Research summaries from each DAPPLE partner

University of Surrey

DAPPLE was a large consortium project, focusing on a case study of traffic, air flow and pollutant dispersion in building lined streets close to the intersection of Marylebone Road and Gloucester Place in Central London. Its objectives included the better understanding of the processes from the emission of pollutants from moving vehicles to the exposure of individuals moving through the study region. Such understanding is applicable to similar areas elsewhere in London and in other European cities.

The work at the University of Surrey focussed on the use of a "meteorological" wind tunnel in an overall programme that also included extensive field measurements and computer "modelling". Wind tunnels are particularly useful as they offer controlled and repeatable conditions, something that can never be achieved in field work. On the other hand, not all of the processes in the real world (e.g. the unsteadiness of weather conditions and the effects of moving traffic) were reproduced in the wind tunnel. The combination of field and wind tunnel experiment with computer modelling offers the ideal basis for studying flow and dispersion in the lower atmosphere.

A 1:200 scale model of the within 500m of the intersection was installed in the wind tunnel and used for extensive series of experiments in which details of the air flow and pollutant dispersion were measured as external factors, such as wind direction and model detail, were varied. Particular attention was given to:

- aiding the design, interpretation and integration of the field work,
- providing detailed data suitable for testing the performance of computer models commonly used to predict flow and dispersion,
- providing detailed data for understanding the behaviour of short duration emissions of hazardous material (as might be associated with a terrorism incident), and
- producing material that could be used for educational purposes and in communications with the general public.

The combination of detailed measurement and visualisation using smoke injection revealed the complex nature of the flow in city streets and, in particular, at intersections. In general, a circulation across the street is driven by the wind above roof level, to be more precise by the component of that wind perpendicular to the street. This frequently results in the wind near street level being in the opposite direction to that above roof level, carrying pollution from vehicles preferentially to one side of the street. Pollution is also carried along a street by a wind driven by the component of external wind parallel to the street. A complex, three-dimensional flow was observed at intersections whereby flow and pollutants were exchanged between the streets. These processes were very unsteady, and the exposure of individuals to pollutants carried by the wind is therefore highly variable.

The loss of pollutants from near street level to the "free" flow above roof level was also studied as this is clearly important in determining the level of pollution that is experienced by pedestrians and other street users. Several mechanisms were shown to be important. These included the intermittent break-down of circulations within streets "ejecting" pollution into the free flow, the complex flow fields at intersections creating intense mixing with the free flow and local vertical flows and mixing induced by tall buildings.

The information and understanding derived from the wind tunnel work, in combination with other project results, will assist in the development of better means of estimating pollution levels and gas dispersion in urban areas, which is of value to local authorities charged with air quality management, to government in assessing the effectiveness of regulations and to emergency services assessing response to releases of hazardous materials in cities. The results are also of great scientific value, this being the first study of such detail in a European city. The research continues, now funded by the Home Office.

University of Bristol

We have conducted a number of experiments (10) where a totally inert and therefore non toxic and non depositing gas (tracer) has been released at a known rate from fixed locations within an urban network of streets for a duration of 15 minutes. The change in concentration of the tracer was monitored at set intervals at sampling points downwind of the release point. These concentration data were then compared with a variety of models.

The point of release was varied so that we could compare releasing material at the ground with up on a roof and also from a moving vehicle. We also carried out some preliminary experiments to look at penetration of material into a building.

The main outcomes of these data show that;

1. Changes in wind direction, even very small ones, can make a huge impact on the concentration of tracer observed as material is channelled in different directions through street networks.
2. Flow at an intersection is complicated and once again wind direction changes can cause rapid changes in concentration.
3. The level of tracer observed downwind at roof top was very similar to that observed at the ground suggesting that the material is rapidly spread in the vertical.
4. Indoor levels are about a factor of 10 lower than those outside but the levels persist for a very long time.

University of Cambridge

The dispersion of pollutants in an urban environment is largely determined by the pollutant emissions, the urban meteorology and the urban topography. The prediction of the concentrations in the atmosphere is essential for the prediction of air quality in cities the development of cost-effective mitigation strategies. Predictions are also required for assessing the consequences of the release of hazardous materials in urban areas. Mathematical modelling is the technique used for prediction purposes and the development and quality evaluation of mathematical models is important as too optimistic or too conservative predictions both have major economic and safety downsides. It has been found useful in the past to try to develop very simple models in order to scope out a problem prior to more detailed investigation. Frequently such very simple models are, nonetheless, directly useful in air quality studies and management. Scientific and statistical evaluation of the predictive models ensures an acceptable quality and can enhance confidence in the predictions. In an emergency response context models need to provide predictions in real time and this also drives an interest in simple models and their quality, "fitness-for-purpose"

The DAPPLE (Dispersion of Air Pollutants and Penetration into the Local Environment) was a collaborative project with teams from the University of Cambridge, Imperial College, University of Surrey, Leeds University and Bristol University. This report addresses the University of Cambridge contribution to the project. A later report will be issued to address the results of the complete project.

A principal goal of the project was to undertake some large scalar releases of tracer materials within a city and to track them over a range up to around 1 km; the "neighbourhood" scale. A limited experiment had been undertaken in Birmingham in 1999, followed subsequently by experiments in Los Angeles and Salt Lake City. Unpublished results from earlier experiments in St Louis were also available. There have been more recent experiments in Oklahoma City and New York City. Data from US cities will be less applicable to typical European cities. The experiments we performed were undertaken near the intersection of Marylebone and Gloucester Road.

Several experiments were successfully performed and the data made available for analysis and interpretation. These experiments were unique in that they provided data at a 3-minute resolution: a fine temporal resolution. Because the tracer release experiments were performed as part of the overall DAPPLE project we also had access to local, in-canopy, meteorology.

Two simple operational models were developed within the project. To these we added two existing simple models and looked at the model performance using the DAPPLE derived data and other existing field data on urban dispersion. These models were found to have adequate quality for many purposes, particularly the simplest that was developed in this project. Extensive Computational Fluid Dynamic (CFD) modelling was undertaken on idealised urban geometries and on the geometry of an area of London (about 1 square km). These were analysed and interpreted to obtain an improved understanding of flow and dispersion in urban areas and by parameterising the relevant processes improve the quality of the simpler models.

Funding of nearly £ 850K has been obtained from the Home Office to continue with this work.

Imperial College

DAPPLE was a large consortium project, focusing on a case study of traffic and air flow in building lined streets close to the intersection of Marylebone Road and Gloucester Place in Central London, to gain understanding that will be applicable to building-lined city streets in general as well as London in particular. Imperial College made a central contribution to the project in two areas:

- combining mean flow & turbulence data with vehicle emissions data at high spatial and temporal resolution to identify what factors have the greatest influence on the spatial and temporal variability of air pollution fields close to city streets, and

- carrying out an assessment of the air pollution exposure of people moving through the city streets as well as in roadside buildings, identifying the capability of operational air dispersion modelling techniques to capture the important features that control exposure and its variability.

The flow and turbulence data came from wind tunnel experiments at Surrey as well as computer simulations using Imperial's advanced adaptive mesh large eddy simulation, supported by field measurement data from measurements made by Reading and Leeds. The information on traffic movement and emissions came from field measurements of vehicle movement and traffic flow made by University of Leeds, supplemented by additional on-street observation and combined with simple assumptions about the relationship between acceleration and emissions.

Imperial College hosted and managed the field campaign, and took full responsibility for the measurements of exposure of bus users, pedestrians, cyclists, car drivers and users of taxis travelling through the study area. The project has exceeded our expectations in providing new insight into what happens in a real city, where people are exposed to high concentrations of pollutants during the short times they spend close to traffic emissions.

Post 9-11 the project was also extended to include more emphasis on applications of the same understanding to a variety of emergency response scenarios including the release of a gaseous or particulate toxin in a dense urban area. For example, it seems obvious now but not until you go out and measure these things do you realise that people move through a city faster than the pollution. Operational models that assume concentrations respond instantly to emissions are simply wrong - clouds of pollutants are still drifting around in a street canyon a minute or two after the emitting vehicles have departed, and people can then walk into the cloud and suffer surprisingly high short-term exposure. Sometimes the timing of traffic signals makes this worse, controlling people to cross at the most polluted point in the cycle. But there are other simple things we can do to reduce our exposure - for example DAPPLE's finding that concentrations drop very rapidly with distance from source shows how valuable it is to develop safe and pleasant back-street routes for pedestrians and cyclists where air quality is so much better than on a main road as little as 20 metres away. Even the trees planted along a major road reduce pedestrian exposure simply by forcing people to walk a couple of metres further from the kerb. So even though the transient flow and dispersion patterns we find in city streets initially appear to be very complicated, DAPPLE has found some simple principles and simplifying assumptions that can be used to give a new and vastly improved understanding of the processes that add up to give us those short-term peaks of pollution exposure that everyone recognises and complains about. Pollution control policy continues to overlook many aspects of these localised pollution hot-spots and there are moves to focus even less on them in future, but DAPPLE's interaction with the public and local government convinces us short-range urban pollution is important. Our dialogue with national policymakers therefore is ongoing.

University of Leeds

DAPPLE provided the opportunity for the traffic demand responsive controlled area of Marylebone in central London to be set up as an urban laboratory. However, for security reasons, it was not possible to automatically collect the data remotely. Instead, the City of London (TfL) captured and stored the data onto a computer at the area traffic control centre and forwarded the data to ITS on disks. The iC, instrumented City database, was configured to enable the traffic and all other survey data to be stored in a consistent way. The quality assurance methods, statistical analysis processes, congestion detection and emissions algorithms have been transferred to London. However, due to the fact that in the London network, one traffic detector spans two lanes, additional surveys and research were needed to understand the effect of masking caused by two vehicles travelling side by side simultaneously across the same detector.

ITS provided significant support to the other elements of the DAPPLE research, transferring knowledge in the use of equipment, survey design, quality assurance of data collected and methodological approaches, in particular the tracer release from the LANTERN instrumented car. This has led to a further, follow on project funded by the Home Office. Through close collaboration of the multidisciplinary research group of the LANTERN (Leeds health Air pollution, Noise, Traffic and Emissions Research Network) and that of DAPPLE, integrated survey data collection methodologies and co-ordinated research activities have resulted in significant mutual benefits and reduced costs. This was facilitated with RA study visits of typically 5 days duration in the partner universities, regular workshops, research meetings and by co-ordinating network and dissemination activities. Much time has been invested in highlighting the importance and relevance of the results of the research to the Intelligent Transport Systems community with positive results. In particular, London was used as an urban laboratory to demonstrate the transferability of models and DAPPLE used those set ups in Leeds and Leicester. This has significant impact on exploitation of the research carried out by the ITS over the recent decade and has resulted in a commercial application of the congestion algorithms in the Medway towns as a sub-contractor to SERCO.

University of Reading

DAPPLE relates to the EPSRC Infrastructure & Environment Programme for sustainable urban environments. It aims to quantify determinants of human exposure to air pollution from outdoor sources in the urban environment and to use the basic understanding gained in the evaluation and development of appropriate decision support tools, risk assessment methodologies, and best practice guidelines for their application, and in assessing the inherent uncertainty in their use.

The group at Reading will make two contributions. Firstly, we shall measure mean winds, turbulence and possibly heat flux during the intensive observation periods using up to 18 sonic anenometers, sited within the streets and above the roofs. These synchronised measurements will allow quantification of the coupling between flow above and within different streets, which will yield insight into the key dispersion mechanisms. Secondly, we shall use a sophisticated numerical model that computes the complex three-dimensional aair flow patterns around idealised cubical buildings to understand what drives the intermittent ventilation events that replaces polluted air from city streets with cleaner air from above."