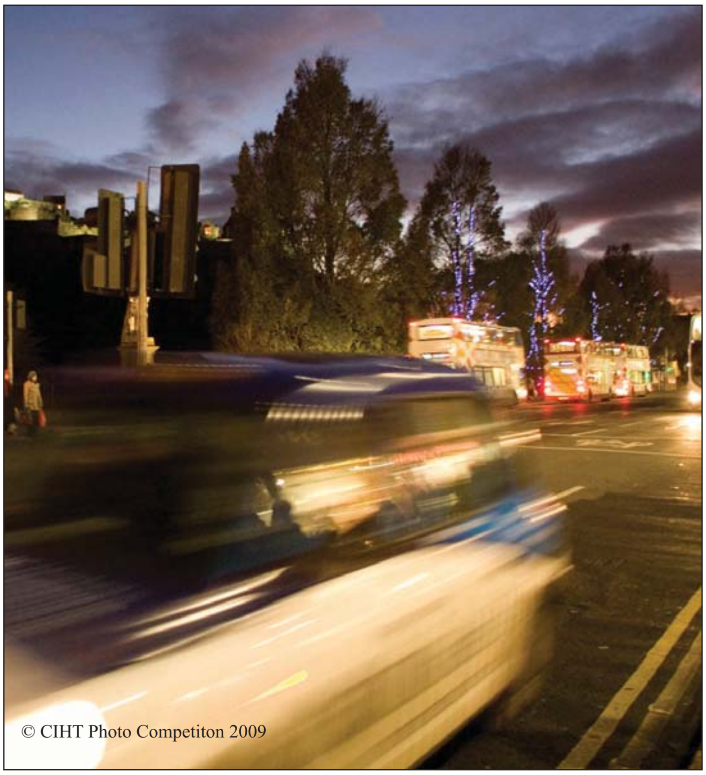
JANUARY 2012

NETWORK MANAGEMENT NOTES

THE CHARTERED INSTITUTION OF HIGHWAYS & TRANSPORTATION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NETWORK MANAGEMENT FOR ENVIRONMENTAL BENEFIT

Introduction

Historically, highway network management has focused mainly on the objectives of delay minimisation, capacity maximisation, safety, and more recently journey time reliability. Network management for environmental benefit has to date tended to be limited to interventions such as queue management and relocation, route information via variable message signing and other communications methods, and public transport priority. The efficacy of such systems is constrained by the quality, timeliness, and spatial resolution of network data.

In recent years, there has been an increasing awareness of the importance of environmental issues in transportation network management and operations, particularly in the context of public health and climate change policy. Previous CIHT Network Management Notes have addressed topics such as Air Quality and Urban Traffic Management and Control Systems. However, there is always the risk that such issues will be seen in isolation, with traffic engineers dealing with traffic issues, and environmental scientists addressing issues such as local air quality and noise. Emerging technologies, combined with innovative communications and data processing applications, present an opportunity to develop far more sophisticated network management tools for policy makers and network managers. The next generation of network management systems will have the potential and flexibility to internalise all of these multi-disciplinary factors, and so the objective of this note is to facilitate the development of a bridge between these disciplines, and at the same time take the opportunity to provide an update on relevant legislation, guidance, and techniques, which is of course constantly evolving.

The focus of the note is on road network management and operation, and not on planning and construction, although often the location of the demarcation line is not easily determined. The environmental issues explicitly considered in the note include local air quality, greenhouse gases (especially CO_2), and noise, but exclude road safety and urban form / streetscape, these latter issues probably meriting publications of their own.

The Cost of Environmental Damage – Why is it important?

Traffic Congestion

UK legislation such as the Traffic Management Act 2004 and related secondary legislation have placed significant emphasis, through the Network Management Duty, on securing and facilitating the expeditious movement of traffic, and reducing traffic congestion. Estimates of the cost of traffic congestion to the UK economy have ranged widely from £7bn to £20bn per annum depending on methodology and price base (Goodwin 2004). More recently, the Eddington Report estimated the cost to the economy of lost travel time due to congestion to increase by £23-£24bn in future years to 2025 unless mitigating action is taken (Eddington 2006).

Poor air quality = Reduced life expectancy

At the same time, the Department for Environment, Food and Rural Affairs has estimated that poor air quality (in particular manmade particulate matter) reduces average life expectancy in the UK by six months, with equivalent health costs estimated to be £15bn per annum, within the range £8-£17bn (DEFRA 2010).

Climate change and CO_2

It is estimated that the level of CO_2e (CO_2 equivalent) emissions attributable to the domestic UK road transport sector was 113.6 million tonnes in 2009 (DfT 2011a). Applying a central estimate non-traded price of carbon (DECC 2011) of £54 per tonne (low estimate £27, high estimate £81) in 2009 gives a total CO_2e cost from road transport in the UK of approximately £6.1bn per annum.

Road noise = health costs, loss of amenity, and loss of productivity

The Inter-departmental Group on Costs and Benefits (Noise) have produced estimates combining WebTag values (per decibel values for the loss of amenity due to road noise) with data on population exposure to road noise in major agglomerations. This work found a total annoyance disutility of current road noise in England of £3-£5 billion per annum. In addition, the cumulative UK impact of noise pollution on health[1] has been estimated at around £2-3bn per annum, and the productivity cost of noise pollution at around £2bn per annum (DEFRA 2008).

So it can be seen that, in terms of public policy, the costs of traffic congestion, poor air quality, noise pollution, and climate change to the UK economy are, whilst different in scale, estimated to be of similar orders of magnitude.

The UK Government has previously stated that “Whilst... the wider costs associated with transport are of similar order, this does not necessarily mean that (Government) spending should be split evenly between the various objectives. Efficient spending decisions will depend on the effectiveness and cost of individual measures and should be considered on a case by case basis through robust cost-benefit analysis. However in terms of option generation, there may be a strong business case for interventions which address these impacts simultaneously” (Cabinet Office 2009).

There is obviously uncertainty regarding the absolute levels of environmental costs imposed on society by these factors, and some problems are easier (and more cost effective) to solve than others. There is also a political dimension to budget allocations in terms of evolving public attitudes. Nevertheless, as the Government has previously stated, there are benefits to be gained in adopting an holistic, multi-criteria approach to network management, informed by local context and local challenges, within a national framework. This is particularly true where there are correlations or relationships between environmental factors.

[1] For example, research indicates a higher risk of high blood pressure and heart disease with exposure to prolonged high noise levels.

The Transport Policy Context

Clearly, transport policy is subject to change with each successive government of varying political complexions. The Department for Transport white paper "Creating Growth, Cutting Carbon: Making Sustainable Local Transport Happen" (DfT 2011b) currently provides the primary policy framework for local transport in the United Kingdom.

Creating Growth, Cutting Carbon

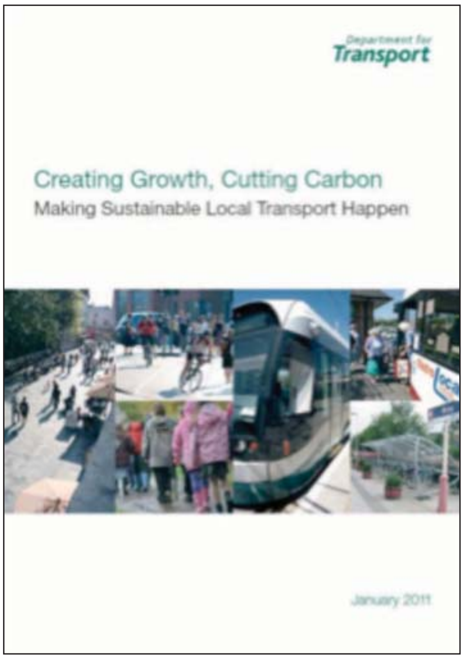
"Our vision is for a transport system that is an engine for economic growth, but one that is also greener and safer and improves quality of life in our communities".

"We will need to build on current progress in reducing transport emissions to meet the United Kingdom's commitments, and current projections suggest that road transport will need to be largely decarbonised by 2050".

"As cars are likely to remain the dominant transport mode, the Government wants to improve their environmental performance and is committed to supporting the market in electric, and other ultra-low emission vehicles."

"The Government is convinced that progressive electrification of the passenger car fleet will play an important role in decarbonising transport, supported by policies to increase generation capacity and decarbonise the grid."

"The Government believes that it is at the local level that most can be done to enable people to make more sustainable transport choices and to offer a wider range of genuinely sustainable transport modes – environmentally sustainable as well as fiscally, economically and socially sustainable."



The Creating Growth, Cutting Carbon white paper

Clearly, the "Creating Growth, Cutting Carbon" white paper has direct relevance to the issues highlighted in this note, in particular reducing carbon dioxide emissions and other greenhouse gases, but also health and life expectancy, and nurturing a sustainable environment.

Consistent with the view from the Cabinet Office, the Department for Transport expects that there will be strong synergies between different goals. For example, they suggest that measures to encourage modal shift to sustainable modes will help to tackle congestion, reduce greenhouse gases, and improve air quality and public health.

However, the biggest challenge identified in the white paper is tackling climate change and economic growth together. With the UK's historical reliance on fossil fuels, the achievement of the Government's targets for reductions in greenhouse gas emissions whilst also achieving the desired levels of economic growth will require significant changes in both travel behaviour, transport technology, energy generation, and over the longer term, land use planning.

Around 20 % of total domestic greenhouse gases emitted in the UK in 2009 came from road transport (Source: DfT 2011a)

Climate Change and CO_2

The Stern Review (HM Treasury 2006) emphasised the need to reduce global emissions of carbon dioxide and other greenhouse gases if we were to avoid dangerous climate change. Consequently, the Climate Change Act 2008 (HM Government 2008) committed the UK Government to achieving at least an 80% reduction in greenhouse gases, relative to 1990 levels, by 2050. The Government's Carbon Plan (HM Government 2011) reiterates the UK's commitment to the reduction in emissions of greenhouse gases, and sets out how the transport sector will contribute to this reduction. This includes supporting new low emission vehicle technologies, high speed rail and electrification, sustainable aviation and shipping, promoting the use of sustainable biofuels, and changing travel behaviour.

UK domestic transport is responsible for around 22% of all UK domestic CO_2 emissions. The majority (circa 92%) of CO_2 emissions from domestic transport comes from road transport. CO_2 emissions from UK domestic road transport increased by around 10.4% between 1990 and 2007, but in 2009 had reduced to approximately 2.2% above 1990 levels (DfT 2011a).

Local Air Pollution and Air Quality Management Areas

Technological improvements have reduced emissions of air pollutants over the last thirty years, although for some pollutants this trend has slowed. Today, sources of UK air pollution are dominated by power generation and transport.

The UK Government and the devolved administrations published the latest Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Command paper No. 7169) in 2007 (DEFRA 2007). The strategy sets out the air quality standards and objectives to be achieved, introduces a policy framework for addressing the problem of fine particulates, and identifies potential new national policy measures which modelling indicates could give further health benefits and move closer towards meeting the Strategy's objectives. Under the legislation, local authorities are required regularly to review and assess air quality in their area and take action when the objectives in regulation cannot be met by specified target dates. When a regulated pollutant exceeds the objective value, the authority must declare an 'Air Quality Management Area' (AQMA) and develop an Action Plan to tackle problems in the affected areas.

Air Quality Management Areas (AQMAs)

To date, 258 Local Authorities – approximately 64% of those in the UK – have established one or more Air Quality Management Areas (AQMAs). Most of these are in urban areas and result from traffic emissions of nitrogen dioxide (NO_2) or particulates (PM_{10}). As at September 2011, 203 Action Plans have been submitted to DEFRA, and a further 55 are in preparation.

Such a plan may include a variety of mitigation measures such as traffic management measures, the introduction of low emissions zones targeting certain vehicle types, demand management measures, and land use planning in the longer term. Road traffic emissions are the main source of air pollution in around 91% of the AQMAs declared; only a few have been designated as a result of industrial sources, domestic or shipping emissions (DEFRA 2011a).

The dieselisation of the UK car fleet

Less than 10% of new cars registered in 1997 in the UK were diesel powered; by 2010, this figure had risen to 46% (DfT 2011c). In 2010, 28.9% of cars operating on UK roads were diesel powered (DfT 2011d). Diesel cars, although more fuel efficient, tend to produce higher levels of polluting particulate matter and oxides of nitrogen in their exhaust gases compared to equivalent petrol powered cars. In particular, there is an increasing body of evidence that modern diesel engines are producing a higher proportion of primary nitrogen dioxide (NO_2) in their exhaust gases, as a result of the adoption of technologies to control particulate matter. This is a problem for local air quality and human health, and the subject of active research by motor manufacturers and the academic community.

Local Air Pollution and Human Health Impacts

DEFRA has stated that there is now clear evidence that there is no 'safe' level for exposure to fine particles (PM_{10} and $PM_{2.5}$, where PM_{10} are particles <= 10 µm in diameter, and $PM_{2.5}$ are particles <= 2.5µm in diameter), i.e. no exposure threshold below which no health disbenefits are expected to occur. The UK Air Quality Strategy therefore concludes that, for this pollutant, a policy based on achieving limit values alone will not generate the maximum benefit in public health for the investment made. This is because such an approach focuses only on the areas where concentrations are highest, while in reality adverse effects on health are likely to be much more widespread (DEFRA 2007). Whilst at the present time, only PM_{10} is a regulated particulate pollutant, targets for $PM_{2.5}$ are included in the Strategy, which include a relative 15% cut in urban background exposure in $PM_{2.5}$ (annual mean) between 2010 and 2020, in addition to an absolute target of 25µg m^{-1} (annual mean). Vehicle brake and tyre wear constitutes over a quarter of air borne particulates, and these sources are now receiving more attention by vehicle manufacturers.

There have been particular challenges in achieving the nitrogen dioxide (NO_2) targets because of the growth in the use of diesel powered passenger cars in recent years, and the growth in the number of diesel powered light duty commercial vehicles or 'white vans'. Current European vehicle type approval regulations applying to new vehicles regulate levels of NO_x (total oxides of Nitrogen) emissions, but not explicitly NO_2 emissions, and there is some evidence to suggest that the proportion of NO_2 in NO_x is increasing as a result of changes in engine technology and exhaust after-treatment systems (DEFRA 2011b).

Health Impacts of Air Pollution

Oxides of nitrogen (NO_x), comprising nitrogen dioxide (NO_2) and nitric oxide (NO) – Can cause inflammation of the airways, affect lung function and cause breathing difficulties.

Particulates – Airborne particulate matter (PM) is made up of a complex mixture of solid and liquid particles, including carbon, complex organic chemicals, dust, and other compounds, suspended in the air. Short and long term exposure can worsen respiratory and cardiovascular illness, including lung cancer, and increase mortality.

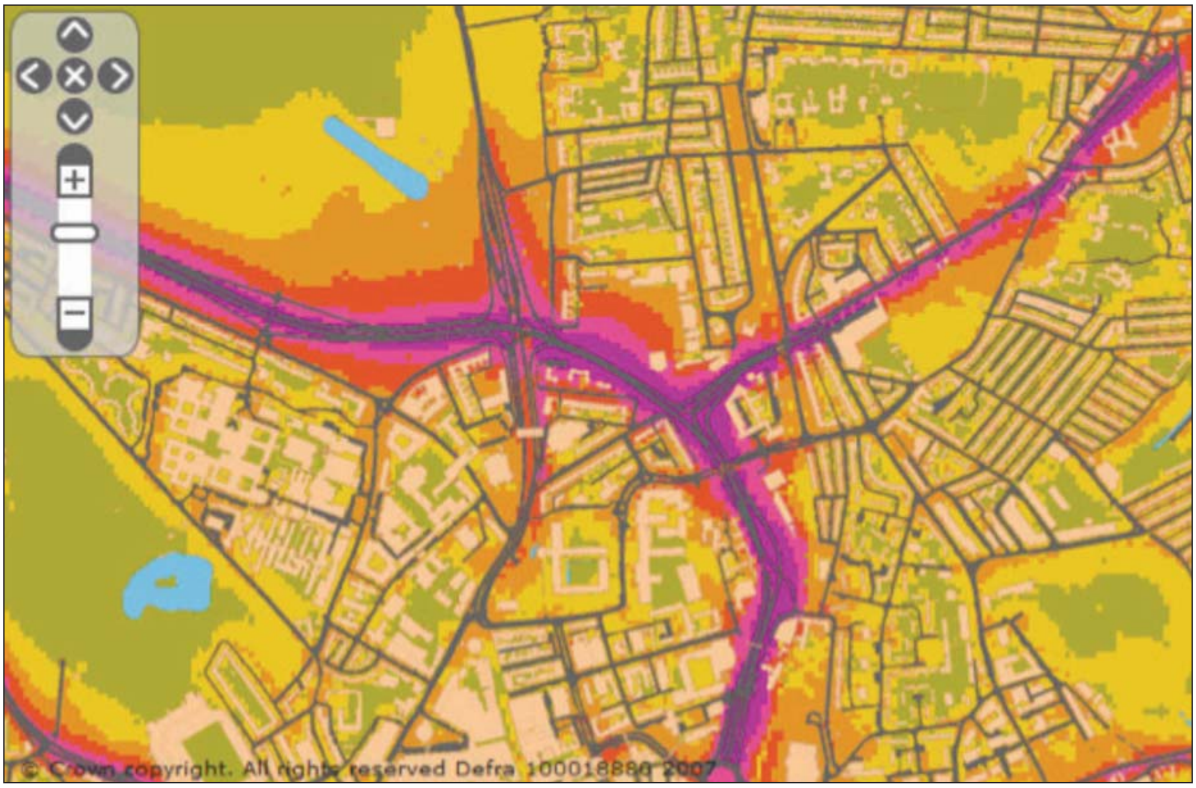
Noise

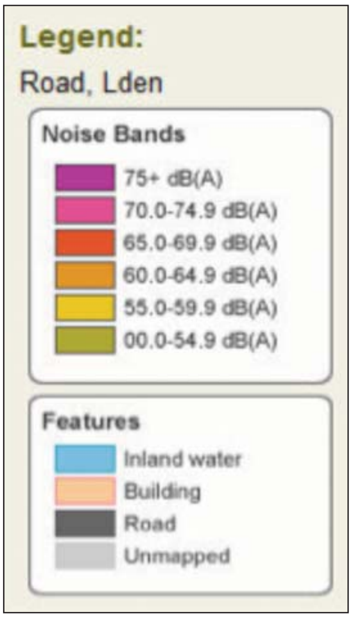
Noise has the potential to cause annoyance, loss of amenity, and negative impacts on human health including high blood pressure and heart disease. Ambient or environmental noise is unwanted or harmful outdoor sound created by human activities. The European Noise Directive 2002/49/EC or 'END' (European Commission 2002) relating to the assessment and management of environmental noise has the aim of providing a common basis for tackling the noise problem across the EU. This includes:

- Monitoring the environmental problem; by requiring authorities in Member States to draw up "strategic noise maps" for major roads, railways, airports and agglomerations. These maps will be used to assess the number of people annoyed and sleep-disturbed respectively throughout Europe.
- Informing and consulting the public about noise exposure, its effects, and the measures considered to address noise.
- Addressing local noise issues by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good. The directive does not set any limit value, nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities.

Type of noise exposure	Impact	Proportion affected, per annum	Potential years of healthy life lost in Europe through noise-related death or disability	Monetised UK Impact (£ million per annum)
Daytime traffic	Heart disease	3% of all heart disease cases across EU	211,000	£1,183
24-hour background noise	Severe annoyance	15% of all Europeans	278,000	£1,571
Traffic / leisure noise	Tinnitus (ringing in the ears)	3% of all tinnitus cases	9,300	£52
Day time and night time noise	Slower learning by children	0.01% of all Europeans	45,000	£252

Health Effects of Noise Pollution. (Adapted from DEFRA 2008)





Example of DEFRA Noise mapping (http://services.defra.gov.uk/wps/portal/noise)

In England the Directive is implemented through The Environmental Noise (England) Regulations 2006 (HM Government 2006). Those areas/noise sources in England for which noise mapping has occurred are identified in The Environmental Noise (Identification of Noise Sources) (England) Regulations 2007 (HM Government 2007).

DEFRA has produced noise maps to meet the requirements of the Environmental Noise (England) Regulations 2006, which are intended to inform the production of noise action plans for large urban areas, major transport sources, and significant industrial sites in England. The maps are based on modelling (utilising traffic flow, road / rail type, and vehicle type data), not actual measurements, and are to be updated every five years.

Similar noise maps are available for Scotland, Wales, and Northern Ireland.

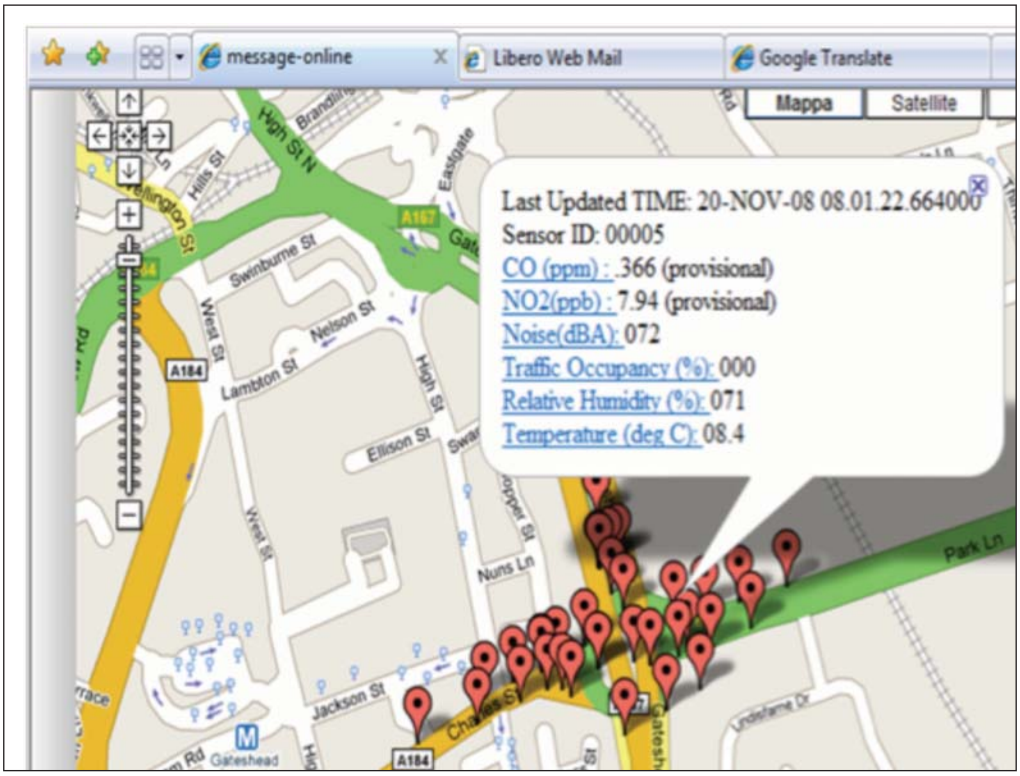
Monitoring the Environmental Performance of Networks

Network managers have a range of potential interventions in their toolkit, depending on the nature of the problem and local context. A prerequisite for effective management of environmental factors at the local level is adequate and timely information at an appropriate level of spatial resolution. This usually implies some form of environmental monitoring system generating data which is converted into management information through appropriate processing. In urban areas, this is increasingly carried out within the scope of an urban traffic management and control (UTMC) system.

Current research is addressing the need for comprehensive information on the environmental performance of transport networks, and making this information available to network management systems. One example of this was the MESSAGE (Mobile Environmental Sensing System Across GRID Environments) project (2006-2009), implemented by an academic consortium comprising Imperial College, Newcastle University, Cambridge University, Leeds University, and Southampton University. The project was funded by EPSRC and the Department for Transport.

The project addressed the issue of a current lack of vehicle emissions and air quality data at an adequate temporal and spatial resolution, suitable to use in real-time UTMC systems. As part of the project, Newcastle University developed a low-cost sensor module or 'mote' which could be deployed in large numbers across an urban area. The system featured a wireless communication system, where environmental sensor data could be transferred in real-time from mote to mote in a 'daisy-chain' configuration, with intelligent data routing, via a gateway node to a UTMC compliant database. The system was deployed in pilot trials in both Gateshead and Leicester in 2009.

Such a pervasive sensor and communications network has the potential to facilitate the development of the next generation of network management systems, allowing planning and operational decisions to be made on the basis of network data which is both real time, and at a high level of spatial resolution, to meet environmental, health, and operational objectives. A commercial development of this system has recently been deployed in the Medway area of Kent to integrate high spatial resolution air quality monitoring with the UTMC system to better inform traffic operations.



Real-time data feed over internet from multiple environmental sensors in Gateshead

Network management for CO_2 reduction

Highway network management with the objective of CO_2 reduction encompasses a wide range of potential interventions to facilitate the movement of people and freight whilst reducing or minimising the amount of fossil fuel consumed (essentially, there is a linear relationship between fuel consumption and CO_2 production). Significant technological progress has been made in recent years by vehicle manufacturers to improve the fuel efficiency of road vehicle engines (grams of CO_2 produced per kilometre travelled). These technological improvements are in turn supported by incentives in the vehicle taxation system. At the local level network managers can adopt measures to manage demand by encouraging modal shift to more fuel efficient modes, by making these modes relatively more attractive than the private car. This might include interventions such as public transport priority, and parking supply management and pricing. The tuning of urban traffic control systems to maximise system efficiency can reduce fuel consumed by managing stop-start traffic conditions and vehicle speeds.

Network management for improved local air quality

Increasingly stringent European emission standards applied to new vehicle type approval over the last twenty years have resulted in modern road vehicles which are far cleaner than their predecessors. Nevertheless, traffic conditions and variability in driver behaviour can influence the amount of pollutant generated by a vehicle. Stop-start conditions, with frequent braking, acceleration, and gear changing, tend to make pollutant emissions worse, since peaks in pollutant emissions from vehicles are often produced by transient events in the vehicle operation. In modern engines, these transient events can dominate the total pollutant emissions produced. It therefore follows that if the highway network can be managed and operated to minimise stop-start conditions, and produce ‘smoother’ flow conditions, the production of harmful exhaust pollutants can be reduced.

The environment and UTMC

Historically, the focus in UTMC has been on delay minimisation and/or capacity maximisation. Simply improving traffic flow in this manner by optimising the performance of the transport system in whole or in part through interventions such as signal coordination, often has an environmental benefit in terms of reduced stop / start operation.

More novel existing techniques in systems such as SCOOT include both public transport priority and gating / queue relocation, where a conscious decision is taken by the network manager to reduce queues in sensitive areas (e.g. near pedestrian areas, street canyons, schools etc where there are more people to pollute), and queue vehicles in less sensitive areas or where the local topography can facilitate dispersion of pollutants in the atmosphere.

SCOOT version 4.5 incorporated the option of including vehicle exhaust emissions estimates in the SCOOT objective function. The SCOOT program was modified so that the user could choose the objective function used in the offset optimiser. It can be changed from the standard objective function of a weighted sum of delays and stops, to the weighted sum of estimated emissions. The program estimates carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO_x), particulates and Volatile Organic Compounds (VOCs) emitted by vehicles on a link, node or region basis, based on traffic flow and average speed. Average speed is not a particularly reliable predictor of some pollutants, but the principle of internalising emissions estimates within the objective function for traffic control is an active area of current academic research.

Encouraging walking and cycling

Encouraging modal shift from motorised modes (in particular the private car) to non-motorised modes such as walking and cycling will clearly achieve benefits in terms of reducing emissions from combustion of fossil fuels, and reductions in noise. However, care should be taken to ensure that appropriate facilities are available for cyclists and pedestrians to mitigate any potential increase in injury accident risk. Almost a quarter of the adult population in England are currently classified by the NHS as obese (NHS 2010). Two thirds of the adult population do not meet recommended activity levels. There are clearly potential synergistic benefits to be gained in terms of both environmental quality, and public health.

Encouraging low / zero emission vehicles

The UK Office for Low Emission Vehicles (OLEV) has been tasked by the Government with promoting the take up of plug-in ultra low carbon vehicles. The Government has confirmed financial support to consumers in the form of a grant of up to £5,000 towards purchase of a plug-in ultra-low carbon car for the life of the current Parliament. The consumer grant reduces the up-front cost of eligible vehicles by 25 per cent, and is open to both private and business fleet buyers. At the same time, the required infrastructure to support electric vehicles and plug-in hybrids needs to be considered. The ‘Plugged in places’ initiative is providing pump priming funding for publicly accessible charging points to help drivers of electric and plug-in hybrid cars recharge when they are away from home.

http://www.dft.gov.uk/topics/sustainable/olev/

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Intelligent Speed Adaptation (ISA)

Intelligent speed adaptation is a system that provides the driver with information on the speed limit for the road currently being travelled on. This information can be used to display the current speed limit inside the vehicle and warn the driver when he or she is speeding. It can also be linked to the vehicles engine and brakes to limit the speed of the vehicle directly, on either a voluntary or mandatory basis. The system was developed primarily to enhance safety, because of the known relationship between speed and injury severity in an accident. However, it has been suggested that limiting vehicle speed in this way can also have environmental benefits. Recent research suggests that reductions in CO_2 emissions can be achieved on motorway-type roads when mandatory speed control is used to limit vehicle speeds to 70mph. However, for most other types of road, constraining vehicles to speed limits was estimated to have less effect on CO_2 emissions. The greater benefit for fuel consumption / CO_2 emissions at higher speeds is logical when one considers that vehicle aerodynamic drag is approximately proportional to the square of speed, whilst the power required to overcome such drag is proportional to the cube of speed. At lower speeds, gear changing behaviour will tend to complicate the analysis, and possibly erode benefits. This suggests that, if CO_2 reduction on motorways is an objective, simple speed limiter devices on passenger cars (as commonly used on commercial vehicles), set to the legal speed limit, might be effective. An alternative method of achieving the same objective would be wider use of average speed camera enforcement on motorways. However, the political acceptability and cost-benefit of such interventions would need to be assessed.

Low Emissions Zones

The London LEZ started operation in 2008 and is currently one of only two such zones in operation in the UK, the other being in Norwich. The aim of the London scheme is to improve air quality in the city by deterring the most polluting vehicles from driving in the area. The vehicles currently affected by the LEZ are older diesel engine trucks, buses, coaches, large vans, minibuses and other heavy vehicles. Cars and motorcycles are not currently affected by the scheme. As a result, the scheme tends to target heavy diesel-powered vehicles, prioritising particulate (PM) reduction.

The London LEZ commenced on 4 February 2008 for lorries over 12 tonnes, buses and coaches. The LEZ emission standards describe the minimum Euro standard which vehicles must meet to be exempt from a charge. Meeting these emission standards can be done by using a vehicle whose engine was type approved to this standard (or better), or by retro-fitting exhaust after-treatment technology to raise the emission standard.

From 3 January 2012, larger vans and minibuses will need to meet the Euro 3 emissions standard for particulate matter (previously exempt), and lorries, buses and coaches will need to meet the Euro 4 emissions standard for particulate matter (previously Euro 3). Daily penalty charges are imposed for contraventions of the low emission zone.

In 2011, DEFRA announced grant funding to support low emission zone feasibility studies in 16 local authorities across England, as part of its Air Quality Grant Programme 2011-12.

http://www.tfl.gov.uk/roadusers/lez/default.aspx

http://laqm.defra.gov.uk/action-planning/measures/low-emission-zones.html

Summary

Network managers are increasingly dealing with multiple objectives. These include minimising delay, maintaining safety, reducing CO_2, addressing local air quality and noise issues, and even improving public health. A key task is to find combinations of management and policy interventions which act in a synergistic and mutually supportive manner to create a virtuous circle. Fortunately, there are positive correlations between many of these issues, so solving one problem often helps to solve a number of others. To operate in such an holistic and dynamic environment, network managers will need to work in an increasingly cross-disciplinary manner, developing sufficient insight into the wide range of disciplines to be able to understand causal relationships, and the implications of taking a particular course of action on all relevant policy objectives. Fortunately, emerging technologies in the fields of sensors, communications, and data processing will facilitate the development of far more sophisticated future network management tools to support practitioners in their decision making.

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Glyn Rhys-Tyler, Transport Operations Research Group, Newcastle University

The Author

Glyn Rhys-Tyler FCIHT is a Senior Research Associate in the Transport Operations Research Group (TORG), within the School of Civil Engineering and Geosciences at Newcastle University. He has worked in transportation planning and research for over 20 years, initially within a consultancy environment at TPA / Oscar Faber, and more recently at TRL where he was a Programme Development Director. Since 2007, he has been pursuing full time research at TORG into the environmental characteristics of highway vehicles, the influence of network infrastructure and control systems, and the significance of variability in driver behaviour on environmental performance. Glyn has been a member of the CIHT Network Management & Operations Panel since 2004.

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