THE INTEGRATION OF AIR QUALITY MONITORING, MODELLING AND INTELLIGENT TRANSPORT SYSTEMS- LEICESTER (UK)

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ABSTRACT :

Leicester identified traffic as the main source of air pollution with adverse impacts on health.

For 10 years Leicester has progressively integrated "nested" European, Regional and Local Air Quality Monitoring and Modelling Systems (AQM) with data from Air Quality Monitoring Stations, roadside pollution monitors, weather stations and the meteorological services together with Intelligent Transport Systems which provides a rich source of monitored, real-time and archived traffic data, from the Urban Traffic and Management Control including the Split Cycle Off-set Optimisation Technique, MIDAS Motorway traffic data, and Automatic Classified Vehicle Counting systems.

The introduction of "WebServices" and "Open Systems Architecture" with Geographical Information System, together with the MESSAGE Project's 'Grid enabled' "e-Science" infrastructure, will enhance the existing Information Society Technology communications and the output of the "nested" AQM to improve the assessment of the impact of traffic on air and noise quality, the environment and health. This will also inform the Climate Change Strategy and the City's Carbon Footprint via the "4M" project.

"Nowcasts" and "Forecasts" of air and noise pollution are being developed to influence public choice on time/mode of travel and assist in the management of the road network in an environmentally friendly manner to satisfy the requirements of the Ambient Air Quality and Access to Environmental Information Directives and the Aarhus Agreement.

***Keywords**: Air Quality Monitoring and Modelling; Intelligent Transport Systems; Air Quality; Noise; Urban Traffic Management and Control; SCOOT; MIDAS; WebServices; Open Systems Architecture.*

1. INTRODUCTION

In Leicester, the demand responsive signal control systems developed by the Transport Research Laboratory, nested within Urban Traffic and Management Control (UTMC) (including Split Cycle Off-set Optimisation Technique (SCOOT)[10] have been integrated with the AIRVIRO Air Quality Monitoring and Modelling System (AQMM) (developed by the Swedish Meteorological and Hydrological Institute); the OPANA Air Quality Model (developed by the Technical University of Madrid); the NAME Air Quality Model (developed by the UK Meteorological Office); the ADMS-URBAN Air Quality Model (developed by the CERC); the Department for the Environment, Food and Rural Affairs' (DEFRA) Emissions Data, Automatic Urban and Rural Network (AURN), and similar Local Air Quality Monitoring Stations (LAMS) and Roadside Pollution Monitors (RPM); the Meteorological Office and Meteorological Mast data; SATURN and TRIPS Traffic Model together with enhancements for Noise Modelling and 3-D visualisation developed with the Institute for Transport Studies, University of Leeds and INFOTERRA.

The infrastructure is supporting the City and County's response to the European Air Quality, Noise and Access to Environmental Information Directives as well as the needs of the joint Leicester and Leicestershire Central Leicestershire Local Transport Plan 2006 – 11 (LTP), the Traffic Management Act 2004 (TMA), the Local Development Framework (LDF) (including the City of Leicester Development Plan), the Strategy for Leicester and the Leicester Public Health Challenge.

The integrated system is being developed to support Strategic Land Use and Transport Policy as well as real-time network and environment management. "Web-based Services"; "Open Systems Architecture" and use of GRID enabled technologies will be embraced to deliver traffic and transport systems and information to enable the community to tackle climate change and reduce its Carbon Footprint.

2. AIR QUALITY MONITORING PRINCIPLES

Data is collected from three generic sources of emissions : - ***Point sources*** - licensed by the Local Authority Environmental Health Department (or the Environment Agency if they are very large e.g. Power Stations, etc); ***Area Sources*** - derived from studies of residential and light industrial areas together with natural emissions from crops, vegetation, water courses etc. ***Traffic Sources*** are derived from Traffic Models (e.g. SATURN , TRIPS etc) and live data from SCOOT together with Emissions Factors
Using Emissions Models, emissions are estimated to form the Emissions Database in grid format. The Air Quality Dispersion Model will then calculate and display the concentrations of each pollutant on a Dispersion Map. These maps can be displayed in near real-time providing an hourly "nowcast" or longer time resolution.

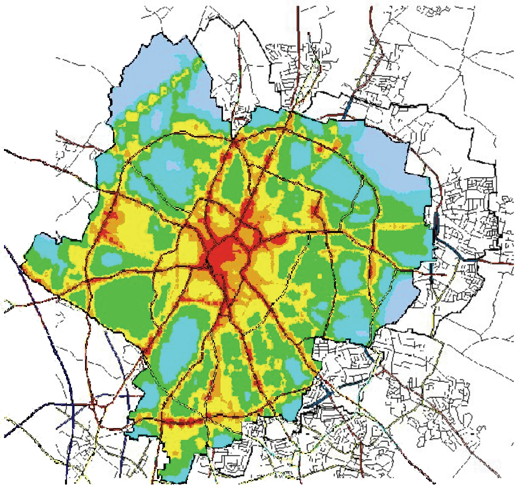

Figure 1: Air Quality Dispersion Map for Nitrogen Dioxide concentrations for Leicester

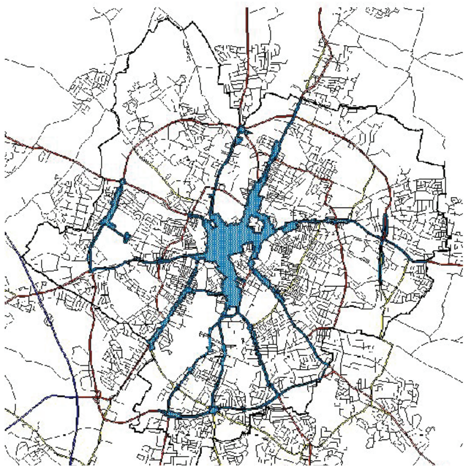

Figure 2: Air Quality Management Areas for Leicester (2000)

Figure 1 shows the Annual Concentrations for Nitrogen Dioxide over Leicester. The colour scale indicates intensity, with red where the NO_2 Limit Values will be exceeded. The Air Quality Management Areas (AQMA) declared in 2000 by Leicester City Council are shown in Figure 2. These areas are commonly called "Hot Spots". The EU Ambient Air Quality Directives (1996 – 2004)[5] require Local Authorities (> 250,000 population; soon to be > 100,000 population) to produce Air Quality Action Plans to reduce the pollution levels to below the "Limit Values". The Local Transport Plan 2006 –2011 process requires Highway Authorities to show how improvements in Air Quality will be achieved and 5% of the allocated budget is deemed to support the required actions. A similar regime is being introduced via the EU Noise Directives [6].

3. ITS AND TRANSPORT & AIR QUALITY PLANNING

The European project Common Information to European Air's (CITEAIR), led by Leicester City Council, "Guidebook on Air Quality Management" [9] provides information on measures and tools to support local authorities in action planning together with a Directory of Solutions, Case Studies and signposting to relevant information (see http:/CITEAIR.rec.org and http://www.airqualitynow.eu). Typical measures /tools which can be deployed as part of an Air Quality Management Strategy (AQMS) include Urban Traffic Management Control Systems, Road User Charging (RUC), Low Emission Zones (LEZ), Work Place Parking (WPP), Integrated Public Transport including Park & Ride, Parking Management, Travel Planning, Pedestrianisation, Fleet Renewals and Retrofitting, Alternative Fuels, Land Use Planning, etc.

Intelligent Transport Systems (ITS) support the identification of the problems in the network; provide the data for validation of models for Strategic Planning scenario assessment, the tools to implement and manage the action plans and the data needed for evaluation. Traditionally air quality action planning, both strategic and tactical, has been delivered offline. However, with the enhanced communication speeds available via Information Society Technologies (IST)/Information Communications Technologies (ICT) it is becoming more practical to work in near real-time, in both the traffic and environmental domains.

In the traffic domain, during the UTMC Development Programme, Leicester participated in several projects. EFFECT+ funded by DfT developed "Gating"strategies which allow traffic flow within a corridor to be managed with queues being relocated away from "Street Canyons" (where high buildings close to the road inhibit natural ventilation and dispersion of pollution) to locations alongside "Open Spaces" or where occupied property is further away from the road (where natural ventilation can help disperse pollution). In UTMC 03, in collaboration with the TRL, traffic was "gated"/"cascaded" along a main radial (see Figure 4) to control the location of the queued traffic and thus manage the level of emissions to ensure concentrations do not rise above the thresholds.

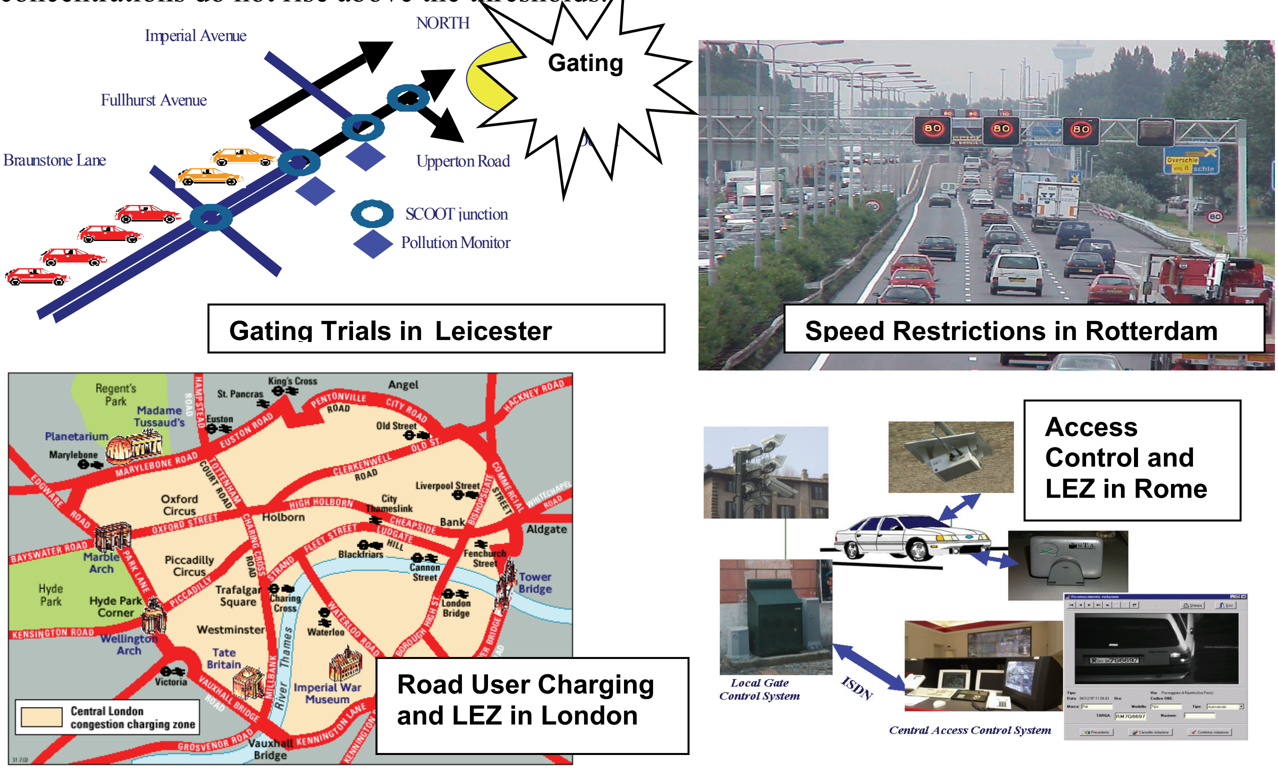

Figure 4: Typical use of IST supported measures

UTMC 04 [11] carried out a comprehensive study of the evolution of congestion over the day on Saturdays (when football and/or rugby matches traditionally took place) compared with non-match days, including comprehensive monitoring and modelling of traffic and air pollution, with an on-street trial of the event management plans designed in the study. UTMC 04 successfully demonstrated the potential for predicting the build-up of congestion associated with event traffic, thereby allowing time for corrective actions, subsequently the European/LTP funded INTELCITIES project [7,8], enabled Leicester to use UTMC/SCOOT in real time to identify the build up of spectator traffic for the Football and Rugby matches, thereby allowing the time for switching signal plans to be optimised. Http://leicester-airweb.co.uk publishes details about Traffic and Roadworks; Bus Stops; Car Parks, CCTV images with further information about Journey Times, Congestion, Air Quality and noise to be added. The StarTrak real-time bus passenger information system is also integrated with the UTMC system to allow allocation of priorities. It has its own www.star-trak.co.uk which provides real-time information about the location of buses and schedules in real-time. Figure 4 provides a few examples of IST supported measures: Overschie (Rotterdam Motorway) produced reductions in NO_2, PM and noise; London Congestion Charging produced 20% plus reductions in NO_2 [since Feb 08, the enforcement infrastructure is used with the new LEZ – within M25); Rome introduced the first LEZ access zone .

The increased calculation speeds have enabled the hourly updated Air Quality "Nowcasts" and "Forecasts" to be published on www.leicesterequal.co.uk together with Congestion Maps, CCTV images, links to Public Transport, StarTrak Realtime Bus Information etc. Work is in progress to migrate this information to http://leicestertravel.info delivering opportunities for integration with travel information. Air Quality data is available also via http://leicester-airweb.co.uk as well as http://www.airqualitynow.eu. The Air Quality Colour coding follows the DEFRA scale. Operators can use a more precise scale to identify "HotSpots" (see Air Quality Map at http://leicesterequal.co.uk and Fig. 5) The Environmental Bulletin in Figure 6 also includes links to Congestion Maps and CCTV and is also made available to the public.

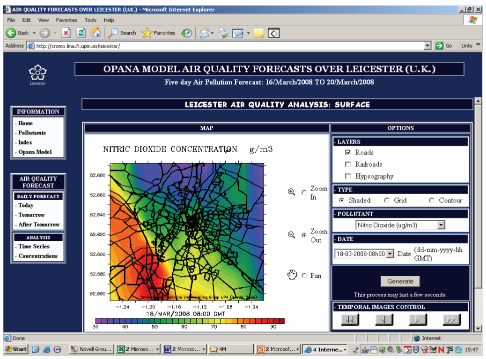

Figure 5: Air Quality Map

Figure 6: Environmental Bulletin Page

4. THE STRATEGY FOR LEICESTER

The Strategy for Leicester (2006) emphasises that Leicester is "a typical European city" / "County Town" as a commuting destination in the Leicestershire hinterland. This mutual support drives collaboration between the various Local Government, (City, Borough, District and County Councils) as well as Commerce, Industry, and Stakeholders including the Health Authorities, Universities, Public Transport, Utilities, Emergency Services, Voluntary Bodies and the Community.

The Strategy, sets out the City Council's vision for Leicester involving working in Partnership with these bodies implementing Strategies covering Air Quality, Environment, Crime and Disorder, Education, Health, Housing, Regeneration, Structure Plans, Local Transport Plan, Waste and Sustainable Development. At the World Summits on Sustainable Development in Rio de Janiero (1992), [Kyoto (1998)] and Johannesburg (2004), Leicester explained how it was delivering Sustainable Development.

Since Leicester's designation as the First UK Environment City, work has developed in many areas to reduce the communities impact on the environment, including a significant cycle network with supporting facilities. With grant aid from the former Department for Education and Skills (DfES) school and college travel plans are being implemented. Many of these feature links with StarTrak bus services. During collaboration with the World Health Organisation, Imperial College, the Institute for Transport Studies University of Leeds et al in the EU HEARTS project pupils completed Travel Diaries, which allowed assessments of exposure to air and noise pollution to be made with data from SCOOT etc. *The Green Travelometer* was developed by ITS's Anforth (2006) during a follow on study to inform pupils of their CO_2, CO, NOx and PM emissions in an attempt to give knowledge to empower and encourage a change in travel behaviour.

The scheme development has involved co-operation between staff from different Departments including Local Authorities, the Health Service, Environment and Highways Agencies. Sir Liam Donaldson, Chief Medical Officer of England, acknowledged that the impact of traffic on health (air pollution, noise, road traffic accidents, transport policy) needed to be considered in the "Leicester Public Health Challenge".

At the operational level, the new tools are presenting challenges to the operation of the UTMC system, given the need for an integration of the transport network and environmental management requirements. This a especially important following the introduction of the Traffic Management Act 2004 with its targets which tend to return us to the "Car Rules" priorities which drove the original UTC systems. In addition, planning for the future aims to achieve 60% reductions of Carbon Emissions (Stern (2006)[12], Eddington (2007)[13), therefore seamless access to operational and modelling tools for traffic transport and the environment for their effective control and management is paramount.

5. IMPACT OF NEW IST AND ICT

Webservices with Open Systems Architecture, offers the potential to bring together data from a variety of sources (different suppliers at Local, Regional, National and European levels; modelled; monitored; etc) to enhance the "nowcasts" and "forecasts". The improved outputs will give the decision makers and the public greater confidence in the "Green Choices" they make. As a result we will be able to complete Health Impact Assessments; support the work on Climate Change and calculate Carbon Footprints. On a "day to day" basis, we will be able to manage the Road Network to meet not only the congestion targets but also our commitment to the Environment and Health. Webservices will also remove the physical infrastructure restrictions, allowing the integrated system to be managed and accessed from any authorised terminals.

Figure 7 illustrates a concept which is currently being developed. Within Leicester City Council the key elements are :-

- Emissions Modelling (EDB) – participating Authorities deliver their Emissions Database modelled data via Web Services e.g., Traffic Models; SCOOT data etc.
- Monitoring - participating Authorities deliver their monitored data via Web Services to assist in the calibration of model output and support the EDB. The Highway Agency monitor along the M1 Local Air Quality between junctions 20-21A. MIDAS traffic flow data is delivered using DATEX II

- Continental Models – provide *Background* data for initialising the Regional and Local Air Quality models using the "Nesting Principle" (see Figure 8)
- Local Models – with the enhanced quality of the Regional *Background* pollution estimate the County, City and Street Canyon AQM's will become more accurate and reliable
- Information Flow – to inform during Air Quality Incidents (e.g. SO_2 from North East Power Stations); Emergency Incidents (e.g. Tanker spillage); Network Management (Congestion and Environment); City Development
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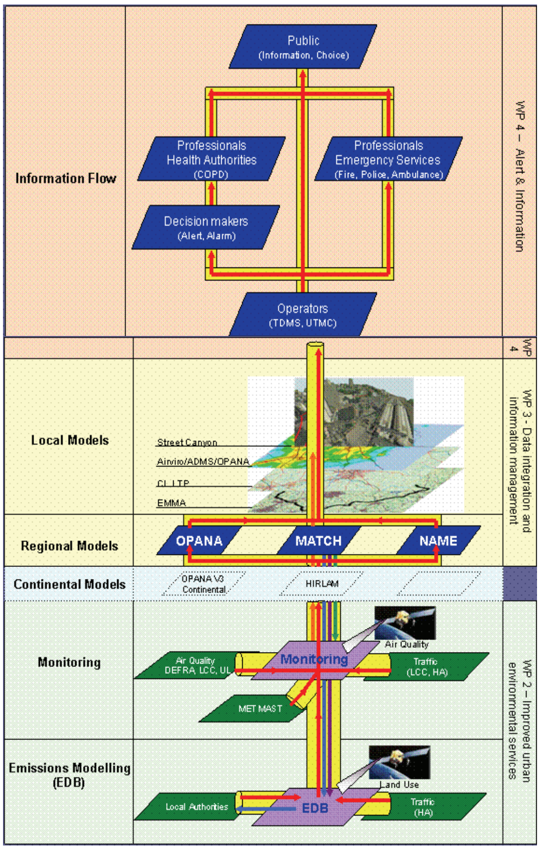


Incident Management
Modal Choice
Network Management
City Development

AIRVIRO AQM
with Street Canyon

AIRVIRO
Data Handling

AIRVIRO AQM
& Data Handling

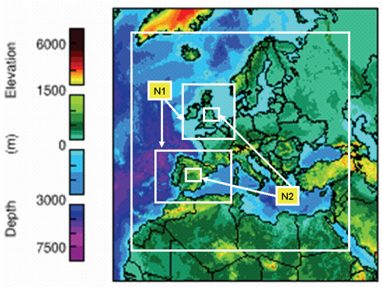
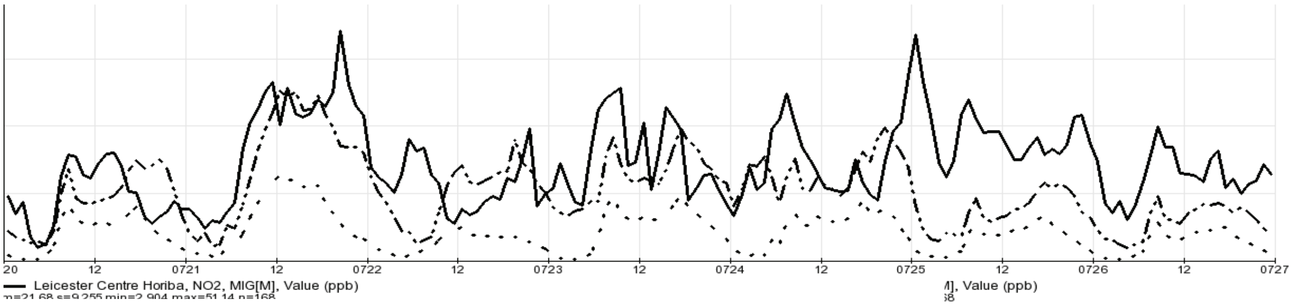


Figure 7 : City Management Concept

Figure 8: "Nesting" of European & Regional Air Quality Models

During the 12 years of development the outputs have progressed :- from basic dispersion maps derived from historic database for scenario comparisons; via simple "Nowcasts" and "Forecasts" using "near realtime" traffic data with AURN calibration and simple background data; to "nested AQM" to deliver more accurate background data.

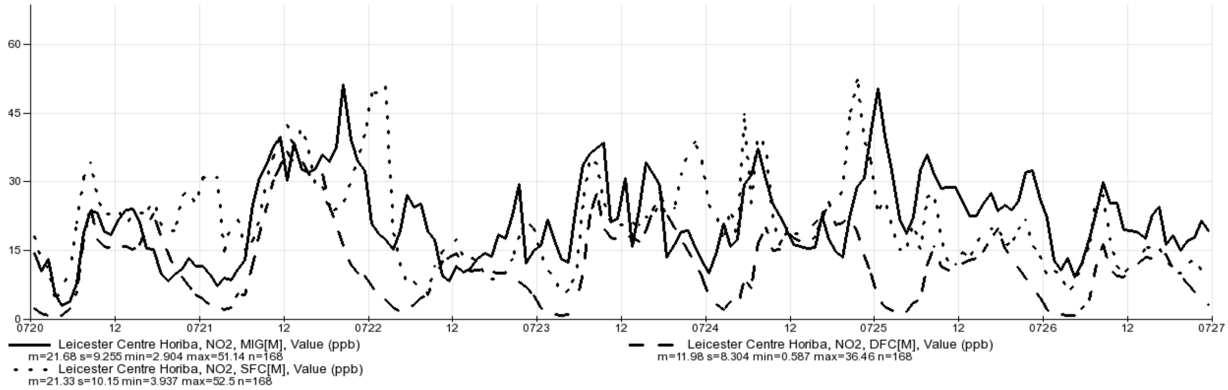
The graphs in figure 9 illustrate the current 2007 outputs from the different combinations of "nested data"



AURN Actual — AIRVIRO + NAME Forecast — AIRVIRO Forecast

- AURN Actual – monitored data from DEFRA's National Network
- AIRVIRO + NAME - AIRVIRO initialised using NAME model for background levels
- AIRVIRO - deterministic forecast
- AIRVIRO Statistical -

We have reached a time where the "nowcast" and the "24hour forecasts" may be considered realible.



AURN Actual — AIRVIRO Deterministic Forecast — AIRVIRO Statistical Forecast

Figure 9: Comparative data July 2007 (updates available in June 2008) .

Given the limitations in accuracy caused by insufficient spatial and temporal detail of traffic and emissions relating to the network in the immediate vicinity to Leicestershire, Initial discussions have started with Environment and Network Management Teams from Leicester, Derby and Nottingham Cities concerning potential collaboration with the development of a Regional version of the City Management Concept including Climate Change Action Planning and establishing Carbon Footprints. This partnership builds upon the successful collaborative bid for funding from the Transport Innovation Fund on congestion relief with exploratory work for a feasibility study into Low Emission Zones.

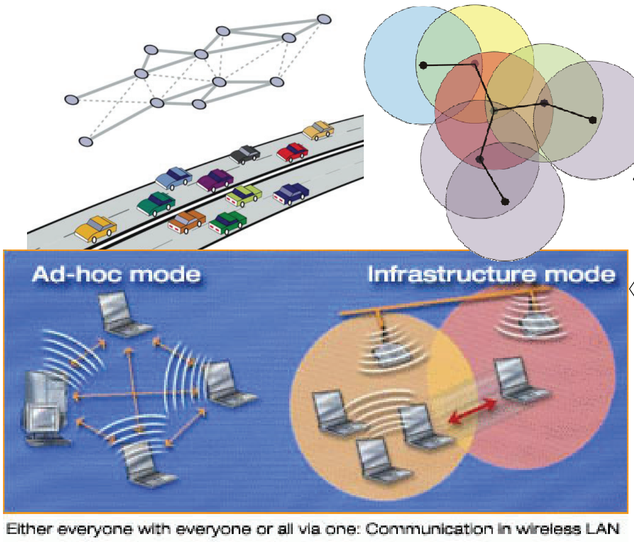
6. CURRENT PROJECTS

Leicester City Council, through its engagement in European projects has maintained a position of leadership in guiding European cities in the implementation of policy and traffic management strategies to maintain good quality air and to assess the impacts of excessive traffic related noise. New challenges include addressing climate change [3], whilst maintaining acceptable levels of noise and air quality impacts. Successfully meeting these challenges will require a radical change in people's attitude to the need to travel on the one hand and to decouple economic growth from the use of the private car on the other. This will require a shift from a systems orientated approach to optimising movements in our city networks to a people oriented approach, [3,4]. Delivery will require the use of novel technologies namely pervasive sensors to monitor in real time, people and vehicle movements, along with their impacts on the network. Also, the integration of data from pervasive sensors with that from traditional legacy systems, [2] to create effective information systems that deliver the information upon which timely decisions can be made. Such information has to be tailored to meet the needs of the different players engaged with the execution and management of each trip. From the public's perspective such details include: availability of services, location of bus stops, bus arrival times, park and ride facilities, car park charges, available routes and levels of service of routes into the network. The traffic operator needs different information relating to the performance of the network, this includes: the position in the network of recurrent congestion; alerts relating to incident; forecasts of air quality and noise problems. In order to deliver knowledge for the longer term decision making and policy formulation it is necessary to build up a historic picture of the changes taking place across a city network with view to creating future scenarios formulated to create and deliver more radical changes to meet the long term goals.

Current technologies rely heavily on statistical models (such as COMET, WebCOMIS, ASTRID, INGRID) and simulation such as SATURN and TRIPS, AIRVIRO, AVTUNE etc but these have limitations in terms of level of coverage and accuracy. They can be costly in terms of infrastructure to initially set up and then maintain. Whilst the network coverage with traffic monitors is fairly good as a by product of signal control (SCOOT), enforcement (ANPR) and planning requirements (core census and remote traffic monitors), the air quality monitoring capability is often confined to a couple of precision background sites and a dozen less-expensive roadside monitoring sites. Whilst vehicle tracking is available to give priority to buses at signals, and to promote public transport through the availability of arrival times at bus stops in real-time, it is confined to specific services and routes, again with limited network coverage. In the future, given the challenge to bring about radical changes in travel and transport systems to address climate change, an entirely new approach to network management is needed. The same legacy systems designed to minimise the delay to traffic, (and maximise the capacity of an urban network for vehicle movements) by integration with Intelligent Transport and novel monitoring and software systems can be used to promote more sustainable modes of travel, keeping our cities vibrant, healthy with zero impact on carbon emissions,[3]. Since 1987 Leicester, in its capacity as the first ***i***nstrumented ***C***ity,[1], has been used as an urban laboratory for research, and it is now involved as a test bed in two high profile research projects MESSAGE and 4M.

7. MESSAGE – MOBILE ENVIRONMENTAL SENSING SYSTEM ACROSS GRID ENVIRONMENTS

MESSAGE is a £3,5m, 3 year, e-Science Transport application, flagship project jointly funded by the EPSRC and the Department for Transport. It involves Imperial (lead partner), Newcastle, Leeds, Cambridge and Southampton Universities, supported by the cities of London (Transport for London), Cambridge, Leicester and Gateshead where on-street demonstrations will be delivered. Prototype pervasive sensors to count traffic, measure temperature, carbon monoxide, nitrogen dioxide and noise with an accelerometer and Global Positioning System (GPS) will be deployed in Leicester during 2008-09. In the future, carbon monoxide and nitrogen dioxide may also be measured. The sensors are equipped with a battery, for continuous monitoring over a period of a year (at a 30 second communication rate), a data logger and wireless communications technologies to relay data from sensor to sensor to a gateway. This is a computer that is able to send the data as a consolidated ftp file over the internet to the main database server. The latter has an online UTMC compliant database that integrates the pervasive monitored data with all other static and dynamic data available from local authority legacy systems. The online component of the database communicates with the data warehouse which supplies the typical profiles against which changes are monitored and receives the post-processed on-line data for storage and further analysis. The MESSAGE project will explore data mining and knowledge fusion techniques to deliver a richer understanding of the cause and effects of traffic and environment related network problems and solutions. MESSAGE will develop scenarios for improved network management and explore policies that address climate change issues. Fundamental to the delivery of the objectives of MESSAGE is the successful implementation of e-Science, in particular GRID technologies that are capable of synchronising in space and time and managing and post processing large volumes of data, delivering robust statistical analysis in real-time from static as well as dynamic data sources, from pervasive and traditional monitoring networks. In Leicester particular emphasis will be the use of the e-Science application to validate and calibrate emissions and dispersion models. Distributed calculations will be undertaken sharing the computing facilities across the sites.



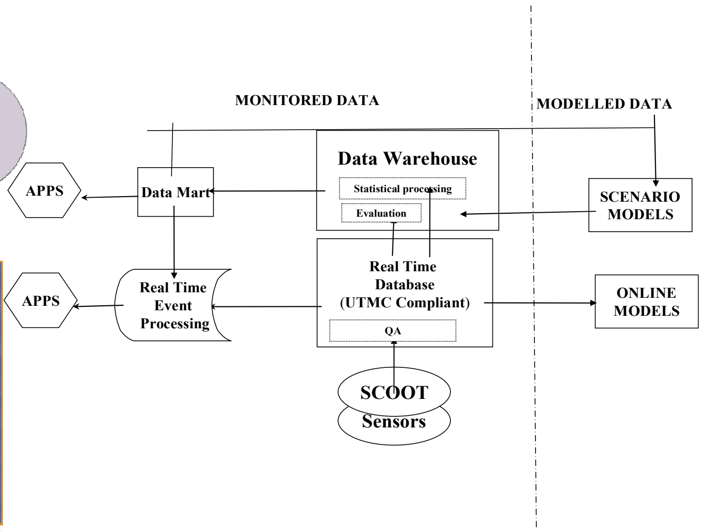


Figure 9: MESSAGE - Pervasive Sensors

Figure 10: Simplified Architecture for MESSAGE and Ad Hoc Networks

8. 4M – MEASUREMENT, MODELLING, MAPPING AND MANAGEMENT

Recognising the need to understand the relative contributions to CO_2 emissions of transport and buildings for cost effective policy decisions within a Local Authority the 4M project "*Evidence-based Methodology for Understanding and Shrinking the Urban Carbon Footprint*" project funded by the EPSRC. A three year project as part of the Sustainable Urban Environments SUE2 Programme involving collaboration between De Montfort (Lead Partner), Leeds, Newcastle and Sheffield Universities. The 4M project focuses on those emissions (Transportation; Heating; Lighting & Appliances; Cooling) and carbon sequestration (soils) that are relevant to urban areas and can be managed either by local authorities or by individual action; where there is greatest uncertainty; and yet scientific advance can be made through fundamental understandings of the complexities of the processes involved (see Fig 11).

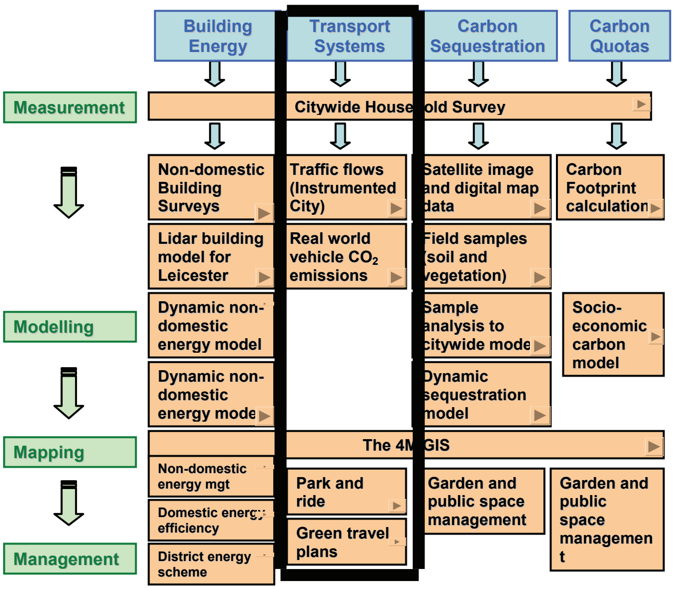


Figure 11: 4M Project Overview

The research plans to produce a carbon emissions inventory for the whole city of Leicester, including buildings and transport and to assess the ability of urban areas to offset emissions through natural carbon sequestration. The 4M project's major challenge is, by mapping and the use of novel statistical methods, to integrate the estimation of carbon emissions across areas of a city (for example wards or post codes) for transport and buildings so that their contributions can be understood in the context of the sources (for households and work places). Figure 11 illustrates the stages where Intelligent Transport Systems will deliver data and assist in assessing different scenarios The link between the UTMC/AIRVIRO systems and the Instrumented City will facilitate analysis of changes in traffic and its impact with time.

4M will begin to develop an understanding of the behaviours and causes of the gross and lean emitters and the barriers to change. The research will be carried out in the policy context so that the relative impacts of pursuing building related energy policies (provide grants for building insulation), as opposed to mass investment in transport (walk to school, green travel plans, implementation of light rapid transit, low emissions zones or use of more sustainable modes or fuels) and managing carbon sequestration rates (recycling garden waste, planting trees, increasing green space etc.).

9. CONCLUSIONS

1. Network and Environmental Management Systems can be integrated, to support Policy Development and Implementation. With realtime data they can support Day to Day Network Management.
2. Operational procedures should be reviewed to optimise the service which the integrated Systems can deliver to the community
3. City Management Concept using WebSevices and Open System Architecture offers potential for further developments
4. Smart pervasive monitoring technologies has the potential to deliver data to assess the current status of the network to support and validate air pollution and noise models within existing Decision Support Systems under-pinned by a real-time decision making information platform.
5. The 4M project will develop techniques for measuring, modelling, mapping and managing the carbon sources and sinks across Leicester, providing an understanding of trip making and barriers to change.

10. ACKNOWLEDGEMENTS

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