-car owners typically drive borrowed and/or hired cars previous to joining car sharing schemes. When their pre-car share driving is taken into account, non-car owners only slightly increase the amount of total kilometres driven after joining. This slight increase is more than offset by the dramatic decrease in car kilometres driven by car-owners. Studies by Switzerland's Department of Energy and Germany's Department of Transportation have found that previous car owners decreased their driving from approximately 10000 km per year to 5000 km per year, and used public transit for their remaining transportation needs.

Europe's oldest and largest car-sharing firm, Berlin's *StattAuto*, is planning on taking the concept of mobility sales one step further. Negotiations are underway with the German Federal Rail Operator and a number of other parties to offer a "mobil-carte" allowing for smooth multi-modal travel. The card will contain a computerised chip that ultimately will allow an individual to be billed monthly for travel by car, train, public transport, taxi and even by bicycle. Such a system, if widely adopted, might help level the playing field between single-owner cars and other means of transport and has the potential to reduce environmental impacts from passenger transport in urban areas. In another innovative move, *StattAuto* is investigating the possibility of creating a "return-lease" car hire programme. Under this scheme, participating members would lease their vehicle much as they might under a traditional leasing arrangement. However, at times when they have less need for a car (e.g. on week-ends) they would be able to return the vehicle to a pool of cars available for car sharing and have their monthly car payments reduced accordingly.

This process of questioning transport’s end-goals was seen as potentially the greatest contribution of eco-efficiency to the transport debate. It implicitly suggests a three-tiered approach to providing transport services, as illustrated in table 1.

Objectives	Possible roles for Government	Possible roles for Private sector
<p>1 <u>ACCESS BY PROXIMITY</u> Minimise the need for travel.</p>	<ul style="list-style-type: none"> • Land-use planning • Infrastructure provision (incl. sidewalks, bicycle infrastructure) 	<ul style="list-style-type: none"> • Development and commercialisation of telecommunications technologies • Siting decisions • Sourcing and Distribution • Infrastructure provision
<p>2 <u>EFFICIENT MOBILITY</u> Reduce the impacts of travel.</p>	<ul style="list-style-type: none"> • Infrastructure provision (incl. parking) • Public Transport • Price signals to private sector via internalisation of external costs 	<ul style="list-style-type: none"> • Improved freight logistics • Multi-modal freight operations • Packaged mobility services (incl. car sharing, multi-modal personal transport services) • Public Transport (incl. paratransit, privately operated rail, etc...) • Vehicle design for refurbishing/recycling with firms retaining ownership of vehicles
<p>3 <u>LOWER MODE-SPECIFIC IMPACTS</u> Reduce the impact of each mode</p>	<ul style="list-style-type: none"> • Vehicle performance standards • Emissions/noise regulation • Internalisation of external costs 	<ul style="list-style-type: none"> • Low emission vehicles • More efficient energy/fuel production/storage

While most current efforts to reduce transport system impacts are concentrated in the third tier, an eco-efficiency approach would suggest that market opportunities for success and the potential for radically decreasing environmental impacts associated with transport can be more effectively found in the first two levels.

Business vs. Government Value Creation

Participants faced considerable difficulty in reaching consensus on how “access” might be useful for policy-making other than as a general, qualitative, goal for transport activity. Some suggested that value creation in transport might be relatively easy at the level of specific private sector products and services since markets serve as an indicator of consumer value. Economic theory suggests that products and services that generate true value for consumers will be successful, while those that do not, will fail. This line of thinking is reflected in the business community’s thinking on eco-efficiency. Others, however

argued that markets are sometimes poor indicators of value since they do not take into account many non-quantifiable factors. Firms also influence the notion of value by creating and/or amplifying certain needs via the use of media messages.

▲
Table 1:
Eco-efficiency in Transport: Hierarchy of transport decision-making suggested by Eco-efficiency

GIVEN THE COMPLEXITY OF INDIVIDUAL AND COLLECTIVE TRANSPORT-RELATED DECISIONS, DEFINING THE "VALUE-ADDED" FROM THE TRANSPORT SECTOR AS A WHOLE IS A DIFFICULT AND UNCERTAIN PROPOSITION AND CERTAINLY ONE IN WHICH IT WAS FELT THAT GOVERNMENTS SHOULD NOT ENGAGE THEMSELVES IN UNILATERALLY

Nonetheless, participants generally agreed that addressing value creation at the level of individual firms and/or products seemed easier than doing so for governments. Given the complexity of individual and collective transport-related decisions, defining the "value-added" from the transport sector as a whole is a difficult and uncertain proposition and certainly one in which it was felt that governments should not engage themselves in unilaterally. With the possible exceptions of land-use planning, public transport and infrastructure development, governments are not typically involved in creating direct value for citizens in the transport sector. More usually, government action serves to guide and encourage value creation in the private sector. Where governments do create direct transport-related value for citizens (e.g. through dictating spatial layout and constructing and maintaining infrastructure), feedback is provided, not through the market, but through political arbitration and voting. Many participants felt that the outcome of these political processes, when accompanied by broad public consultation at the local level, might better reflect true social and economic value than, for instance, the aggregate purchasing decisions of individuals in transport markets.

Value creation in freight vs. passenger transport

Participants also discussed the differences between value creation in freight and passenger transport. They generally agreed that it was conceptually easier to address value creation for passenger transport (e.g. providing greater access) than for freight transport where value is ultimately generated through meeting demand for consumption. Many underlined the difficulty of defining boundaries for thinking about the value of freight -- should, for example, increasing globalised demand and access to products be taken as a given and, if not, to what extent could local substitutes be found for more distant goods? Participants also had difficulty identifying opportunities for providing greater service value to consumers when it came to freight.

4 DE-MATERIALISATION OF TRANSPORT: FROM PRODUCTS TO SERVICES

The converse of increasing transport value is decreasing resource intensity per unit of value. This “de-materialisation” of transport can be achieved through production and/or product efficiency improvements or by increasing the service intensity of a firm’s activities. Stora’s efforts to increase the environmental performance of its freight sub-contractors through its *Transport Chain Assessment* programme is one example of de-materialisation through efficiency improvements (see box on page 26). In this case, the comprehensive environmental assessment of multi-modal transport chains leading from production centres to customers has allowed Stora to partially dematerialise its freight operations (principally through decreased fuel use and greater load factors).

Another example of efficiency improvements leading to a partial dematerialisation of transport activity can be seen in Greenpeace’s SmILE¹ car -- a lightweight, aerodynamic and fuel efficient reformulation of the Renault Twingo (see box on page 28). Less material and energy intensive than its production line cousin, the SmILE delivers essentially the same performance and, presumably, the same value to consumers. Car manufacturers, however, have generally been reluctant to mass-produce similar vehicles citing what they perceive as the lack of demand and tight competition. Some participants, however, pointed out that eco-efficiency might provide these companies with a mechanism for linking de-materialisation to increased competitiveness. Some of the examples cited previously already indicate that this may be happening on a small scale within certain firms.

Efficiency gains can also be realised through the re-organisation of logistics chains for freight transport, as in the example of Kassel’s City Logistik programme and German freight logistics firm Fiege Logistik (see box on page 28). While generally accepting the level of freight activity as a given, these efforts can help to reduce environmental impacts per ton of freight movement by increasing load factors, streamlining operations and switching freight from road and air to other, less environmentally harmful modes. Participants, however, generally pointed out the limited scope for de-materialisation to take place as long as firms did not take responsibility for their goods and services throughout the life-cycle.

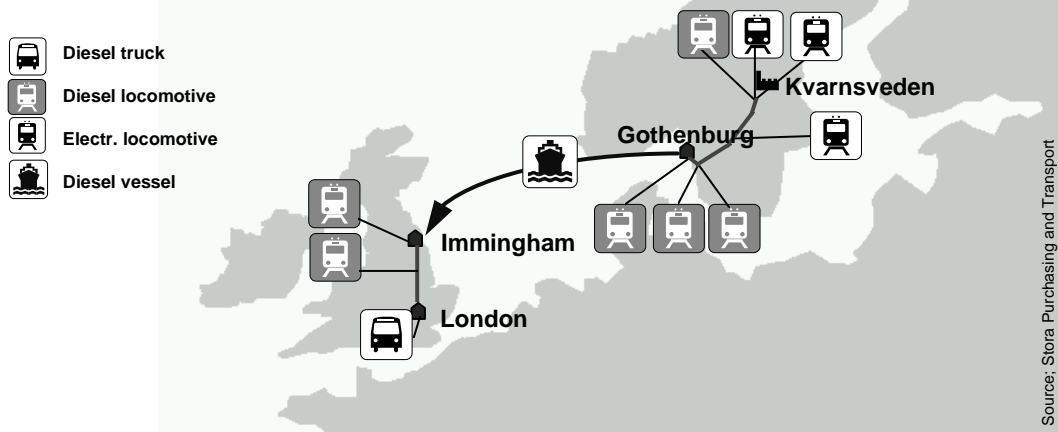
PARTICIPANTS...GENERALLY POINTED OUT THE LIMITED SCOPE FOR DEMATERIALISATION TO TAKE PLACE AS LONG AS FIRMS DID NOT TAKE RESPONSIBILITY FOR THEIR GOODS AND SERVICES THROUGHOUT THE LIFE-CYCLE

¹ *Small, Intelligent, Lightweight and Efficient.*

STORA TRANSPORT CHAIN ASSESSMENT

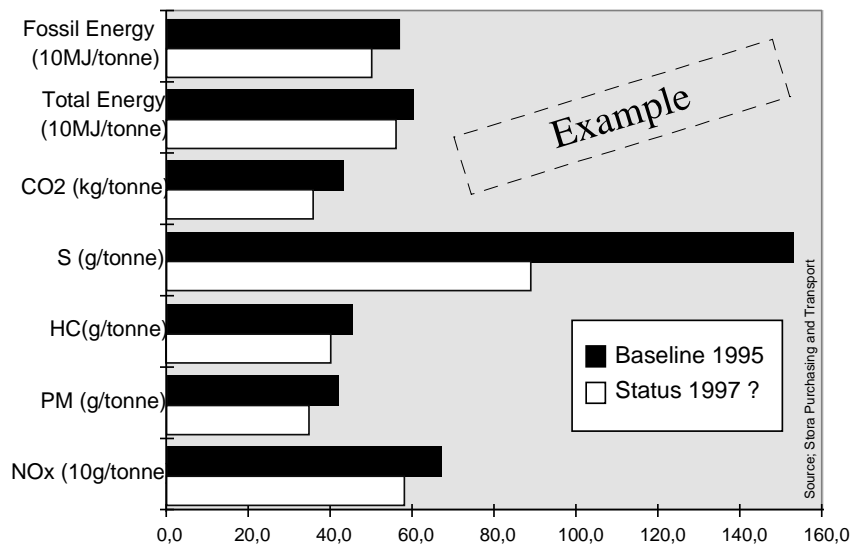
The Swedish pulp manufacturer Stora's Transport Chain Assessment (TCA) is an innovative example of one company's efforts to decrease the environmental impacts stemming from its own and its subcontractors' freight operations. TCA analyses the complete transport chain from mill to customer and creates emissions and energy usage profiles for each type of vehicle employed in the shipping *and* handling of goods. For example, the Kvarnsveden to London transport chain includes several handling operations in freight yards that must be accounted for – especially since they are mostly carried out by diesel locomotives operating in sub-optimal conditions.

THE TRANSPORT CHAIN FROM KVARNSVEDEN TO LONDON



Stora establishes a baseline energy and emissions profile and works with its transport suppliers to identify ways in which their environmental performance can be improved (fig. B). These may include increasing load factors, using more efficient vehicles and/or modes and changing operating procedures, among others. TCA has also allowed Stora to better understand some of the environmental trade-offs between different transport chains.

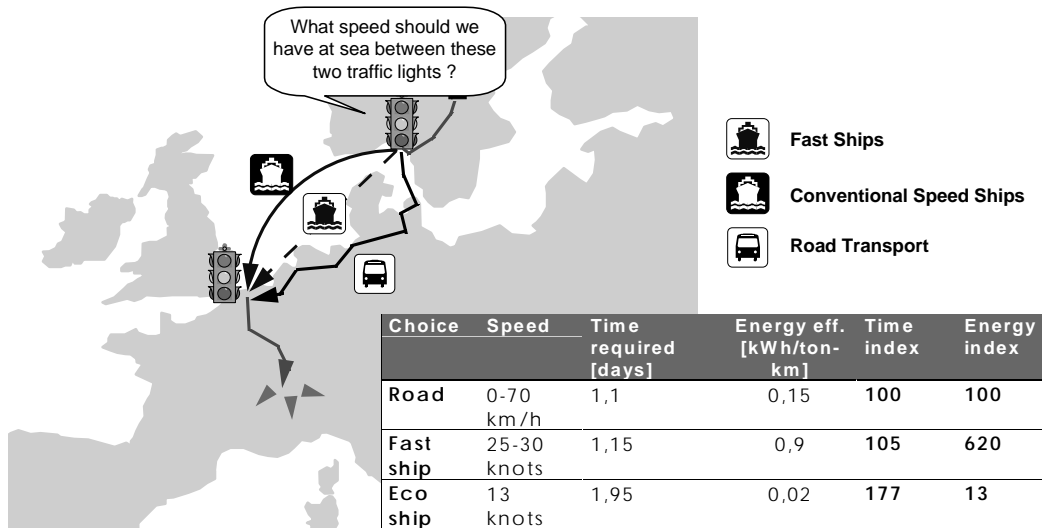
KVARNSVEDEN - LONDON: THE CUSTOMER TRANSPORT ENVIRONMENTAL PROFILE



STORA TRANSPORT CHAIN ASSESSMENT (CONTINUED)

For example, when comparing road transport to both fast and “conventional” speed ships, Stora was able to determine that, although shipping was a preferable environmental option to road transport in both cases (taking into account ships’ greater carrying capacity), the meagre time savings afforded by faster ships did not seem to justify their significantly greater fuel consumption.

FAST SHIPS VS. CONVENTIONAL SPEED SHIPS - TIME SAVINGS VS. ENERGY EFFICIENCY-




Examples of full product internalisation -- where companies treat products as wealth-generating assets to be leased to customers and recycled into new products at the end of their life-cycle -- are rare in the transport sector. The few examples which exist have only recently been put into place or are still on the drawing board -- and most of these concern passenger travel. For example, both Micro Compact Car GmbH (with the joint Mercedes/Swatch venture’s SMART urban micro-car) and General Motors (with the EV1 electric car) currently plan to lease their most innovative vehicles. Leasing arrangements where firms retain ownership of vehicles allows for the possibility of designing vehicles expressly for refurbishment and remanufacture. This type of product internalisation within companies can lead to more durable products, parts and/or materials – such as reusable polymers for body panels. Some participants pointed out that this process of product internalisation can be accelerated through the use of specific product responsibility legislation -- as in the case of German product take-back requirements for cars.

With the possible exception of leasing freight capacity as a way of better matching payloads to actual vehicle capacity (e.g. Mercedes’ Charterway programme enables customers to adapt their vehicle leases

according to the amount of freight capacity needed), participants had difficulty identifying ways to increase freight service intensity, although this did not necessarily mean that such examples did not exist.

GREENPEACE SMILE



Source: Greenpeace Germany

Greenpeace started development of the SmILE car in 1994 as a practical exercise aiming to show how automobile fuel consumption could be drastically reduced through the clever use of existing technology. The guiding philosophy behind the design of the prototype (based on a production-line Renault Twingo) was to develop a car that had essentially the same performance characteristics as the original Twingo with only half of the fuel consumption. The environmental organisation hopes to demonstrate that such technology not only has potential for smaller niche markets but that it could be adopted throughout the automotive sector.

The principal innovation leading to the SmILE's 3.3 litres/100 km fuel consumption (down 50% from the original Twingo's 6.7 litres/100 km) is in its use of a high-performance two cylinder engine that maximises engine output in the lower and middle ranges typically used by cars as they drive in urban traffic. Drawing on motorcycle racing technology, the Swiss firm WENKO AG, drastically reduced the Twingo's engine capacity while providing essentially the same acceleration and power output through supercharging (e.g increasing the air pressure in the cylinder).

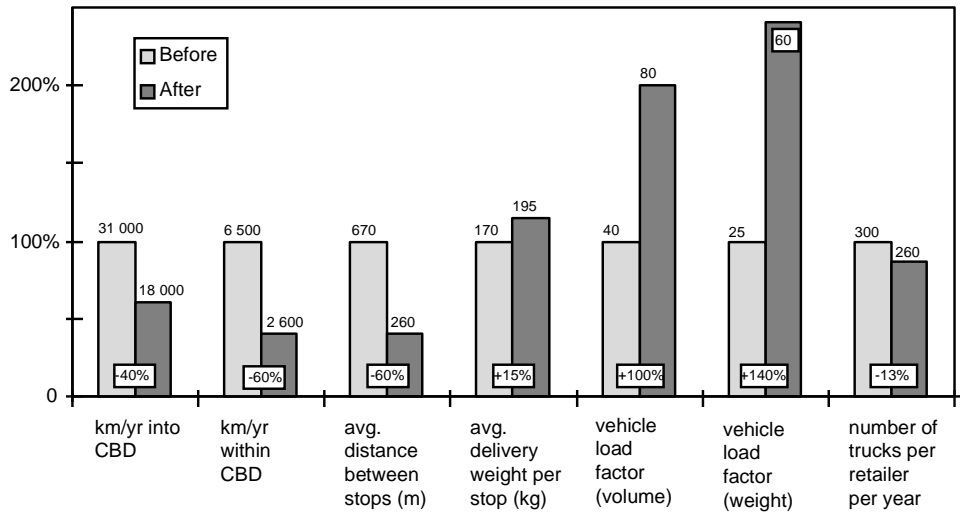
Other improvements include a 30% reduction in aerodynamic drag (while preserving much of the Twingo's styling, a 35% improvement in rolling resistance, and a 23% weight reduction (without having recourse to exotic materials and/or components).

Dematerialising Freight Transport

City Logistik Kassel

The distribution of goods is an essential activity in urban areas. It is, however, typically characterised by the inefficient use of overall private carrier freight capacity leading to unnecessarily high levels of human health and environmental impact. Growing traffic congestion also renders the task of delivery goods within cities more and more difficult, time consuming and expensive. In response to these constraints, several private freight operators in the city of Kassel came together in 1994 to address the economic and environmental impacts of their delivery operations. Their solution, "City Logistik Kassel" became one of the first of a growing number of similar initiatives aiming to rationalise inner-city freight distribution. City Logistik Kassel united ten delivery firms into a partnership that agreed to co-ordinate and bundle deliveries at a dedicated transshipment facility for distribution by a neutral carrier. The partnership expected to save costs by increasing vehicle utilisation, rationalising delivery routes and better scheduling deliveries. Analysis of the project by the University of Kassel has confirmed these some of these expectations (see figure).

Dematerialising Freight Transport (continued)

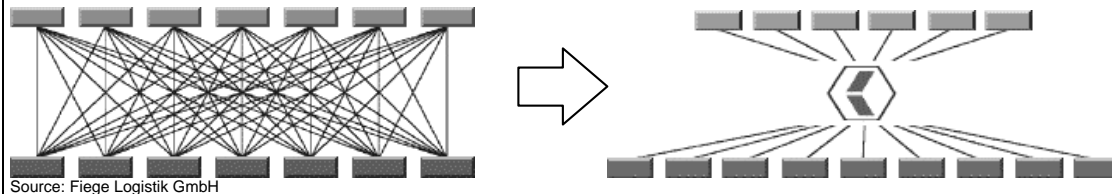


*Effects of City Logistiks in Kassel (for the ten participating carriers)
Source: Strauss, 1997*

Nevertheless, the researchers pointed out several drawbacks to the City Logistik experiment, not the least of which was the limited absolute impact on freight distribution within Kassel’s central business district (City Logistik only accounts for 3% of CBD freight distribution). Other drawbacks included the initial underestimation of transshipment and bundling costs which reduced expected cost savings from City Logistiks. The researchers also noted that, while City Logistik increased the efficiency of freight distribution for participating carriers, it did not address the overall growth in freight volumes.

Fiege Logistik

As seen in the previous example, Freight logistics management can prove to be a fruitful arena in which companies can combine cost reduction and environmental initiatives. Fiege Logistik GmbH, a German freight logistics management company, is one of a large and growing number of firms that help streamline freight transport operations within and between companies in an effort to better rationalise freight transport. By helping companies develop flexible freight delivery boundaries, bundle consignments and increase load factors, set dedicated delivery dates and reduce friction in multi-modal transport chains, Fiege has helped firms significantly reduce the number of vehicle trips necessary for getting goods to consumers. In one example cited, Fiege was able to help a large company reduce its total yearly number of trips between suppliers and outlets from 12800 to 640 by bundling loads at a trans-shipment facility -- representing a factor of 20!



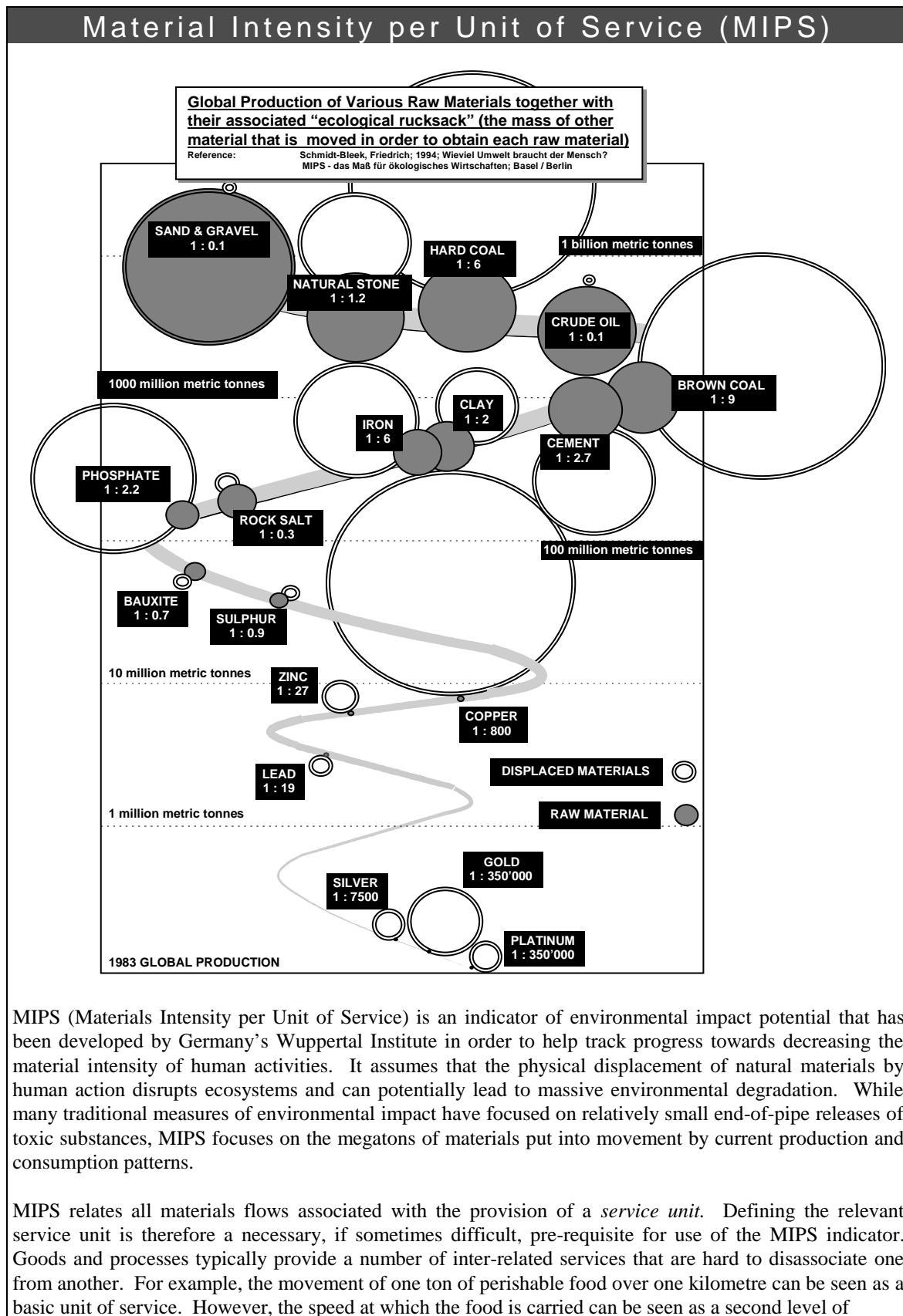
5 INDICATORS AND MEASURES OF TRANSPORT'S LIFE-CYCLE IMPACTS

Participants underscored the gap between eco-efficiency's potential for de-coupling material and energy use from value creation on the one hand, and the operational difficulties of measuring eco-efficiency -- especially at levels beyond the individual firm and/or product -- on the other. This difficulty is linked to the multiplicity of potential indicators of eco-efficiency and their frequently subjective nature.

Some have advocated the use of one single indicator to serve as a proxy for all of the environmental impacts associated with any given human activity. Noting that most materials extracted from the environment become wastes very shortly after their extraction and that even those materials that do make their way into durable products are usually returned to the environment as waste within several years, many have argued that the total material intensity of products might serve as such a proxy. Supporters of the MIPS concept (Materials Intensity per Unit of Service -- see box on page 32) felt that it might provide transport-sector decision-makers with an indication of the total environmental impact of their decisions. However, many workshop participants doubted the usefulness of such an all-encompassing indicator -- not least because of the inherent difficulty of accounting for all of the material inputs to transport activity. Some questioned, for instance, where the boundaries should be drawn for such an indicator to be useful. Should, for example, the material inputs of local road construction be included when evaluating the impact of long distance freight transport (trunk roads have little value in themselves without the networks of local roads they serve to connect) - - if so, should the material inputs of constructing road construction equipment be included?, etc. While the question of boundaries is not unique to the MIPS indicator, participants felt it did pose an important obstacle to its use. Others pointed out the limitations of aggregating all materials (and wastes) together without accounting for their specific impacts (e.g. toxicity, place of extraction, where and how the waste is disposed of, etc.). When discussing freight transport, however, some participants indicated that MIPS might serve as a useful guide for longer-term strategic decision-making.

Some workshop participants indicated that transport intensity -- e.g. the total distance travelled in order to provide one "unit of service" -- might serve as a useful indicator of transport eco-efficiency. However, using transport intensity as the sole indicator of transport system performance might mask important environmental impacts. For instance, in the break-out group on freight travel, participants discussed

PARTICIPANTS UNDERSCORED THE GAP BETWEEN ECO-EFFICIENCY'S POTENTIAL FOR DE-COUPLING MATERIAL AND ENERGY USE FROM VALUE CREATION ON THE ONE HAND, AND THE OPERATIONAL DIFFICULTIES OF MEASURING ECO-EFFICIENCY -- ESPECIALLY AT LEVELS BEYOND THE INDIVIDUAL FIRM AND/OR PRODUCT -- ON THE OTHER



MIPS (Materials Intensity per Unit of Service) is an indicator of environmental impact potential that has been developed by Germany's Wuppertal Institute in order to help track progress towards decreasing the material intensity of human activities. It assumes that the physical displacement of natural materials by human action disrupts ecosystems and can potentially lead to massive environmental degradation. While many traditional measures of environmental impact have focused on relatively small end-of-pipe releases of toxic substances, MIPS focuses on the megatons of materials put into movement by current production and consumption patterns.

MIPS relates all materials flows associated with the provision of a *service unit*. Defining the relevant service unit is therefore a necessary, if sometimes difficult, pre-requisite for use of the MIPS indicator. Goods and processes typically provide a number of inter-related services that are hard to disassociate one from another. For example, the movement of one ton of perishable food over one kilometre can be seen as a basic unit of service. However, the speed at which the food is carried can be seen as a second level of

Material Intensity per Unit of Service (continued)

service and the specific variety of food carried as a third. These related units of service can make substitution by a more resource efficient option difficult, if not impossible. In practice, MIPS typically links transport-related material flows to passenger/kilometres for the transport of people and tonne/kilometres for the movement of goods.

MIPS considers all material flows related the provision of a unit of service. These include materials that are actually embodied in the final product (or directly related to the provision of a service) as well as those that are displaced in pre-manufacture and disposal processes. For many products, these “hidden” material flows (called the “ecological rucksack”) associated with goods can be several orders of magnitude greater than the materials incorporated in the good itself (see figure). Supporters of materials intensity analysis acknowledge that the MIPS indicator can only serve as a rough proxy for measuring environmental impact (e.g. MIPS does not necessarily indicate the environmental health risks of certain toxic compounds) although they argue that the magnitude of certain material flows and the relative size of ecological rucksacks are such that they should alert the public to potential problems. For instance, platinum has an extremely large ecological rucksack (1:350,000 -- bottom of figure). Demand for platinum is expected to continue to rise if and when direct-injection gasoline engines become more widely adopted as this technology is well suited for the extremely high air:fuel ratios of these engines. While, in absolute terms, little platinum is actually extracted, the high MIPS figure for current catalyser technology ought to alert manufacturers to the need to develop less material intensive alternatives.

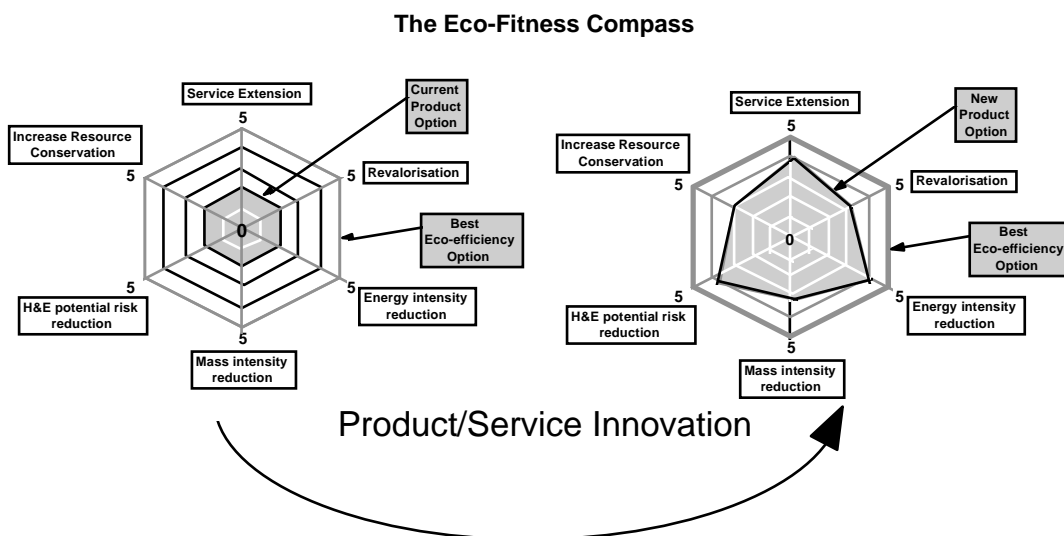
how the use of transport intensity might distort an analysis of tomato consumption in the Netherlands. In this case, winter tomatoes can be shipped via truck from Spain or produced and shipped locally from heated greenhouses. A rigorous analysis of the transport intensity of tomato consumption would conclude that shipping from local sources is a better option. A different conclusion might be reached if, however, a total materials and energy analysis of winter greenhouse tomato production is carried out and contrasted with the same analysis of growing and shipping tomatoes from Spain.

As with MIPS, use of transport intensity implies that the “unit of service” provided by transport activity is fairly well defined. The workshop discussions underlined the difficulty of defining what exactly might constitute a “transport service unit”. Was it access? If so could “access” be expressed in discrete units? Could GDP serve as a reasonable approximation of the service derived from transport? If so, what did it leave out? Ultimately, participants found it generally unsatisfactory to attempt to define transport “service units” beyond their strict numerical expression (passenger kilometres and tonne kilometres travelled). However, these expressions of transport service units did not succeed in capturing the qualitative notion of transport value creation and, therefore, did not seem to be good indicators of eco-efficiency.

Some firms have chosen to measure eco-efficiency by incorporating multiple indicators into one composite measure. Dow Chemical’s eco-compass, for example, tracks seven indicators and displays the result in an easy-to-read graphical display (see figure 4). While noting that applying the eco-compass to transport decision-making seemed

difficult at any level above individual projects and/or products, participants did see the utility in combining several types of indicators to measure transport sector eco-efficiency. These might include combining measures of energy efficiency, MIPS, transport intensity, life cycle analyses of toxics releases, etc. Ultimately, however, participants seemed at a loss to identify a quantifiable indicator of “value added” in transport. Some strongly supported the use of individuals’ and firms’ market behaviour as evidence of value while others, just as strongly, viewed these as skewed because of the inability of prices to reflect certain non-quantifiable but nonetheless, valued services (e.g. current price structures favouring automobiles do not reflect the value given by many to children’s ability to walk to school in safety from traffic).

Figure 4:
Dow Eco-Fitness
Compass
Source: Manfred
Wirth, 1997



6 CONCLUSION: PUBLIC POLICY AND TRANSPORT ECO-EFFICIENCY

Table 2 reflects the general consensus that emerged at the end of the workshop regarding the overall “value-added” of the eco-efficiency concept to transport decision-making. In it, three important contributions of the concept to transport policy-making are highlighted:

1. LIFE-CYCLE IMPACTS

Eco-efficiency’s focus on the complete life-cycle of products and services provides firms and government with a framework with which to better analyse specific transport alternatives. Accounting for impacts from the manufacture and disposal of vehicles, fuels and infrastructure, in addition to vehicle’s use-related impacts, may sometimes significantly alter the context for transport decision-making. In particular, participants addressed using indicators of the total material intensity per service unit (MIPS) of transport activity. MIPS measures both direct use of materials (e.g. those materials incorporated into final products) as well as indirect material flows (e.g. those materials displaced or discarded in the process of manufacturing final products and/or providing services). Participants also examined the use of transport intensity (as measured in distance per unit of transport service) as an indicator of transport eco-efficiency.

2. DEMATERIALISATION

Eco-efficiency provides a conceptual and operational framework for increasing the resource and energy productivity of *specific* transport products and services. By focusing on increasing the knowledge and service intensity of transport activity, firms and governments can significantly reduce unit- and/or service-specific environmental impacts. These improvements can be technology-based, or process-based; examples of the former include very low-impact vehicles (e.g. Greenpeace’s SmILE) while examples of the latter include efforts to reduce environmental impacts throughout products’ transport and logistics chains (as practised by the pulp and paper manufacturer STORA with their *Transport Chain Assessment* programme).

3. VALUE CREATION: MEETING CONSUMER NEEDS AND MOTIVATIONS

The concept of eco-efficiency, as a framework for transport decision-making, has the potential to radically alter the way in which transport systems are conceived, developed and used. By encouraging firms, governments and citizens to re-assess the importance of material inputs in meeting transport demand, new, less-environmentally harmful products, services and practices can be developed in such a way that overall welfare increases. Such a re-assessment has already lead to significant, albeit limited, improvements in material and energy productivity in transport and has fostered increased innovation in transport problem-solving. For example, some entrepreneurs and established auto-makers are re-defining their roles as “mobility-providers” rather than “car providers”. This has led to several promising initiatives which have pioneered new car-owner relationships in which “car-sharing” firms sell the service cars provide (e.g. flexible, near-instant mobility) rather than the cars themselves. Such “pay-for-use” leasing arrangements allow customers to more closely match their actual travel needs with the mode best suited for each trip -- reducing participating households’ dependence on -- and use of -- automobiles. Some manufacturers are similarly planning to bundle smaller urban vehicles with car hire services allowing owners access to larger vehicles when necessary.

	Passenger Transport	Freight Transport
Public Sector	<ul style="list-style-type: none"> 👍 Broadly defining transport policy end-goals can lead to innovative solutions ❓ defining “value creation” 👍 Efficiency improvements are relative and do not take into account absolute limits to growth 👍 Difficulty in Measurement: “access efficiency”, “Unit of service” 👍 Low public acceptance of policy tools 	<ul style="list-style-type: none"> 👍 Broadly defining transport policy end-goals can lead to innovative solutions ❓ defining “value creation” 👍 Efficiency improvements are relative and do not take into account absolute limits to growth 👍 Policy tools are unclear
Private Sector	<ul style="list-style-type: none"> 👍 opportunities for more broadly defining consumer value 👍 de-materialisation of transport activity via increase in service intensity 👍 increases of resource productivity per unit of value 👍 greater responsibility for life-cycle impacts ❓ Unit of value (e.g. “access”) somewhat vague 👍 Efficiency improvements are relative and do not take into account absolute limits to growth 	<ul style="list-style-type: none"> 👍 re-defining “value created” can lead to innovation in transport product/service development 👍 Framework for reducing impacts through logistical re-organisation 👍 Life-cycle perspective focuses on entire transport chain ❓ Difficulty in defining unit of value 👍 Efficiency improvements are relative and do not take into account absolute limits to growth 👍 Limited opportunities for increasing service intensity
👍 Good value 👎 Poor value ❓ Uncertain value		

*Table 2: Eco-efficiency in Transport
Summary of some key conclusions regarding the concept’s value.*

ISSUES TO BE ADDRESSED BY GOVERNMENTS

The workshop discussions identified two principal limitations of the eco-efficiency concept as applied to transport:

1. REDUCTION IN ABSOLUTE VS. RELATIVE ENVIRONMENTAL IMPACTS

There is little firm evidence that eco-efficiency, alone, can lead to a reduction in the absolute levels of environmental impacts resulting from transport activity. While eco-efficiency’s potential for relative improvements in material and energy productivity at the level of firms, products and services seems clear, the concept does not seem to provide a framework for governments to prevent “re-bounce” effects leading to greater overall energy and material use. Eco-efficiency, at least in the transport sector, does not seem to be able to take into account environmental impacts stemming from growing consumption. This shortcoming needs to be addressed when promoting the concept for central government policy-making. However, where governments provide specific products and services (e.g. public transportation, land-use planning, infrastructure provision), eco-efficiency can help lead to decreases in specific environmental impacts. Participants generally viewed the role of central governments as fostering and facilitating eco-efficiency at the local level and in the private sector rather than promoting eco-efficiency as an overall transport policy framework.

2. DEVELOPMENT OF ECO-EFFICIENCY INDICATORS

Workshop participants underlined the complexity and difficulty of measuring eco-efficiency in the transport sector. Tracking progress in reaching both environmental and economic objectives will likely require several indicators applied differently depending on the scale and/or nature of the activity (e.g. products vs. firms, passenger vs. freight travel, local vs. national levels). While some of these indicators are quantitative and, therefore, fairly easy to measure (e.g. vehicle kilometres, passenger kilometres, etc.), many others are qualitative and open to subjective judgements (e.g. access, transport value, unit of service). These judgements are difficult, if not impossible to aggregate and are therefore hard for central governments to use in any but the broadest manner.

CONCLUSIONS

Participants highlighted eco-efficiency's potential to reduce the *specific* environmental impacts resulting from the design and production of transport-related products and/or services. However, they generally agreed that broadly applying the concept to the transport sector was, at best, a difficult and uncertain exercise. In particular, they saw only limited use of the concept for government transport policy-making. At the close of the workshop, participants were generally sceptical as to the usefulness of subsuming *transport and environmental* policy-making under the banner of eco-efficiency.

ANNEX A: WORKSHOP PROGRAMME

Monday, 7 July 1997

<p>09:10-09:30 Opening</p>	<ul style="list-style-type: none"> • Welcome by the German Federal Environmental Agency. • Opening by OECD Environment Directorate 	<p><i>Prof. Dr. P. - Ch. Storm, UBA</i> <i>J. Cinq-Mars, OECD</i></p>
<p>09:30-10:50 ① Plenary Session Eco-Efficiency in Transport</p>	<p><u>Overview:</u> Eco-efficiency in transport implies <u>maximising “value”</u> associated with current transport needs, while <u>minimising environmental impacts</u> generated by the fulfilment of those needs. After opening presentations on the concept of eco-efficiency and its applicability in the transport sector, participants will be invited to consider several environmental goals that might serve to guide transport eco-efficiency.</p> <p>The Eco-efficiency Challenge</p> <p>Eco-efficiency in Context Eco-efficiency, <i>Material Inputs per Service Unit (MIPS)</i>, and Sustainability Life-cycle impacts of transport Questions and comments</p>	<p>Chair: <i>Jeremy Eppel, OECD</i></p> <p><u>Video Presentation</u> <i>Manfred Wirth, Dow Europe</i></p> <p><u>Speakers</u> <i>Yoshiharu Miyauchi, Sony Europe</i> <i>Friedrich Schmidt-Bleek, Wuppertal Institute</i> <i>Mr. Maibach, INFRAS, Zurich</i></p>
<p>10:50-11:10</p>	<p>Coffee Break</p>	
<p>11:10-11:40 ① Plenary Session (continued)</p>	<p>“Eco-efficiency in the Transport Sector: Applying the Concept to Public Policy and Individual Travel” (OECD background report)</p> <p>Comments and Questions</p>	<p><i>Tim Young, ERM, United Kingdom</i></p>
<p>11:40-13:00 ② Plenary Session Business Perspectives on Transport Sector “Value Creation”</p>	<p><u>Overview:</u> The second and third plenary sessions will explore several different interpretations of the “value” created by transport. These issues will be discussed from the perspective of the private sector in the second plenary, and from the perspective of government in the third.</p> <p>Car-Sharing SMILE Car Transport Chain Assessment- A Tool for Eco-efficient Logistics Provider of Freight Services</p> <p>Questions/comments and discussion.</p>	<p>Chair: <i>Axel Friedrich, UBA</i></p> <p><u>Panel</u> <i>Conrad Wagner, European Car Sharing</i> <i>Wolfgang Lohbeck, Greenpeace Germany</i> <i>Olle Widigsson, Stora</i> <i>Ulrich Lohaus, Fiege Logistik GmbH</i></p>
<p>13:00-14:30</p>	<p>Lunch</p>	

<p>14:30-15:50</p> <p>③ Plenary Session</p> <p>Government Perspectives on Transport Sector “Value Creation”</p>	<p>British Least-Cost Transport Planning (reducing transport intensity)</p> <p>Transport Policy in the Netherlands: Access vs. Mobility</p> <p>Planning for Access by Proximity vs. Access by Mobility</p> <p>City Logistik Kassel</p> <p>Questions/comments and discussion</p>	<p>Chair: <i>Jeremy Eppel, OECD</i></p> <p><u>Panel</u></p> <p><i>Tom Worsley, UK Dept. of Environment, Transport and the Regions</i></p> <p><i>Marien Bakker, Ministry of Transport and Waterworks, Netherlands</i></p> <p><i>representative of CBB, Berlin</i></p> <p><i>Susanne Strauss, Univ. Kassel/MOVE Hannover</i></p>
<p>15:50-16:10</p>	<p>Break</p>	
<p>16:10-17:40</p> <p>Parallel Working Groups A</p> <p>Eco-Efficiency in Freight and Passenger Transport</p>	<p><u>Passenger Transport</u></p> <p>Facilitator: R. Gilbert, Canada</p> <p>Rapporteur: S. Peake, IEA</p>	<p><u>Freight Transport</u></p> <p>Facilitator: N. Gorisson, UBA</p> <p>Rapporteur: L. Michaelis, OECD</p> <p>Based on the foregoing presentations and participants own practical experience, the working groups will address the following questions:</p> <ul style="list-style-type: none"> • Are there other dimensions of eco-efficiency in transport that have not yet been discussed? • Are there common strands in the different visions of transport eco-efficiency?
<p>17:40-18:10</p> <p>④ Plenary Session</p> <p>Reports back from Working Groups A</p>	<p>Chair: <i>Axel Friedrich, UBA</i></p> <ul style="list-style-type: none"> • Overview of key points of the discussion. • Specific conclusions and insights • Unresolved issues. 	
<p>18:10</p>	<p>End of first day</p>	

Tuesday, 8 July 1997

<p>09:00-09:10</p> <p>Opening</p>	<p>2nd day opening by Chair.</p> <p style="text-align: right;"><i>Jean Cinq-Mars, OECD</i></p>
<p>09:10-10:20</p> <p>⑤ Plenary Session</p> <p>Indicators and Measures of Eco-Efficiency in Transport</p>	<p><u>Overview:</u> Chair: <i>Jean Cinq-Mars, OECD</i></p> <p>Measuring eco-efficiency and assessing its performance in satisfying “<i>human needs and bring[ing] quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle</i>” poses some challenges. The focus here will be to discuss a). how to quantitatively measure eco-efficiency and set targets and goals for performance, b). how different actors interpret those goals and targets and c). how complete a picture would these indicators give; are other indicators of aggregate impacts on the environment needed?</p> <p style="text-align: right;"><u>Video Presentation</u></p> <p>Eco-innovation <i>Manfred Wirth, Dow Europe</i></p> <p style="text-align: right;"><u>Speaker:</u></p> <p>Indicators and Measures of Eco-Efficiency: <i>Hartmut Stiller, Wuppertal Institute</i> Research Community Perspective</p> <p>Questions/comments and discussion</p> <p>Discussion questions:</p> <ul style="list-style-type: none"> • <i>What is(are) the basic unit(s) of service in passenger and freight transport?</i> • <i>How can access efficiency and transport intensity of goods and services be measured?</i> • <i>At what scale (firm, industry sector, region, nation, etc...) will eco-efficiency indicators be appropriate?</i>
<p>10:20-10:40</p>	<p>Coffee Break</p>
<p>10:40-11:25</p> <p>⑥ Plenary Session</p> <p>Frameworks for Promoting Eco-Efficiency:</p>	<p><u>Overview:</u> Chair: <i>Axel Friedrich, UBA</i></p> <p>Using eco-efficiency as a framework for reducing the overall environmental impact of transport activity will require co-operation between governments, industry and other stakeholders to develop appropriate incentives and institutional support. After a brief overview of the potential of different policy instruments to reduce environmental impacts from transport, two examples will be given of government approaches to transport policy that have the potential for leading to greater eco-efficiency.</p> <p style="text-align: right;"><u>Speakers:</u></p> <p>Overview of Policy Instruments' Potential for Reducing Environmental Impacts from Transport <i>Laurie Michaelis, OECD</i></p> <p>Swedish EST Stakeholder Approach <i>Stefan Andersson, Swedish EPA</i></p> <p>United States ISTEA Planning Guidelines <i>Roy Kienitz, Surface Transportation Policy Project, Washington</i></p> <p>Questions/comments and discussion</p>

<p>11:25-12:55</p> <p>Parallel Working Groups B:</p> <p>Frameworks for Promoting Eco-Efficiency: Government and Business Roles</p>	<p><u>Passenger Transport</u></p> <p>Facilitator: R. Gilbert, Canada Rapporteur: S. Peake, IEA</p>	<p><u>Freight Transport</u></p> <p>Facilitator: N. Gorisson, UBA Rapporteur: Laurie Michaelis, OECD</p> <p>The two working groups will discuss (for freight and passenger transport respectively) what might be appropriate roles for governments and businesses in promoting more widespread use of eco-efficiency in transport decision-making.</p>
<p>12:55-14:25</p>	<p>Lunch</p>	
<p>14:25-15:55</p> <p>Plenary Session</p> <p>Reports Back from Working Groups B</p>	<p>Chair: <i>Axel Friedrich, UBA</i></p> <ul style="list-style-type: none"> • Overview of key points of the discussion. • Specific conclusions and insights • Unresolved issues. 	
<p>15:55-16:55</p> <p>⑦ Plenary Session</p> <p>Eco-Efficiency in Transport: An Evaluation</p>	<p><u>Panel Discussion:</u></p> <p>The session will open with a panel composed of business, research and government representatives each summarising how they view the potential contribution of eco-efficiency towards satisfying both business and environmental imperatives. The panel will address the following questions:</p> <ul style="list-style-type: none"> • What, from a transport policy-making perspective, can be said about the "value added" of the concept of eco-efficiency -- as opposed to other concepts? • What are some of the principal limitations of the concept as applied to the transport sector? • Does eco-efficiency as a framework for a) private and b) public transport-related decision-making have the potential for reducing the environmental impacts of transport activity? <p><u>Panel</u> Speakers representing business, government, research and ngo's Discussion</p>	<p>Chairs: <i>Jean Cinq-Mars, OECD</i> <i>Axel Friedrich, UBA</i></p>
<p>16:55-17:05</p> <p>End of Workshop</p>	<p>Chair's conclusions/ end of 2nd day</p> <p style="text-align: right;"><i>Workshop Chairs, UBA/OECD</i></p>	

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II. Background Paper

ECO-EFFICIENCY IN THE TRANSPORT SECTOR:
*APPLYING THE CONCEPT TO PUBLIC
POLICY AND INDIVIDUAL TRAVEL*

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July 1996

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EXECUTIVE SUMMARY

*This study builds on the OECD workshop held in Rosendal, Norway in July 1995, where **eco-efficiency** was identified as currently the most promising strategy for developing policies for more sustainable patterns of consumption and production. In simple terms, eco-efficiency means achieving economic and environmental gains from 'doing more with less': maximising the value created for a given set of environmental impacts and resource use. The study examines the implications and usefulness of eco-efficiency for public policy in relation to individual transport.*

Reducing emissions and noise, improving the energy efficiency of different modes, and encouraging the use of less environmentally-damaging modes are major themes in policy on transport and the environment. A policy based on the concept of eco-efficiency would include continuing this process, and developing indicators and models to manage it better.

*However, applying eco-efficiency principles to the transport system implies going further: replacing **mobility** - the ability to move from A to B - with **access** to goods, services and other people as the ultimate aim of policy in relation to transport. This shift in thinking is beginning to happen in some OECD countries, and suggests that the concept of eco-efficiency may be useful as a 'banner' under which to accelerate these changes. 'Eco-efficiency' could also help in integrating environmental and economic policies in relation to transport through the simple idea of 'doing more with less'.*

Eco-efficiency also implies, however, achieving the same degree of access with less movement: 'reducing the need to travel'. Many conventional tools of transport policy (such as cost-benefit analysis) were developed for the assessment of infrastructure investments and are ill-suited to the management of the interaction between transport and land-use that is implied in reducing the need to travel. New tools which promote eco-efficiency at this level, such as the accessibility profiles used in Dutch land-use planning, are needed. The concept of 'transport intensity' - the amount of transport associated with a particular service - may offer a basis for developing some of these. The report suggests that transport intensity may be used both as an aid to land-use planning and as a retrospective indicator of the success of policy in practice.

Leading-edge companies in the private sector are developing a number of tools to improve the eco-efficiency of their operations, and indicators to measure progress. However, these indicators are still at an early stage and other sector-specific approaches are likely to be needed for the development of indicators for public policy on transport.

The report concludes that eco-efficiency is a concept that can be usefully applied in the context of public policies in relation to individual travel. As with eco-efficiency in the private sector, it picks up the leading edge of thinking in relation to transport, the environment and the economy, and offers an underlying approach which cuts across sectoral boundaries. Applying the principles of eco-efficiency to public policy on transport can also be expected to lead to new indicators or policy tools specific to this particular application.

1 INTRODUCTION

1.1 BACKGROUND

This report has been prepared by Environmental Resources Management (ERM) for the Environment Directorate of the Organisation for Economic Co-operation and Development (OECD). It forms part of the OECD's work on transport within the programme on Sustainable Consumption and Production.

The growth of individual travel and freight transport in OECD countries has been rapid in the last few decades. With it has come a range of environmental problems: local problems (e.g. urban air pollution) have been experienced more intensely; and our knowledge of and concern about the global and regional impacts of transport emissions has increased. Most of the growth in travel witnessed in the last fifty years has been accounted for by the car. It is now widely recognised that, in many urban areas, it will be physically impossible to meet the demand for car-based transport that rising personal incomes brings with it. But effective policies to restrain this growth in transport have proved elusive. Progress has been made in reducing the impacts of supporting a given level of mobility, but these have generally been outweighed by the absolute growth in transport. There is thus an urgent need to identify new approaches to policy on transport which will be effective in curbing both the demand for mobility and the impacts associated with supplying it.

This study examines the potential for applying the concept of eco-efficiency to transport policy. It builds on previous work carried out as part of this programme, notably the workshop held at Rosendal, Norway, in July 1995. This workshop, entitled *Sustainable Consumption and Production: Clarifying the Concepts*, aimed to improve the conceptual basis for policy development in OECD countries and to focus the efforts of other international organisations on the most promising conceptual approaches to developing policies for more sustainable patterns of consumption and production. One of the main conclusions of the workshop was that eco-efficiency offers the most promising strategy, not only for business, but also for governments and households. This conclusion was reinforced at the February 1996 meeting of OECD Environment Ministers, where eco-efficiency was identified in the resulting communiqué as a key research area for the next two years.

1.2 OBJECTIVES

The main aim of the study is to identify the central issues relating to the application of eco-efficiency to transport-related public policy. The study examines:

- eco-efficiency and policy *goals* - that is to say, eco-efficiency as a broad concept to guide policy, and as a basis for developing specific objectives in relation to transport; and
- eco-efficiency and policy *tools*, where the concept is operationalised into quantitative indicators.

The key questions addressed by the study are:

- How useful is the concept of eco-efficiency in the context of public policy, given that it was originally developed by and for business?
- Does eco-efficiency suggest any new directions for transport policy?
- What are the implications of eco-efficiency for policy tools?
- Can quantitative indicators of eco-efficiency be developed to assist the formulation and implementation of public policy in relation to transport, and, if so, what might these be?

1.3 SCOPE AND STRUCTURE

The study focuses on the use of eco-efficiency in guiding *public policy* which has impacts on individual travel behaviour and transport, including policies on transport, land use and telecommunications. The study does not explore the application of eco-efficiency in private sector transport operations or vehicle manufacturing, except where this highlights important issues for public policy.

The report is structured as follows:

- *Section 2 - What is Eco-Efficiency?* examines the origins of the term, its definition, and how it is understood in this study. It presents an initial assessment of the relevance of corporate eco-efficiency, and a more general assessment of its implications, for transport policy. Finally, this section also introduces some specific terminology used in the study.
- *Section 3 - Goals: Value Creation*, discusses eco-efficiency objectives in corporate and public policy contexts. The focus is on the concept of value creation explicit in eco-efficiency.

- *Section 4 - Tools: Working Towards Eco-Efficiency*, examines how companies are improving their eco-efficiency and how public policymaking might learn from this process. It presents an initial assessment of the scope for developing quantitative indicators of eco-efficiency in transport which could be used in guiding public policy.
- *Section 5 - Eco-Efficiency and Current Transport-Related Policy*, explores the compatibility of eco-efficiency with current policies in terms of both their goals and tools. It examines both conventional and emerging transport policy trends.
- *Section 6 - Conclusions*, presents the findings of the report in relation to the objectives set out in *Section 1.2* above.

1.4 METHODOLOGY

The study was conducted primarily on the basis of analysis of written documentation already held in-house by ERM. This information was supplemented with a literature review of papers presented at recent European Transport Forum conferences; and contacts with selected organisations and individuals, both face-to-face and by telephone. The aim of this approach was to maximise the resources available for analysis, whilst ensuring that the study covered important developments in the transport field. The result is that many of the examples presented have a UK focus; however, by drawing out some general principles we believe that the analysis in the report is applicable to OECD countries in general. Additional work to examine the conclusions of the report within the context of specific national conditions in selected OECD countries might be valuable.

The report has been reviewed by the OECD, and informally by a number of others working in the field of transport.

2 WHAT IS ECO-EFFICIENCY?

2.1 ORIGINS AND DEFINITION

Eco-efficiency is a term that was coined by the Business Council for Sustainable Development in *Changing Course*, its report to the United Nations Conference on Environment and Development in Rio⁽¹⁾. It is a concept that is being pioneered primarily by business, for business. *Table 2.1a* summarises the key features of eco-efficiency to arise from this work; whilst *Annex A* presents a more in-depth exploration of the concept⁽¹⁾.

In this study, the WBCSD's⁽¹⁾ working definition of eco-efficiency (as presented in *Table 2.1a*) is adopted and developed. The key development is a distinction between eco-efficiency as a broad concept to guide policy; and eco-efficiency as the basis for a set of tools which public bodies could use to make decisions in practice:

- *Eco-Efficiency and Policy Goals.* This approach reflects a view of eco-efficiency as a *strategic thought process*, 'a way of using environmental constraints to re-think business'.⁽¹⁾ At a corporate level, eco-efficiency is being promoted as a concept to change the way business is done in the same way that the idea of 'quality' has done in recent years. In this sense it has value both as a 'banner' under which to promote continuous environmental improvement, and as a framework within which to develop specific policy objectives: this is the value added of the concept, even where it is difficult to present numerical indicators which can adequately chart progress towards eco-efficiency.
- *Eco-Efficiency and Policy Tools.* This approach implies using eco-efficiency as the basis for indicators and tools to be used for measuring and managing the performance of the transport system. It involves maximising quantified *outputs* (value added) per unit of resource *input* and/or environmental impact; or put another way, minimising inputs and impacts for a given level of 'output'.

⁽¹⁾ Schmidheiny, 1992.

⁽²⁾ *Annex A* is an extract from the final report of the OECD's Rosendal Workshop on Sustainable Consumption and Production (OECD, 1995).

3(3) In 1994 the Business Council for Sustainable Development (BCSD) merged with the World Industry Council of the Environment (WICE) to form the World Business Council for Sustainable Development (WBCSD), which is the principal body now promoting and developing eco-efficiency on the part of business..

⁽⁴⁾ WBCSD, 1995b, p.11

Table 2.1a What is Eco-Efficiency?

Definition	<i>Eco-efficiency is reached by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity.</i>
Key elements	<p>Seven key elements identified by WBCSD:</p> <ol style="list-style-type: none"> 1. Reduce the material intensity of goods and services 2. Reduce the energy intensity of goods and services 3. Reduce toxic dispersion 4. Enhance material recyclability 5. Maximise sustainable use of renewable resources 6. Extend product durability 7. Increase the service intensity of goods and services <p>The WBCSD emphasises eco-efficiency as a <i>process</i> or way of thinking rather than as a received template. There is also academic interest in the concept of the '<i>utilization-focused economy</i>' i.e. a high service intensity economy.</p>
Promoted by	The World Business Council for Sustainable Development (WBCSD) is a vigorous advocate. Leading-edge companies are also beginning individually to use the term. Policymakers are just beginning to examine what its implications for government might be.
Aimed at	Businesses, especially those which have direct interface with consumers.
Relation to other concepts	<p>WBCSD has described eco-efficiency as creating 'a needed bridge between the macro-level concept of "sustainable development" and the micro-level of corporate behaviour'.</p> <p>Eco-efficiency is seen by the WBCSD as relating to 'Sustainable Production and Consumption' (SP&C) in a similar way - 'eco-efficiency focuses on the operations of the enterprise, while SP&C encompasses the entire commercial system and its interrelations'.</p> <p>Eco-efficiency embraces other concepts, such as 'pollution prevention', 'source reduction', 'waste reduction', 'waste minimisation' and 'clean (or cleaner) production'. It captures the idea of <i>pollution reduction through process change</i>, as opposed to earlier end-of-pipe approaches to tackling the problem of pollution.</p>
Relation to government	Eco-efficiency was developed primarily by business, for business. The eco-efficiency literature of the WBCSD makes clear, however, that 'external constraints do matter', and calls for shifting the tax burden away from labour and onto resources.
Limitations	<ul style="list-style-type: none"> • Some commentators doubt whether a 'win-win' path for economic and environmental improvement is available - it may not be possible to continue 'doing more with less' without some losers as well as winners. • If eco-efficiency is improved within the existing macro-economic framework, there is a danger that goods/services will become cheaper, boosting consumption and thereby offsetting or negating efficiency improvements.

Source: based on WBCSD, 1996 and OECD, 1995

2.2 The Relevance of Corporate Eco-Efficiency for Transport-Related Policy

Many of the key environmental impacts associated with transport are dissimilar from those associated with consumer products. One major difference is that the greater part of the impacts of transport occur during the *use* of vehicles, not in their manufacture, packaging, delivery etc. - although the material intensity of the transport system is also of concern. Nevertheless, although certain aspects of eco-efficiency (eg. reducing toxic dispersion, extending product durability, enhancing material recyclability) may be of secondary importance relative to the problems stemming from vehicle use, the seven key elements listed in *Table 2.1a* provide a general set of directional indicators for public policy formulation.

In addition, other aspects emerge from the preliminary analysis of eco-efficiency carried out for this study which suggest that the concept has potential to stimulate new directions in transport-related policy, for the following reasons:

- *Eco-efficiency is a micro-level concept linked to macro-level objectives.* Eco-efficiency links macro-level ideas such as sustainable development or sustainable production and consumption to the micro-level arena of corporate behaviour. Some modification would be required to make eco-efficiency directly relevant for public policy-making.
- *Eco-efficiency acknowledges the finite nature of the environment.* Eco-efficiency explicitly recognises that environmental 'carrying capacity' is limited, and is in part a response to the challenge of a Factor 10 reduction of the material/energy intensity of the developed world⁽¹⁾. This challenge is particularly acute for the transport sector, which is characterised by a high income elasticity of demand for individual travel. Quantifying carrying capacity, however, remains difficult.⁽¹⁾
- *Eco-efficiency implies promoting a utilisation / service economy.* One of the elements of eco-efficiency (see *Table 2.1a*) is an increase in the service intensity of goods and services. This has particular implications for policies related to individual travel behaviour, including the need to define objectives related to travel in a different way.
- *Eco-efficiency uses an input/output framework.* This implies a careful focus on what outputs (i.e. what value to individuals and

⁽¹⁾ Wuppertal Institute, 1994 (*Carnoules Declaration*)

⁽²⁾ OECD, 1995

society) transport provides, and at what cost in terms of resources, environmental impacts, and quality of life. This is a valuable exercise even if it is not possible to quantify all the 'outputs' of the transport system.

- *Quantitative indicators of eco-efficiency offer additional value.* Indicators of eco-efficiency would measure outputs provided per unit of input or impact; or, more usefully, the inputs/impacts per unit of output. This would enable operational tools to be developed for guiding public policy decisions on transport and related areas.
- *Eco-efficiency aims to reach a 'win-win' development trajectory.* The idea that it is both necessary and possible to 'do more with less' is important in securing the uptake of the eco-efficiency concept by business. It may be possible to promote eco-efficiency in public policy on transport on a similar basis: that a more eco-efficient transport and land use system would, in the long term, leave individuals and society better off in economic, environmental and quality of life terms.

2.3 TERMINOLOGY

The following terms have special meaning in this report.

- *the mobility system* - is the system which supports movement of people from one place to another by any means; it includes the infrastructure directly required to facilitate that movement i.e. cycle paths, roads, railways etc.;
- *the communications system* - is the system which supports the transfer of all forms of information between people and organisations, both electronically and conventionally (i.e. postal services, insofar as they deliver information rather than goods);
- *the land-use system* - is the spatial distribution of activities and journey origins/destinations, and the physical structures within which those activities take place (housing, retail, offices, agriculture, open/recreational space etc.);
- *the access system* - is the result of the interaction of the mobility/communications systems with the land use system, so as to provide people with services, goods, information and contact with other people.
- *Corporate eco-efficiency* is the term used in this report to mean eco-efficiency as it has been developed for application by companies.

3 GOALS: VALUE CREATION

3.1 INTRODUCTION

In a strict physical definition, the efficiency of a system is the ratio of useful work performed to total energy expended (or heat taken in).⁽¹⁾ Corporate eco-efficiency, by analogy, means delivering more value to customers with fewer environmental impacts and less energy/resource use. The question then arises: what does eco-efficiency mean in the context of transport?

This section approaches this question by developing an understanding of what eco-efficiency means for the firm, and applying the same 'template' to transport. The concepts are developed in two stages:

- in *Section 3.2*, corporate eco-efficiency is explored using a very simple input-output model, which is then applied to the transport system;
- in *Sections 3.3 and 3.4*, the systems are analysed in more detail to examine the process by which they create value.

3.2 AN INPUT-OUTPUT MODEL

3.2.1 *Corporate Eco-Efficiency*

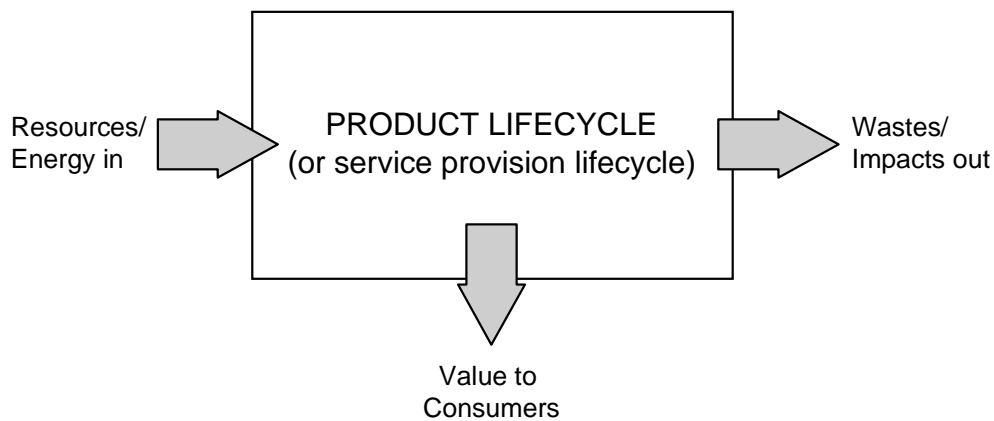
Figure 3.2a illustrates the objective of eco-efficiency in its conventional application in the context of the firm. The system which is 'optimised' is the product life-cycle, or the life-cycle associated with the provision of a particular service. The 'output' of the system is the value provided to consumers. Of the two other flows, one - resources and energy - represents a physical 'input' with associated economic and environmental costs; the other - wastes and environmental impacts - is a physical 'output' but still has associated economic and environmental costs. Since both these flows have costs associated with them, they may both be considered 'inputs'. Thus consumer value is typically compared with material or energy intensity, or impacts, or both.⁽¹⁾

⁽¹⁾ Oxford English Reference Dictionary

⁽²⁾ In *Section 4.2*, three different tools for quantifying eco-efficiency are presented corresponding to these three possibilities: consumer value is compared with material or energy intensity in Material Intensity Per unit of Service; with environmental impacts in Procter & Gamble's value:impact analysis; and with both in Dow's Eco-Fitness Analysis.

Without some way of relating materials/energy to wastes/impacts, optimisation of the system as a whole is not in principle possible - since it might be possible for greater resource efficiency to be associated with greater environmental or health impacts of other types (e.g. toxicity), and there would be no mechanism for making this trade-off.⁽¹⁾ The same problem also applies if greater material efficiency is achieved at the cost of a deterioration in energy efficiency - as might be the case, for instance, in the manufacture of an aluminium versus a steel vehicle body. Some of the tools used in eco-efficiency address these problems, although there is no accepted solution to them. In some cases, however, it may be that resource, energy and impact intensity all vary together so that no trade-off between different factors is necessary.

Figure 3.2a Corporate Eco-Efficiency



It is clear that firms also aim not only to provide value to consumers but also to provide profit for their owners. In this analysis, however, it is assumed that firms remain profitable as a result of providing value to consumers. This benign model, in which firms aim to maximise consumer value in order to remain profitable, does not consider the question of whether firms influence consumers' preferences in order to *create* demand for goods and services so as to sell into new or larger markets. The question of how much influence firms have over consumers' preferences is a controversial one⁽¹⁾ and is not considered

⁽¹⁾ For instance, asbestos can be used to manufacture fibre cement sheets. One study has shown that asbestos cement performs better in terms of life-cycle material, energy and environmental impacts than alternatives such as steel. However, some countries have banned the use of asbestos cement on the basis of the health risks posed by asbestos. This is a case where some mechanism is needed to evaluate this risk against the benefits offered.

⁽²⁾ A good example is the debate over whether the advertising of tobacco products increases the total market for tobacco, or merely affects the choice of an existing set of consumers between different brands.

further here. However, it is an important question, since it is possible that efficiency improvements alone will not be sufficient to sustain current (and future) levels of demand within global carrying capacity. In the context of transport, for instance, it seems likely that a change in consumer preferences will be needed if the dominance of the car in personal travel is to be changed.

Box 3.2a illustrates how eco-efficiency involves meeting existing needs in new ways. Increasing service intensity - in this case, moving from selling a product to leasing a service - is an important part of developing a more eco-efficient system of consumption and production. There are clear analogies to this process for transport, especially in moving towards different ownership structures for cars and similar vehicles.

Box 3.2a Increasing Service Intensity: A New Approach to Leasing 'Comfort

'Interface Inc., a commercial floor covering company, has launched an innovative program aimed at selling the 'functionality' of comfort. Working in collaboration with fibre producers, the new product line, made from recycled products or waste materials, is converted into new carpeting or floor tiles. The customer 'leases' the product, or the 'comfort' provided by the carpet. Once the customer's carpet reaches the end of its useful life, a new floor covering replaces the old, with the 'spent' product re-introduced into the marketplace after refurbishment, re-manufacture or a fashion facelift.'

Source: WBCSD, 1995a

3.2.2 *Eco-Efficiency in Transport Policy*

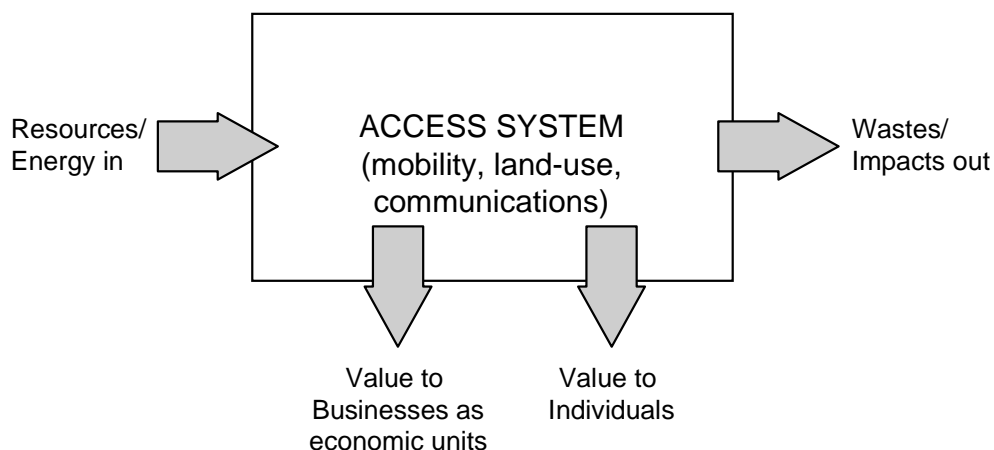
Figure 3.2b illustrates the objective of eco-efficiency as applied to transport policy. Here the system whose efficiency is to be optimised is the access system rather than the product/service life cycle. The flows of resources/energy and wastes/impacts are conceptually the same as in the case of the firm, although the value provided by the system is different. There are two value flows⁽¹⁾:

- value created directly for individuals, in meeting their access needs; and
- value created indirectly by meeting the access needs of the wider economy, which enables economic value to be created.

⁽¹⁾ The access system also creates value for society, much of which results from the value created for businesses and for individuals. This point is discussed in more detail in *Section 3.4.1*.

Even at this simplistic level, this analysis has important implications. The first is that transport creates little value in itself - most of the value created by transport is in the access which it facilitates (this point is argued in more detail below). Related to this point is the realisation that transport does not create access on its own, but only in conjunction with land uses - transport simply links spatially-separated people, activities and locations. If this point is accepted then it is clear that other forms of communications may also achieve this link. For these reasons, this study refers to the *access system* as the sum total of the transport or mobility system, the land use system and the communications system. In practice policies may be focused on these three subsystems individually, but it is vital to understand their interaction and to recognise that it is in this interaction that value is created. The separation of the value provided to individuals directly, from that which is gained through facilitation of economic activity, also suggests the possibility that different policies may be needed to enhance these two distinct roles.

Figure 3.2b Eco-Efficiency in Transport Policy



The problems for the optimisation of a system with multiple and incomparable inputs and outputs are the same as for corporate eco-efficiency.

3.3 CORPORATE ECO-EFFICIENCY

Figure 3.3a illustrates in more detail the system which is optimised in corporate eco-efficiency. The figure illustrates the flow of materials through the economy, rather than an individual product/service life-

cycle, but the stages in this cycle are not the main focus of interest in this figure. The most important way in which *Figure 3.3a* develops the earlier *Figure 3.2a* is in a more detailed treatment of value flows.

It is helpful to distinguish between two different meanings of the word 'value':

- *Value flows* are a conceptual device used in this report to illustrate how different functions of the environment, economy and society contribute (directly or indirectly) to quality of life.
- *Cultural values* are the filter through which people as individuals (and as a society) interpret the world around them, making judgements about what is important to us and what enhances our quality of life. Cultural values also embody ethical beliefs and judgements.

'Quality of life' is thus understood as arising from the interaction of value flows with cultural values. In this model, the economy influences quality of life in three ways:

- (V_{F1}) by providing consumers with value in the form of products and services;
- (V_{F2,F3}) by providing people as employees with employment; and
- (V_{F4}) via its impact on the physical environment, which in turn contributes to quality of life.

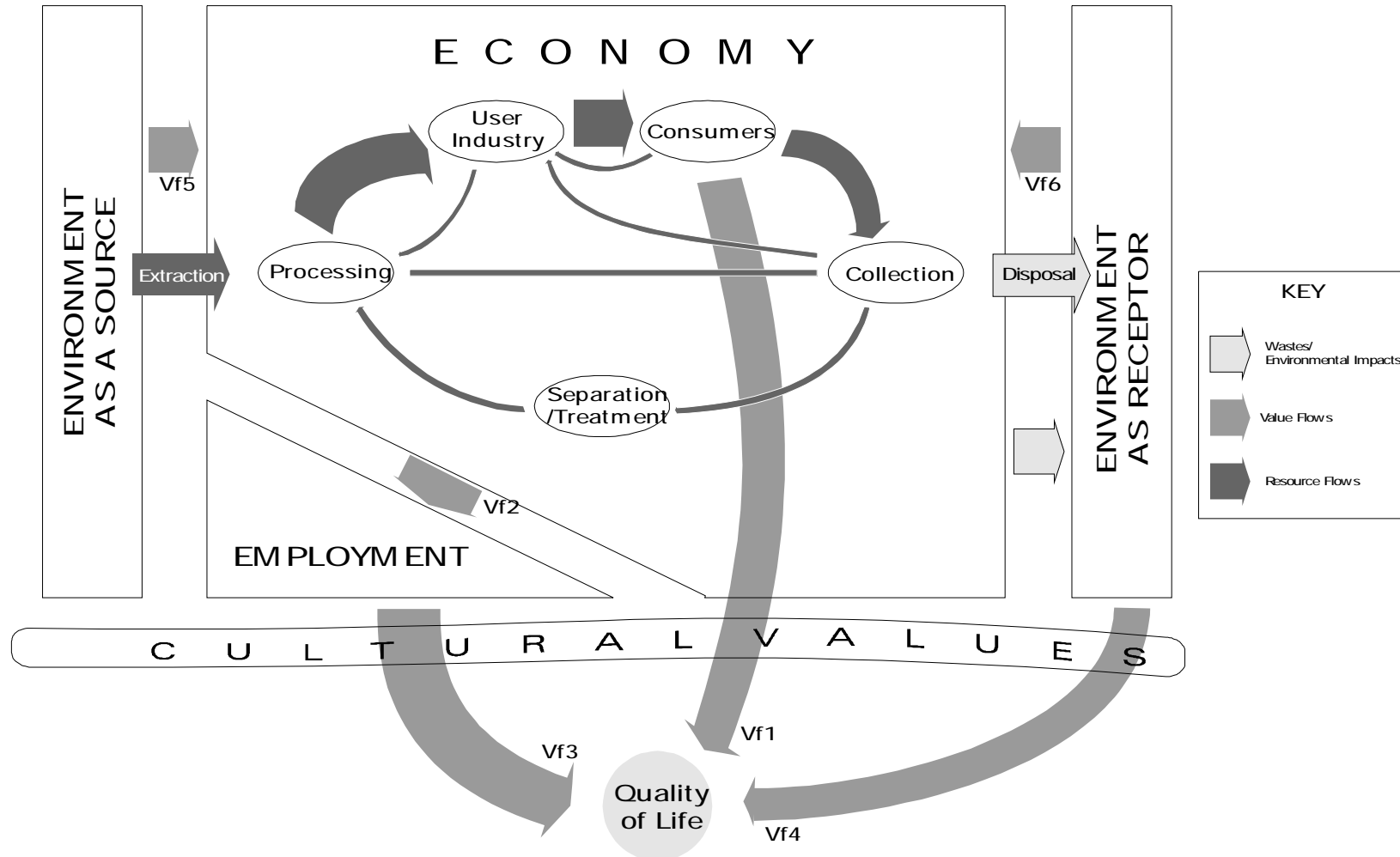
The physical environment also contributes to quality of life in three ways:

- (V_{F5}) as a source of materials and energy for the economy;
- (V_{F6}) as a sink for wastes from economic activities; and
- (V_{F4}) as the physical environment within which people live.

Corporate eco-efficiency focuses on providing value to consumers with minimum resource use and impacts on the environment. In macro-economic terms, it focuses on meeting the needs of the demand side of the economy with minimal impacts on the environment. It does not directly consider the contribution that firms make to quality of life as employers - although it is argued that, indirectly and at a macro-level, eco-efficiency is likely to mean the substitution of skilled labour for materials and energy, resulting in increased demand for skilled and semi-skilled employment⁽¹⁾. This increase in labour-intensity is one of the objectives often stated for ecological tax reform.

⁽¹⁾ Ayres, 1995, p.49

Figure 3.3a Corporate Eco-Efficiency



3.4 ECO-EFFICIENCY IN THE ACCESS SYSTEM

Figure 3.4a illustrates the interrelationships between the elements in the access system. Here there are six value flows shown as contributing to quality of life.

- (V_{A1}) Access contributes to quality of life directly as people value the ability to carry out their social, leisure and personal business activities.
- (V_{A2,A3}) Access contributes to quality of life indirectly via its contribution to the productive capacity of the economy, which then provides people with value as consumers of goods and services. The economy also offers quality of life to people as employees.
- (V_{A4}) Mobility may contribute to quality of life directly, such as via the psycho-social functions of the private car, ⁽¹⁾ or via the health benefits to be had from increased use of non-motorised modes. ⁽¹⁾
- (V_{A5}) The access system influences the quality of the physical environment, mostly in a negative way such as in air pollution and noise, and hence quality of life.
- (V_{A6,A7}) The access system also interacts with the social environment, such as by promoting or discouraging social interaction, and in this way affects quality of life. This mechanism is theoretically distinct from the value which access provides to people directly (V_{A1}).

Finally, the economic activities which support the access system generate employment themselves (V_{A11,A12,A13}), which in turn contributes to quality of life (via V_{A3}).

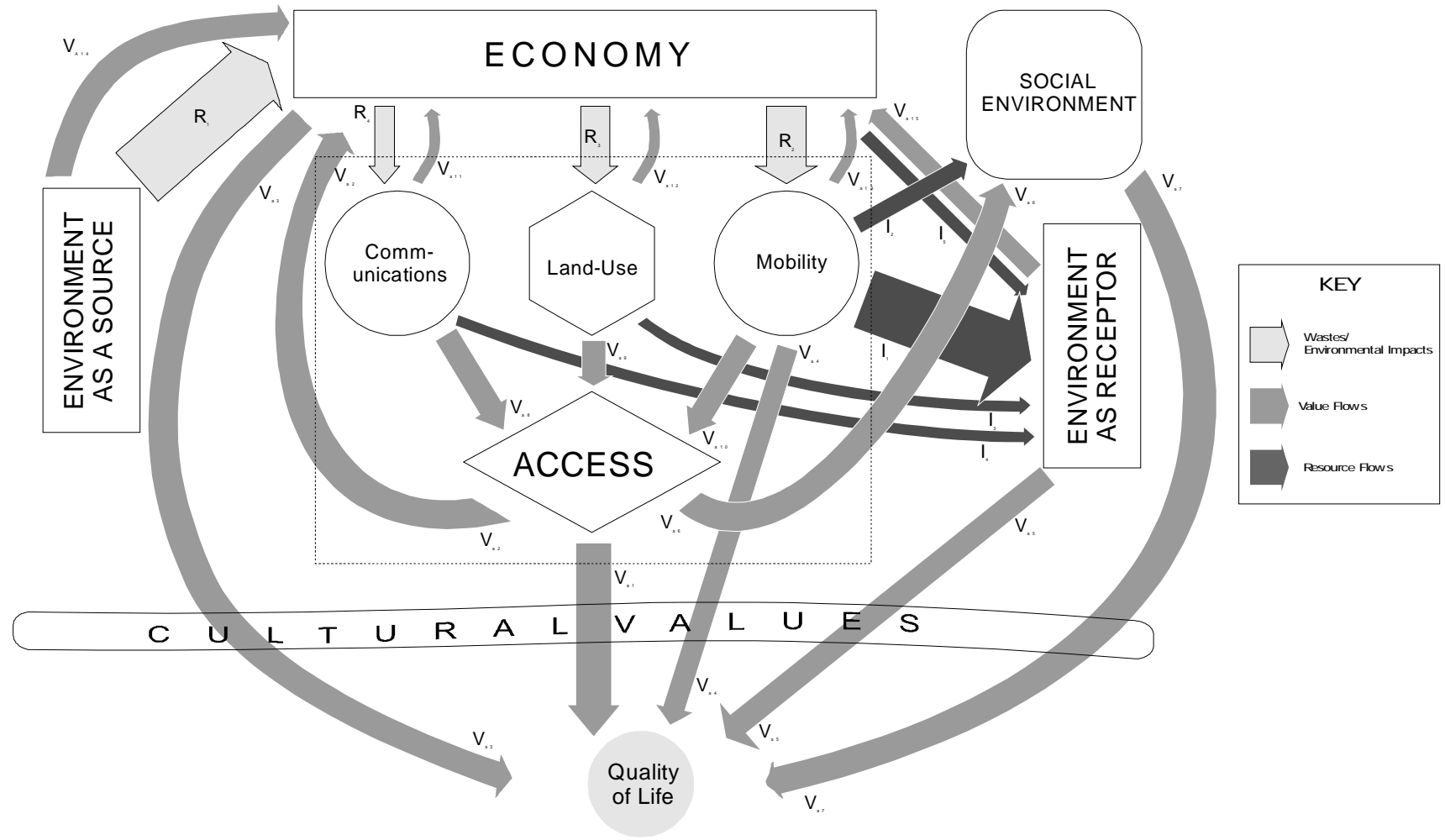
The physical environment contributes to quality of life in the same ways as it does for corporate eco-efficiency - as a source, sink, and as the physical surroundings in which we live. *Figure 3.4a* also introduces the social environment, since the linkage between the access system, the social environment and quality of life has been explicitly raised by some commentators ⁽¹⁾.

⁽¹⁾ Kroon, 1996

⁽²⁾ Hillman, 1993a

⁽³⁾ Appleyard, 1981 and Hillman, 1993b

Figure 3.4a Eco-Efficiency in the Access System



The relative importance of these different value flows is not quantifiable. However, it is assumed for the purpose of this report that the two forms of value created by the access system (V_{A1} and V_{A2}) are of 'first-order' importance, whilst the value created by mobility *per se* (V_{A3}) is of 'second-order' importance.⁽¹⁾ The value created by the access system for the social environment is considered to be of second-order importance because it is difficult to distinguish between value created directly (V_{A1}) and value created via the social environment ($V_{A6,A7}$), which in any case is likely to be more difficult to characterise and quantify directly.

It is also assumed that the benefits resulting from the employment which the access system generates ($V_{A11,A12,A13}$) are of second-order importance relative to the employment benefits which result from the contribution of access to the wider economy. This assumption is on the basis that, in the long term, if the access system were less labour-intensive, labour released from that sector could in principle be re-employed elsewhere.

This discussion highlights an important difference between eco-efficiency for the firm and as it might be applied to the transport/access sector(s): firms aim to maximise profits and not to maximise social welfare. The advocates of eco-efficiency suggest that profitable firms are increasingly also likely to be eco-efficient firms, so that the responsibility and interests of the profitable firm extend beyond 'the factory gates' (although it is recognised that there are limits to how far this process can move within existing macro-level constraints⁽¹⁾). However, there is a real difference between profit and social welfare as goals. The result is that the system which the public policymaker has to grapple with is a larger, and more complex, one.

In order to characterise the system whose eco-efficiency is to be measured, *Annex B* tabulates and explains all the linkages identified in *Figure 3.4a*. It also presents a set of cause-effect relationships and provides explanations and examples of how these different interactions work. It is clear, from the number of cause-effect relationships in particular, that managing such a complex system is likely to be difficult.

⁽¹⁾ This assumption is on the basis that access is fundamentally necessary for almost all aspects of human activity and cannot be substituted for, whilst mobility in itself is of less universal significance and may have potential substitutes.

⁽²⁾ Ayres, 1995, pp.14-16.

4 TOOLS: WORKING TOWARDS ECO-EFFICIENCY

4.1 INTRODUCTION

This section examines the scope for developing quantitative indicators of eco-efficiency for the access system:

- *Section 4.2* describes three indicators that have been developed for corporate eco-efficiency, and analyses their usefulness as the basis for indicators in the access system;
- *Section 4.3* assesses the scope for developing indicators of eco-efficiency in the access system.

4.2 QUANTITATIVE INDICATORS OF ECO-EFFICIENCY

Operationalising eco-efficiency means developing indicators which capture some measure of value added per unit of resource input. Methodologies for measuring eco-efficiency are in their infancy. This section reviews three:

- 'Material Intensity Per unit of Service' (MIPS), being developed by the Wuppertal Institute in Germany;
- 'Value : impact assessment', as developed by Procter & Gamble; and
- 'Eco-fitness analysis' at Dow Europe.

4.2.1 *Material Intensity Per Unit of Service (MIPS)*

MIPS meets the basic criterion for an eco-efficiency measure by attempting to quantify material intensity (the input) per unit of service (the output). It has been developed by the Wuppertal Institute on the basis that material flows can be used as a proxy for all environmental impacts. The validity of this assumption is open to serious question, but MIPS is still of interest as a measure of material intensity for its own sake.

In its 'purest' form, material intensity is taken to be the unweighted summation of all the life-cycle material movements which form the inputs to a process or product, even including flows such as rainwater diverted by buildings, and oxygen consumed in combustion. Some form of distinction between different material flows is likely to be necessary to make the concept useful in practice.

The output - units of service - is a concept which captures the eco-efficiency notion of replacing goods with functionality or services as the aim of the 'production' process. Operationalising the concept in mathematical form is more difficult, although the Wuppertal Institute has proposed some simple formulae.

MIPS can be applied both at the firm level, for individual products or processes, and at higher levels - measuring the material intensity of an entire economy, for instance. There is also work which is attempting to make the concept more useful in practice by developing a *Computer Aided Material Flow Analysis* software package as a tool for:

- holding material flow data in an accessible form;
- conducting macro-scale resource intensity analysis; and
- developing eco-efficient products.

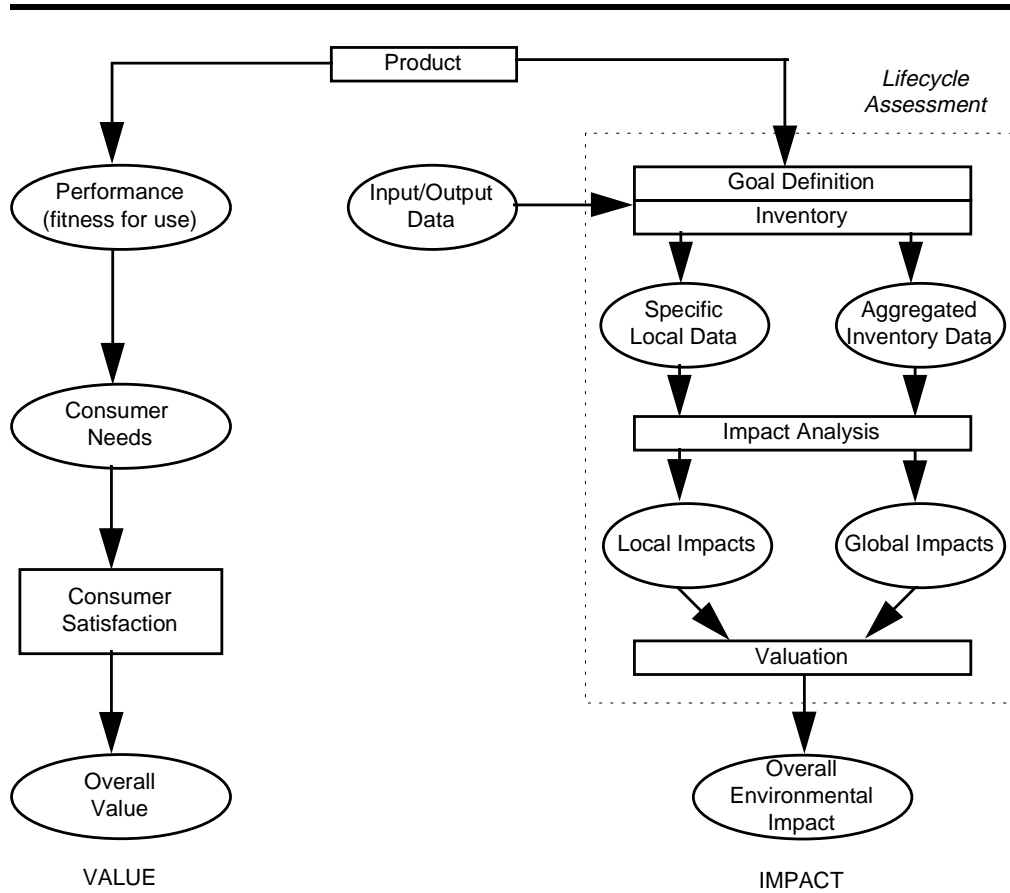
4.2.2 *Value : Impact Analysis at Procter & Gamble (P&G)*

This tool is similar in many ways to MIPS, but with a broader understanding of both value and impact:

- For *impacts* - in place of the assumption that material flows provide an adequate proxy for all environmental impacts, this methodology substitutes a full life-cycle assessment, which considers materials and energy use, and environmental impacts.
- For *value* - in place of the idea that physically similar services can be compared, P&G take a more commercially-driven view that products and services should perform in the marketplace if they are truly providing more value to consumers (i.e. they should maintain or increase market share).

Figure 4.2a illustrates the structure of P&G's value:impact assessment methodology.

Figure 4.2a Value : Impact Assessment Methodology at Procter & Gamble

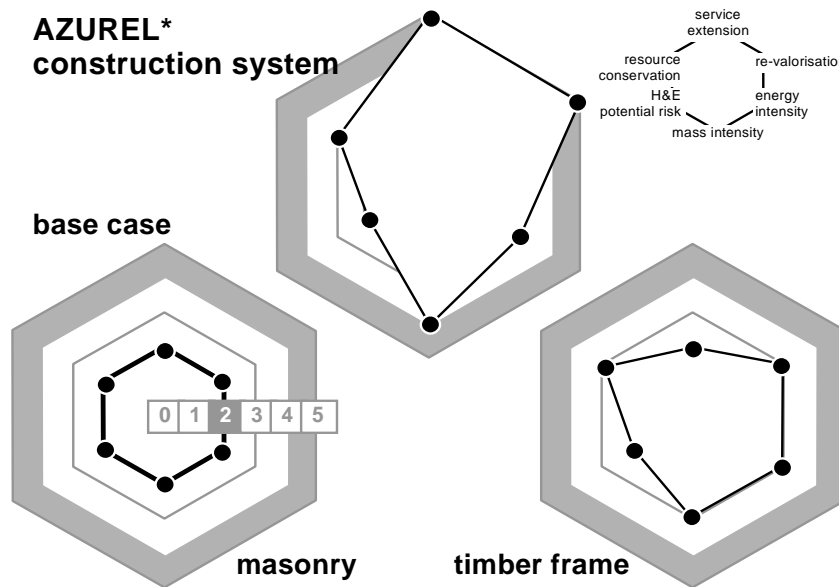


Source: Hindle et. al, 1993

4.2.3 Eco-Fitness Analysis at Dow Europe

Dow Europe has developed an 'eco-fitness analysis' methodology which is strongly related to the seven elements of eco-efficiency identified by the WBCSD (see Table 2.1a). In common with the other two approaches reviewed, this aims to compare the life-cycle environmental burdens of different ways of providing a product or service. The distinguishing feature of this approach is that it does not attempt to aggregate all environmental impacts into a single figure. Instead, it offers a visual representation of six different indicators:

Figure 4.2b 'Eco-compass' Diagrams of Environmental Impact at Dow Europe



The external boundary of the hexagon in Dow's 'eco-compass' diagrams represents the 'ideal' eco-profile, while the inner shape shows how far each of the three designs is removed from this ideal on the six parameters of eco-efficiency.

Source: Ayres, 1995

- *Material (mass) intensity* - based on a life-cycle inventory approach
- *Energy intensity* - also based on a life-cycle inventory approach
- *Resource conservation* - based on an assessment of the proportion of materials used which are renewable or abundant
- *Re-valorisation* - the potential for re-using, recycling or generating energy from the incineration of a product
- *Durability and functionality (service extension)* - how long does the product last and does it provide any additional value to its user?
- *Environmental and health risk potential* - an assessment of ecotoxicity based on around 20 different parameters.

These indicators are presented visually as an 'eco-compass' (see *Figure 4.2b*). The aim is to enable choices to be made about how genuinely to improve overall eco-efficiency, which make different trade-offs explicit.

4.2.4 *Implications for Indicators in the Access System*

These approaches are still at an early stage of development, and have been developed primarily for internal use in product/process design and improvement. This suggests that they would require further work to make them sufficiently robust to be transferred to the public arena.

There are difficulties associated with the approaches in quantifying both 'inputs' and 'outputs'. On the input side, all the approaches identified are built around some form of life-cycle inventory of impacts or material/energy flows. However, the question of how to aggregate environmental impacts and energy/resource use is still open since there is no standard methodology for the final valuation stage.

On the output side, there does not yet appear to be a robust methodology that enables the provision of a service to be evaluated independently of the means by which that service is delivered. However, all three approaches described here at least make reference to the service or value delivered, enabling the possibility of evaluating unconventional ways of providing services.

Finally, the value provided by the access system is of a very different nature to that provided by a product such as a laundry detergent. It is not clear from this analysis that the same type of approach is appropriate for access system indicators as for indicators of corporate eco-efficiency, other than by very loose analogy.

4.3 QUANTITATIVE INDICATORS FOR THE ACCESS SYSTEM

This section explores:

- the issues involved in attempting to use an input/output framework in guiding public policy on transport; and
- possible indicators and methodologies for the quantification of eco-efficiency, for the mobility system and the access system respectively.

It is not within the scope of this study to develop working methodologies, but an initial assessment of the likely feasibility of different approaches is presented.

4.3.1 *Developing Indicators of Eco-Efficiency in Transport Policy*

Eco-efficiency in the access system is a function of the interaction of mobility, communications and land use. *Ex-ante* indicators should identify what policies will work best and how great their contribution is likely to be; *ex-post* indicators should assess overall eco-efficiency so that the performance of policy can be tracked over time.

Eco-Efficiency in Mobility

It is widely acknowledged that improving the environmental performance of existing modes of transport, and achieving a modal shift in favour of less environmentally-damaging modes, are unlikely *alone* to achieve sufficient gains in eco-efficiency to move transport systems in OECD countries in the direction of sustainability. This conclusion is echoed in the OECD/ECMT study cited in *Section 5.2.2* of this report.

Nevertheless, policies which aim to improve vehicle efficiencies and reduce their impacts have an important role to play. Other policies aiming to influence modal choice are also important, although as long as trends in journey patterns remain the same, these can have only a limited impact. Measures of the eco-efficiency of mobility are therefore a necessary element in improving the eco-efficiency of the access system as a whole, but must be considered in relation to the total quantity of movement generated by the system.

Section 4.3.2 considers these indicators only briefly, since the characteristics of different modes on an 'impact per person-km' basis are well-known⁽¹⁾.

Eco-Efficiency in Access

Managing land use is increasingly seen as the key to achieving more sustainable transport policies, since it is only by halting the trend towards greater journey lengths that a sustainable access system can ultimately be reached. *Section 4.3.3* considers indicators for the access system in more detail than for mobility. The interaction between land use and transport, for which trip length is the most important indicator, is however poorly understood. Trends in land use are long-term and incremental and are the outcome of the interplay of a great number of factors. The discussion here is thus necessarily of an exploratory nature.

⁽¹⁾ See, for instance, RCEP (1994)

4.3.2 The Mobility System

Mobility eco-efficiency could be a helpful indicator for transport policy-makers. It could be used to provide a measure of the environmental performance of the mobility system in a readily understandable way. The concept has already been demonstrated in studies comparing different modes, and could readily be applied to more sophisticated models comparing the impacts on an area such as a city of different mobility-system policies (eg. policies aiming to influence vehicle technology or modal choice). In this application, however, it is important to recognise that most transport models today are ill-equipped for modelling a dynamic process of change, even just within the mobility system (see *Section 5.3.2*).

Whilst not a trivial exercise, it is in principle not difficult to quantify the environmental impacts and resource/energy intensity of different parts of the mobility system. *Section 5.3.2* below identifies two approaches (LCA and SEA) which have already been used to identify the impacts associated with different modes. In the studies examined, various environmental impacts were calculated per person-kilometre⁽¹⁾, and no attempt was made to aggregate them together - as discussed in *Section 4.2.4*, this is a problematic process for corporate eco-efficiency also.

The types of impact which are likely to be most difficult to quantify are impacts which relate to quality-of-life via the social environment. For instance, the severance effects of traffic may reduce social activity; or the fear of traffic danger may force parents to restrict the independent mobility of their children. This does not mean that these effects cannot be considered; but it is probable that they cannot easily be operationalised within a measure of mobility eco-efficiency.

4.3.3 The Access System

Transport Intensity

It has been argued that the implications of eco-efficiency for transport are stronger in relation to the interaction of land-use and transport than in relation to mobility alone. But, unlike mobility, there are no convenient measures of 'access'. It is difficult to see how it would be possible to measure directly the value that access to particular activities provides different people with - although stated or revealed preference methods could perhaps be used to attempt this task. It seems much

⁽¹⁾ In this report, the term 'person kilometre' is used in preference to the more normal term 'passenger kilometre', to avoid the implication in the word 'passenger' that travel by the non-motorised modes is excluded.

more promising to pose the question the other way round: to ask how much transport is associated with access to a given activity; to assess, in other words, its *transport intensity*.⁽¹⁾

A key issue associated with this approach is that the same activities do not provide people with the same 'value' over time. The rise of the out-of-town supermarket, for instance, has been related to the increasing participation of women in the labour market, which has meant that frequent trips to local shops have been replaced with less frequent supermarket shopping. Trips to the supermarket are more likely to use the car than local shopping trips, and to be longer. Comparing the transport intensity of supermarket shopping with local shopping, as if 'shopping' offered people the same value in both cases, is therefore problematic. Nevertheless, the analysis in this section proceeds on the basis that in most cases, activities which are nominally the same (over time or between places) are sufficiently similar in reality to make comparison of their transport intensity possible and useful. Certainly there are fewer problems in making this kind of comparison than in trying to compare completely different activities.

The section examines two approaches to using transport intensity⁽¹⁾ as a quantitative measure of eco-efficiency for public policy-making:

- as an *ex-post* indicator, or means of analysis; and
- as an *ex-ante* indicator, or means of decision-making.

It also briefly examines whether transport intensity could be usefully promoted as an indicator for the private sector.

Transport Intensity as a Means of Analysis

As a first step, it is important to assess trends in transport intensity at an aggregated level. National time-series data on travel behaviour can be used to compare the movement associated with particular journey-ends (or journey purposes) over time. *Table 4.4a* presents data from the UK showing how travel to selected journey ends is reported to have increased over a period of some 6 or 7 years. Shopping and escort education (i.e. escorting children to school) have increased faster than the general rate of increase in distances travelled and in this sense have become more travel intensive, in both relative and absolute terms. This type of macro-scale analysis is not very sophisticated but, providing adequate data is available:

⁽¹⁾ Transport intensity' is an established term. The Confederation of British Industry, in its 1995 report *Moving forward: A business strategy for transport*, specifically acknowledges reducing transport intensity as a policy aim.

⁽²⁾ The scope of this study is restricted to individual travel, and does not include freight transport, but it seems likely that much the same approach could be applied to freight transport.

- it provides essential background information which may be used to guide policymakers towards potential areas of concern, and general findings can be explored with more in-depth studies of the type discussed below; and
- it provides a useful form of feedback on the effectiveness of policy over time.

Table 4.4a Macro-scale Transport Intensity: the UK National Travel Survey

Miles per person per year by <i>selected</i> journey purpose			
	85/86	91/93	Percentage change
Commuting	1 075	1 199	+12%
Education	147	171	+16%
Shopping	577	747	+29%
Escort education	38	64	+68%
All journeys	5 190	6 357	+22%

Source: National Travel Survey 1985/86, 1991/93

This type of macro-scale analysis can also be buttressed with more detailed analysis of the transport intensity of particular activities at a general level. *Boxes 4.3a* and *4.3b* illustrate case-studies for the transport intensity of education and shopping in the UK.

The transport implications of some land-use and other trends may be clear (as in *Box 4.3a*) or less clear (as in *Box 4.3b*). There is however a general problem in attempting to conduct this kind of transport-intensity analysis on a per function basis (i.e. for individual journey ends/purposes alone). Examining impacts on a function-by-function basis is analogous to a partial equilibrium approach to economic analysis: the transport intensity of a particular function is analysed assuming that the rest of the system is not affected by it. In practice, however, this is unlikely to be the case.

The attempt to gauge the transport impacts of telecommuting offers the best example of this phenomenon. If people cease to travel to work on a daily basis, there are numerous implications for overall environmental impacts:

- The availability of the car, if the car was used for the work trip, might enable car-based trips previously not available to other household members.

- The reduction in congestion attributable to large-scale telecommuting might be negated as suppressed demand for commute and other journeys is released.⁽¹⁾
- Telecommuting may enable people to live further from the workplace, resulting in a lifestyle which is more travel-intensive overall or in other aspects than commuting.

Box 4.3a Transport Intensity of Education: Evidence from the UK

The Policy Studies Institute conducted two matched surveys of children's travel behaviour patterns in 1971 and 1990. The changes in travel patterns detected in the two surveys provide evidence which offers some explanation of the trends described in *Table 4.2a* with respect to the strong growth in the travel related to escorting children to school (equivalent to about 8% per annum between 1985/86 and 1991/93).

First, the 1990 survey confirms the strong link between the distance of the journey to junior school and the mode of travel used: the proportion of children travelling on foot falls from four in five for those living within half a kilometre, to less than one in three of those living more than two kilometres away. Changes in this distance were not found to be the dominant driver of changes in travel behaviour, however.

The proportion of children travelling to school unaccompanied is reported as having fallen dramatically from 1971 to 1990, moving from the 1971 situation where the large majority of children (aged 7 to 11) travelled unaccompanied, to the 1991 situation where the majority were accompanied. This trend has also been accompanied by a marked rise in the proportion of children being driven to school, from under one in ten up to about one in three. Traffic danger was cited by over 40 percent of parents as a reason for restricting junior schoolchildren from travelling to school alone - cited about twice as often as the next most frequent reasons, the unreliability of the child and the fear of molestation.

The irony is that, as more children are brought to school by car, the traffic danger to those that continue to walk increases, thereby encouraging more parents to bring their children to school by car in a 'vicious circle'.

One English local authority has responded to this trend by developing the concept of 'Safe Routes to School', involving collaboration by parents, teachers, and local authority officers to identify the most important pedestrian routes to school, and to take measures to make them less dangerous for the children using them.

Source: based on Hillman, 1993b

However, in the absence of system-wide models which are able to model the type of dynamic illustrated in *Boxes 4.3a* and *4.3b*, a function-by-function approach is still of considerable practical relevance. It is likely to clarify some of the mechanisms involved and may be able to provide recommendations for policy. These are likely

⁽¹⁾ This problem is analogous to the problem identified in *Table 2.1a* for eco-efficiency at the firm level: more eco-efficient goods may be cheaper goods, which people may consume more of, offsetting the efficiency improvements.

to be in the form of insights into *what* policies are most effective, rather than quantified estimates of *how* effective they might be. For this type of quantification, modelling is needed.

Box 4.3b Transport Intensity of Shopping: Evidence from the UK

There has been considerable controversy in the UK surrounding the role of the supermarket in relation to the travel intensity of shopping, which, as *Table 4.2a* indicates, increased by about 4% per year through the second half of the 1980s and early 1990s (measuring travel intensity by the average distance travelled per person per year for shopping purposes).

On the one hand it has been argued that more superstores leads to less car-based travel, on the basis of evidence suggesting that those with access to a car will use it for their main shopping, regardless of the location of their chosen store. Thus a more dense dispersal of out-of-town sites should reduce journey lengths, with the frequency of trips remaining unaltered.

On the other hand, it has been argued that out-of-town or edge-of-town superstores tend to attract a greater proportion of trips by car than centrally located stores, providing a similar service but with greater transport intensity. An indirect effect is that town centre stores may reduce in number following competition from their out-of-town competitors.

Both these arguments have been supported with quantitative studies. Policy has eventually come to reflect the latter view, as reflected in planning guidance suggesting that local authorities should give preference to town centre sites for retail development over edge-of-centre and out-of-centre sites.

Source: based on Whitelegg, 1995

In addition to time-series analysis, it is also possible to take a cross-sectional approach. It is this type of analysis⁽¹⁾ which has established the well-known correlation between the location of housing and the travel associated with it, rural areas being associated with more travel (per person per year) than urban ones. Research at a smaller scale can elaborate further the mechanisms which may influence the relationship between location and travel behaviour.⁽¹⁾

It is unlikely that all of the mechanisms identified by such research could have useful policy tools associated with them; and policies which attempt to improve access eco-efficiency by reducing transport intensity may also have profound social consequences. Raising the cost of transport might be expected to encourage people to live where they would be less dependent on movement in meeting their access needs, but it might also mean that local people would be 'priced out' of rural areas. Nevertheless, some understanding of the mechanisms

⁽¹⁾ eg. ECOTEC, 1993

⁽²⁾ eg. Headicar and Curtis, 1996

influencing the relationship between land use and transport is a prerequisite for effective policymaking.

Transport Intensity as an Aid to Decision-Making

In principle it would be possible to assess the transport intensity of a service-delivery location such as a shop or hospital. This would involve collecting and analysing data on the transport associated with that location, of goods as well as of people. Significant changes associated with that location - land use changes - could be made subject to an assessment of transport intensity, in much the same way that they are already likely to be subject to traffic and environmental impact assessments. If it appears that the proposed change is likely to increase transport intensity, the applicant might be required to demonstrate that there were benefits which made this increase justifiable, or to implement a set of mitigation measures.

For instance, the centralisation of healthcare provision is likely to have scale economy benefits which would be partly internal to the healthcare provider, and partly passed on to the public. However, there would also be costs to the public as some people would have to travel further to receive essentially the same service. An assessment of the transport intensity of the option to centralise would at least make this cost, which would normally be substantially 'external' to the healthcare provider, into a visible disbenefit.

If the proposed increase in transport intensity were judged to be (potentially) acceptable, this would provide a starting point for identifying appropriate mitigation/compensation strategies.

One study ⁽¹⁾ has concluded that this form of 'transport intensity assessment' or 'mobility impact assessment' would be best integrated into the existing procedures for project-level environmental assessment and the emerging approach to strategic environmental assessment, rather than being established as a wholly separate technique. It seems likely that an assessment of transport intensity could be integrated into traditional environmental/traffic assessments without difficulty.

Transport Intensity and the Private Sector

There is evidence that distribution-intensive businesses have been able to decrease their transport intensity with the assistance of measures of eco-efficiency. The retailer Sainsbury's, for instance, has used a gallons/mile/product unit measurement to monitor fuel efficiency and

⁽¹⁾ 1995 project for the Mobility Studies Unit of the Flemish Ministry for the Environment, examining how mobility impacts are dealt with in different EU and non-EU jurisdictions.

the effectiveness of initiatives to improve it.⁽¹⁾ There may be possible parallels for personal travel: for instance, some companies are reporting the number of 'business miles' saved by substituting telecommunications for face-to-face meetings.⁽¹⁾

To the extent that the external costs of transport are not reflected in the costs to users, it is not clear how far the private sector would obtain benefits from this type of 'transport-intensity improvement analysis'. The most forward-looking companies, especially those with transport-intensive activities, might consider reducing transport intensity as a way of reducing their exposure to the risk of a sharp rise in the costs of transport; but in general existing incentives to reduce costs should - in theory - already have taken companies to the point where further improvements do not increase profitability. In practice, of course, this may not be the case (as experience of waste minimisation schemes has widely shown), and there may be potential cost savings to be had from a focus on transport intensity. Public policy could encourage this type of initiative from the business community. Pressure groups are also beginning to focus attention on company performance in this respect, such as in the 'Food Miles' campaign of the Sustainable Agriculture Food and Environment Alliance (SAFE) - see *Box 4.3c*.

Box 4.3c Food Miles as a Measure of Transport Intensity

A study by the Wuppertal Institute in Germany examined the transport intensity of producing and delivering strawberry yoghurt to a distribution outlet in southern Germany.

The study attempted to quantify the transport associated with producing the yoghurt, including bringing to the production facility:

- Strawberries from Poland
- Yoghurt from northern Germany
- Corn and wheatflour from the Netherlands
- Jam from western Germany; and
- Sugar beet from the east of the country.

Aggregating these movements together, the study calculated that the transport associated with bringing one truckload of 150g packs of strawberry yoghurt to the distribution outlet amounted to one 'theoretical' truck moved a total of 900km.

Source: based on Boge, 1993

⁽¹⁾ Sainsbury's, 1995

⁽²⁾ Design to Distribution Ltd, 1995

Areas for Further Work

There are other interesting and innovative ideas which may provide a basis for quantitative indicators of eco-efficiency in transport. One of these is the concept of the 'personal travel budget', which is understood to be particularly well-developed in the Netherlands. This may have some value as the basis for measures of personal eco-efficiency in transport.

In addition, it was suggested in discussions of an initial version of this report that there may be value in taking the proposed indicators further, to attempt to express existing data in a more rigorous mathematical formulation of eco-efficiency. This approach is likely to be particularly valuable for eco-efficiency in the private sector (notably in freight transport services); operationalising eco-efficiency for public policy indicators may be more difficult.

5 ECO-EFFICIENCY AND CURRENT TRANSPORT-RELATED POLICY

5.1 INTRODUCTION

This section examines the compatibility of eco-efficiency with current transport policy in terms of both its goals and its tools. It examines both conventional transport policy at the broad level and also the direction in which policy is currently changing. The aim of this analysis is to identify:

- what value the concept of eco-efficiency can bring to transport policy, over and above existing approaches; and
- the extent to which current thinking can already be said to be promoting eco-efficiency.

5.2 ECO-EFFICIENCY AND TRANSPORT POLICY GOALS

5.2.1 *An Absence of Clearly-Defined Goals?*

The goals of transport policies are often not clearly set out. This lack of clarity reflects difficulties in:

- defining meaningful objectives for a system as complex as the transport/land use/communications system;
- separating general or strategic objectives from operational ones; and
- separating the aim of policy from the means by which it is to be implemented.

There are advantages to a pragmatic approach which does not consider the goals of policy without some reference to how those goals are to be achieved. The scope for action by transport policy-makers is constrained, and there is little purpose in setting unattainable goals.

Also, the goals of different organisations vary with respect to transport just as they vary with respect to other policy areas. For instance:

- The transport policy goals of the *European Commission* refer, *inter alia*, to 'improving the functioning of the single market', and to 'fostering the access of EU operators to other transport markets'⁽¹⁾.

⁽¹⁾CEC, 1995

- The 'principles' which the *UK government* has recently published as central to its approach to transport include the principle that 'the efficiency of markets needs to be strengthened, providing the minimum necessary regulation, increasing the role of the private sector, and offering the best prospects for meeting users' needs'⁽¹⁾.

In both these cases, objectives for transport policy are set with reference to other, wider policy goals or principles.

5.2.2 *Trends in Transport Policies: the Rise of the Environment*

The OECD and ECMT⁽¹⁾ published in 1995 the results of a three-year enquiry by the Project Group on Urban Travel and Sustainable Development. This report, also with the title *Urban travel and sustainable development*⁽¹⁾, includes an analysis of the transport / environment policies of 20 countries and 132 cities.

One of the principal conclusions of the study is that:

Present land-use and transport policies in OECD/ECMT countries are leading to excessive travel by car in cities and their immediate surroundings.

Such policies are the cause of growing congestion, air pollution, noise, acid rain, and the risk of global warming. These trends are increasingly seen as unacceptable by Member Governments.

The OECD/ECMT study provides important evidence that environmental objectives are increasingly set alongside more traditional objectives for transport policy, such as those set out for the Chicago Area Transportation Study in the early 1960s⁽¹⁾:

- greater speed;
- increased safety;
- lower operating costs;
- economy in new construction;
- minimising disruption; and
- promoting better land development.

⁽¹⁾ DoT, 1996, p.15

⁽²⁾ European Conference of Ministers of Transport

⁽³⁾ OECD/ECMT, 1995

⁽⁴⁾ CATS, 1962

Box 5.2a Policy Objectives for Urban Transport Identified by the OECD/ECMT

The problems faced by OECD cities are of two kinds. In the first are the familiar, long-established problems of congestion, casualties, emissions, the isolation of those without access to cars, and so on. Most existing policies have been geared to tackling them.

However, during the late 1980s, a second set of concerns began to crystallise in many Member countries. These included awareness of the impracticality of catering for forecast volumes of car travel, concern about resource consumption and anxieties about the possibility of climate change. This led in turn to the identification of a new set of policy objectives, which were not only more wide-ranging, but were concerned with the underlying causes rather than the symptoms of the problem - too much traffic in our cities.'

Both sets of objectives 'can be encapsulated as follows:

- i. reduce the need to travel;
- ii. reduce the absolute levels of car use and road freight in urban areas;
- iii. favour more energy-efficient modes for both passenger travel and freight;
- iv. reduce noise and vehicle emissions at source (i.e. make engines quieter, cleaner and more energy efficient);
- v. encourage a more efficient and environmentally-sensitive use of the vehicle stock to reflect the goals of energy saving, higher vehicle-utilisation and less pollution;
- vi. improve the safety of pedestrians and all road users in urban areas; and
- vii. improve the attractiveness of cities for residents, workers, shoppers and visitors.'

Source: OECD/ECMT, 1995

Box 5.2a summarises the key transport/environment objectives identified by the study, which are characteristic of policies in the 12 cities which were the subject of in-depth case-studies. As well as evidence of the importance of environmental concerns, these objectives also illustrate the points made above in connection with the difficulty of identifying clear goals for transport policy:

- Only objectives (vi) and (vii) (which aim to improve safety in urban areas, and to improve the attractiveness of cities) can be seen as 'pure' objectives, in the sense that they express a quality-of-life end without reference to how it is to be achieved.
- The other objectives all, to a greater or lesser extent, reflect conclusions about how to achieve certain ends as well as those ends in themselves. For instance, in order to achieve a quieter urban environment, making engines quieter [part of objective (iv)] is a sensible step. However, the ultimate aim is a quieter environment, and this can be achieved in other ways as well as by reducing engine noise.

5.2.3 Objectives-Led Transport Policies

Eco-efficiency suggests a focus on how transport really provides value to travellers and to society as a whole, and this in turn suggests that transport policy objectives may benefit from being set out with greater clarity. *Box 5.2b* presents the arguments which have been advanced in support of an 'objectives-led' approach to transport planning.

Critics of this approach, however, point out that operational, quantifiable objectives have rarely been derived from strategic objectives when an 'objectives-led' philosophy is implemented in practice. The contribution of different alternatives to the strategic objectives is then likely to be assessed in a subjective and arbitrary way. In the UK at least, this approach has therefore remained at the fringes of transport policymaking.

Box 5.2b An 'Objectives-Led' Approach to Transport Planning

An objectives-led approach to transport planning involves relating transport to quality-of-life objectives in a way which is similar to that presented in this study on eco-efficiency. The approach has been described as being 'based on the idea of setting overall objectives for transport, deriving operational objectives which can be accurately measured from them, and using these both in the assessment and the option development stages [of transport infrastructure proposals].' A number of transport studies have been undertaken in the UK which attempt to use this approach.

The advantages of this approach include:

- Keeping ultimate objectives at the forefront of the policy process, rather than allowing them to become submerged in the detail of assessment techniques, means that they are less likely to be biased by practical issues such as what parts of the transport system are most amenable to modelling.
- Separating strategic objectives from the question of how to achieve them is helpful in ensuring that a wide range of options are considered when drawing up transport policies and plans. This is important since new options may be needed in the face of new problems.
- The process of obtaining an agreed set of objectives, and then using those objectives to guide policy, is likely to make policy more transparent, and to make judgements and trade-offs more explicit. This in turn may reduce confrontation and improve the acceptability of transport policies in the face of opposing interest groups.
- Having an a set of objectives may assist in the design of transport schemes by providing a framework or checklist of issues for their designers to address.
- Objectives are necessary in order to assess the effectiveness of policy. Without such *ex-post* assessments of policy, it is difficult to learn lessons for the future.

Source: adapted from Buchan, 1991

Box 5.2c presents the 'Objectives for a Sustainable Transport Policy' identified by the UK's Royal Commission on Environmental Pollution in its 1994 report on *Transport and the Environment*. This report reflects both:

- an approach which is based on strategic objectives which are fleshed out with operational targets; and
- objectives which can be related to eco-efficiency.

Objective C, below, for instance, refers both to quality of life as an objective, and to 'means of access', rather than means of mobility; whilst objective A highlights the link between land use and transport. Objective G is close to the aim of reducing the material intensity of the transport system. The response of the UK government to the report was in the form of a Green Paper⁽¹⁾ which establishes a set of 'key principles' and accepts that operational targets may be useful in some contexts; in general, however, it does not follow the Royal Commission's objectives-led approach.

Box 5.2c 'Objectives for a Sustainable Transport Policy' Identified by the UK Royal Commission on Environmental Pollution

- A. To ensure that an effective transport policy at all levels of government is integrated with land use policy and gives priority to minimising the need for transport and increasing the proportion of trips made by environmentally less damaging modes.
- B. To achieve standards of air quality that will prevent damage to human health and the environment.
- C. To improve the quality of life, particularly in towns and cities, by reducing the dominance of cars and lorries and providing alternative means of access.
- D. To increase the proportions of personal and freight transport by environmentally less damaging modes and to make the best use of existing infrastructure.
- E. To halt any loss of land to transport infrastructure in areas of conservation, cultural social or amenity value unless the use of the land for that purpose has been shown to be the best practicable environmental option.
- F. To reduce carbon dioxide emissions from transport.
- G. To reduce substantially the demands which transport infrastructure and the vehicle industry place on non-renewable materials.
- H. To reduce noise nuisance from transport.

Source: RCEP, 1994

5.2.4 *Access Instead of Mobility as the Aim of Policy*

The rise of concern about the environment in relation to transport does not in itself constitute a move towards eco-efficiency, although it is probably a necessary antecedent to it. It was argued in *Section 3.2.2*

⁽¹⁾ DoT, 1996

that eco-efficiency implies replacing mobility with access as the ultimate aim of policy. There is evidence that this shift in emphasis is both being increasingly advocated, and being adopted in conventional transport policy. Some examples of access-based policies are presented below.

Box 5.2d **Contrasting Local Policies in the UK: Mobility versus Accessibility**

Mobility-based (Devon)	Access-based (Bedfordshire)
<p>Goals are:</p> <ul style="list-style-type: none"> • to <i>improve personal mobility</i> for everyone rather than just the car user; • to allow the efficient movement of people and goods to stimulate employment and the economy; • to reduce accidents, by lowering speeds, especially those involving the more vulnerable road user; • to improve the environment through reduced congestion, CO₂ emissions, noise, pollution, nuisance and by increasing the efficiency of use of fuel and social conditions in living areas. <p><i>Source: Devon CC, 1993 (emphasis added)</i></p>	<p>Goals are:</p> <ul style="list-style-type: none"> • to integrate all forms of transport and transportation policy to <i>reduce the need to travel</i> and distances travelled; • to provide pedestrian, cycling and public transport priority <i>access to places and facilities</i>; • to reduce the risks and fear associated with transport; • to develop and conserve the local environment; • to develop efficient travel facilities to minimise consumption of resources and impact of pollution; • to enhance economic opportunities, particularly to encourage growth of the economy of southern Bedfordshire, and to support the expansion and growth of London Luton Airport, including facilitating an air/surface transport interchange. <p><i>Source: Bedfordshire CC, 1995 (emphasis added)</i></p>

Box 5.2d presents a straightforward comparison between the policy objectives of two local authorities in the UK. This comparison shows how 'access' is beginning to replace 'mobility' or 'movement' as the stated aim of transport policies. Whether this difference in emphasis at the highest level of policy formulation translates into real differences at the level of implementation is less certain.

Box 5.2d also illustrates the link between 'reducing the need to travel' (and transport demand management in general) and improving access as a policy aim. Reducing the need to travel appears now to be firmly established as a policy goal - it heads the list of policy objectives identified in the recent work of the OECD (see Box 5.2a). Acknowledging the possibility of reducing the need to travel without

compromising quality of life is to recognise implicitly that access rather than mobility is the primary source of value created by the transport/land-use (and communications) system.

Transport policy in the Netherlands is among the most advanced in the world in terms of placing access at the forefront of policy objectives, as *Box 5.2e* indicates. The Second Transport Structure Plan (SVV-II) also illustrates how an objectives-led approach can encourage clarity and transparency in policy.

Box 5.2e National Transport Policy Goals in the Netherlands

The Second Transport Structure Plan (SVV-II) states clearly: *The purpose of transport policy is to ensure accessibility.* When the Government's transport proposals were published at the end of 1988, the proposed strategy was based on 'striking a balance between individual freedom, accessibility and environmental amenity'. By the time the SVV-II was published as a Government Decision in 1990, the emphasis had shifted:

In line with the agreement reached between the parties now in government the yardstick for policy is to be the concept of the **sustainable society**, defined as *a society which meets the present generation's needs without jeopardising future generations' ability to meet theirs....*It must be established from the start that the notion of the sustainable society places limits on the extent to which the transport system can be allowed to serve narrowly economic goals. Economic growth which fails to accord quality of life its due importance will saddle future generations with a heavy environmental burden, jeopardising and perhaps even destroying future generations' chances of achieving the rising living standards to which we ourselves aspire.'

The SVV-II identifies two fundamental problems which transport policy must address: offering adequate accessibility whilst maintaining environmental quality and amenity.

Five steps are identified in the strategy to meet these goals:

- Step 1: Tackling problems at their source** - better vehicle technology, limits on the expansion of infrastructure
- Step 2: Managing and restraining mobility** - for both goods and passenger transport, using a combination of land-use planning, pricing and other demand-management measures (eg. flexible working hours, telematics)
- Step 3: Improving the alternatives to the private car** - improved cycling facilities, higher standards in public transport, encouraging the shared use of vehicles
- Step 4: Selective accessibility on the roads** - considering any expansions to the road network on a case-by-case basis, taking into account alternative options and their strategic importance to the Netherlands as a distribution centre
- Step 5: Strengthening the foundations with support measures** - recognising that some of the institutional pillars of transport policy are weak and need strengthening

Source: MVW, 1990

The SVV-II identifies two basic objectives that transport policy must aim to meet: offering adequate accessibility whilst maintaining environmental quality and amenity. It also places emphasis on 'managing mobility' - managing the demand for transport - as well as improving accessibility by improving transport systems. Policy areas identified in the SVV-II as relevant for the management of demand include both land-use planning and tele-innovations (communications) - which are placed in this report alongside transport in an eco-efficiency framework. It is therefore possible to argue that there is a degree of continuity between leading elements in current thinking and the approach suggested by eco-efficiency.

The Ministry of Transport in the Netherlands is also evaluating the success of SVV-II policies in its 'Meten = Weten' ('measuring = knowing') project. This aims to provide a methodology for assessing and reporting the impacts of SVV-II policies using quantifiable indicators for both mobility and accessibility.

5.3 ECO-EFFICIENCY AND TRANSPORT POLICY TOOLS

5.3.1 *Conventional Transport Planning and Policy Tools*

Transport planning tools have traditionally focused on assessing public infrastructure and other transport investments, so as to direct public funds towards the most beneficial projects. This type of assessment is clearly an exercise of great policy relevance. However, the construction of new transport infrastructure is now seen as just one way of improving the access system (the OECD/ECMT study⁽¹⁾ identified 19 possible urban transport policy tools, of which only 2 relate to the provision of new infrastructure - road and rail). Thus tools and methodologies which were developed to assess new infrastructure may no longer be as useful as they were once seen to be.

Table 5.3a examines the strengths and weaknesses of four assessment tools. The first two of these, cost-benefit analysis and (project level) environmental assessment, have typically been used together, although with no explicit integrating mechanism, in the economic and environmental evaluation of new infrastructure projects. Apart from the methodological problems associated with cost-benefit analysis of transport infrastructure proposals (especially roads in a congested network), the lack of an integrating mechanism to measure value

⁽¹⁾ OECD/ECMT, 1995

provided per unit of impact (or impacts) means that this approach does not offer a measure of eco-efficiency as defined in this report.

Economic valuation of the environment (see *Table 5.3a*) is intended to bridge this gap and to integrate environmental costs into a cost-benefit framework. Despite a significant research effort in attempting to improve methodologies for valuing the environment, there are still considerable problems associated with them; and some commentators doubt whether these can ever be resolved.⁽¹⁾ Tools for firms to improve their eco-efficiency typically do not attempt to use monetary valuation of environmental impacts as a mechanism for integrating economic and environmental concerns.⁽¹⁾ It therefore seems unlikely that cost-benefit analysis, whether or not augmented with environmental valuation, will provide a methodology able to express the concept of eco-efficiency.

Considerable effort has also been expended in trying to quantify the economic impacts of transport infrastructure, and (to a lesser extent) the impacts of revenue support for public transport. There are several different types of economic effect that have been identified and numerous different methodologies that have been employed to estimate them.⁽¹⁾ In general however it appears that efforts over many years to determine the economic impacts of transport infrastructure have not been rewarded with robust conclusions. This means that aggregate measures of eco-efficiency for the transport sector based on (traditional) economic foundations - such as value added per unit of resource/energy input - may be difficult to develop. The scope for using a traditional economic approach to develop measures of eco-efficiency related to particular projects is likely also to be limited.

Finally, multiple criteria analysis offers another approach that has been used to inventorise the socio-economic and environmental impacts of transport proposals. Its relevance to eco-efficiency is slight, insofar as it is not quantified and does not attempt to link (in any formal way) value created to resources and impacts.

⁽¹⁾ eg. Jacobs, 1991

⁽²⁾ There is interest in corporate environmental accounting, but this methodology is simply attempting to identify all the costs which companies already bear in relation to the environment, such as staff costs, costs of recordkeeping and reporting, etc. At present there is no attempt to measure costs which do not accrue to the firm itself (Ditz *et al.*, 1995).

⁽³⁾ see Cheung, 1994

Table 5.3a Comparison of Selected Economic and Environmental Assessment Methodologies

	Cost-Benefit Analysis	Environmental Assessment	Environmental Valuation	Strategic Environmental Assessment
Typical applications	Evaluation of public infrastructure investments (roads, bridges, public transport schemes etc.)	Assessing the environmental impacts of proposed public infrastructure projects	Means of integrating environmental considerations into a traditional cost-benefit framework of analysis	Environmental assessment of plans, policies and programmes (PPP)
Objectives	To monetise the costs and benefits associated with a particular proposal and thereby determine the economic value of the scheme. It is often used to rank alternative investments.	To identify and inventorise systematically the environmental impacts of a proposed scheme	To value environmental assets or quality, so that degradation of the environment can be given an economic value	SEA aims to provide a means of assessing the environmental impacts of strategic decisions, before they reach project level implementation.
Methodology	Benefits are typically valued on the basis of predicted traffic flows as: <ul style="list-style-type: none"> ·time savings to motorists ·reduction in accidents ·savings in vehicle operating costs (fuel etc.) Costs typically considered are capital and maintenance expenditures. Costs and benefits are then both discounted to calculate a benefit:cost ratio and a net present value (NPV) for the scheme.	The EC Directive on environmental assessment (85/337/EEC) states that an EA should identify, describe and assess the direct and indirect effects of a project on: <ul style="list-style-type: none"> ·human beings, fauna and flora ·soil, water, air, climate, landscape ·the interaction between the factors mentioned in the first and second points ·material assets and the cultural heritage. 	· <i>Revealed preference</i> - using observed behaviour, in conjunction with real economic costs or market prices, to infer a value for environmental assets · <i>Hypothetical preference methods</i> (contingent valuation / stated preference) - asking people how much they would be willing to pay (WTP) to prevent environmental degradation, or how much they would be willing to accept (WTA) in compensation for it	Likely to include discussion of: the PPP and its main objectives, and how environmental effects were taken into account when formulating these; likely effects on the environment of the PPP; main alternatives and reasons for choosing the proposed course of action; mitigation measures proposed for the PPP; compatibility of the PPP with other policies
Strengths	<ul style="list-style-type: none"> ·Established methodology ·Easy to interpret 	·May encourage project design that mitigates certain environmental impacts	<ul style="list-style-type: none"> ·Integrates the environment into traditional cost-benefit methodologies without needing to revise them ·If successful, could have very wide applications 	<ul style="list-style-type: none"> · Overcomes a limitation of project EA by assessing strategic impacts · Avoids duplication of effort in considering strategic issues at project EAs
Weaknesses	<ul style="list-style-type: none"> ·No in-built mechanism for the consideration of the environment ·Does not consider land-use / transport interactions ·Does not consider the cumulative / strategic impacts of many schemes 	<ul style="list-style-type: none"> ·No explicit mechanism by which to integrate assessment of the environmental impacts into the decision-making process ·May not capture secondary, cumulative and long-term impacts 	<ul style="list-style-type: none"> ·It is argued that it may not be legitimate to place an economic value on some (or all) environmental assets ·It may not be helpful to try to value the environment within the static framework of a cost-benefit analysis (since it makes no contribution to a political process) ·There are serious methodological questions surrounding hypothetical preference methods 	<ul style="list-style-type: none"> · No explicit means of integrating economic and environmental considerations · Difficulties in operationalising it in practice, eg. there may be no clear moment when a policy decision is made and an SEA should be initiated
Related Methodologies	<ul style="list-style-type: none"> ·Environmental valuation ·Environmental assessment 	·Cost-benefit analysis	·Cost-benefit analysis	<ul style="list-style-type: none"> · Project-level environmental assessment · Cost-benefit analysis

5.3.2 *Emerging Transport Planning and Policy Tools*

In contrast to project-level environmental assessment, strategic environmental assessment (SEA) (see *Table 5.3a*) may offer a methodology which approaches eco-efficiency in some aspects. SEA is not a well-established technique and so must be assessed with caution; but some SEAs of the transport sector assess different modes on the basis of impacts per unit of mobility provided. One study for the European Commission ⁽¹⁾ considered the European high speed train network and compared land use, primary energy consumption, emissions to air and fatalities per person-kilometre for car, high speed train, and air transport. These are basic measures of eco-efficiency. In general terms, however, SEA is as much a mechanism for integrating environmental issues into the decision-making process in government as a technically-rigorous and quantitative assessment methodology.

A similar outcome can be reached by the application of a life-cycle assessment (LCA) methodology to transport. This methodology also lends itself to a comparison between competing modes, such as in a study ⁽¹⁾ which (similar to the SEA referred to above) compared high speed train with three other modes, over long distances and including impacts related to the construction and maintenance of infrastructure. From this study it is clear that LCA can be applied to give a measure of eco-efficiency in movement.

Urban modelling is emerging as a framework within which numerous transport and environmental parameters can be simulated. *Box 5.3b* describes the Integrated Transport Effects Model System (ITEMS) being developed for the European Commission. One of the key benefits claimed for this type of modelling approach is the ease with which it enables policy-makers to consider environmental impacts alongside traditional transport objectives of mobility and the economy. This is not because of any fundamental conceptual innovation, however; it results instead from the ease with which computational improvements enable planners to visualise the environmental impacts of different policy options.

⁽¹⁾ Dom, 1994

⁽²⁾ Lafleche and Sachetto, 1995

The Integrated Transport Effects Model System (ITEMS)

ITEMS is a consortium of European partners developing an integrated urban model for the European Commission. The system aims to model transport demand, associated economic and environmental costs, and certain economic benefits, for a range of policy measures including fiscal measures, traffic management, vehicle emissions legislation and vehicle efficiency improvements.

The consortium has not developed any new models, and has approached the problem instead by linking together existing models of four systems: transport, the economy, energy/emissions and environmental valuation. At present the model is automating an existing philosophy, being based on a cost-benefit framework augmented with environmental valuation. This approach has enabled the concept to be proved in practice, with a minimum of developmental work.

Source: Hitchcock et al., 1995

In theory, the computational and methodological progress made with this sort of model should enable it to be used within an eco-efficiency framework, since the model includes most of the important flows of value, resources/energy and environmental impacts identified in *Section 3.4*. (It has been argued in this report that some way of measuring these is central to operationalising eco-efficiency.) In practice, such models may be limited because of the assumptions and simplifications which are built into them. In particular, the response to radical policy shifts is likely to be poorly modelled, because most transport models are based on equilibrium rather than dynamic foundations. New modelling approaches based on dynamic rather than equilibrium methodologies ⁽¹⁾ are beginning to emerge and these are likely to prove more useful.

Tools developed for integrating land use and transport planning are *a priori* likely to be a means of achieving eco-efficiency in transport. This inference arises because the access system provides value to society out of the interaction between movement and land-uses (or journey origins and destinations). Thus tools which attempt to link these two systems together are likely to improve the efficiency of their interaction. Among the best-known of such tools is the Dutch 'ABC location policy', described in *Box 5.3c*.

⁽¹⁾ A good example of a model based on dynamic rather than equilibrium concerns is the TIGRIS model being developed in the Netherlands (van Koningsbruggen and Borgman, 1995).

Box 5.3c 'ABC Location Policy' in the Netherlands

This policy introduces two concepts: the 'accessibility profile' of a location and the 'mobility profile' of an office, factory or any other activity. The idea is to 'get the right business in the right place' by matching the two profiles up.

Locations are classified into three types according to accessibility:

- Type A locations* are situated close to important railway stations. Employment density is high, parking capacity is limited, and access to the motorway network is not important. Typically this type is found in city centres.
- Type B locations* have a lesser quality of public transport access and better motorway access. Employment density is lower and parking capacity higher.
- Type C locations* are situated close to a motorway junction and the quality of public transport is low. No limits are set on parking capacity.

The mobility profile of an activity reflects the potential public transport use of its employees and visitors. It is based on attributes such as the number of employees and visitors per unit of area, the dependence of employees on car use for their work, and the importance of freight transport.

The policy was introduced in response to the increasing number of offices built near motorway junctions, resulting in movement-intensive activities situated in locations where that movement could only be supported by car use.

Source: adapted from Ploeger and Baanders, 1995

Effective use of this type of policy tool is likely to lead to a more eco-efficient transport system in the long run, by influencing the location of important land uses (and other factors such as parking provision at those facilities).

Finally, the research carried out for this study indicates that there is work being conducted in Italy⁽¹⁾ which relates closely to the concept of eco-efficiency. The aim is to analyse urban systems in terms not only of physical infrastructure and the locations of origins and destinations, but also in terms of 'urban functions' such as health, education, commerce, production, financial services etc. The basic proposition is that it might be possible to manage the 'units of supply' of these urban functions (hospitals, offices, etc.) as well as the mobility system that links them in space (and time). This work appears still to be in its early stages.

⁽¹⁾ Alise, 1995 and Urciuoli, 1995

6 CONCLUSIONS

There are major differences between the goals and the tools of individual businesses, whose ultimate aim is to be profitable, and those of public policymakers, who seek to improve social welfare. Nevertheless, this study has found that eco-efficiency is a concept that provides a broad framework for developing public policy on the environmental and economic aspects of individual transport.

6.1 GOALS

Two of the major elements within eco-efficiency are:

- the use of an input/output framework to measure performance; and
- an emphasis on delivering a service rather than on the physical means used to do so.

The application of these principles to the transport system implies replacing mobility with *access* as the ultimate aim of policy in relation to transport. This shift in thinking is beginning to happen in OECD countries: for instance, the language of demand management recognises the need to manage the length of trips as well as the mode by which they are made, and the environmental impacts of those modes. This compatibility suggests that eco-efficiency may be well-placed to function as a 'banner' under which to accelerate these changes. At a minimum, eco-efficiency could play a useful integrating role, linking policy efforts in many sectors to the basic idea of 'doing more with less', and creating a closer link between environmental objectives and economic development.

A second conclusion is that placing access at the centre of public policy on transport raises the need to co-ordinate policies which affect it. Access is created by the interaction of mobility and communications with land uses, and policy in any one of these three areas must be scrutinised in its implications for the other two.

6.2 TOOLS

The formal tools of corporate eco-efficiency are at an early stage, but developing rapidly. There may be some areas in which they provide a starting point for developing indicators which are relevant to public

policy on transport - notably in assessing the environmental impacts of different forms of mobility - but in general it seems that an approach specific to the transport sector is needed.

Eco-efficiency in the 'mobility system' means supporting a given level of movement with the minimum of environmental degradation and energy/resource use. These impacts are generally well-understood, and have been the subject of transport policy over many years. Nevertheless, the ability to model the effects of changes in policy on 'mobility eco-efficiency' is essential if policymakers are to choose the most effective strategies. The further development of dynamic modelling techniques is a prerequisite if the output of these models is to be meaningful.

Eco-efficiency in the 'access system' means reducing the need to travel, as well as improving 'mobility eco-efficiency'. Indicators of eco-efficiency in this wider context are more difficult to define than indicators related to movement alone, since quantifying the value that individuals gain from access to different activities is problematic. Indicators of 'transport intensity' provide one possible solution to the problem of valuing access, by measuring changes in the amount of movement associated with access to a given service. Such indicators may have value both in analysing and reporting trends retrospectively (*ex-post*), and in making decisions about different land uses (*ex-ante*); and have the added advantage that the term 'transport intensity' is already being used by government and business.

The most well-established tools of transport policy were developed for the assessment of different transport infrastructure investments. These tools are of little value for assessing eco-efficiency, because:

- methodologies for integrating economic and environmental concerns are weak; and because
- these methodologies do not provide the multidimensional framework needed to achieve eco-efficiency in transport.

However, there are some newly-developed and developing operational tools, such as accessibility profiles which are being used in conjunction with operation-specific 'mobility profiles' to link land use and transport planning in the Netherlands in an eco-efficient manner. If successful these and similar approaches will promote eco-efficiency in practice.

6.3 EVALUATION

This study has found that eco-efficiency is a concept that can be usefully applied in the context of public policies in relation to individual travel. Just as with corporate eco-efficiency, it picks up the leading edge of thinking in relation to transport, the environment and the economy, and offers an underlying approach which cuts across sectoral boundaries. It is also to be expected that a systematic attempt to apply the principles of eco-efficiency to public policy on transport would lead to new indicators or policy tools.

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Annex A

Exploration of the Eco-Efficiency Concept⁽¹⁾

⁽¹⁾This table is reproduced from the final report of the Rosendal Workshop on Sustainable Consumption and Production (OECD, 1995).

Characteristic	Comment
Intellectual Origin	The term eco-efficiency was coined by the Business Council for Sustainable Development (BCSD) in <i>Changing Course</i> , its report to the United Nations Conference on Environment and Development in Rio ⁽¹⁾ . The concept has been embraced by environmentalist groups who stress the ecological necessity of reduced throughput more than the economic benefits of efficiency.
Key Factors	A quantitative approach using input-output measures to determine the ecological efficiency of economic activities. Stresses the output limitations to current production/consumption patterns (the environment as a sink for wastes) rather than resource scarcities.
Underlying Assumptions	<p>Existing opportunities for energy and material efficiency gains are vast and should be exploited ⁽¹⁾. They represent the obvious 'first step' in moving towards sustainable production and consumption patterns (though attitude and behaviour changes will also be required).</p> <p>There is an applied assumption in some expert analysis that technical efficiency will automatically lead to reduced consumption and waste. The opposite may be the case since increased efficiency can reduce costs, encouraging expansion of capacity and/or generation of additional income and expenditure on more goods (the rebound effect). ⁽¹⁾</p>
Linkage with Sustainable Development	Eco-efficiency offers one means of translating 'sustainability' goals into operational targets. For example, the Dutch Advisory Council for Research on Nature and the Environment (RMNO) has estimated key reductions in resource use and polluting emissions required by 2040 if the global economy is to stay within the earth's (currently estimated) ecospace. ⁽¹⁾ These reductions have been estimated as equivalent to production efficiency improvements of between five and fifty times, or an average 20-fold improvement on 1990 levels. ⁽¹⁾
Measures/ Indicators	<p>Global level eco-efficiency targets have been proposed, for example by the <i>Factor 10 Club</i> ⁽¹⁾ who suggest, over the next 50 years, a 50% reduction in global flows of non-renewable resources, achievable through a 10-fold increase in average resource productivity of (presently) industrialised countries.</p> <p>A national measure of eco-efficiency exists: energy intensity (energy consumption per unit GNP). Materials intensity (and tracking) measures are highly recommended (e.g. by Ayres) but current mass balance data are not adequate for the purpose. Some progress is being made with establishing eco-efficiency targets, measures and indicators at organisation and plant level.</p>

⁽¹⁾ Schmidheiny S, *Changing Course: A Global Business Perspective on Development and the Environment*, MIT Press, Cambridge, Mass. London, England, 1992.

⁽²⁾ See, for example, World Resources Institute *Transforming Technology: An Agenda for Environmentally Sustainable Growth in the 21st Century*, WRI, 1991 which argues that technology is the most easily manipulated variable of the equation $I = P \times A \times T$. *Missing Links: Technology and Environmental Improvement in the Industrialising World* (WRI, 1994) highlights the role of "environmentally superior technologies" in the developing world.

⁽³⁾ See Jevons W, *The Coal Question*, Reprint of the Third Edition (1906), New York: Augustus M Kelly, 1965. Quoted in Rees WE, *Sustainability, Growth and Employment*, paper prepared for the IISD Employment and Sustainable Development Project, June 1994.

⁽⁴⁾ RMNO, *The Ecocapacity as a Challenge to Technological Development*, Rijswijk, The Netherlands, 1992.

⁽⁵⁾ Jansen LM, *Towards a Sustainable Oikos: En Route with Technology*, CLTM, the Netherlands, 1993. Quoted in *Getting Eco-Efficient* op cit.

⁽⁶⁾ Factor 10 Club, *Carnoules Declaration*, Wuppertal Institute, 1994.

Characteristic	Comment
<p>Economic Implications (e.g. wealth, production/consumption patterns, competitiveness, employment)</p>	<p>Eco-efficiency, as promoted by its business advocates, offers the best chance of maintaining economic growth and competitiveness while achieving improved environmental quality. Arguments include:</p> <ul style="list-style-type: none"> • pollution prevention can save money through avoiding waste disposal costs and end-of-pipe remediation; • acting voluntarily can minimise future risks and possible environmental liabilities; • moving ahead of the field can bring competitive advantage; • green' products can increase a company's consumer appeal and open new markets; • a 'green' image is good for corporate morale and recruitment. <p>Many environmental economists argue that, despite significant energy/waste efficiency improvements in recent decades, agricultural, industrial and consumer activity is still almost entirely dependent on fossil fuel consumption and on dissipative use of toxic chemicals and heavy metals. This pattern is clearly incompatible with long term sustainability.</p> <p>In addition, Ayres, for example, argues that a politically feasible win-win development path would have to involve very few or no losers and that each incremental socio-economic change must leave every interested party better off - or at least no worse off. To date, serious attempts to reverse some of the 'wrong trends' (e.g. energy taxes) have been resisted on the grounds that continued growth and prosperity absolutely depend on the continuation of current patterns of energy supply. His conclusion is that the win-win path development trajectory (no pain) may not exist⁽¹⁾.</p>
<p>Trade and Development</p>	<p>Achievement of eco-efficient economies in the North would have major implications including:</p> <ul style="list-style-type: none"> • probable establishment of product criteria relating to constituent materials and energy consumption in production and use. These could constitute a trade barrier; • stable or reduced level of demand in the North for commodities and finished goods; • an increase in the 'wealth gap' if significant economic activity is transferred from processing/manufacture of materials/products (exported from the South) to recycling/repair of materials and products (within closed loop Northern economies). Efficiency considerations are likely to militate against repair/recycling of exported products in their country of origin.

⁽¹⁾ For criticism of win-win 'ideology' see Walley N and Whitehead B, "It's Not Easy Being Green" *Harvard Business Review*, May-June 1994.

Technology	<p>Key elements in eco-efficient technologies include:</p> <ul style="list-style-type: none"> • energy and materials efficiency throughout process and product life cycle. Encompasses reduced volume and toxicity of materials, energy saving, product quality; • shift from linear to circular production/consumption systems (closing the loop); • (longer-term) shift from fossil to renewable energy technologies.
	<p>A recent major study⁽¹⁾ has concluded that we must recognise limitations to even the most innovative technologies. Improving eco-efficiency might not halt degradation of some key renewable resources e.g. topsoil, biodiversity, clean air and water (the non-substitutables); and might exacerbate world-wide inequities and human suffering (if the North maintains its economic and technical dominance).</p>
Appropriate Scale of Action	<p>Indicators and macro-measures will be most useful at national and global level. Measurable actions are already being started by national and local government, enterprise and households (e.g. the Global Action Plan initiative).</p>
Proposed Policy Approaches	<p>Approaches recommended include price reform (shifting tax burden towards pollution and resource use; internalising externalities), energy transition (fossil fuels to renewables) demand side management (especially through supply of function by services in place of products), regulatory frameworks (e.g. extended producer responsibility, recycling targets) efficiency standards, accounting innovation (new measures of industry/national performance) and information (technology sharing, product labelling).</p> <p>The technology forcing role of substance bans/phase-out requirements should not be overlooked, though the transition costs can be high.</p>

⁽¹⁾ US Environmental Protection Agency and World Resources Institute, the *Environmental Futures Project*, 1992. A summary of key findings is presented in the report *Challenges Ahead for the US EPA in the 21st Century*, December 1, 1992.

Annex B

Eco-Efficiency in the Access System

Table B1 Relationships Between Elements in the Access System

Label	From	To	Explanation
Resource Flows			
R ₁	Environment as Source	Economy	The environment provides materials and energy to the economy to sustain the access system. Sectors most closely related to the access system include the construction industry, the automotive industry, and the transport industry (freight and passenger).
R ₂	Economy	Mobility	The economy supplies materials and energy to the mobility system, eg. by the extraction, refining and distribution of fuel. There is no explicit distinction made between capital and running costs in this crude model.
R ₃	Economy	Land Use	The economy supplies the resources to maintain, renew and incrementally alter the land use system.
R ₄	Economy	Communications	The economy supplies the resources to maintain and operate electronic and non-electronic communications systems. Postal systems are included in the communications system insofar as they deliver information rather than goods.
Environmental Impacts			
I ₁	Mobility	Environment as Receptor	The mobility system has numerous adverse impacts on the physical environment, including CO ₂ emissions, other air (and water) pollution, ecological damage, noise and visual intrusion.
I ₂	Mobility	Social Environment	Some negative external impacts of mobility act more or less directly on the social or human environment, with no strong intermediary role for the physical environment. Notable examples are accidents and community severance.
I ₃	Land Use	Environment as Receptor	Construction of new buildings has some negative environmental impacts, such as noise, the need to dispose of waste, and (in some cases) new land-take.
I ₄	Communications	Environment as Receptor	Construction, operation and maintenance of electronic communications systems has some negative environmental impacts which are probably small by comparison with those of both the mobility and land-use systems. Postal services rely on physical distribution networks and are therefore also part of the mobility system.

I ₅	Economy	Environment as Receptor	The operation of supplying resources to the mobility and land use systems has impacts of its own, eg. in the refining of oil.
Flows of Value			
V _{A1}	Access	Quality of Life	Access in itself offers quality of life: the ability to reach journey ends is fundamental to all human activity.
V _{A2}	Access	Economy	Access, for both goods and people, is an essential element in the functioning of the economy.
V _{A3}	Economy	Quality of Life	With access as an essential prerequisite, the economy creates value, which contributes to quality of life.
V _{A4}	Mobility	Quality of Life	Mobility contributes to quality of life independently of access. The car may serve many psycho-social functions, for instance; and travel is often part of leisure/tourism activities.
V _{A5}	Environment as Receptor	Quality of Life	The quality of the physical environment affects quality of life directly, eg. air pollution damages health.
V _{A6}	Access	Social Environment	Access contributes positively to the social environment, in addition to its direct function for individuals, such as by facilitating social interaction.
V _{A7}	Social Environment	Quality of Life	The social environment influences quality of life strongly. If for instance, community severance by transport links reduces the frequency and intensity of social interaction, this is likely to have a negative impact on quality of life.
V _{A8,A9,A10}	Mobility, Land Use, Communications	Access	Access to journey ends is the primary value added by the access system: most travel is in order to gain access to a function such as the provision of goods or services, or social interaction. NB: The term 'access' is distinguished in this study from the term 'accessibility'.
V _{A11,A12,A13}	Mobility, Land Use, Communications	Economy	It might be argued that the role of the industries which support the access system in the economy is so important that the provision of mobility and construction of new land uses has economic value in itself, independent of whether they perform an economically useful service.
V _{A14}	Environment as Source	Economy	The flow of resources provided by the environment is of fundamental value to human society.
V _{A15}	Environment as Receptor	Economy	The ability of the environment to receive by-products and wastes from human activity is also of fundamental value, although the role has only been realised more recently. When the environment is unable to absorb these by-products, this role becomes transparent in costs to human activity eg. the phase-out of CFCs.

<i>Cause-Effect Interactions</i>			
C _{1a}	Mobility	Land Use	Mobility affects land uses via the mechanism of <i>accessibility</i> (as distinct from <i>access</i> , which is the value provided by the ability to reach certain ends). For instance, new infrastructure - ie. cheaper mobility - changes patterns of accessibility and thereby generates pressures for new or modified land uses to take advantage of that accessibility. In general, journey lengths tend to increase.
C _{1b}	Land Use	Mobility	Land use also affects mobility by the mechanism of accessibility. For instance, more mobility will be required to service the access requirements of a less accessible work or home location. There are other mechanisms than accessibility, however, eg. existing land use patterns in many cities constrain the provision of further parking space and hence the expansion in car ownership and its associated mobility.
C _{2a}	Communications	Land Use	The increasing value of communications as a means of access is making teleworking more feasible. There is evidence that teleworkers in some areas, and information-intensive activities in general, may be beginning to relocate to rural environments where the quality of life is perceived as higher ⁽¹⁾ .
C _{2b}	Land Use	Communications	Dense settlement patterns may be necessary to support certain communications technologies such as cable television and associated telematics applications.
C _{3a}	Communications	Mobility	There is a link between 'telecommuting' and mobility patterns: the direction and magnitude of that impact, however, is unclear and still the subject of research ⁽¹⁾ .
C _{3b}	Mobility	Communications	Communications and information technology may provide a tool for improving the eco-efficiency of the mobility system. Public transport guidance and tracking schemes, as well as in-car information systems, are already moving in this direction.
C _{4a}	Mobility	Social Environment	Increasing mobility is likely to have profound social consequences, which may be both positive (eg. possibility of more travel for leisure purposes) and negative (eg. as a contributory factor in the disintegration of community). These effects are in addition to the negative effects on the human/social environment of accidents, severance etc.
C _{5a}	Land Use	Social Environment	Land use changes may influence the social environment, eg. as peripheral locations become more accessible and hence attractive, a decline in town-centres as high-quality residential and business districts may lead to the creation of urban ghettos.

⁽¹⁾ Local Transport Today, 1994

⁽²⁾ Mokhtarian *et al.*, 1994

C _{6a}	Communications	Social Environment	If more functions are performed electronically rather than with physical access (eg. education, libraries, shopping etc.), some foci for social interaction may be lost.
C _{4b,5b,6b}	Social Environment	Mobility, Land Use, Communications	The social environment influences mobility and land use directly, independently of cultural values and attitudes. For instance, a tendency towards smaller households creates demand for new housing; whilst a more mobile society is likely to create demand for mobility as well as communications.
C _{7a,b}	Social Environment	Cultural Values	There is clearly a strong relationship between these two, with cause and effect in both directions.
C _{8,9}	Cultural Values	Mobility, Land Use	Some aspects of cultural values may influence mobility or land use, eg. a cultural preference for urban life may make policies aimed at increasing urban density more acceptable. There are also strong cultural values associated with cars.
C _{10a,b}	Economy	Social Environment	There are multiple interactions between the economy and the social environment, in both causal directions. The economy, for instance, may exert an influence on the social environment and hence on the access system via advertising.
C ₁₁	Environment as Receptor	Social Environment	The quality of the physical environment is likely to have an important influence on the social environment. In particular, support for policies aimed at restraining mobility is likely to be stronger in a situation where the damaging consequences of unrestrained mobility are apparent.
C _{12a}	Mobility	Economy	The cost and quality of mobility may have an influence on the economy independently of access, eg. by enabling the use of 'just-in-time' manufacturing methods, which rely on frequent and reliable deliveries.
C _{12b}	Economy	Mobility	Economic developments and events can have a direct influence on mobility eg. via the price of oil, or the development of technologies with important transport applications; or geographical imbalances in labour markets may create demand for migrant workers. 'Transport poverty' - ie the inability of the poorest sections of the population to gain a minimum basic mobility through poverty - is clearly also related to wider issues of income distribution.
C _{13a}	Land Use	Economy	The spatial distribution of land uses at a regional or national level has important regional economic implications, so that a largely rural, agricultural area might seek to attract other land uses in order to boost its economic prospects.
C _{13b}	Economy	Land Use	Economic developments - such as agricultural production techniques - have a profound long-term impact on land uses. More short-term trends, such as the state of the housing market, may also have an influence.

C _{14a}	Communications	Economy	New communications technologies are having a profound impact on the economy, in combination with other elements in the 'information revolution', as they become both major industries in themselves and a driving force for change in other economic sectors ⁽¹⁾ .
C _{14b}	Economy	Communications	Economic forces may also generate demand for communications, eg. via the globalisation of economic activities.

⁽³⁾Freeman, 1992