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**Scope of Transport Impacts on the Environment
(2000-DS-4-M2)**

Final Report

Prepared for the Environmental Protection Agency

by

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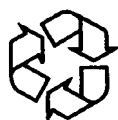
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Table of Contents

Acknowledgements	ii
Disclaimer	ii
Details of Project Partners	iii
Executive Summary	ix
1 Introduction	1
2 Air Pollution	2
2.1 Introduction	2
2.2 Motor Vehicle Emissions	2
2.3 Greenhouse Gas Emissions	2
2.4 Ambient Air Quality	2
2.5 Modelling Traffic Emissions and their Effects	3
2.6 Traffic Management and Air Quality	3
2.7 Future Research Needs	3
2.8 Summary	4
3 Waste Impacts of Transport	5
3.1 Introduction	5
3.2 End of Life Vehicles	5
3.3 Vehicle Waste Products	6
3.4 Road Runoff Pollution	7
3.5 Future Research Needs	7
3.6 Summary	8
4 Eco-Audits and Strategic Environmental Assessments	9
4.1 Introduction	9
4.2 Environmental Management Systems	9
4.3 Environmental Impacts of Transportation	9
4.4 Strategic Environmental Assessment	10
4.5 SEA of Transport Corridors (TEN-T Pilot Projects)	10
4.6 SEA Research Projects	10
4.7 EMS/SEA in Ireland	11
4.8 Future Research Needs	11
4.9 Summary	11
5 Economic Instruments	13
5.1 Introduction	13
5.2 Economic Instruments and their Relevance to Transport Policy	13
5.3 Monetary Valuation of Externalities	13
5.4 Obstacles to the Use of Economic Instruments	14

5.5	Future Research Needs	14
5.6	Summary	15
6	Land Use	16
6.1	Introduction	16
6.2	Planning & Development Act 2000	16
6.3	Roads Act 1993	16
6.4	Integration of Land Use and Transportation Planning Through Legislation	17
6.5	Other EU Policies with Spatial Impacts	17
6.6	National Development Plan	17
6.7	Residential Density Guidelines 1999	17
6.8	Retail Planning: Guidelines for Local Authorities (DoELG, 2000b)	17
6.9	EEA 2000 – Indicators on Transport and Environment Integration	18
6.10	Future Research Needs	18
6.11	Summary	18
7	Public Awareness	19
7.1	Introduction	19
7.2	Attitudes to Transport and the Environment	19
7.3	Travel Awareness Campaigns	19
7.4	Future research needs	20
7.5	Summary	20
8	Noise	21
8.1	Introduction	21
8.2	Noise from Transportation Activities	21
8.3	Noise Measurement	21
8.4	Quantification of the Health Impacts of Noise	22
8.5	Future Research Needs	22
8.6	Summary	22
9	Natural Heritage	23
9.1	Introduction	23
9.2	European and National Protection for Natural Habitats	23
9.3	Future Research Needs	24
9.4	Summary	24
10	Public Transport	25
10.1	Introduction	25
10.2	Urban Transport	25
10.3	Rural Transport	25
10.4	Future Research Needs	25
10.5	Summary	26

11 Information Technology	27
11.1 Introduction	27
11.2 The Use of IT in Transport	27
11.3 Future Research Needs	27
11.4 Summary	27
12 Inventory of Current and Recent Research in Ireland	28
13 Summary of Future Research Needs	30
13.1 Introduction	30
13.2 Identification of Impacts	30
13.3 Methods of Assessment and Information Requirements	30
13.4 Impact Assessments and Information Acquisition	30
13.5 Mitigation of Impacts	31
14 Conclusions and Recommendations	32
14.1 Conclusions	32
14.2 Recommendations	32
References	33

Executive Summary

The study entitled Scope of Transport Impacts on the Environment was commissioned by the EPA as part of the Environmental RTDI Programme 2000–2006. The aims of the project included a review of the recent international literature on the environmental impacts of the transport sector and on the integration of environmental considerations into transport planning and operations. Ten topic areas were identified from the project brief and in consultation with the EPA, and these ten sections form the basis for the structure of the report. The topic areas are air pollution, waste from the transport sector, eco-audits and strategic environmental assessment, economic instruments, land use, public awareness, noise, natural heritage, public transport and information technology.

Relevant published reports were reviewed to determine the environmental significance of the transport sector in Ireland. Organisations were consulted so that an inventory of ongoing research could be compiled. Finally, recommendations are made on the essential research necessary to integrate environmental considerations into the transport sector. In the executive summary, each topic area is mentioned briefly, highlighting the important concerns in each and identifying the priorities for further research in the area.

The **atmospheric pollutants** emitted from the road sector are carbon monoxide, carbon dioxide, oxides of nitrogen (nitric oxide in particular) and nitrogen dioxide, particulate matter and volatile organic compounds, including hydrocarbons such as benzene. Data collected by Dublin City Council suggest that PM₁₀ concentrations are close to 2005 limit values, and in Cork and Dublin the NO₂ concentrations are also close to the European Directive limit values. **Future research needs** in **air pollution** include focusing on the PM₁₀ and NO₂ concentrations in urban areas. An assessment of the potential reduction in peak urban concentrations that could be achieved at various levels of reduced local motor **vehicle emissions** should be initiated. Air quality management requires modelling and monitoring to provide the information flow for management initiatives.

Modelling offers significant potential, but for high quality, model calibration vehicle emissions from Irish driving cycle profiles using instrumented vehicles are required. Better meteorological measurements within urban areas would also provide significantly richer data for modelling purposes.

The transport sector results in significant **waste** production, in particular the construction, operation, maintenance and final disposal of transportation systems. Tyres, scrap vehicles, etc., are the more direct **waste** outputs but there are also more subtle waste streams such as underground petrol tanks and road runoff. European Directives are increasingly targeting minimisation of this waste output. Although some recycling currently takes place, a significant amount of material cannot be recycled (25–30% of the car weight). This material can be a hazardous mix, and is presently sent to landfill. A new European Directive requires that, from 2007, the vehicle manufacturer is made responsible for all of the costs of dismantling the vehicle at the end of its life. **Future research needs** in this area include a study of the vehicle **waste** industry in Ireland. An audit of garages to determine where batteries and oil are sent, an investigation into the imposition of a tax on new batteries to support disposal facilities and a similar investigation into providing a government subsidy for oil recycling plants to encourage collection from remote areas would also help fill gaps in knowledge in this area.

Eco-audits are a means of attaining a systematic and rigorous approach to environmental management by companies as part of a formalised **Environmental Management Scheme (EMS)** whilst **Strategic Environmental Management** provides a framework for the assessment of the environmental consequences of policy decisions, plans and programmes. A project currently focusing on eco-auditing of government policy of a number of pilot projects mainly within the NDP should result in useful information in this area. In addition to that, **further research needs** include work on environmental indicators so that comparisons can be made, and environmental performance benchmarked

across industries. An evaluation of how incorporation of an **EMS** can be measured, and the level of improvement in environmental performance that can be achieved, also require attention. Another suggestion for further research in this topic is how far into the realm of strategic decision-making at a company level should an **EMS** framework extend.

Although **economic instruments** are dealt with here specifically, they are also alluded to in some of the other topics areas, e.g. **taxing for transport waste**. There are three questions to be answered when addressing economic instruments – what price to charge? how to get political and public acceptability? by what means should the policy be implemented? All three questions have been the subject of considerable research internationally, particularly at a European level, and require similar attention in the Irish context. Quantification of the costs of environmental damage, particularly air pollution and noise, has resulted in monetary valuations of the damage. Theoretically, these valuations should form the basis for the charges imposed although in most cases, e.g. congestion charging proposals in London, this is not the case. **Future research needs** in this area would require attention to each of the questions mentioned above in Irish conditions, recognising that urban and inter-urban contexts will be quite different.

Intuitively, the relationship between **land use** and transportation is a clear and straightforward one but in practice it is a difficult relationship to manage, given the complexities of the issues involved and the demands placed on what is typically a limited resource: land. The Planning and Development Act 2000 is far more extensive in its treatment of transportation issues than previous legislation, e.g. it supports the ability of local authorities to achieve transportation objectives through supplementary development contribution schemes. **Future research required** includes examining the relationship between the location of various types of **land use** and consequent transportation demand, policies focusing on increased density, optimum urban size and improved data collection on **land use**.

Research has indicated that people are becoming more **aware** of the effect that their cars are having on air quality, on quality of life and on the natural environment.

Some innovative methods in **travel awareness**, such as car blending, researched in Australia, focus on examination of an individual's travel patterns, and then suggestions on how they might reduce their demands for car travel are put forward to them. **Future research** required for Ireland in this area would include a review of **attitudes** to transport and the environment, similar to the study done on Irish **attitudes** to the environment by the DoELG. Pilot tests of individualised marketing and travel blending could also be initiated on a small scale to determine the possibilities.

Noise emissions from road transport depend on flow, speed, the proportion of heavy vehicles, topography, distance from the noise source and the surfacing on the road. Significant reductions in **noise** from the vehicle itself have been made and so now the concentration is on tyres and road surfacing. Another topic of interest is the design of the attenuation barriers used to reduce **noise** levels. In terms of **future research needs**, there is a deficiency in respect of noise mapping which needs to be addressed in light of the Noise Directive. However, some work is ongoing, such as the EPA study on noise in quiet areas. Dublin City Council has also done some noise mapping. Noise monitoring has been completed for a number of road schemes but the centralisation of noise data has not been a priority to date. This will pose difficulties when new EU proposals requiring each country to provide **noise** information (most likely in contour form) are introduced. Data collection should therefore be given the highest priority in this area. In addition, tyre manufacture and road surfacing are other areas for potential improvement and should be investigated for Irish conditions.

The Habitats Directive aims to ensure **biodiversity** through the conservation of **natural habitats** and of wild fauna and flora. It encourages member states to incorporate nature conservation considerations into their land-use development and planning policies. Environmental Impact Assessment is the formal means of ensuring that significant adverse impact must require mitigation measures to be incorporated into the design of the scheme. This must include mitigation with respect to the natural environment, if required. There is a lack of information on the impacts of transportation on sensitive

and **natural environments**, although monitoring work is currently underway at Pollardstown Fen, the objective of which is to monitor the impact, if any, of lowering the water table, which is required as part of the construction work for the Kildare Bypass.

Ireland has a relatively high level of car use compared with other European countries but one of the lowest levels of **public transport** use. Although there are some **rail-based options** for inter-urban journeys, stiff competition from road-based **public transport** is in existence. This dependence on road-based modes is one of the critical drivers of environmental consequences. To reduce the environmental impact, **research** on alternative fuels is necessary, the interaction between land use and public transport needs **further investigation** and some attention to traffic demand management strategies is

needed, in order that **public transport** use might be encouraged.

Information technology (IT) pervades almost all of the topics mentioned already. Traffic management systems influence emissions levels by limiting or reducing queuing. **Travel information services** can also help, such as improved information services for public transport users but also for other road users. Monitoring facilities and the capacity for data can also be improved using the most advanced **IT**, e.g. noise pollution can be monitored for much longer periods and in some cases, the data can be transmitted from remote sites without the need to visit them. **Future research** in this area should be on the implementation of the most advanced existing technologies and evaluation of their impacts on the environment and monitoring of the state of the environment.

1 Introduction

Mobility demands in most economies present major challenges for the environment. Ireland's growing economy in recent years has led to increased car ownership and usage, resulting in increasing negative impacts on the environment. As part of the Environmental RTDI sub-Measure of the Operational Programme for the Productive Sector (2000–2006), a desk study was commissioned by the Environmental Protection Agency (EPA) entitled "Scope of Transport Impacts on the Environment" to examine more fully the relationship between transport and the environment in an Irish context.

The objectives of the study were:

- To review all available information, taking account of any ongoing studies likely to provide further information on environmental impacts of the transport sector in Ireland.
- To identify the information gaps and research needed in order to provide better guidance on the integration of environmental considerations into the transport sector.

The study commenced in December 2000. Ten topics were identified from the Terms of Reference and in consultation with the EPA. They were **air pollution, waste from the transport sector, eco-audits and strategic environmental assessment, economic instruments, land use, public awareness, noise, natural heritage, public transport and information technology.**

The project was divided into two phases. Phase 1 was the scoping part of the work, where documentation was sourced, collated and reviewed. At an early stage, a

meeting with the EPA was held to develop an agreed strategy on how to proceed. Preliminary meetings were also held with relevant organisations. An Interim Report was produced as the output from Phase 1. Phase 2 involved developing each of the phases in detail and a comprehensive document was submitted as the output from that Phase. During this phase, further meetings with relevant agencies were held. This final report is a scaled-down version of the output from Phase 2.

The following is a list of organisations who were consulted or whose documents were included as part of the review: Environmental Protection Agency (EPA), Department of Environment and Local Government (DoELG), National Roads Authority (NRA), European Union (EU), Economic and Social Research Institute (ESRI), Department of Public Enterprise, European Environment Agency, UK – Department of Environment, Transport and the Regions, Trinity College Dublin, Transport Research Laboratory – UK, Society of Irish Motor Industry, Dublin Transportation Office and the Central Statistics Office (CSO).

Dissemination of the results will include copying the report electronically to all of the above entities as well as to the EPA mail base, all environmental research groups in Universities and Institutes of Technology and all relevant Government Departments.

The report has 10 main chapters, each addressing one of the topics mentioned above. This is followed by an inventory of current relevant research in Ireland. A summary of future research needs is then presented, followed by a chapter outlining conclusions and recommendations from the study.

2 Air Pollution

2.1 Introduction

Motor vehicles emit a variety of pollutants into the air. The type and quantity of pollutant emitted depends on the number and type of vehicles present, their age, engine type and operating conditions. These emissions impact on the environment in the form of elevated ambient concentrations, which depend on proximity to the roadside and meteorological conditions. Local ambient concentrations are normally compared with limit or guideline values to ascertain whether a pollution problem exists. These concentrations may be obtained in either or both of two ways: air quality monitoring or atmospheric dispersion modelling. This chapter examines each of these issues, and concludes with the relationship between traffic management and air quality and identifies the most relevant future research needs.

2.2 Motor Vehicle Emissions

The more important atmospheric pollutants emitted from motor vehicles are carbon monoxide (CO) and carbon dioxide (CO₂), oxides of nitrogen (NO_x), especially nitric oxide (NO) and nitrogen dioxide (NO₂), particulate matter, especially PM₁₀, and volatile organic compounds (VOCs), including hydrocarbons (HCs) such as benzene.

The complete combustion of a fuel gives rise to emissions of CO₂ and water only. However in real engines, incomplete combustion also gives rise to emissions of CO, unburnt HCs and particles, while nitrogen oxides are formed by the high-temperature oxidation of nitrogen present in the air. Approximately 50% of NO_x, 60% of VOC and 80% of CO emissions originate from transport sources. Most of these pollutants are involved in chemical transformations which cause the composition of pollutants in the air to differ from those emitted from vehicle exhausts. In addition to exhaust emissions, evaporative emissions of fuel HCs also occur, as do particulate emissions due to wear and resuspension.

Pollutant emission rates are highly dependent on vehicle operation mode. The highest emission rates for CO and HC occur at the low average speeds typical of urban driving, in which frequent starts and stops, accelerations

and decelerations occur. At higher average speeds, engine efficiency improves and emission rates reduce on a distance-travelled basis. However, as engine temperature increases at these higher average speeds (when fuel consumption per unit time is high), the rate of formation of NO_x also increases. The contribution of individual vehicles to overall pollution levels can be expressed in terms of emission factors. These seek to quantify the mass of a pollutant emitted by a given vehicle under a set of operating conditions, and are combined with vehicle activity information in order to obtain emissions inventories. The effects of some operational factors are better understood than others, and most research has concentrated on the speed dependence of emission rates for different pollutants. In Ireland, the CORINAIR methodology appears to be applied most often. There is convenient software for road transport, COPERT II, which facilitates the required calculations. A comprehensive national inventory has been prepared for the period 1990–1998, and this is updated annually (McGettigan and Duffy, 2000).

2.3 Greenhouse Gas Emissions

Of the three greenhouse gases CO₂, nitrous oxide and methane, only CO₂ is emitted in significant quantities by road transport. Current trends indicate that the rate of increase in total greenhouse gas emissions in Ireland is well above that allowed under the Kyoto Protocol. Data presented in *Ireland's Environment: A Millennium Report* (EPA, 2000) suggest that greenhouse gas emissions from transport increased by 80% between 1990 and 1998. Also, whereas the transport sector was responsible for just under 10% of total greenhouse gas emissions in 1990, this had risen to nearly 15% in 1998. Ireland's Climate Change Strategy (DoELG, 2000a) contains a commitment to put in place an appropriate framework of taxation, prioritising CO₂ emissions, from 2002.

2.4 Ambient Air Quality

Motor vehicle emissions impact on the atmospheric environment as elevated ambient concentrations. At a local level, regulation of these impacts in future years

will be carried out with reference to the EU Framework Directive on ambient air quality assessment and management (96/62/EC; EU, 1996) and its associated daughter directives. These daughter directives set out limit values for ambient concentrations of a range of pollutants. With respect to vehicle emissions, the most relevant values are those specified for CO, NO₂/NO_x, PM₁₀, and benzene. Different dates for the attainment of the limit values are specified, as are the reasons for each value. According to the UK Expert Panel on Air Quality Standards, the ways in which the limit values are expressed are related to the mechanisms of their actions on the human body. Hence, since the effects of sulphur dioxide may occur rapidly, a short (15 min) averaging period is employed, whereas an annual average suffices for benzene, for which no such rapid effects occur.

Currently, nearly all urban residents in the EU still experience exceedences of EU air quality standards (EEA, 2000). Data collected by Dublin City Council suggest that in recent years, PM₁₀ concentrations in Dublin have been close to the limit values to be attained by 2005, and above those to be attained by 2010. Measurements obtained by Dublin and Cork City Councils also suggest that ambient NO₂ concentrations in the centre of both cities are close to the Directive's limit values.

2.5 Modelling Traffic Emissions and their Effects

The EU Framework Directive includes air quality modelling as an acceptable assessment technique, especially where ambient concentrations are expected to be low, and where monitoring would not be justified. While no reference technique is specified in the Directive, the most commonly used technique is atmospheric dispersion modelling, usually based on the Gaussian plume approach. Two types of dispersion models can be identified: urban air quality models, which calculate ambient concentrations due to a variety of emissions over a wide urban area, and highway models, which calculate concentrations in the vicinity of a single road or an isolated network of roads. In addition to calculating present air quality, dispersion models also allow the effects of future developments or abatement scenarios to be compared.

2.6 Traffic Management and Air Quality

The following measures can be considered for the management of traffic during high pollution episodes (McCrae *et al.*, 2000): (i) environmental road pricing (to encourage modal shift), (ii) environmental access control (to prevent access by a proportion of vehicles), (iii) traffic re-routing away from pollution 'hotspots', and (iv) traffic signal control. Cloke *et al.* (1998) identify a number of traffic management measures which have the potential to reduce vehicle exhaust emissions, including urban traffic control, parking control, park and ride, mass transit systems and public transport pricing policies. In recent years, demonstration projects of environmental access control measures have been carried out in Paris, Athens and Rome.

2.7 Future Research Needs

Future research should address the ambient concentrations of PM₁₀ and NO₂, especially those in urban areas. A current project on the *Nature and Origin of PM₁₀ and Smaller Particulate Matter in Urban Air* will provide valuable information in this regard, but there is a need for a similar project on NO₂. An assessment should be made of the potential reduction in peak urban concentrations that could be achieved at various levels of reduced local motor vehicle emissions. This will require information on the sources and formation of PM₁₀ and NO₂, and knowledge of the meteorological conditions that give rise to elevated concentrations in Irish cities.

Air quality modelling offers great potential for future air quality management. To improve the accuracy of model results, there is a need for increased motor vehicle emission measurements using driving cycles that reflect Irish conditions and focusing on the characteristics of the national vehicle fleet. As a complementary activity, the driving profiles experienced in Irish cities should be defined in surveys using instrumented vehicles. Improved model results would also be achieved if measurements of meteorological conditions were obtained within urban areas, as those made at synoptic stations are unlikely to be representative of those pertaining where the highest conditions occur. The dependence of model accuracy on all of these parameters needs to be assessed.

2.8 Summary

Motor vehicles emit a variety of atmospheric pollutants and these emissions lead to elevated ambient concentrations, the magnitude of which depend on both traffic and meteorological conditions and which may be assessed through air quality monitoring and modelling. Inventories of motor vehicle emissions are normally produced using emission factors that take into account fleet characteristics and operating conditions, such as average speed. In coming years, the EU Framework

Directive on ambient air quality assessment and management will play an increasing role in the regulation of the impacts of these emissions. As with most cities in the EU, available evidence suggests that PM₁₀ and NO₂ concentrations in Dublin and Cork are approaching or exceed the limit values set out in this Directive. However, it is difficult to achieve reductions in the ambient concentrations of these pollutants because NO₂ is a secondary pollutant and PM₁₀ is emitted by a variety of source types.

3 Waste Impacts of Transport

3.1 Introduction

The construction, operation and maintenance and final decommissioning of transportation systems results in a myriad of waste products which can adversely impact upon the natural environment. Certain forms of such waste are manifest, generated directly from the transportation itself (tyres, scrap vehicles, etc.), but other waste products occur as an indirect consequence of the transportation infrastructure (underground petrol tanks, road runoff, etc.). Waste minimisation within the transportation industry is increasingly the target of national/international environmental legislation, particularly for Ireland, in the form of European Directives. This section focuses on the waste aspects from road transportation, which remains the most important form of transport in Ireland, generating diverse waste products with inherently dispersed environmental impacts.

3.2 End of Life Vehicles

Ireland's increasing economic growth over the past few years has yielded concurrent increases in new vehicle purchases whereby there are currently in excess of 1.6 million vehicles on the road with over 250,000 new private cars purchased each year (CSO, 2001; DoELG, 2001a). The average age of private cars on the road in Ireland has fallen from 6.8 to 6.3 years over the 4-year period from 1994 to 1998 (EEA, 2001), presumably due to the high levels of growth in consumer demand over the past decade, whilst the average age of an End of Life Vehicle (ELV) in Western European countries is 12–14 years (Charles Trent, 2000). The scrapping of the ever-growing numbers of ELVs does result in the recycling of certain material (particularly of a ferrous nature) but the process also generates large volumes of waste for disposal to landfill. The current situation in Ireland with regard to ELVs is difficult to quantify accurately due to the disparate nature of breakers yards and dismantlers. The vast majority of vehicles are abandoned on the side of the road once they have reached the end of their useful life, presumably due to the fact that the dismantlers currently charge owners for the disposal of their vehicle.

The abandoned vehicles are removed and brought to the dismantlers either by the Local Authorities or by members of the travelling community. At the dismantlers, the vehicle is generally treated as a homogenous lump and passed through a crude shredding and gravity separation process to split the material into three distinct waste streams. The shredded vehicle passes through magnets which sort the ferrous material (approximately 65% by weight) from the rest. This ferrous material is sent for recycling either in Ireland or to steel mills in Europe depending on contemporary market prices. The remaining waste is sorted into a 'heavy fraction' and the so-called Auto Shredder Residue (ASR). The heavy fraction, which contains aluminium, copper, brass, and some other non-metallic material such as rubber and glass, is normally sent to the UK for recycling and is generally valued according to its aluminium content. The remaining ASR (forming 25–30% of the car by weight) contains a hazardous cocktail of material, including plastics, glass, rubber and heavy metals, which is sent to landfill sites.

A new EU Directive (2000/53/EC) concerning ELVs will have far-reaching implications on the vehicle dismantling and recycling industries. The Directive defines many requisite actions of the car industry, several of which are aimed at improvements in vehicle design in order to facilitate dismantling and reuse of their parts and materials. However, a key aim of the Directive is that the vehicle manufacturer will be responsible for all of the costs of dismantling the vehicle at the end of its life from 1st January 2007. The charge to the manufactures will be in the form of a levy per vehicle. This legislation is to be phased in from 1st July 2002, at which point an ELV is officially categorised as hazardous waste. The treatment facilities (dismantlers/scrapping centres) will have to meet strict criteria (EU, 2000a) to ensure that the dismantling operation achieves an environmentally satisfactory outcome (Table 3.1).

These targets should be compared with the estimated average rate of 75% ELV reuse and recovery achieved at present in the European Member States. Hence, the

Table 3.1. Criteria for the dismantling of ELVs in Europe (based on average weight per ELV per year).

By 1st January 2006	By 1st January 2015
85% to be reused and recovered	95% to be reused and recovered
80% to be reused and recycled	85% to be reused and recycled

statistical prophesy of ever-burgeoning numbers of ELVs in Ireland, together with the impending Directive (2000/53/EC), will create significant impacts on this waste industry in the near future, particularly if net environmental impacts are to be reduced.

3.3 Vehicle Waste Products

The choice of materials used in vehicles, and their overall design, will start to impact much more heavily upon the dismantling industries as a result of the new reuse, recovery and recyclability requirements in the ELV Directive. An ELV contains a wide variety of both hazardous and non-hazardous materials (steel, heavy metals, plastics, glass, rubber, natural fibres, etc.), several of which are intimately bound together into complex compounds. Technologies are developing whereby the majority of generic materials and fluids from vehicles can be separated and then reused or recycled by appropriate processes (ECRIS, 1999).

The maintenance of vehicles during their lifetime continually generates waste products (tyres, batteries, etc.), often with unsatisfactory disposal solutions. Some of these ongoing wastes can be sent to independent disposal facilities where varying degrees of reuse and recycling are achieved. The disposal of tyres in Ireland is a looming environmental problem considering the ever-increasing number of vehicles on the road. Many garages pay a nominal cost to have their used tyres periodically collected by a contractor who then sells the tyres on to farmers for use on their silage pits. This disposal route would appear to be fairly limited in the future due to the increasing numbers of used tyres expected and also the widespread changes in agricultural practice towards silage baling. In addition, a recent EU Directive on the Landfill of Waste (1999/31/EC; EU, 1999) came into force in July 1999 with the result that Member States must prohibit the dumping of whole tyres in landfill sites by July 2003 and cease the landfilling of shredded tyres by July 2006. A variety of tyre disposal alternatives are

currently being practised in other countries, which fall into the general categories of remoulds, reuse options, materials recovery and energy recovery. The remould market has been declining in many of these countries recently due to the poor public perception of the quality of the tyres and reduced profitability compared to other new tyres. Reuse options for tyres include part-worns, landfill engineering, dock-fenders, playgrounds, artificial reefs and several other small-scale applications. The materials recovery sector has received strong interest over the past few years whereby a granulated end product (crumb rubber) from the shredded tyres has been used in asphaltic concrete mixes for road surfaces and can also provide the shock absorbing element required for surfaces such as playgrounds or sports tracks. Energy recovery from used tyres is another sector that has received a lot of interest and many European countries achieve significant energy recovery from waste tyres, particularly in cement kilns, which seem to offer the most significant short-term potential due to its proven technology. Pyrolysis has been proven to be a feasible way of converting waste tyres into economically valuable products of liquid and gaseous HCs, although to date it has never been proved in any large-scale operations. Old lead-acid batteries from vehicles are currently collected by one company in Ireland (Returnbatt Ltd). The batteries are shredded, baled and then sent to the UK or mainland Europe, where the lead is recovered. The acid is neutralised and the resultant precipitated 'cake' is sent to landfill. However, figures reveal that out of the 14,213 waste batteries generated in Ireland in 1998, only 5175 had been disposed of correctly. Equally, the waste oil from vehicles in Ireland is estimated at 36,000 t/year, although the recycling outfits can only account for 24,500 t of recovered oil (EPA, 1998). The lost oil is probably due to owner maintenance with subsequent disposal to soil, watercourse or sewer, but includes atmospheric emissions from the fraction burnt in poorly maintained engines. Spent oil filters contain significant quantities of oil and can also be recycled.

3.4 Road Runoff Pollution

Stormwater runoff from road surfaces often contains significant loads of particulates and dissolved solids, metal elements and organic compounds. These waste products emanate from traffic activities, component wear, fluid leakage, pavement degradation, atmospheric deposition, and road maintenance procedures. Common examples of pollutants occurring in road runoff include particulates from brake pads, tyres and worn bearings and in other forms from fuel leaks, herbicides and de-icing salts. Road runoff in non-urban areas passes to the side of the road where it either travels directly or indirectly into watercourses, or infiltrates into the groundwater regime. The toxicity and ecological impact of runoff water has been the focus of much study; however, the transport and dispersion of these pollutants during stormwater events is a more complex phenomenon and is not so well understood (Marsalek *et al.*, 1999). Sustainable drainage is currently an expanding subject, prevalent in progressive engineering design, whereby all aspects of the urban water cycle are weighed against the holistic environmental impact. Hence, road runoff is one facet to be considered with respect to the overall picture which embraces water use, runoff and related land use, wastewater treatment processes, effluent discharges and receiving water quality (INTERURBA II, 2001). There are several treatment systems that can be installed to mitigate such pollution from road runoff, including grassed ditches (swales), detention ponds, natural or constructed wetlands, infiltration areas, exfiltration trenches and gully pots (Martin and Roux, 1999). A 3-year research project has just been commissioned by the EPA and NRA entitled *Impact assessment of highway drainage on water quality* under the Environmental RTDI Programme 2000–2006. The study will be undertaken in a collaboration between the Departments of Civil Engineering at Trinity College and University College Dublin.

3.5 Future Research Needs

A study of the vehicle waste industry in Ireland should be undertaken at this time of increasing car sales and the imminent new ELV Directive in order to identify optimum strategies and opportunities for viable recycling

industries. A revised approach towards dismantling operations will be needed in order to meet the Directive's requirements, in line with methods being developed in Scandinavia and Holland (ARN, 2000).

An overhaul of the extent and quality of information collected on the large quantity of waste associated with vehicle maintenance is required. Technically, it would require relatively simple information technology to compile a register of all garages in order to evaluate the extent whereby batteries, oil, etc., are sent to the limited number of recycling plants. This would help to tighten the regulations and improve the recovery rate. However, for all types of waste, recycling technologies are advancing all the time, contemporary developments which should be researched in relation to the Irish context (for example, a planned pyrolysis plant for waste tyres in Wolverhampton, UK). More specific issues for investigation include the feasibility of imposing a government tax on new batteries to support disposal facilities (as operated in several European countries) and a government subsidy for oil recycling companies to collect waste oil from remote areas of the country which are currently not economically feasible to service.

There is currently no legislation limiting the amount of pollutants that can be released onto the road through wear and tear of vehicle components, and consequently there are very few source-based measures for reducing the release of pollutants into the environment. The manufacturers of vehicles and respective components should be targeted to develop their designs to mitigate such emissions at source. This will start to have an increasingly beneficial impact on the roads in Ireland as the newer technology vehicles become phased in over the longer term. However, in the short-term, the renovation or expansion of existing routes provides an opportunity to retrofit the carriageways with appropriate treatment practices for the current levels of pollutant emissions. For example, the major investment in road infrastructure that has been planned over the next few years as part of the National Development Plan (NDP) (Government of Ireland, 1999), presents an opportunity to incorporate such treatment practices into the design of the road schemes for subsequent evaluation.

3.6 Summary

This disposal of ELVs is the focus of recent new European legislation whereby the financial costs for the ultimate disposal of all new vehicles will rest with the car manufacturers, thus imposing whole-life implications upon those companies. Responsibilities are also placed upon the vehicle owners to ensure that the vehicle is scrapped at registered dismantling facilities. Hence, it is an opportune time to consider these aspects in some detail, including the current ELV practices, implementation of the new Directive, and manufacturers'

developments in materials and design of vehicles that will eventually end up as ELVs in Ireland. Equally, the environmental impacts of wastes associated with vehicle maintenance both by individual vehicle owners and from garages should be quantified and addressed. Finally, the more diffuse pollutants deposited onto the highways need to be recognised and a dual strategy of source-based mitigation in the design of vehicle components, together with the incorporation of appropriate treatment practices on highways, should be adopted.

4 Eco-Audits and Strategic Environmental Assessments

4.1 Introduction

In European Member States, environmental instruments (Regulations, Directives, etc.) are the basis for most of the environmental legislation in force. However, despite such legislation, environmental quality is still not improving as rapidly as could be expected. Hence, a broader range of instruments have been developed to tackle the ever-more diffuse sources of environmental pressures that are increasingly being identified. These aim to promote information, awareness and commitment across the public and within the business community and ensure the integration of the environment into other policies. Eco-audits have emerged within the past few years as a means of attaining a systematic and rigorous approach to environmental management by companies as part of a formalised Environmental Management Scheme (EMS), whilst Strategic Environmental Assessment (SEA) provides a framework for the assessment of the environmental consequences of decisions concerning policies, plans and programmes.

4.2 Environmental Management Systems

The recent growth of EMSs signifies a maturing of the relationship between companies, regulators and other stakeholders, moving from a position where companies merely aim to meet specific consents set by a regulator, to the point whereby organisations voluntarily question and evaluate the environmental impacts of all their activities and routinely implement measures to reduce them. There are currently two main accreditation bodies: the European Commission's Eco-Management and Audit Scheme (EMAS) and the International Standards Organisation ISO14001 certification. Both forms of EMS are relatively new but are gaining wider acceptance every year. At the end of 2000 there were 3752 EMAS-accredited firms compared to 22,892 ISO14001-accredited organisations in Europe (EMAS, 2001). In general neither system establishes absolute requirements for environmental performance beyond a commitment in the policy to compliance with applicable legislation and regulations and to continual improvement. The

organisation must establish and maintain procedures to identify the environmental aspects of its activities, products or services, which it can control, and must also establish documented objectives and targets for each relevant function. The organisation has to monitor key indicators on a regular basis from which they judge the significance of their environmental impacts as defined by their own criteria. Ideally, the chosen criteria are compared by a method for classifying and characterising the environmental threats, and then weighted indices can be developed which enable comparisons to be made over time and between different processes. A common method used is the Weighted Environmental Theme Index, where suitable themes include global warming, ozone depletion, acidification, eco-toxicity, human toxicity and eutrophication. Another method used is the Environmental Protection Strategies method, which considers five safeguard categories of human health, biological diversity, production, resources and aesthetic values. In addition, methodologies are available that attempt to aggregate the potentially unwieldy mix of data generated on performance and impacts including Life-Cycle Analysis or using an Ecological Footprint Indicator.

4.3 Environmental Impacts of Transportation

The introduction of an EMS should help to promote a continual improvement in the environmental performance of transport-related activities of an organisation whether transport is the core business or not. A recent study by the carpet manufacturer Interface Europe serves as an interesting example of a manufacturing industry that found that their transport-related impacts in the form of emissions from the freight distribution, company cars and air travel were by far the most significant compared to electricity consumption by the manufacturing processes, effluent discharges and solid waste disposal (ENDS, 2000). Other examples of transportation initiatives that have been introduced as a result of implementing an EMS have primarily related to patterns of employee travel, including the promotion of cycling, changes to company car policies, refunds to

public transport users and a reduction in company car parking.

4.4 Strategic Environmental Assessment

The concept of SEA and its practical application have experienced a substantial evolution over the past decade across a variety of sectors. The widespread nature of transport systems has meant that it has been a sector where the potential benefits of SEA have been particularly identified with regard to strategic transport infrastructure plans. Currently the practice of SEA in most sectors has been limited to plan and programme levels although further developments are also beginning to be made at policy level, an area that will undoubtedly increase as a result of the introduction of a new EU "SEA Directive" (2001/42/EC; EU, 2001) which was formally adopted on 5th June 2001 and will have to be implemented by Member States by the summer of 2004 (EU, 2001). SEA developed due to the limitations of project scale Environmental Impact Assessment (EIA) when attempting to determine cumulative and large-scale impacts. Hence, the past decade has seen the development of SEA as a technique and a process that aims to contribute to the achievement of sustainable development by being applied at an earlier and more strategic level of decision-making. Typical environmental objectives for SEAs on transport actions cover climate change, acidification, air quality, nature and biodiversity, water quality, coastal zones, soil quality and noise, and can include additional issues, such as the use of natural resources, accidents and land-use impacts (COMMUTE, 1998). The assessment of environmental impacts requires a range of methods and tools such as Geographical Information Systems and the COMMUTE software, which focus on the measurement of single impacts or methods such as Multi-Criteria-Analysis and Cost-Benefit Analysis, which can aggregate individual measurements into a single framework for easier assimilation by decision-makers. The significance of the impact is thus evaluated and recommendations such as the preferred alternative, mitigation and monitoring measures are proposed. Public participation is also an important requirement in SEA.

4.5 SEA of Transport Corridors (TEN-T Pilot Projects)

The SEA methodology has been tested by several pilot projects on transport corridors through the co-ordination of EU-funded research activities. Five SEA pilot studies were selected in 1996 to assess the environmental implications of the Trans-European Transport Network (TEN-T): the Gotthneburg–Jönköping transport corridor (Sweden), the Trans-Pennine corridor (UK), Austrian section of the Danube corridor (Austria), the road corridor between the port of Ravenna and Venice (Italy), and the Corridor Nord between Paris and Brussels (France/Belgium). The studies were successfully completed in 1999 and a report was commissioned to review the pilot SEAs and to seek out the most relevant aspects of good practice (ERM, 2001). In general, the projects demonstrated that the SEA framework holds potential for future exploitation although it was recommended that a coherent strategy needs to be developed whereby SEA of the corridors becomes an iterative process encouraging continuous communication between all parties involved in the planning process (ECMT, 2000). A guide *European Manual on Strategic Environmental Assessment for Transport Infrastructure* has recently been published for use in the assessment of transport infrastructure initiatives proposed within the TEN-T guidelines framework (EU, 2000b).

4.6 SEA Research Projects

The European Union's 4th Framework project COMMUTE (Common Methodology for Multi-Modal Transport EIA) was the first project to deal explicitly with SEA, which defined a methodology for the strategic assessment of environmental impacts of transport policy at a European level when considering multi-modal transport. The project also developed the COMMUTE software tool, which can be used to model impacts in key areas of energy use, emissions, safety and noise and can also be expanded to address other environmental impacts such as land use and biodiversity. The INTERNAT project was then set up with the aim of establishing an Integrated Tool for SEAs derived from issues developed during the COMMUTE project, dealing with issues related to spatial impacts of transportation infrastructure and ecological impacts (particularly biodiversity) (INTERNAT, 2001). The most recently commissioned

project is the Analytical Strategic Environmental Assessment (ANSEA) project which is a research project aiming to provide an enhanced theoretical and methodological background for SEA. It also aims to provide a framework for assisting in the implementation of the European and national Directives and other procedural requirements in this area (ANSEA, 2001).

4.7 EMS/SEA in Ireland

In Ireland there are currently around 170 companies with an accredited EMS, which fall broadly within the manufacturing, pharmaceutical and chemical industries. No organisations operating directly within the transportation sector (e.g. Bus Éireann, Iarnród Éireann, etc.) have attempted to implement an EMS to date, with the exception of Aer Rianta who received ISO accreditation in 1996. An EMAS registered company, Novartis Ringaskiddy Ltd in Cork, have demonstrated a reduction in their environmental impacts due to transportation, by the installation of a large-scale process with the result that fewer solvents now have to be produced, transported and subsequently disposed of (LIFE, 1998). SEA in Ireland is being considered for legislative proposals, plans and programmes and policy statements at a governmental level. In 1999 the Irish government approved proposals for a system of “eco-auditing of governmental policy” resulting in a number of pilot projects in specific areas by Government departments, mainly with respect to the NDP (ERM, 2000). Several of the pilot studies contain aspects of transport, since a significant portion of the expenditure from the NDP will be within the transport sector, especially new-roads infrastructure. The results of these pilot projects are being collated and evaluated, although no information has yet become available.

4.8 Future Research Needs

The adoption of an EMS by an organisation and the requisite demonstration of improvement year-on-year are largely affected by the formulation of the Environmental Indicators. This does not necessarily indicate that a compliant organisation is environmentally sound if the company has started from a low level of environmental awareness compared with a more conscientious equivalent company. Research into a series of generic indicators should be developed across different industrial

types so that comparisons can be made and environmental performance benchmarked. For example, airports could relate their environmental performance indicators to baseline passenger numbers so that comparisons can be made against other airports in Europe or throughout the world. It is also prudent to research whether cited improvements in environmental performance have been due to the adoption of an EMS alone or complementary with incoming national or international legislation (for example, the new ELV Directive). Improvements have certainly been demonstrated in areas that also generate economic savings, such as management of utilities and raw materials, but it is not so clear whether these improvements can always be equated with a corresponding reduction in environmental risk. Finally, studies should be carried out into whether the EMS framework extends into the realm of strategic decision-making at a company level.

Although European countries have benefited from a number of pilot studies and practical applications of SEA in the transport sector, it can be difficult to find examples of SEAs that have had a clear influence on the final decision (Bina, 1999). The majority of the SEAs applied to date relate to land-use planning, and have focused on formal plans with spatial reference, whilst little has been done in relation to informal plans or programmes without spatial reference, or indeed to private sector plans and programmes. Experience of assessing policies or broad legislation is much more limited and should be encouraged.

4.9 Summary

The widespread nature of transport systems and their consequent environmental effects have meant that it has been a sector where the potential benefits of both EMS and SEA have been particularly identified and are being increasingly applied. The introduction of accredited EMS is increasing every year and should yield reductions in transportation-related environmental impacts whether the organisation is within the transport sector or not. SEA is being increasingly applied with regard to strategic transport infrastructure plans, particularly in Europe and the USA. The SEA of policies, plans and legislation that are likely to have significant implications for the

environment and natural resources will become a mandatory procedure in many European countries due to the new SEA Directive. An SEA should not be viewed simply as an assessment but should be woven into the process fabric of strategy formulation and analysis. The

development, refinement and relationship between SEA and other general assessment methodology is still in progress and is bound to be influenced within the transport sector by the development of SEA procedures in other sectors.

5 Economic Instruments

5.1 Introduction

The aim of this section is to examine the background, the current thinking and the potential for using economic instruments as a means of regulating transportation demand and its associated environmental impacts. The importance of this topic is highlighted in [CEC \(1995\)](#) and [EEA \(1999\)](#), where economic instruments are identified as having particular importance as a method of controlling environmental damage as well as the other externalities associated with transportation such as noise, accidents and congestion.

This section commences with a description of the type of instruments one might use, followed by more detail on the monetary valuation of the environmental externalities, for which, in theory, the prices are used to offset. Obstacles to the use of economic instruments have resulted in a reluctance to incorporate such policies more fully and some attention is given to this issue. This is followed by the future research needs for Ireland in this area.

5.2 Economic Instruments and their Relevance to Transport Policy

The most common economic instruments are presented in Table 5.1 along with the other available policies for

regulating emissions, fuel consumption and traffic demand management. It is widely accepted that economic policies are the more flexible and effective, with the added benefit of generating revenue which can be used to compensate those individuals who have changed their behaviour. Ireland has used several of the policies mentioned, such as fuel taxation, scrapping of old vehicles, parking charges and phasing out of high-polluting fuels.

5.3 Monetary Valuation of Externalities

The monetary valuation of externalities is important if the charges (fees) to be applied by means of economic instruments are to be fairly distributed and related to actual levels of transport usage. Little work has been done in this area in Ireland to date except for the studies under the EU funded TRENEN project ([Proost et al., 1998](#)).

To give an idea of the monetary levels found in international studies, some examples are presented here. The most common evaluation methods used for noise are market value of buildings and attenuation actions. The cost of noise is estimated to be 1.4%, 0.5% and 0.1% of GNP for Germany, the UK and Austria, respectively ([Quinet, 1994](#)). The noise cost per traffic unit ranges from

Table 5.1. Summary of economic instruments.

	Market-based incentives		Command and control regulations	
	Direct	Indirect	Direct	Indirect
Variable	Emission fees	Tradeable permits	Emissions standards	Compulsory inspection and maintenance of emissions control systems
		Differential vehicle taxation		Mandatory use of low-polluting vehicles
		Tax allowances for new vehicles		Compulsory scrapping of old vehicles
Fuel		Differential fuel taxation	Fuel consumption	Fuel economy standards
		High fuel taxes	Phasing out of high-polluting fuels	Speed limits
Traffic		Congestion charges	Physical restraint of traffic	Restraints on vehicle use
		Parking charges	Designated routes	Bus lanes and other priorities
		Subsidies for less polluting modes		

€0.13 to €0.2/100 passenger km for rail, from €0.03 to €0.11/100 passenger km for road, and €0.5/100 passenger km for bus (Diekman, 1990). The health costs of local pollution range from 0.01% to 0.59% of GNP for Germany, Switzerland, Sweden and the Netherlands. The cost of local pollution in €0.01 per traffic units varies widely across the same countries: €0.11–€1.94/passenger km for car, €0.02–€0.4 for bus, and €0–€0.15 per passenger km for rail. Estimates for local pollution, global pollution and noise costs will be made in the UNITE study (O'Mahony et al., 2002).

5.4 Obstacles to the Use of Economic Instruments

Although use has been made of fuel taxation and parking charges in Ireland, there is generally a reluctance to use economic instruments due to the public and political unacceptability issues. There are several reasons why the public and politicians tend to refuse to use economic instruments (Rothengatter, 1994). They include:

- Free rider problems

Public opinion usually supports the idea that existing taxation levels are too high. In the case of road pricing, the distributional effects are normally cited as unfair – low-income workers will no longer be able to drive to work. As long as individuals can profit from inefficient social cost allocations, there will be no incentives for them to agree to pay for those costs.

- Private misunderstanding about public infrastructure

The public sector allocates transport infrastructure according to public rules, e.g. a road is provided without charges imposed for its use. Individuals will use that road without payment and when capacity is reached will call for additional capacity. They will put pressure on politicians to increase capacity without revealing their true willingness to pay for the additional infrastructure when in fact there is a strong possibility that individuals would pay for the use of infrastructure, if required.

- Public misunderstanding about private transport

Transport infrastructure provides additional indirect benefits such as the development of remote areas,

creation of new consumption patterns, new patterns of industrial and residential location and innovations linked to services of the transport system (Rothengatter, 1994). Some researchers consider that subsidies or tax reliefs should be introduced to balance these positive externalities. However, the general belief is that this is incorrect and that there are no relevant external benefits of road transport that could justify monetary compensation in the form of reduced road charges (Rothengatter, 1994).

- Enforcement of psychological barriers by lobbyists

Traditionally strong lobby groups, such as automobile associations, put pressure on politicians against the use of economic instruments for curtailing car use.

- Transport networks

It is difficult in some cases to apply wide area pricing systems due to the nature of the network. It is not so difficult to charge for use of a tunnel but charging for entering a city poses considerably more complex issues.

- Privacy

The most efficient of road-use pricing systems require some form of video and photographing if violators are to be deterred. This poses difficulties for some individuals relating to invasion of privacy. However, these problems appear to have been overcome on the ETR 407 in Toronto. In this case, a photo is only taken of a vehicle number plate if the vehicle has passed under the gantry and not paid the charge. The details are only kept until the penalty has been processed.

5.5 Future Research Needs

In an Irish context, the following have been identified as the research topics requiring further attention in the area of economic instruments.

- Transport demand data collection and analysis. Estimates of vehicle mileage for all modes of transport need to be disaggregated to vehicle type, time of day, etc. These data are required to enable

accurate estimates to be made of the external costs of transport and the levels at which prices should be set.

- Air and noise pollution data are required for input to monetary assessment models so that health costs, etc., can be identified and quantified more clearly.
- Congestion estimates and public transport delays need to be collected so that accurate assessments of the monetary costs of congestion and user costs, e.g. delays, can be estimated.
- Having established the marginal costs of the externalities from the three research tasks listed above, the next stage is to examine the feasibility and the means by which economic instruments can be introduced to internalise the costs.
- Political and public acceptability needs some attention as it is now identified as the main barrier to the introduction of economic instruments in the transport arena. Issues like hypothecation of revenue for transport purposes or to help repair

environmental damage are some of the topics worth considering.

- Further attention is needed on the subject of the most suitable policies for Ireland to enable internalisation of the marginal external costs. Fuel taxation, parking charges, cordon pricing, distance- and time-based charging, etc., are some of the options but they need to be examined in an Irish context.
- The complexities of introducing, e.g. cordon pricing in Dublin requires considerable attention as do the methods of charging and enforcement that would be required.

5.6 Summary

In terms of effectiveness in reducing road-based transport, economic instruments have distinct advantages. However, there are inherent difficulties, of both a technical and a political nature, in implementing this type of policy. Future research needs include estimation of the charge levels, gaining acceptability, implementation issues and the integration of these policies with other demand management strategies.

6 Land Use

6.1 Introduction

Land use and transportation are inextricably linked. The location, scale and type of various land uses will dictate the type of access that is most appropriate. Therefore, as land-use activities create demand for transportation and accessibility, it is an essential issue in the consideration of the environmental effects of transport. The aim of this section is to examine the relationship between land use and transportation, to identify the most critical issues and future research needs, particularly in relation to policy research.

6.2 Planning & Development Act 2000

The Planning & Development Act (2000) ([Government of Ireland, 2000](#)) is the most recent piece of planning legislation in Ireland, and consolidates all previous legislation in this area since 1963. For the purposes of integration of land use and transportation, Part II, Plans and Guidelines, and Part III, Development Control, have the most relevance, and contain more specific and broad-ranging references to transportation provision than previous legislation.

6.2.1 Part II, plans and guidelines

Under the new legislation, planning authorities are now obliged to renew development plans every 6 years and to take all necessary steps to attain the objectives of the development plan (S. 15(1)). The objectives to be contained in development plans include “the provision or facilitation of the provision of infrastructure including transport...”. The new legislation gives statutory recognition to local area plans. Local Authorities are now obliged to produce local area plans for any town within its jurisdiction with a population of over 2000. The Local Area Plan must be in accordance with the objectives of the relevant development plan, which would include objectives in relation to transportation. Chapter III of the act also gives statutory recognition to regional planning guidelines. Where regional planning guidelines are

produced, they must contain proposals relating to transport and public transport.

Strategic Development Zones (SDZ) are a new concept in the Irish planning system. A planning scheme for an SDZ must contain proposals relating to transportation, including public transport, roads layout, the provision of parking spaces and traffic management (S. 168(2)(d)). An important point to note is the requirement for all plans (development plans, local area plans, regional planning guidelines, and strategic development zones) to contain information on the likely significant effects on the environment of its implementation (S. 10(5)(a); S. 19(4)(a); S. 23(3)(a); S. 168(3)). Presumably, this will include an obligation to highlight any likely environmental effects of transportation proposals, since all plans must contain objectives or proposals covering such matters.

6.2.2 Part III, development control

Of interest in the context of this study are the provisions in the Act relating to conditions that may be attached to planning permission, and development contributions. S. 34(4)(m) provides for conditions requiring the provision of roads, including traffic-calming measures, and car parks. The power to require development contributions for the granting of planning permission is covered in S. 48, which allows planning authorities to require contributions in respect of public infrastructure and facilities benefiting the development, which it is intended will be provided by or on behalf of the planning authority.

6.3 Roads Act 1993

The main provision of the Planning & Development Act 2000 in relation to roads is the transfer of responsibility for the approval of motorway schemes, compulsory-purchase orders and EIS from the Minister for the Environment to An Bord Pleanála. Also, S. 22 of the Act deals with the NRA's role in the physical planning process.

6.4 Integration of Land-Use and Transportation Planning Through Legislation

The Planning & Development Act 2000 is far more extensive in its attention to transportation issues than previous land-use planning legislation. This is particularly evident in the provision made for the specific inclusion of public transport and sustainable, integrated transport and settlement planning by way of development plan objectives.

The new legislation will also strengthen the ability of local authorities to achieve their transportation objectives through the application of supplementary development contribution schemes. This will have the added advantage of passing some of the responsibility for provision of sustainable transport modes for new development to the developers. A certain degree of environmental protection should be ensured through the requirement that all plans present details of the likely significant effects of their objectives and proposals. A degree of integration of land-use and transportation planning should be achieved through the consultation procedures for the making of development plans and other plans, and through the development control process.

6.5 Other EU Policies with Spatial Impacts

Various other EU policies have spatial impacts. The most important of these are: European Spatial Development Perspective (ESDP), Community Competition Policy, Trans-European Networks (TENS), Structural Funds, Common Agricultural Policy (CAP), Environment Policy, Research, Technology and Development (RTD), and Loan Activities of the European Investment Bank.

6.6 National Development Plan

The NDP, published in November 1999, is the Government's spending strategy over the next 6 years. The philosophy that underpins the NDP is the promotion of more balanced regional development. The total budget over the period of the Plan is €51.3 billion. The National Spatial Strategy (NSS) translates Government policy on balanced regional development into a more detailed blueprint for spatial development with a 20-year

perspective. The co-ordination of development strategies with transport needs assessment and the identification of spatial development patterns to contribute to efficient energy usage will be important elements of the NSS (DoELG, 2001b). Of the total budget of €22,361 m for economic and social infrastructure, €8805 m, almost 40% (39.4%), is to be spent on transportation. An additional €2108 m is also available for transportation through the Regional Operational Programmes. Therefore, the entire budget for transportation infrastructure is €10,913 m, divided as follows: roads €8000 m (73.3%), public transport €2837 m (26.0%) ports & airports €76 m (0.07%).

6.7 Residential Density Guidelines 1999

The Residential Density Guidelines were produced by the DoELG (1999), in response to recommendations in the Bacon Report (Bacon, 1998), increasing traffic congestion and an urgent demand for new houses. The Guidelines identify a number of appropriate locations for increased densities, which include sites served or those proposed to be served, by public transport.

A Quality Public Transport Corridor is defined in the Guidelines as a route with dedicated, high frequency and reliable public transport services that are accessible, user friendly and integrate with other parts of the public transport network. The primary catchment for quality public transport corridors extends to:

- Rail – lands within 1 km distance of the station;
- LRT – lands within 1 km distance along the route;
- Bus – lands within 500 m along the route.

6.8 Retail Planning: Guidelines for Local Authorities (DoELG, 2000b)

The Guidelines recognise and emphasise the importance of accessibility of retail facilities for all sections of society, and which are of a scale to allow the continued prosperity of traditional town centres and existing retail centres. It is recognised that the preferred location for retail development should be within town centres. Where no development sites are available within a town centre, then the next preference should be a location on the edge of the town centre. Only where there are no sites, or potential sites, within a town centre or on its edge, should

out-of-centre development be contemplated. Throughout the Guidelines, the importance of access and transport in relation to the location of retail facilities is detailed. Emphasis is placed on reducing reliance on the private car, and facilitating access by public transport and other modes.

6.9 EEA 2000 – Indicators on Transport and Environment Integration

The Transport and Environment Reporting Mechanism (TERM) was set up to establish indicators by which to measure policy objectives in the EU. The TERM report addresses seven key integration questions, and uses 31 indicators to measure progress. The third of the key questions has most relevance for land use and spatial planning – “Are spatial and transport planning becoming better co-ordinated so as to match transport demand to the needs of access?” The key findings of the first TERM report relating to spatial planning and accessibility are of particular relevance to the consideration of land use and environmental impacts of transportation. Results from the updated TERM report in 2001 uphold the findings of the first publication.

6.10 Future Research Needs

Some suggested areas for further study in Ireland are:

- the linkages between location of various types of land use and consequent transportation demand;
- the success or otherwise of policies to increase densities and create balanced, polycentric development;
- optimum urban size in various scenarios and the transportation requirements of each;
- the provision of up-to-date, comprehensive data on land use and transport to facilitate detailed research.

6.11 Summary

Land use and transportation are inextricably linked, and should therefore be planned for together, both at a strategic and local level. As is evident from the foregoing analysis, such thinking is being reflected in current legislation and policy guidance in Ireland. The linkages between location of various types of land use and consequent transportation demand require further study, as does the success or otherwise of policies to increase densities and create balanced, polycentric development. Optimum urban size in various scenarios and the transportation requirements of each and the provision of up-to-date, comprehensive data on land use and transport to facilitate detailed research are also areas for attention.

7 Public Awareness

7.1 Introduction

This section describes the growing concern of the public about the impacts of transport on the environment and it attempts to identify the measures that have been taken both in Ireland and abroad to educate the public about the negative impacts of car use. Research has indicated that people are becoming more aware of the effect of their cars on air quality, on quality of life and on the natural environment (Cullinane, 1992; Blessington, 1994; Drury Research, 2000). However, there is a gap between people's attitudes and their behaviour. They continue to increase the amount by which they drive.

7.2 Attitudes to Transport and the Environment

The public is aware of the fact that increasing private car use causes problems. Jones (1993) points out that 80% of car drivers in the EU recognise that traffic-related problems are serious and 95% are worried about air pollution resulting from traffic. It is recognised that reduced congestion and lower levels of traffic growth will only come about by reducing private car use (Jones, 1993). Providing better quality public transport is seen as one way of encouraging people to use their cars less. At the moment, people see public transport as being slow, infrequent and unreliable, especially when compared with the car (Jensen, 1999). People see the car as convenient and will even use it on very short trips, of less than 5 miles, due to its convenience and what is perceived as a lack of realistic alternatives (Mackett and Ahern, 2000).

In the UK the Commission for Integrated Transport (CfIT, 2002) carry out an annual review of the public's attitudes to the environment and to transport, involving 2202 respondents. This report showed that people are aware of the environmental problems of car use. In the survey, 32% of respondents rated the reduction of pollution leading to global warming as one of their top six priorities for transport policy. However, 47% of the same respondents rated reducing the cost of car use as one of their top six priorities for transport policy, while 34%

rated reducing the cost of owning a car as one of their top six priorities for transport policy.

Research into the attitudes of the Irish public to transport issues and the environment and the role of attitudes in people's modal choices has been quite limited. A recent study of the public's attitudes to the environment was carried out by the DoELG, but this study did not focus only on transportation issues (Drury Research, 2000). The study concluded that the Irish public are aware of some of the negative consequences of car use such as those associated with air pollution and noise. However, they are not changing their behaviour in accordance with this awareness: motorists have not cut back on driving, they do not consider the environment when purchasing a car and they are unlikely to cycle or car pool. In addition, public transport use is much lower than in the rest of Europe.

7.3 Travel Awareness Campaigns

There have been some initiatives taken to try to change motorists' behaviour in Ireland. On the 21st of August 2001, the Society of Irish Motor Industry (SIMI) and the DoELG launched a scheme to encourage drivers to buy more environmentally friendly cars.

All car showrooms now have to provide information concerning the fuel emissions from new cars and all cars in the showrooms must display a CO₂ sticker on the windscreen. A guide has been issued which informs drivers of the environmental properties of different fuels and details of the environmental performance of all makes and models of cars (SIMI, 2001). The guide also gives details of how to reduce car driving and how to drive in an energy-efficient manner.

There is funding available for travel awareness campaigns in Ireland through the DoELG's Local Environmental Partnership Fund (LEPF), set up in 1997 and revised in 2001. This allows projects that have been approved by the local authority to receive between €6350 and €20,300 from LEPF. This funding is then matched by funding from the local authority. A total of €254,000 is

available from LEPF. The EU also funds environmental awareness programmes under the LIFE programme.

Some very innovative programmes have been developed in Australia. One is "Travel Blending[®]" (Rose and Ampt, 2001). This was originally developed in Australia by consultants Steer Davies Gleave (SDG). Travel Blending[®] means that people's travel patterns are explained to them and they are given advice and information about the alternatives that are available to them for each of their trips. They then make small changes in their travel patterns and car use.

Analysis of the success of these strategies is still at an early stage. However, travel blending is now very popular in Australia and programmes have been set up in Adelaide, Sydney, Brisbane and Perth. SDG report that the schemes have been successful in Australia, although independent researchers point out that in the UK the reduction in car trips that was achieved was minimal (Jopson, 1999).

Another travel awareness initiative that originated in Australia is "individualised marketing". As with Travel Blending[®] individualised marketing involves contacting people personally, meeting them in their homes and giving them a transport package that is individualised to their travel patterns. They are also given public transport vouchers and vouchers for bicycle shops. In Perth, the campaign claims to have reduced car driver trips by 14% and car kilometres travelled by 17%. This TravelSmart campaign was launched in February 2000 (John, 2001).

7.4 Future research needs

The following areas are recommended as requiring further research.

- This study by Drury research was the most comprehensive study ever of the attitudes of the Irish public to the environment. However, it did not focus on people's attitudes to transport and the environment. It is unfortunate that in Ireland so few studies have been carried out on attitudes to transport and the environment, and researchers are reliant on the Eurostat surveys, in the large part, to understand Irish people's attitudes to transportation issues. Therefore, it is recommended that a review of attitudes to transport and the environment in Ireland be undertaken and that this is repeated at regular intervals. This review could be conducted along lines similar to that of the CfIT in the UK.

Travel awareness schemes in Ireland need to be proactive. The use of individualised marketing should be explored as it appears that it may reduce car use more successfully than the more traditional mass travel awareness campaigns currently favoured in Ireland. Some pilot schemes using methods such as Travel Blending[®] or TravelSmart could be instigated on a small scale and the results and impacts observed.

7.5 Summary

This section has described how attitudes to transport and its impact on the environment have changed, although this change has not always been accompanied by any change in behaviour. Studies of attitudes to the environment that have been carried out in the UK and Ireland have been described.

In addition, some innovative travel awareness schemes, which aim to translate a change in attitudes to a reduction in car use, have been described. In particular, recent developments in "individualised marketing" in Australia and the results of these travel awareness initiatives have been explained.

8 Noise

8.1 Introduction

The aim of this section is to examine the issue of noise in the context of current thinking and the future research needs in terms of the quantification of noise and its amelioration. The section will look at noise from transportation activities, noise measurement, the quantification of the health impacts of noise and future research needs in this area. The section concludes with a summary of the findings of this section.

A lot of work has been undertaken to reduce noise from the vehicle and it is generally believed that further improvements will only result in marginal improvements (SOU, 1993). There appears to be more scope for noise reduction in the areas of tyre manufacture and alternative road surfacing. If speed limits were reduced, tyres could be made narrower and of softer rubber, leading to less noise (Alenius and Forsberg, 2001). Some road surfacings show considerable reductions in noise levels, e.g. the families of porous and thin surfacings.

8.2 Noise from Transportation Activities

Table 8.1 shows an estimate of the number of persons (in millions) in Ireland exposed to various noise levels. Although this table shows estimates for all noise sources, a significant proportion is attributable to transport activities.

Noise emissions from road transport depend on traffic flow, speed and the proportion of heavy vehicles, but also on the topography, distance from the noise source and the road surfacing, amongst others. At low speeds, it is the engine of the vehicle that dictates the noise level whereas when speeds exceed 40 km/h, the properties of the tyres and carriageway are of greater significance. A narrow tyre emits less noise than a wide one, and a carriageway

of normal surfacing emits less noise than one with coarse surfacing.

The EEA (1999) finds that in Germany, France and the Netherlands, 10.2% of the population are exposed to rail noise in excess of 55 dB(A). Noise-control measures have been applied to high-speed trains and most passenger trains, but not to freight trains which remain the biggest problem. The application of modern technology to track and vehicles can reduce noise by 20 dB(A) (EEA, 1999). It has been suggested by EEA (1999) that an indicator-based evaluation of the current state of noise in Europe is necessary. Some countries have already established noise nuisance levels, for example, the highest equivalent level allowed in Sweden is 55 dB(A). There is no common/or agreed noise indicator available for noise data in Europe.

Noise from aircraft is the subject of much research at the aircraft level. In terms of evaluating aircraft noise using hedonic pricing, Tinch (1995) and Schipper (1998) have tried to identify consensus values of a noise sensitivity depreciation index (NSDI). The figures they found are between 0.5% and 1% per dBA. This means that a 1 dBA rise in quantity of noise is likely to reduce house prices by 0.5–1%.

8.3 Noise Measurement

Statistics (EEA, 1999) from Denmark, France, Greece, the Netherlands, Spain and Sweden show that the proportion of exposed people is larger in cities where there are more inhabitants. Between 20% and 30% of inhabitants in Amsterdam, Madrid and Munich suffer noise levels in excess of 55 dB(A). Extrapolating this level to the EU15 suggests that 120 million people are exposed to noise levels greater than 55 dB(A).

Table 8.1. Estimate of population exposed to various noise levels (Tinch, 1997).

	Noise levels (dB(A))					
	50–55	55–60	60–65	65–70	70–75	75+
Road	0.80	0.59	0.38	0.22	0.07	0.02
Rail	0.15	0.11	0.07	0.03	0.01	0.01

Measurement of noise is one topic in which Ireland is falling behind compared with other European countries, although a study entitled Environmental Quality Objectives for Noise in Relatively Quiet Areas, funded by the EPA, is currently under way (EPA, 2002). In terms of the UNITE project (O'Mahony et al., 2002), no measurements of noise exposure could be obtained and so the estimates by Tinch (1997) had to be used. Monitoring of noise levels from different transport modes, and the proportion of the population exposed to various noise levels are two topics that require attention.

8.4 Quantification of the Health Impacts of Noise

O'Mahony et al. (2002) will quantify the costs of transport noise for Ireland in the UNITE project using the model of Bickel and Schmid (2002). Bickel's model was developed within a series of ExternE projects funded by the EU on "External Costs of Energy". The model quantifies the environmental impacts by following a detailed site-specific 'impact pathway' (or damage function) approach. The causal relationships, from the release of pollutants, through their interactions with the environment, to a physical measure of impact, are modelled and where possible valued monetarily. The model has been used in many studies to evaluate the impact of air emissions, but more recently has been enhanced to examine the costs of noise exposure.

8.5 Future Research Needs

Based on the work mentioned above and on wider reading, the following would appear to be the most important research topics for further work in this area.

- Monitor noise levels for various conditions for all transport modes.

- Estimate the noise exposure levels experienced by the public.
- Re-estimate the costs of noise to Ireland in monetary terms using the measurement data obtained from the above two steps.
- Development and calibration of noise models so that monitoring of noise levels at a spatial level can be undertaken and local 'hot spots' identified.
- Conduct further research into the potential noise reduction capability of road materials.
- Quantify the medical and non-health impacts of noise in Ireland and their associated monetary costs.

8.6 Summary

Noise has been recognised as a stress inducer for those who are exposed to high and/or continuous levels. The health impacts of noise impacts are well documented. Transport is a major source of noise, particularly on inter-urban corridors, in urban areas and close to airports. Quantification of noise levels and monitoring are likely to feature strongly in the future in terms of compliance with EU initiatives. Noise monitoring to date in Ireland includes a study on noise in quiet areas funded by the EPA, noise measurement for specific road projects and some limited noise mapping by one of the city authorities. Extensive further research is required to establish noise levels from transport sources at a centralised level. More research is needed on the design of noise barriers and the use of innovative methods and materials in them. There is some further potential for noise reduction in tyre manufacture, and research into specialist road surfacings offers significant scope for reducing road noise.

9 Natural Heritage

9.1 Introduction

The aim of this section is to examine the environmental impacts of transport on natural heritage – a very broad-ranging area of study. Protection of the natural environment through the land use planning system and associated legislation is considered here, and future research required in this area is also presented.

9.2 European and National Protection for Natural Habitats

9.2.1 *Habitats directive*

The EU Habitats Directive of 1992 (92/43/EEC; [EU, 1992](#)) requires Member States to establish a coherent network of Special Areas of Conservation (SACs) as part of the Natura 2000 Network. The network will also include Special Protection Areas (SPAs) established under the EU Birds Directive ([79/409/EEC](#)). The Habitats Directive was transposed into National law through the European Communities (Natural Habitats) Regulations, 1997 (SI 94/97). The stated aim of the Habitats Directive is to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the member states of the Community by way of Natura 2000. Article 10 of the Directive encourages Member States to incorporate nature conservation considerations into their land-use development and planning policies.

9.2.2 *Land-use controls in SACs*

Conservation of Natura 2000 sites is achieved by controlling the use to which the land is put. The Directive does not, however, prescribe that all use of land is necessarily incompatible with conservation of the sites. Despite a negative assessment of the impact of a development proposal, the relevant authority may give consent to the proposal for imperative reasons of overriding public interest, including those of a social or economic nature, provided compensatory measures are adopted and the Commission is advised of same.

9.2.3 *Planning & Development Act, 2000*

The notion of providing protection for amenities was introduced in the 1963 Planning and Development Act,

and is revised in the 2000 Act under Part XIII, SS. 202–209. S. 202 allows for the making of Special Amenity Area Orders (SAAOs). Where it appears to the planning authority or the Minister that an area, by reason of its outstanding natural beauty, or its special recreational value, and having regard to any benefits for nature conservation, should be declared an area of special amenity, they may make an order to do so. The 2000 Act introduced added protection for the environment by way of Landscape Conservation Areas (S. 204). Within such an area, exempted development status may be withdrawn from any development. Tree preservation orders (TPO) are provided for under S. 205, and may apply to a single tree, group of trees or woodlands in the interests of amenity or the environment. Remedies for planning offences against any of the above-mentioned orders are provided for in Part VIII of the Act, dealing with Enforcement. Enforcement action can be taken against any person who has carried out or is carrying out an unauthorised development (S. 151).

9.2.4 *Environmental impact assessment*

The primary piece of legislation in Ireland in relation to EIA is the European Communities (EIA) (Amendment) Regulations, 1999. Sections 14 and 15 of the Regulations provide for amendments to the Roads Act (1993) ([Government of Ireland, 1993](#)) in relation to road construction, and the Transport (Dublin Light Rail) Act (1996) in relation to construction of the LUAS. In relation to national roads, protection of the natural environment is based on the route selection procedures set out in the NRA Road Project Management Guidelines. Most national road schemes are subject to an EIA, which will further identify potential impacts on the natural environment and propose the appropriate mitigation measures. In one particular case, major environmental monitoring is under way at Pollardstown Fen. Also, S. 22 of the Act deals with the NRA's role in the physical planning process.

The European Communities (EIA) (Amendment) Regulations, 2000, are the most recent amendment to EIA legislation in Ireland to date. The purpose of the

Regulations is to transfer the function of certifying environmental impact assessments of local authority developments from the Minister to An Bord Pleanála. The transfer of the certification function coincides with the transfer of the Minister's function in relation to the approval of compulsory purchases of land by local authorities in accordance with sections 214 and 215 of the Planning and Development Act, 2000. Under section 172 (3) (a), An Bord Pleanála can grant an exemption, under exceptional circumstances, from the requirement to submit an EIA with a planning application where it is required in accordance with the Regulations.

9.3 Future Research Needs

The evidence from research undertaken is that there is a lack of information on the impacts of transportation on sensitive and natural environments, although the extensive ongoing study of Pollardstown Fen should go some way to providing information in this area.

It is recommended that the exact scope and definition of the term 'natural environment' ought to be determined, and specialised studies undertaken in each area. Part of this investigation could look at opportunities to provide greater protection for the natural environment through legislation.

9.4 Summary

The study of the environmental impacts of transportation on natural heritage is potentially a very broad area of research. At a European level, Infra Eco Network Europe is an independent grouping of international specialists which has representatives from at least 20 European countries including Ireland. They are involved in research under the COST Programme, the goal of which is to produce a European state-of-the-art report on habitat fragmentation due to infrastructure, and a handbook on defragmentation measures. At a national level, the NRA has initiated the preparation of a set of Guidelines for the Treatment of Ecology and Fisheries in National Road Schemes.

10 Public Transport

10.1 Introduction

Ireland has one of the highest levels of annual car use and the lowest levels of public transport use in the EU (Banister *et al.*, 2000). Public transport is more energy efficient per passenger kilometre than cars. This section describes the developments in public transport in urban and rural areas with relevance to the environment, and identifies research topics that could be developed to encourage higher levels of public transport use.

10.2 Urban Transport

The Dublin Transportation Office (DTO) has recently released a document entitled “A Platform for Change” outlining their strategy for transport in Dublin (2001). This makes extensive proposals to radically change and improve the city’s public transport network. This network will cater for 300,000 trips a day in the morning peak by 2015 (DTO, 2001). By 2016, it is intended that most trips in the Greater Dublin Area will be achieved with only one inter-/intra-modal transfer and that the majority of people living in the Dublin metropolitan area will live within only 10 min of public transport.

The development of sustainable modes in Irish cities is very important for maintaining and improving quality of life and the urban environment. Light rail systems, such as LUAS, can be effective at reducing car use in densely populated urban areas.

All cities in Ireland need to develop their public transport networks. The Department of Public Enterprise has stated that outside of Dublin people have very few options other than the private car for most trips (DPE, 1999). Congestion and environmental pollution due to transport are on the increase in regional centres. Cork City Council and Cork County Council have already produced a strategic plan, with an emphasis placed on improving public transport access to the city centre. The provision of dedicated vehicle lanes, such as the Quality Bus Corridors, automatic vehicle location and integrated ticketing with other modes of public transport will augment the role played by buses in reducing car use and thereby reducing emissions. Better integration of bus

services with other public transport also increases use of buses (Scott Wilson, 2000).

10.3 Rural Transport

In rural areas, access to basic services in Ireland is often largely dependent on access to a car. Patronage of rural urban transport is declining and, both here and in other countries in Europe, non-car owners in rural areas have a much-reduced access to facilities (EEA, 2000). Public transport services that will bring people to services and jobs need to be supplied.

In addition, there is a need for greater integration between land use and transport planning (EEA, 2000). Reducing the need to travel through better spatial strategies reduces the need for new public transport infrastructure. At present, it is felt that increased transport demand should be catered for by increasing public transport infrastructure. While it is a fact that public transport infrastructure in Ireland has been largely neglected, it is increasingly important that transport policy and decisions are integrated with spatial strategies (EEA, 2000).

The NDP recommends the upgrading of the bus network outside of regional centres and the improvement of rail infrastructure in the country. Irish people travel less by train than anyone else in Europe, mostly due to an under-developed rail network. The NDP proposes that €635 m should be invested in the railways in Ireland.

10.4 Future Research Needs

The following areas of research are recommended:

- The use of alternative fuels for public transport fleets (such as LPG and CNG) is recommended by the Department of Public Enterprise (DPE, 1999) and research is needed to explore how this can be done. In particular, distribution of these fuels must be examined.
- Considerable investment is planned for public transport in Ireland and it is intended that it will play a role in improving the environment, by reducing car use: careful monitoring of the impacts of the new

services on the environment is required. Not all of these impacts will be positive. The use of SEAs for all projects is recommended.

- The interaction between land use and public transport should be more carefully assessed as sensible transport–spatial strategies can reduce car use.

10.5 Summary

This section has outlined briefly the strategies taking place in Ireland to develop public transport, and has made some recommendations about where future research should take place to ensure that public transport is being developed in such a way as to reduce the impacts of transport on the environment.

11 Information Technology

11.1 Introduction

Information technology (IT) is useful in terms of its impact on the environmental aspects of transportation. Typically, IT helps in an indirect way, e.g. traffic signal control manages traffic in such a way that queuing is minimised and this has the added benefit of reduced air pollution. The NRA is involved in two research projects with an emphasis on IT, the results of which will be very informative. This section identifies where IT is currently used and looks at its potential for the future. Future research needs in the area are identified at the end of this section.

11.2 The Use of IT in Transport

There are various methods of using IT in traffic control. The SCATS system, a responsive system, manages traffic movement in Dublin and Waterford, whereas a similar UK-based system, SCOOT, is used in Cork. These adaptive traffic-control (ATC) systems optimise signal timings to reduce average delay and thereby pollution. Typical reductions in delay of 10–20% have been noted when ATC is used. Improvements to the dynamics of current systems by means of mobile phones (or units) may well result in more interesting next-generation traffic-control methods with added benefits.

A recent research project commissioned by Dublin City Council used traffic data from the SCATS system to compile congestion maps for use via the Internet and mobile phone. The aim is to provide information on current traffic conditions to potential users of the network. Another example of improvements resulting from IT is the provision of information to public transport users on a real-time basis. A trial by Dublin Bus, which is currently being extended, demonstrated the provision of real-time information to variable signs at bus stops.

Although the environmental benefits as a result of such a measure may not be obvious, improving the attractiveness of public transport can increase ridership of a more environmentally friendly transport mode.

The Easypass demonstration project on the Westlink demonstrates the potential for electronic toll collection, which has the potential to reduce queuing. The INSTANT project, in which the NRA is currently involved, investigates the provision of multi-modal traffic and travel information for the Dublin–Belfast corridor. The NRA is also involved in the EU-funded STREETWISE project, which aims to deliver seamless, reliable and accessible travel information services of a consistent quality and common standard to road users on the Trans-European Transport Network in the UK and Republic of Ireland.

11.3 Future Research Needs

Future research in this area should focus on the implementation of the most advanced existing technologies and the evaluation of their impacts on the environment and the monitoring of the state of the environment.

11.4 Summary

This section examined traffic signal control, provision of information to private and public transport users, electronic toll collection and improved networking of information between the UK and Ireland. Monitoring facilities and the capacity for data can also be improved using the most advanced IT, e.g. noise pollution can be monitored for much longer periods and in some cases, the data can be transmitted from remote sites without the need to visit them.

12 Inventory of Current and Recent Research in Ireland

An inventory of current research on each of the topics addressed in the report is provided in Table 12.1. The

table lists the various research topics and where the research is taking place.

Table 12.1. Inventory of the current research on topics within the present report.

Topic	Project Title	Researchers
Air pollution	Air Quality in Street Canyons	University College Cork – Environment Research Unit
	Studies of the Chemical Composition of Size-Fractionated Atmospheric Aerosols	University College Cork – Environment Research Unit National University of Ireland, Galway – Atmospheric Research Group
	Designation of Monitoring Networks	Cambridge Environmental Research Consultants Ltd
	Validation of Air Pollution Dispersion Modelling for the Road Transport Sector under Irish Conditions	Trinity College Dublin – Civil, Structural and Environmental Engineering National University of Ireland, Galway – Atmospheric Research Group
	The Nature and Origin of PM ₁₀ and Smaller Particulate Matter in Urban Air	National University of Ireland, Galway – Atmospheric Research Group University College Cork – Environment Research Unit University of Birmingham Dublin Corporation
	Evaluation of options for reducing Irish diesel particulate pollution	University College Dublin – Mechanical Engineering Urban Institute
Waste	Pilot scheme where 1 million crushed and recycled glass bottles have been used in the subsurface layers of a road	National Roads Authority Monaghan County Council Repak
	Impact Assessment of Highway Drainage on Water Quality	Trinity College Dublin – Civil, Structural and Environmental Engineering University College Dublin – Civil Engineering
Eco-audits and Strategic Impact Assessments	Evaluation of eco-auditing of the NDP/CSF 2000–2006	Economic and Social Research Institute
	Demonstrating the feasibility of recovering and reusing complex waste solvent streams	Novartis Ringaskiddy Ltd (EU funded – LIFE) 1998/1999
Economic instruments	Carbon taxes: macroeconomic effects	Economic and Social Research Institute
	Compilation of air emission accounts for Ireland 1997–2000	Economic and Social Research Institute
	Distributive effects of carbon taxes	Economic and Social Research Institute
	UNITE – Unification of accounts and marginal costs for Transport Efficiency	Trinity College Dublin – Civil, Structural and Environmental Engineering

Table 12.1. *contd*

Topic	Project Title	Researchers
	Road use pricing and its alternatives in transport demand management	Urban Institute Trinity College Dublin – Civil, Structural and Environmental Engineering
	Modelling of road-use pricing impacts using parallel computing models	Trinity College Dublin – Civil, Structural and Environmental Engineering
	An assessment of parking pricing strategy as a tool for the management of road space through the influence of modal choice	Urban Institute Environmental Studies – University College Dublin
Land use	Priority Environmental Research to meet the needs of the National Spatial Strategy	Environmental Protection Agency
Public awareness	None	
Noise	Noise contour modelling/noise implications of road surfacings (about to commence)	Trinity College Dublin – Mechanical Engineering and Civil, Structural and Environmental Engineering
	Environmental Quality Objectives for Noise in Relatively Quiet Areas	Environmental Protection Agency
Natural heritage	Impact of cars on Bull Island	Trinity College Dublin – Civil, Structural and Environmental Engineering
Public transport	PROMAIN: maintenance of rail infrastructure	Irish partner: Interactions Ltd European Commission
Information technology	INSTANT – investigate provision of multi-modal traffic and travel information for the Dublin/Belfast corridor	National Roads Authority
	STREETWISE – Seamless and effective travel information on the TEN-T	National Roads Authority
	Real-time passenger Information Study	WS Atkins Dublin Transportation Office
	Integrated ticketing	RPA
	TimeToGo is an effort to monitor transportation data and then act as a travel sensitive alarm clock	Media Lab Europe
	Infopolis: Telematics in public transport	University of Limerick

13 Summary of Future Research Needs

13.1 Introduction

The preceding chapters have identified information gaps and research required to further the integration of environmental considerations into transport planning and operations. Each of these may be associated with one or more of the following themes:

- the identification of different types of environmental impacts;
- the development of methods of assessing these impacts and the identification of the information required to characterise them;
- the execution of impact assessments and the collection of relevant information;
- the mitigation of impacts through improved transport management and policy.

The following sections examine each of these themes in the context of the findings of the preceding chapters. Two issues are observed to arise repeatedly: the absence of sufficient data on transport operations and environmental concerns, and the need to address recent EU directives on air quality, noise and ELVs. In a number of cases, it is clear that the links between the various topic areas addressed must be considered, and these are identified later.

13.2 Identification of Impacts

It is clear that for both air quality and noise, the types of impacts imposed by transport are well established. What remains in these areas is to identify the magnitudes of the impacts due to transport and to compare these with those due to other sectors. The waste impacts of transport are not as well established. With respect to ELVs, the non-heavy fraction of Auto Shredder Residue (ASR) (which is sent to landfill) requires greater characterisation, and a study of the vehicle waste industry in Ireland has been recommended to address this issue, amongst others. The toxicity and ecological impact of road runoff have received much attention, but the fate of these pollutants during stormwater events is not so well understood.

There is a lack of information on the impacts of transportation on sensitive and natural environments, and further specialised study has been recommended in this area, possibly following a case-study format. On a fundamental level, further research on relationships between land use and transport demand is required before the associated environmental implications can be assessed. Most research on public transport has concentrated on congestion and travel impacts, with relatively little focusing on environmental impacts.

13.3 Methods of Assessment and Information Requirements

In many topic areas, international research has led to the development of methods for assessing the environmental impacts of different transport modes. In many cases however, there is no agreement on the type of information desired from these assessments, or there is insufficient local information to perform such assessments in Ireland.

Numerical modelling is an efficient method of air quality assessment, but depends on the availability of reliable input data. To this end, studies on driving cycles and meteorological conditions in Irish urban areas have been recommended. The increased use of traffic noise models is also recommended. A methodology is required for the qualitative and quantitative assessment of pollutants released onto roadways from motor vehicles, with a view to improving treatment practices. To aid the application of EMS to transport, a series of generic indicators should be developed which would allow comparison with other sectors.

13.4 Impact Assessments and Information Acquisition

In the field of air quality, continued monitoring should be supplemented by improved modelling studies. These would benefit most from research into vehicle emission factors (ideally examining real-world emissions using instrumented vehicles) and urban meteorology. Of the priority pollutants identified, there is most urgent need for research into the sources and formation of nitrogen

dioxide, especially an assessment of the potential reductions in peak concentrations achievable through improved transport planning. The use of alternative fuels in public transport vehicles should receive continued attention with a view to reducing particulate emissions in urban areas. Nationally, very little noise measurement data are available, and data on the impact of all transport modes are required, including information on public exposure levels. Adequate noise and air quality data (along with disaggregated information on transport activity, congestion and public transport delay) are essential input parameters of the monetary assessment models employed to guide the use of economic instruments. Any plans for the use of such economic instruments would benefit from the recommended study on public attitudes to transport and the environment. Related studies already completed in Ireland and the UK could form a starting point for this work. Future studies will need to consider that the application of economic instruments will be quite different in the urban and inter-urban contexts. For waste management, an audit of garages leading to the establishment of a waste register, is recommended.

13.5 Mitigation of Impacts

As with many other sectors, there remains much potential for reducing the waste impacts of transport through

improved recycling and reuse of vehicles, tyres, batteries and fluids. There is also potential for the reduction of traffic noise through the use of different types of tyres and road materials, as well as attenuation barriers. In urban areas especially, there is considerable activity under way to improve and promote public transport, and it is suggested that future developments in this area would benefit from the use of strategic environmental assessments. While the public are aware of the environmental impacts of transport, this does not appear to affect their behaviour, and individualised travel awareness schemes offer a means of addressing this contradiction. Quantitative evaluations of environmental management systems in the transport sector should be carried out.

Finally, a number of links between the separate topic areas addressed have been identified. These include the basing of economic instruments on accurate air quality/noise-impact assessments, the dependence of the success of economic instruments on public awareness of environmental issues, the imposition of new taxes to promote vehicle waste recycling, the impact of public transport on air quality and noise, and the relationships between land use, public transport and environmental benefits.

14 Conclusions and Recommendations

14.1 Conclusions

- (a) A review of international and national literature on the environmental impacts of the transport sector and on the integration of environmental considerations into transport planning and operations was conducted.
- (b) Relevant organisations were consulted to identify the gaps in knowledge at the interface of transport and the environment, to determine ongoing research projects of relevance to the study and finally to identify future research needs.
- (c) The study was divided into ten topic areas considered to be the most important. The ten topics were air pollution, waste from the transport sector, eco-audits and strategic environmental assessment, economic instruments, land use, public awareness, noise, natural heritage, public transport and information technology. One of the common findings in terms of pollution or damage imposed was the absence of data, even at quite fundamental levels. Apart from air-pollution studies, funded mainly by the EPA, data on noise levels and disposal of waste from transport are not collected.
- (d) The dearth of models for forecasting waste and pollution levels is also noticeable from a review of what is in use in Ireland but the lack of data may well be influencing this finding. High-quality calibration data are necessary if models are to produce realistic and useful outputs.
- (e) A particular concern in terms of points (c) and (d) above is the apparent lack of adequate preparation under way to meet EU Directive requirements (End of Life Vehicle Directive) such as comprehensive monitoring of transport waste levels.
- (f) A similar concern exists for noise monitoring. Although some noise monitoring has been done in particular instances, this will only go some way to meeting Directive requirements. Significant enhancement of capability in the noise-monitoring area is needed, particularly in relation to noise mapping, and considerably more monitoring is required.
- (g) Some work has been done on economic instruments but the lack of good data is also impacting on the potential output from this research in terms of quantifying the costs of the environmental impacts and the likely impact if these costs were internalised in some form of charging or taxation.
- (h) A project on eco-auditing is currently under way and the results are likely to provide useful and pertinent results. Strategic environmental assessment is slowly permeating into the transport sector but further work is necessary in this area.

14.2 Recommendations

Recommendations have been made on the research required to further the integration of environmental considerations into transport planning and operations. These may be considered on four levels: the identification of different types of environmental impacts, the development of methods of assessing these impacts, the execution of impact assessments, and the mitigation of impacts through improved transport management and policy. There is greater need for work on the latter two levels, especially in the collation of the information and data required to characterise the range of environmental impacts imposed by transport.

References

- Alenius, K and Forsberg, B. (2001) *Consideration of health aspects in environmental impact assessments for roads*. National Institute of Public Health, Sweden.
- ANSEA (2001) *Analytical Strategic Environmental Assessment*. Project financed under the 5th Framework Research Programme of the European Union. Website: www.taugroup.com/ansea
- ARN (2000) *Environmental Report 1999*. The Auto and Recycling Foundation and Auto Recycling Nederland BV Report **98**, 17.
- Bacon, P. (1998) *An economic assessment of recent house price developments*. Report to the Minister for Housing and Urban Renewal, Dublin.
- Banister, D., Stead, D., Steen, P., Akerman, J., Dreborg, K., Nijkamp, P. and Schleicher-Tappeser, R. (2000) *European Transport Policy and Sustainable Mobility*. Spon Press, London and New York.
- Bickel, P. and Schmid, S. (2002) *Approach for estimating costs due to air pollution, global warming and noise*. Draft report in UNITE project. In preparation.
- Bina, B. (1999) SEA to date, recent advances and current priorities for development. *OECD/ECMT Conference: Strategic Environmental Assessment, Warsaw 14–15 October, 1999*.
- Blessington, H.K. (1994) Approaches to changing modal split: a strategy and policy context. *Traffic Engineering and Control* 63–67.
- CEC (Commission of the European Union) (1995) *The Citizens' Network: Fulfilling the Potential of Public Passenger Transport in Europe*. Green paper, Office for Official Publications of the European Communities, Luxembourg.
- Charles Trent (2000) *The Disposal of End of Life Vehicles in the UK*. Charles Trent Ltd., UK.
- Cloke, J., Boulter, P., Davies, G.P., Hikman, A.J., Layfield, R.E., McCrae, I.S. and Nelson, P.M. (1998) *Traffic management and air quality research programme*. TRL Report 327.
- CfIT (Commission for Integrated Transport) (2002) *Annual Reviews*. Commission for Integrated Transport, London.
- COMMUTE (Common Methodology for Multi-modal Transport Environmental Impact Assessment) (1998) *Final report*. Commission of the European Communities – 4th Framework funded project.
- CSO (2001) *Vehicles licensed for the first time, 2000*. Bulletin 29, Central Statistics Office, Ireland.
- Cullinane, S. (1992) Attitudes towards the car in the UK: some implications for policies on congestion and the environment. *Transportation Research A* 26, 291–301.
- Diekmann, A. (1990) Nutzen und kosten des Automobils. *Internationales Verkehrswesen* **42**, 332–340.
- DoELG (1999) *Residential Density Guidelines*. Stationary Office, Dublin.
- DoELG (2000a) *National Climate Change Strategy*. Department of the Environment and Local Government, Dublin, Ireland.
- DoELG (2000b) *Retail Planning: Guidelines for Local Authorities*. Stationary Office, Dublin.
- DoELG (2001a) *Irish Bulletin of Vehicle and Driver Statistics 2000*. Department of the Environment and Local Government, Ireland.
- DoELG (2001b) *The National Spatial Strategy: Indications for the way ahead. Public consultation paper*. Department of the Environment and Local Government, Ireland.
- DPE (1999) *Green Paper on Sustainable Energy*. Department of Public Enterprise, Ireland.
- Drury Research (2000) *Attitudes and Action: A National Survey on the Environment*. Department of the Environment and Local Government, Ireland.
- Dublin Transportation Office (2001) *A Platform for Change*. DTO, Dublin.
- ECMT (2000) *Sustainable development – strategic environmental assessment for transport*. European Conference of Ministers of Transport, Council of Ministers, Report CEMT/CM(2000)8/Final. Prague 30–31 May, 2000.
- ECRIS (1999) *ECRIS – A Research Project in Environmental Car Recycling 1994–1998*.
- EEA (European Environment Agency) (1999) *Towards a transport and environment reporting mechanism (TERM) for the EU*. Technical Report 18, European Environment Agency.
- EEA (2000) *Are We Moving in the Right Direction? Indicators on Transport and Environment Integration in the EU: TERM 2000*. European Environment Agency.
- EEA (2001) *Indicators on Transport and Environment integration in the EU: TERM 2001*. Office for Official Publications of the European Communities, Luxembourg.

- EMAS (2001) *Regulation (EC) No. 761/2001 of the European Parliament and of the Council of 19th March 2001 Allowing Voluntary Participation by Organisations in a Community Eco-management and Audit Scheme (EMAS)*. EMAS website: europa.eu.int/comm/environment/emas/
- ENDS (2000) *Report 304*. Environmental Data Services Ltd., London.
- EPA (1998) *National Waste Database Report 1998*. Environmental Protection Agency, Ireland.
- EPA (2000) *Ireland's Environment - A Millennium Report*. Environmental Protection Agency, Ireland.
- EPA (2002) *Environmental Quality Objectives for Noise in Relatively Quiet Areas*. Environmental Protection Agency, Ireland.
- ERM (2000) *Strategic environmental assessment in the transport sector: an overview of legislation and practice in EU Member States*. Report prepared for the European Commission, DG Environment by Environmental Resources Management.
- ERM (2001) *Strategic environmental assessment of transport corridors: lessons learned comparing the methods of five Member States*. Report prepared for the European Commission, DG Environment by Environmental Resources Management.
- EU (1979) *Directive 79/409/EEC of the European Parliament and Council on Birds*. European Union.
- EU (1992) *Directive 92/43/EEC of the European Parliament and Council on Habitats*. European Union.
- EU (1996) *Directive 96/62/EC on Ambient Air Quality Assessment and Management; OJ L 296*. European Union.
- EU (1999) *Directive 99/31/EC on landfill of waste*. European Union.
- EU (2000a) *Directive 2000/53/EC of the European Parliament of 18 September 2000 on end of life vehicles*. European Union.
- EU (2000b) *Manual on Strategic Environmental Assessment of Transport Infrastructure Plans*. European Commission DG Energy and Transport. http://europa.eu.int/comm/transport/themes/network/english/bground_doc/index_en
- EU (2001) *Directive 2001/42/EC of the European Parliament and Council on environmental assessment of certain plans and programmes*. European Union.
- Government of Ireland (1993) *Roads Act (1993)*. Stationary Office, Dublin.
- Government of Ireland (1999) *National Development Plan 2000–2006*. Stationary Office, Dublin.
- Government of Ireland (2000) *Planning & Development Act (2000)*. Stationary Office, Dublin.
- INTERNAT (2001) *Integrated trans-European network assessment techniques – final report*. Commission of the European Communities – 4th Framework funded project UR-98-RS.3039.
- INTERURBA II (2001) *Interactions between sewers, treatment plants and receiving waters in urban areas – INTERURBA II. Proceedings of the 2nd International Conference in Lisbon, Portugal, 19–22 February, 2001*.
- Jensen, M. (1999) *Passion and heart in transport – a sociological analysis on transport behaviour*. *Transport Policy* **6**, 19–33.
- John, G. (2001) *The effectiveness of the TravelSmart individualised marketing programme for increasing walking trips in South Perth*. In: *Proceedings of Australia: Walking the 21st Century, 20th–22nd February, 2001, Perth*.
- Jones, P. (1993) *Changing attitudes to traffic growth*. *Local Transport Today*, February, 1993.
- Jopson, A. (1999) *Reducing car use: the role of the Theory of Planned Behaviour*. In: *Proceedings of UTSG, 6-8 January 1999, University of York*.
- LIFE (1998) *EMAS demonstration project: promoting EMAS as an integral part of total quality management*. EU funded LIFE project 1998–2001 by GOM-West Vlaanderen, Belgium. LIFE 98 ENV/B/262.
- McCrae, I.S., Green, J.M., Hickman, A.J., Hitchcock, G., Parker, T. and Ayland, N. (2000) *Traffic management during high pollution episodes*. TRL Report 459.
- McGettigan, M. and Duffy, P. (2000) *Emissions to Air 1990–1998*. Environmental Protection Agency, Ireland.
- Mackett, R.L. and Ahern, A., (2000) *The potential for mode transfer of short trips*. Report for the Department of the Environment, Transport and the Regions. Available at: <http://www.ucl.ac.uk/transport-studies/shtrp.htm> (accessed on 22nd of August, 2001).
- Marsalek, J., Rochfort, Q., Brownlee, B., Mayer, T. and Servos, M. (1999) *An exploratory study of urban runoff toxicity*. *Water Science and Technology* **39**, 33–39.
- Martin, J.-C. and Roux, J.-C. (1999) *Pollutions Accidentelles Routières et Autoroutières – Manuals et Méthodes* 36. Éditions BRGM, France.
- O'Mahony, M., Link, H., Steward, L. and Bickel, P. (2002) *Deliverable 5 - The pilot accounts of UNITE – The pilot accounts of Ireland, Appendix Report*. In preparation.
- Proost, S., Van Dender, K., Courcelle, C., De Borger, B., Peirson, J., Sharp, D., Vickerman, R., Gibbons, E., O'Mahony, M., Heaney, Q., Van den Bergh, J., Verhoef, E. (1998) *TRENEN STRAN II Final Report*. 4th Framework Programme, European Union, Brussels.

- Quinet, E. (1994) The social costs of transport: evaluation and links with internalisation policies. *In: Internalising the Social Costs of Transport*, OECD.
- Rose, G. and Ampt, L. (2001) Travel blending: an Australian travel awareness initiative. *Transportation Research D* **6**, 95–110.
- Rothengatter, W. (1994) Obstacles to the use of economic instruments in transport policy. *In: Internalising the social costs of transport*, OECD.
- Schipper, Y., Nijkamp, P. and Rietveld, P. (1998) Why do aircraft noise value estimates differ? A meta-analysis. *Journal of Air Transport Management* **4**, 117–124.
- Scott Wilson (2000) *Bus network strategy appraisal report for the Greater Dublin Area*. Dublin Bus, Ireland.
- SIMI (Society of the Irish Motor Industry) (2001) *Guide to Passenger Vehicle's Fuel Economy*. Available at: www.simi.ie (accessed on 21st August, 2001).
- SOU (1993) *65 Handlingsplan mot buller. (Plan of action against noise)*. Miljö- och naturresursdepartementet, Goteborg (in Swedish).
- Tinch, R. (1995) *Valuation of environmental externalities*. Report to DOT, UK.
- Tinch, R. (1997) The valuation of environmental externalities. *Conference Paper; Determining the Monetary Values of Environmental Impacts*, University of Westminster, October 1997.