DAPPLE - CASE FOR SUPPORT

The case for support includes a technical annex that describes the work-package methodologies and contains the full reference listing.

Previous track record

***University of Bristol*.**
Professor Peter Simmonds has over 35 years experience in the development of novel analytical methods and in atmospheric chemistry studies. He is also a member of the AGAGE international team of scientists concerned with long term measurements of many of the important atmospheric trace gases. Prof. Simmonds has been the PI in the BOA EU-funded project concerned with ozone levels in the atmosphere as well as in the URGENT (NERC funded) project on the dispersion of atmospheric gases in urban environments. In addition to his activities as a consultant to government and industry in both the United Kingdom and the United States. He has held the position of visiting Industrial Professor in the School of Chemistry at the University of Bristol since 1994. His research activities at Bristol are focussed on the development of automated, ultra-sensitive, analytical instrumentation which can be used at remote sites to determine the lifetime and trends of environmentally sensitive trace gases. Dr. Graham Nickless was Reader in Analytical Chemistry at Bristol for some 25 years and is now Honorary Senior Research Fellow and has led an active analytical group for over 35 years. During the last twelve years he has closely collaborated with Prof. Simmonds, being equally concerned with the measurement of the important atmospheric trace gases, especially those attributing to ozone depletion and radiative forcing. He is responsible for the day to day management of the laboratory where the development of the instrumentation takes place. A relatively recent development in their work is the application of these and related techniques, in conjunction with controlled tracer emissions, to the study of dispersion processes in urban areas [1,2].

***University of Cambridge*.**
Dr. Rex Britter, who spent several years working with the US Environmental Protection Agency at Research Triangle Park (North Carolina), has been a Reader in Environmental Fluid Dynamics since 1991 and has published very extensively on topics of relevance to the present proposal. He is currently completing his fourth book [3], co-authored with Professor Steve Hanna, that is due out in October 2001 and treats Wind Flow and Vapour Cloud Dispersion in Industrial and Urban Sites; it was commissioned and is to be published by the American Inst. of Chemical Engineers. He has recently been invited to write an article for the Annual Review of Fluid Mechanics on the same topic. With three others he co-founded, in 1985, Cambridge Environmental Research Consultants Ltd. (CERC), now a 25 strong company providing environmental and safety related consultancy and modelling services internationally to government agencies, industrial and other groups. He was one of the two editors of the Journal of Hazardous Materials from 1984-1995 and remains on the Editorial Board. Much of his recent work has addressed problems of urban air quality [4,5]. He is on the steering committee of SATURN, a European consortium studying urban air quality problems and was a member of TRAPOS, an EC funded project to study flow and pollutant dispersion in street canyons.

***Imperial College*.**
Professor Helen ApSimon is internationally recognised for her work on the integrated assessment of air pollution abatement options. She is best known for work on trans-boundary air pollution and acidification [6], but the work of the Imperial College Integrated Assessment Unit in recent years has widened to embrace impacts of air pollution on human health, including work at shorter length scales in the urban environment. The Urban Scale Integrated Assessment Model (USIAM) is under development to investigate the effectiveness versus acceptability or cost of a variety of policies for abatement of urban air pollution emissions. It currently considers attainment of air quality standards for the protection of human health, but is being extended to include more direct assessment of potential health benefits by considering exposure distribution at fine scale. Dr Roy Colvile has over ten years' experience of atmospheric science bringing together field experiment, computational modelling and laboratory measurement, initially studying the processes determining pathways of pollution through hill cap cloud. His interest moved into the urban environment on joining Imperial College in 1996. This has included leading Athena Scaperdas' seminal work on street canyon intersections in collaboration with Prof. Robins at Surrey [7,8,9], and the development of techniques for the assessment of the spatial variability of air pollution in the field. This includes development of links with transport as a major source of urban air pollution [10]. Prof. ApSimon and Dr Colvile are both Principal Investigators of the Pan-European urban air pollution SATURN sub-project [11] of the EUREKA environment project EUROTRAC. Dr Mark Nieuwenhuijsen also came to Imperial College in 1996, bringing a wide experience in environmental and occupational epidemiology especially

exposure assessment [12]. His work in collaboration with Dr Colvile includes application of atmospheric dispersion modelling to an assessment of exposure to arsenic in Slovakia . Directly preceding DAPPLE is their work together on the EPSRC Inland Surface Transport project on exposure of road users to particulate air pollution, including the development of the necessary sampling and modelling techniques [13].

University of Leeds.
Professor Margaret Bell holds a chair in the Institute for Transport Studies (ITS) at the University of Leeds. ITS has approximately 50 staff members and is one of the leading research units in the UK maintaining research income generation and publications securing a 5* rating in RAE 1996. ITS attracts £1.5m research income per annum and carries out a broad spectrum of research reflected by the specialist interest groups, including Safety, Economics and Driver Behaviour, Modelling, Network Modelling, Transport Policy and Appraisal, Traffic and Statistics and Overseas expertise. Both research facilities managed by ITS, the Advanced Driving Simulator (ADS) and the Instrumented City (IC) Facility, have made unique contributions to several prestigious international research projects. Professor Bell has an international reputation in the fields of traffic, air pollution and noise monitoring, modelling, control and management. The Instrumented City Facility (initially funded by the EPSRC) has provided the platform for her research since 1988 including the development of a roadside pollution monitor, on-line congestion assessment, real-time traffic emissions algorithm for air quality forecasting, evaluation methodology for traffic schemes and air quality management assessment and microscopic noise estimation in urban environments [14,15]. She is a member of the EPSRC Engineering College for peer assessment, gave evidence to the Transport Select Committee in July 1994 and has given expert advice on air quality in Bangkok.

University of Reading.
Dr Stephen Belcher is Reader in Meteorology in the 5*-rated Department of Meteorology, University of Reading, where he has led the research group in boundary-layer meteorology since 1994. Urban meteorology and exchange processes between the urban canopy and the boundary layer above have become one of the main topics of the group's research [16,17]. Further experimental work is currently being planned with the Department of Chemistry, University of Bristol (funded by the Met Support Unit of the UK Ministry of Defence) between buildings to elucidate the mechanism for venting of pollution out of street canyons. Methods have been developed for modelling urban areas as `porous media', where the effects of individual buildings are averaged, to produce a continuum [18]. A large eddy simulation of boundary layer flow through groups of buildings is now being developed. Dr Belcher also leads the UWERN Urban Meteorology Programme, which has funding from NERC, MoD, and the Ove Arup Partnership.

University of Surrey.
Prof. Alan Robins holds the WS Atkins, Westlakes Scientific Consultants, Royal Academy of Engineering Chair of Environmental Fluid Mechanics and is Director of the Environmental Flow Research Centre (EnFlo). EnFlo was established in 1993 as a focus for UK research activities based on laboratory scale simulation of atmospheric flow and pollutant dispersion. It is based around a large thermally stratified wind tunnel and a salinity stratified towing tank. EnFlo's research activities broadly cover flow and dispersion around buildings and groups of buildings, as well as orographic flows. Recent work relevant to this application includes collaborative research with Imperial College concerning dispersion at urban street intersections [8, 9, 19], CFD simulations of gas dispersion around buildings [20] and development and evaluation of the building effects model in ADMS, which has been a long standing activity [21]. Dr Eric Savory and Dr Sue Hughes are lectures in Civil Engineering. Dr Savory's research interests include physical modelling of pollutant plumes and local street canyon flows [19], numerical modelling of extreme wind events, such as tornadoes and micro-bursts, and their effects on structures. Dr Hughes is an applied mathematician with an extensive background in numerical modelling. She joined the University in 1995 and has directed her research interests towards the fields of traffic-related air pollution, local urban air quality and their modelling, in collaboration with County and Borough councils, evaluation of data from monitoring stations in rural and urban areas and studies of public perception of air quality [22].

Background and reasons why DAPPLE is important, relevant and timely

DAPPLE addresses the concerns of the EPSRC Infrastructure and Environment Programme for sustainable urban environments. Its key aim is to enhance understanding of pollutant dispersion processes in realistic urban environments and thereby make possible improvements in predictive ability that will enable better planning and management of urban air quality. Specifically, DAPPLE aims to quantify determinants of human exposure to air pollution from outdoor sources, over short periods of time as sources and people move together through the urban environment, as well as over longer periods of time in roadside buildings and the urban environment in general. In particular, interactions between the pollutant dispersion capability imposed by the urban infrastructure and the capacity and operation of its local transport system will be studied. The basic understanding gained will be used in the evaluation and development of appropriate decision support tools and risk assessment methodologies, and best practice guidelines for their application, and in assessing the inherent uncertainty in their use and their contribution to the sustainable development of safer, more pleasant cities.

Sources and pathways of exposure to air pollution in urban environments world-wide are many and varied, and are changing rapidly in response to increasing pressure from society for clean cities and sustainable development. Vehicle exhaust emissions are currently top of the agenda and will remain there longest in large cities outside Western Europe. In Europe (following the US in some respects) cleaner vehicles are penetrating the fleet, and further initiatives to control air pollution are becoming less cost-effective as the health risk from air pollution decreases. Nevertheless, society remains likely to demand exposure reduction measures as tolerance of risk declines, especially where exposed people are neither responsible for the emissions nor benefiting from the polluting activity (such as where cyclists and pedestrians are exposed to vehicle exhaust). This pressure will be greatest at the locations where the environment is most polluted (for example where traffic densities are very high or there is a high proportion of cold-start emissions), for carcinogenic pollutants to which there is no safe exposure limit, and when nuisance such as odour or visible pollution is also present. Non vehicle-exhaust emissions will also become more significant, including fine dust from roads and construction, traffic noise, carcinogens from dry cleaners and other small industrial or commercial activities that have similar potential to be sources of local urban pollution, and domestic emissions from heating and cooking.

Within UK academia, local and national government, we have internationally leading capabilities in the development and application of emissions and dispersion modelling tools for the assessment and improvement of urban air quality. Regulatory modelling, however, is currently applied with coarse spatial and temporal resolution, based on an unsubstantiated assumption that health effects are linear over a wide range of pollutant concentration. Operational model performance is good enough to produce useful air-quality maps in situations where pollutant concentrations are determined largely by emissions from sources more than a few hundred meters away from the receptor, over averaging times of hours to months. Higher spatial resolution for temporally averaged roadside air quality is available from two-dimensional semi-empirical street-canyon plume models. Where these are applicable, they provide an indication of what order of magnitude enhancement of concentrations can be expected at the most polluted locations, but they are not designed to provide any information about specific situations and are not applicable in many situations of interest (e.g. at busy urban street intersections). They cannot explain why empirical studies of personal exposure have revealed large differences between the amounts of pollution encountered by pairs of individuals following almost identical paths through a city. Environmental Health Officers, architects, traffic engineers and epidemiologists would like to know which source locations are typically responsible for exposure of road-users queuing at traffic signals at a junction, or which roads contribute most to back-street and indoor air quality [23]. We have empirical results from detailed studies of some individual cases and some generic urban topographies. Recently, some impressive examples have appeared of the application of complex engineering and research models of traffic micro-simulation, dispersion at street canyon intersections and penetration of pollution into buildings [7, 8, 9, 15]. However, we are far from establishing what constitutes best practice in the use of such models. Further, we have no general understanding of the process involved, especially over the first few hundred meters of fetch and over short time scales. Because of this, complex modelling cannot be applied to the solution of real built environment or urban sustainability problems, other than by the very time-consuming and costly procedure of developing suitable approaches on a case-by-case basis, often through the simulation of complementary wind tunnel experiments. Furthermore, the use of complex methods will remain an expensive option because of the large number of situations that must be analysed in any one application. There is a clear incentive to increase the level and range of detail that can be treated with 'regulatory' models and to optimise the process of linking the use of regulatory and complex models for the solution of individual problems.

The risk posed by the accidental or deliberate release of acutely toxic materials in a heavily populated centre is an additional and growing focus of concern. Much that has been discussed above is equally relevant to this issue since the management of such events, should they arise, requires knowledge of the pathways by which point-like sources disperse within the urban environment, the time scales over which this occurs and the inherent variability in the dispersion processes. Although expressed in terms of exposure to vehicle exhaust emissions, our proposed activities will have considerable bearing on problems of acute exposure, as was confirmed in discussions with HSE and (primarily) MoD, Porton Down. This established that MoD's main concern lay in ranges considerably greater than those addressed by DAPPLE and that, consequently, DAPPLE very usefully complemented the extensive experimental work and model development that had been commissioned [24]. A agreement was reached whereby the experimental work conducted for Porton Down would be made available to the DAPPLE consortium, with Porton Down becoming a key member of the DAPPLE stakeholder group (see later). A two-way interaction between the MoD work and DAPPLE will clearly prove most beneficial to all concerned.

Programme and methodology

DAPPLE brings together a multidisciplinary research group that is capable of undertaking monitoring and tracer experiments in the field and carrying out wind tunnel and computational simulations so as to provide better understanding of the physical processes affecting street and neighbourhood scale flow and pollutant dispersion. This will draw upon and complement related activities in the areas of traffic movement and control and emissions modelling. The consortium is of a size that will enable the understanding gained to be applied to the development of operational tools and procedures that are of value to the whole community. The proposed programme has seven objectives, as specified in detail below, and its overall success will be measured by the extent to which the outcomes of these fit together, in addition to the completion of each separately. A alternative division of the programme of research into five work-packages (Field measurement, Laboratory experiment, Air pollution modelling, Traffic modelling and emissions, Integration and dissemination) is used in the technical annex to this proposal.

1. Tracer dispersion measurements in field and laboratory, and their use to identify and characterise exposure pathways

(i) Make controlled emissions of a tracer from a near-kerb location in the field and in the wind tunnel, and make point measurements of its concentration in and around a street canyon intersection as well as in nearby back-streets (field and laboratory) plus inside a roadside building (field only).
(ii) Deduce from these measurements the paths followed by plumes and the advection time from source to receptor under the limited range of conditions to be observed in the field and a similar systematically varied set of incident wind parameters in the wind tunnel.
(iii) Assess the relative contribution of advection around and over buildings in the field and quantify, in the wind tunnel, at what distance advection around buildings at street level ceases to be the dominant exposure pathway.

2. Flow and turbulence measurements in field and laboratory, and assessment of the dispersion capability of the urban infrastructure

(i) Collect one or two four-week data sets of nearly continuous field measurements of flow and turbulence around a street canyon intersection, with measurements of pressure on building surfaces.
(ii) Measure the flow and turbulence parameters with greater spatial resolution in a wind tunnel for a set of conditions representative of the range of conditions encountered in the field, for detailed and reduced-detail models of the roadside building shapes and configuration and for generic building arrangements
(iii) Deduce from this how the pollutant dispersion capability of the urban infrastructure is determined by its topography, and use this to explain the descriptive information from Objective 1 (including an assessment of pollutant transfer across the building surface using the pressure measurements).

3. Vehicle movement field observation and micro-simulation to derive a high resolution local emissions inventory

(i) Collect and analyse real-time measurements of traffic movement, augmented during the intensive field study periods by observations of fleet composition and related parameters such as queue length.
(ii) Use these data with a traffic micro-simulation software linked to a high resolution emissions factors database, to produce a high resolution spatially and temporally resolved emissions map of the study area, quantifying the relative contributions of different length and time scales of emissions variability, and establish the quality of these results.

4. Pollutant mapping and CFD modelling to rank sources of spatial and temporal variability in air quality

(i) Collect one or two nearly continuous four-week field data-sets of measurements of one or more pollutants of vehicle exhaust origin with high spatial and temporal resolution, synchronised and co-located with the flow, turbulence and pressure measurements of Objective 2.

(ii) Set up and run computational fluid dynamics (CFD) models of a range of realistic conditions, to quantify the relative contributions of spatial and temporal variability of traffic conditions and emissions (from Objective 3), urban topography, weather conditions and flow & dispersion conditions (from Objective 2) to the spatial and temporal variability of concentrations on length scales from 1 m to 500 m and time scales from 1 second to days.

(iii) Use the field and laboratory data (from this objective and Objective 1), alongside the assessment of the emissions data quality from Objective 3, to assess the quality of the CFD simulations and reliability of the conclusions to be drawn from this objective.

5. Assessment of the representativeness of the DAPPLE case study periods

(i) Obtain long-term monitoring data describing local weather, traffic and pollution conditions.

(ii) Use these data to assess the extent to which the set of conditions studied during the intensive field campaigns and the conclusions drawn from them can be extrapolated to the whole year.

6. Assessment of human exposure and future requirements of operational modelling

(i) Make field measurements of exposure of individual people moving through and spending time in the study area, synchronised with the tracer dispersion field measurements, and construct a statistical regression model describing the variability in exposure in terms of route, weather conditions and other parameters.

(ii) Apply operational air quality management decision support software at high spatial resolution to the study area, and assess its capability to represent the processes that previous objectives identify as being important in determining exposure, its variability and source apportionment.

(iii) Recommend enhancements to current operational models and establish the resulting improvement in their performance.

(iv) Develop models, akin to those used for dispersion near buildings, to predict concentrations in the immediate wake of vehicles and evaluate their usefulness.

(v) Make recommendations for future operational modelling practice, specifically what output parameters might usefully be calculable and what level of detail in dispersion and traffic/emissions modelling is needed to underpin an effective decision support tool, including how to bridge the gap that currently exists between advanced and operational models.

7. Integration and dissemination of results

(i) In collaboration with CUPT, define data survey methodologies, data collection methodologies and data dictionaries, and adopt data structures and/or data mark-ups, that are aligned with CUPT (the Centre of Urban Pollution from Traffic) and other projects (LANTERN [14], MAPLE [25], Instrumented City [26], LAQN [27]) in order to facilitate data storage in a common database. Within this context address issues of data quality and measurement QA/QC procedures.

(ii) Document fully the project achievements and the extent to which each objective is achieved, how they relate to each other and to related work on the edge of DAPPLE (such as indoor air quality modelling), and their potential contribution to sustainable development.

(iii) Maintain web site with this information for reference by project partners during the project and to support other methods of dissemination on completion.

(iv) Hold regular workshop meetings with user-groups both for monitoring progress and to receive feed-back regarding potential and actual end-products.

The study will treat distances of order 1-500 m in the vicinity of a specific signal-controlled intersection of building-lined city streets (over times from seconds to a year), as well as a number of generic configurations. Pollutants to be considered will be those from outdoor sources, including emissions from buildings into the air outside, such that exposure levels out of doors will tend to be higher than most indoor levels of these pollutants. The processes to be studied are common to any pollutant that is chemically non-reactive and physically unchanged on the short time scales concerned, and to accidental releases as well as day-to-day emissions. Our study will therefore use examples of two or three specific pollutants that are most amenable to measurement in the field or laboratory, to generate results applicable to any pollutant of current or future interest.

The street canyon intersection is the simplest case that includes sufficient complexity to demonstrate most of the factors that will apply in a wide range of urban situations. We will aim to maximise our understanding in conditions of moderate wind and slow-moving traffic, for short and long-term releases on and alongside the road. Our remit will be to study the influence of roadside buildings on dispersion, the movement of vehicles on emissions variability, and interactions between these. The understanding derived from the situations studied in DAPPLE will provide a foundation for the application of work in progress elsewhere on the vehicle-induced turbulence and thermal effects that become more important in light-wind pollution episode conditions with faster moving vehicles. Within

DAPPLE, we aim to assess the extent to which our understanding of the basic street-canyon intersection under typical dispersion conditions reveals principles that are applicable to other urban situations and more adverse weather conditions. Detailed testing of the assumptions involved in such extrapolation will then be the subject of further investigation outside DAPPLE as appropriate.

The schedule for completion and the interaction between the work-packages (Field campaigns and longer-term measurements; Laboratory studies; Computational fluid dynamics studies; Traffic monitoring and emissions prediction; Integration and wider exploitation) is shown in Figure 1, at the end of this document. The field work is to be carried out during periods favouring windy, neutral boundary layer conditions and congested traffic, which implies the late autumn and early spring. With a project start data of 1/3/02, this in turn implies that the earliest dates for the two field campaigns are November, 2002, and February, 2003. This provides sufficient planning time ahead of the first, whilst there is sufficient scope overall to move this to February 2003 with the other trial in the November of that year, if so constrained. The laboratory work can commence as soon as the initial round of detailed planning considerations are completed. The timing of other programme items is largely determined by the schedule of the field work. A four year project duration has been set so that all sub-projects can be completed with sufficient time in-hand to ensure that the data-bases and reporting is properly accomplished before the project end.

Relevance to beneficiaries

Future EPSRC research on built environment, infrastructure and health, needs to provide the scientific and technological underpinning and the assessment tools to deliver sustainable development [28]. Large research projects should have sufficient impact to deliver this. Sufficient interdisciplinary expertise and concentration of effort will be brought together in DAPPLE in a focussed investigation to deliver the basic understanding that has been impossible to obtain by a piecemeal sequence of small, single-discipline investigations. DAPPLE will study a congested urban area where development is impeded by limited capacity of the urban infrastructure to permit the circulation and movement of people, goods, services, pollution and fresh air. We will observe situations where increasing activity is unsustainable because it results in congestion, increased occupancy of roads and buildings, decreased capacity, increased pollution (despite the introduction of cleaner vehicles), and hence increased exposure per unit mass of pollutant emitted. Furthermore, there will be examples of sub-sections of the urban population being exposed to levels of pollution out of proportion to their contribution to emissions. This is also unsustainable as it removes an incentive for individuals to adopt less polluting patterns of activity. We will investigate how activity can be increased whilst reducing pollution output per unit activity by changing the pattern of occupancy of the urban environment to reduce exposure per unit mass of pollutant emitted, especially the exposure of those who choose to adopt less polluting patterns of activity themselves. In the first instance, the efficient networking between DAPPLE and stakeholders that the project will build will allow incremental changes within existing urban structure to be identified that make the urban environment more pleasant and maintain its prosperity. We will then work to ensure that DAPPLE will attain a high profile nationally and internationally so that future urban development is carried out with regard to microscale sustainability issues. This will promote a step change in urban planning for sustainable development. This will need to be combined with analysis at larger spatial scales [29] to obtain the full picture, but omission of the microscale detail provided by DAPPLE would result in a total analysis that is incomplete and subject to significant error. This includes not only the identification of solutions to the problem, but also the continual process of improving the accuracy of assessments of the severity of the problem, for example environmental epidemiology where good exposure estimates are required to measure the impact of pollution on human health in the field. Commercial exploitation of DAPPLE's output will be in the development of urban environment decision support tools, such as air quality management software, which the investigators have an excellent track record of achieving. The future use of these evolving tools will also contribute to the debate on how to achieve sustainable urban development, including facilitation of the wider participation of stakeholders by the use of user-friendly graphical and GIS-based computer interfaces. The wide range of groups who should benefit from DAPPLE is listed on the EPS(RP) forms.

Dissemination and exploitation

A stakeholder group will be established and regularly consulted regarding the development of project plans as well as being kept fully in touch with progress through workshops and progress reports and the DAPPLE web-site. This will be particularly important in guiding the development of end products that are intended for operational use. Beneficiaries will be included in the stakeholder group and thus contribute directly to the project. Key stakeholders (e.g. TfL Streetmanagement, where there is interests in all parts of DAPPLE), in addition to having a representative at the stakeholder group meetings will, at appropriate points in the project, have selected members of the DAPPLE team visit and present to them aspects of the project of particular interest. Our intention is to make the project description and the information that we obtain available to other researchers and the user community through timely provision on the web-site and at conferences. Beneficiaries will therefore have access to the project output as it develops. At the end of each year of the project we will hold an open meeting (similar to previous APRIL Network mini-conferences) to provide opportunities for the benefit of potential users of the output and others not directly involved in the work. Finally, publication of interim and final project results and conclusions will be targeted to a range of journals, from those that are accessible to local government through leading specialist journals in transport, air dispersion, wind engineering, built environment and environmental policy, to the highest impact more general journals such as *New Scientist* and *Science*.

Justification of resources and project management

In addition to the six Principal Investigators and four Co-Investigators at the six participating institutions, support is requested for a team of 19. The main field campaign and, to a lesser extent, the preceding practice campaign, will benefit from an "all hands on deck" approach, including drawing in Ph.D. and M.Sc. students working on related projects. (Funds are requested to employ additional M.Sc. students on an hourly-paid basis to carry exposure sampling equipment.) A total of three full-time PDRAs, and one part-time technician (Imperial and Bristol) are to work solely on the field campaigns, with a part-time research officer at Leeds to interface with use of LANTERN equipment. A PDRA will be assisted by a PGRA at Surrey for the extensive wind tunnel experiments there. The modelling work will have PDRAs at Cambridge, Reading and Imperial, and a PGRA at Imperial on the CFD side, plus a team of four at Leeds (part-time while supported mostly on other contracts) on the traffic side. The responsibilities of these are discussed in more detail in the Technical Annexe. One final full-time PGRA will work at Imperial from September 2001, possibly after completing a DAPPLE-related M.Sc. dissertation project, to make a major contribution to the delivery of Objective 7 and to co-ordinate the personal exposure measurement campaign. A separately funded PhD student at Imperial will develop operational modelling of exposure as well as the Cambridge PDRA’s linking of tracer dispersion work to operational modelling. Part of an IT manager’s salary is requested to support the other seven Imperial College staff, plus part-time clerical support at Surrey devoted to project-specific tasks such as keeping up to date records of project progress linked to a project web site and feeding in to final reporting.

Consumables and equipment are requested at Imperial, Bristol and Cambridge for the field campaigns and Surrey for the wind tunnel. Surrey’s exceptional items cover electricity costs for running EnFlo wind tunnels (standing charge and power use charge) and contributions to the general facility maintenance and development costs (based on 200 days use). The Imperial College budget includes a contribution to the running costs of the APRIL Network (mostly staff costs for the network co-ordinators). This is vital to the effective dissemination and stakeholder participation in the development and application of the research in and for London and beyond. It will also ensure an effective interface is maintained with the Marylebone Road super-site and other London air quality monitoring activity. Significant travel and subsistence funding is requested by all the consortium partners, inevitably by some because of their deep involvement in field work in London, and also to ensure that there is a wide exchange of knowledge and expertise amongst all those involved. This is considered a key element of a consortium proposal and one that will be carefully managed during the DAPPLE project.

An annual workshop/meeting of the whole project team will be a focal point for management of the project with progress reports, target setting and agreement on publication and dissemination timetables. The Principal Investigators’ first priority will be to develop detailed plans. These will include technical and operational detail in each work-package along with establishment of data-base structures, quality assurance and control procedures, and the timing of deliverables. Dependencies, targets and time-scales will be established and the project managed against their satisfactory completion. More frequent meetings will take place before and after field campaigns for detailed planning and interpretation of the results. Selected team members will spend extended periods of time (weeks) working at other DAPPLE participant institutions. Periods of secondment will also be arranged for staff to work at Kings College alongside researchers in the South East Institute for Public Health who are responsible for the air quality monitoring super-site adjacent to our field study area. Alongside the APRIL Network support mentioned above, this will ensure cross-fertilisation between DAPPLE and the significant amount of measurement and modelling work in progress at and around that site.

Overall responsibility for the project management will be in the hands of Prof. Robins. Roy Colvile will work closely alongside him ensuring the parts of the project fit together, especially the field experiments that Imperial will co-ordinate, as well as interface with users through the APRIL Network.

DAPPLE - Schedule of activities

Work-package	Objectives	Year 1	Year 2	Year 3	Year 4
Field campaigns and longer-term measurements	1(i)				
	1(ii), (iii)				
	2(i), 4(i), 6(i)				
	5(i)				
	7(i)				
Laboratory studies	1(i)				
	1(ii), (iii)				
	2(i), (ii), (iii)				
	7(i)				
Computational fluid dynamics studies	4(ii)				
	4(iii)				
	6(ii)				
	6(iii), (iv)				
Traffic monitoring and emissions prediction	3(i)				
	3(ii)				
	4(i)				
	6(v)				
Integration and wider exploitation	5(ii)				
	6(v)				
	7(i)				
	7(ii)				
	7(iii), (iv)				

DAPPLE - Technical Annex

Work-package Methodologies

A1. Introduction

The general methodology used in DAPPLE has been tried and tested with great success over many years, but has not been applied before to a full interdisciplinary study of microscale urban air pollution, as some of the component tools have only recently reached a sufficiently advanced state to form part of an integrated project of this type. The combined use of field and wind tunnel flow and tracer dispersion studies allied to computer modelling provides the most secure and effective scientific approach. The field data contain all the complexities of the real problem, whereas the wind tunnel enables detailed and controlled experiments in repeated conditions, allowing for planned parameter variation. The proposed computer modelling covers the full range of techniques likely to be applied in practice and can be used both to develop an assessment of those methods and, where that is favourable, use those methods in conjunction with the experiments to develop the required scientific understanding. With that, further development of the operational level of modelling in particular becomes enabled.

Work to complete the project objectives will be organised into five work-packages: 1, Field campaigns and longer-term measurements; 2, Laboratory studies; 3, Computational fluid dynamics studies; 4, Traffic monitoring and emissions prediction; 5, Integration and wider exploitation.

A2.1 Field campaigns and longer-term measurements

Two field campaigns will be carried out at the junction of Marylebone Road and Gloucester Place [30], close to the Marylebone Road "super-site" air quality monitoring station. The experimental design is not highly sensitive to weather conditions, but a duration of four weeks for each campaign should avoid long periods of persistent calm conditions or atypically stormy weather. A single successful campaign will be sufficient to achieve all the project objectives, so the duplication will provide insurance against any difficulties with logistics, instrumentation or weather conditions. Tracer dispersion measurements during selected hours of the field campaign will be made using repeated twenty minute duration releases of alternatively perfluoromethylcyclohexane and perfluoromethylcyclopentane with collection of bag samples every 3 minutes for laboratory analysis by gas chromatography or negative ion chemical-ionisation mass spectrometry [1, 2]. Twelve receptor locations will be sampled per release run, from close to the source, around side streets into back-streets and including some indoor measurements. The source location will be held constant during conditions of varying wind speed and direction, but varied when weather conditions are fairly constant. Roadside buildings used for indoor measurements will also be instrumented for building surface pressure measurements. Up to eighteen sonic anemometers will make continuous measurements of flow and turbulence throughout the campaign, providing data that will allow quantification of the coupling between flow above and within different streets and which will yield insight into the key dispersion mechanisms.

Carbon monoxide measurements, using electrochemical cell instruments, will be co-located with the sonic anemometry and light scattering instruments (Osirus, Grimm) and deployed at three of the measurement sites to give an indication of spatial variability of particle concentrations in several size ranges. (The potentially poor sensitivity of such instruments to ultra-fine particles in fresh exhaust is acknowledged, but we expect to see some spatial variability in the larger particles from the most polluting vehicles, in dust from the road surface and in particles that have coagulated after emission, to which these instruments have good sensitivity and excellent time and particle size resolution. Detailed assessment of the dust suspension process and modelling of the particle microphysics are the subject of separate projects outside DAPPLE.). Traffic flow data will be obtained from the SCOOT traffic control induction loop system, with human observation to validate key parameters such as queue length, as in [26]. Fleet composition will also be determined by recording vehicle registration plates and relating these to entries in the DVLA database. Long-term continuous measurement data from several years will also be obtained from a roof-top automatic weather station, and compared with data from the London Weather Station and Heathrow Airport synoptic station, as well as air quality data from the nearby Marylebone Road "super-site" and other selected permanent monitoring sites in and around London [27].

Measurements of the exposure of people moving through the traffic on foot, on bicycles, in cars and buses will be made by a fleet of five portable $PM_{2.5}$ samplers with foam impactor for particle size discrimination sampling at 16 l/min [31]. Samples will be collected over approximately 20 minutes per sample [32] and then weighed for total mass and analysed for reflectance as a surrogate for diesel exhaust, calibrated *in situ* against elemental carbon measurements [33]. The sample lines downstream of the filter on the personal exposure samplers will be fitted with solid state carbon monoxide sensors, logged at one-minute time resolution, for comparison with fixed point electrochemical cell concentration measurements of the same gas. Calibration checks between the two instrument methods will be included [34]. A member of the team carrying exposure sampling equipment will also carry an alcohol supersaturation particle counter sensitive to particles below 10 nm in size; i.e. fresh vehicle exhaust emissions with a time resolution of several measurements per minute. For an homogeneous vehicle fleet, particle number and CO concentration would have a linear relationship with each other (after subtraction of background concentrations). Departures from such a relationship will therefore be attributable to differences in emissions between different types of vehicle and different phases of idling, acceleration, etc.. The exposure measurements, made by systematic sequences of repeated movements through the study area, will be synchronised with the tracer release experiments.

A2.2 Laboratory studies

Wind tunnel studies will be carried out in the 20 x 3.5 x 1.5m EnFlo wind tunnel at the University of Surrey, largely in neutral stability flows, though some work will be undertaken with moderately stable and unstable conditions to assess the sensitivities in the dispersion processes. A detailed model of the Marylebone Road field site will be constructed, along with simplified versions with progressively less detail, ending with generic urban street intersection models made from smooth, regular cuboids. Dispersion studies will use flame ionisation detector measurement of a hydrocarbon trace gas released into the flow from point sources; a 16 channel sampling and off-line analysis system will be used for mapping mean concentrations, in conjunction with 4 channels of on-line 'Fast FID' instrumentation that will also be used to provide concentration fluctuation and, in conjunction with anemometry, mass flux measurements. Flow-field measurements will utilise hot-wire, pulsed hot-wire and two-component laser-Doppler anemometry, with the latter being the preferred instrumentation. Flow, dispersion and flux measurements will first be made with the generic models in three or four wind directions representative of the conditions in which field measurements of tracer dispersion were made. Fluxes will be measured from the top of the street canyons and round the corners of buildings to develop understanding of pollutant transport mechanisms within and above simple urban intersections, and their dependence on wind direction and intersection geometry. This will build on and make use of the techniques developed in other studies completed and in progress and also provide empirical input for the development and evaluation of operational dispersion models. Initial studies of equal height buildings will build on recent work [7, 8, 9] and extend this to the first two refinements towards a more realistic model of the Marylebone Road site: unequal building height and variations in building distances from road centrelines.

The detailed full model will then be used and the full range of wind directions together with a number of source locations examined, before repeating selected cases using progressively simplified models until results showing the same salient features as the generic cases are obtained. Two sets of emission duration will be used, one scaled to match those of the field experiments and the other effectively continuous. Flow and turbulence measurements will be made at locations corresponding to those where sonic anemometers were deployed in the field, and at other locations covering a larger volume of the study area with higher spatial resolution. Similarly, tracer concentration measurements will be made at locations including those sampled in the field for the tracer release experiments as well as the locations of the CO measurements. It is anticipated that there will be some differences between the wind tunnel and the field that will be need to be explained. Most valuable will be the opportunity to study sensitivity to fine detail and to assess the spatial representativeness of the field measurements, which will make an important contribution to our ability to understand and explain the field observations. Specifically, the spatial representativeness of the roof-top weather station in the field will be assessed in the wind tunnel for the purposes of determining wind tunnel and computational model upstream wind speed and directions corresponding to conditions observed during the campaigns. This phase of the work will include the simulation of the field campaigns and the evaluation of the wind tunnel simulations that these provide. This phase of the work will benefit from collaboration with related research at the Meteorological Institute of the University of Hamburg. Additional experiments will be undertaken to resolve issues highlighted in the analysis of the first set of generic studies and the site simulations, and to address the importance of approach flow conditions, such as boundary layer height, stability, etc.

A 2.3 Computational fluid dynamics studies

Recent research [35, 36] has shown that dispersion near urban street intersections is an extremely complicated process that is very sensitive to topographical and source distributions, with significant flow and pollutant flux between the intersecting streets. This is not treated in current operational urban air quality models but was found to be quite well predicted by computational fluid mechanics (CFD) simulations with a two equation turbulence model, at least for the relatively simple geometries considered. Nevertheless, the best practice procedures and associated uncertainty in using CFD methods is far from clear, particularly when applied to real urban topography; the same can be said of operational models. Further, the most effective ways to develop operational models have yet to be established. DAPPLE is designed to tackle these issues and in doing so will make full use of related work within the EU TRAPOS programme [37] and, in particular, at the Ecole Centrale de Lyon and the University of Hamburg.

Much of CFD work will be undertaken with the StarCD code that has already been successfully used by the applicants in previous research related to urban street intersections [36], though in DAPPLE extending use to prediction of the statistical properties of short-term concentration levels. The code provides sufficient flexibility for present purposes in terms of grid design, the selection of accurate numerical schemes and the choice of turbulence model. The Reading Urban Canopy model (developed under NERC URGENT funding) will also be applied and its performance assessed relative to the CFD techniques and the operational models. This novel approach, which is of intermediate complexity, represents the urban canopy as a porous medium. DAPPLE will provide the first major systematic test of this methodology applied to fine scale urban air quality and will determine where it 'sits' in the hierarchy of operational modelling tools.

Calculations will be undertaken for the chosen field site and the generic cases using a number of strategies regarding model set-up (i.e. resolution, domain size, boundary conditions, turbulence schemes, etc.) and assessed through inter-comparison of solution response and by direct comparisons with the detailed flow and dispersion measurements from the wind tunnel programme. Together with comparison with the wind tunnel study of the effect of model refinement, this will then be used to relate performance measures to modelling approaches and thus to identify examples of best practice. Modelling strategies will be designed to reveal the relationships between model performance, model set-up and computational requirements. CFD calculations following the recommended best practice will then be used to aid and extend interpretation of the wind tunnel and field experiments. Sensitivity studies will be carried out, initially in parallel with those in the wind tunnel but then extending into areas that will not or cannot be covered by the wind tunnel work (e.g. thermal effects due to solar heating or vehicle heat emissions). The whole programme will be designed to work with and build upon the developing best practice guidelines of the ERCOFTAC Special Interest Group on "Quality and Trust in Industrial CFD".

A2.4 Traffic monitoring and emissions prediction

The full problem has (at least) two additional features that are as important in practice as those discussed above. The first is the estimation of emissions and the second the evaluation of the exposure to pollutants of individuals within the street system. Traffic flow and emissions modelling is a discipline in its own right. Without skill at this level, subsequent dispersion and dose modelling become almost purposeless. Within DAPPLE we will initially use the current best practice in emission modelling but subsequently improved methodologies that will result from related, but separate research work. The target is a congested street system in central London, an situation not previously addressed in developing these emission models. Thus within DAPPLE the applicability of current methods to conditions like those in central London will be determined along with the relative improvement resulting from application of the enhanced methodologies.

High resolution maps of temporally varying emissions of major vehicle-related pollutants, including the specific pollutants that were measured in the field, will be derived using traffic micro-simulation models, traffic flow and vehicle emissions data. This will first be carried our using current simulation capabilities. A link will be installed to collect data from SCOOT Region Marylebone Road, from which traffic flow will be determined with a five minute resolution. A SCOOT network data-base will be established which, along with relevant topographical data, will be used to set up the COMIS analysis of the Region. Manual validation of traffic characteristics will be undertaken because video camera surveys are not practical in heavily congested traffic as number plates cannot be reliably viewed. SCOOT and other vehicle and fleet characteristics data collected during the survey periods will be used to calculate hour-by-hour traffic emissions for input to the air quality model, so that their performance can be assessed against field data. This will include analysis of their sensitivity to uncertainty in the input data. A statistical analysis and evaluation of the traffic performance of the

SCOOT region throughout the active period of the project will also be carried out. The traffic emissions model will be revised in the light of the achievements of the proposed CUPT programme that will run concurrently with DAPPLE. The earlier calculations with the air quality models will then be reassessed, thus providing improved air quality predictions as well as an independent examination of the transferability and performance of the new emission models.

A2.5 Integration and wider exploitation

The relation between personal exposure and fixed point monitoring results is complex and not at all well understood. It is however an essential factor in providing a realistic assessment of the effects of urban air pollution on human health. DAPPLE will provide valuable field data that can be used with statistical regression analysis to describe the variability in exposure in terms of route, weather conditions and other parameters. The ability of operational air quality management decision support software to represent these processes can then be assessed and developments to the underlying modelling techniques proposed and tested. This important and complex problem will be used as a focus for bringing the various facets of DAPPLE together, though the applicability of the understanding thus gained will not be restricted to exposure assessment. The needs associated with the assessment of exposure to "continuous" releases of pollutants such as vehicle exhaust emissions will then be compared and contrasted with those associated with the assessment of the impact of accidental and other short-term releases. In this way, we will gain a hitherto elusive understanding of how a modelling or assessment tool developed for one purpose can be fit for application to a different but related problem, and learn to identify where caution must be exercised in such adaptations.

As part of the integration activity of DAPPLE, operational models (such as ADMS-Urban, and the urban dispersion model, UDM [24]) will therefore be run to assess and inter-compare their current level of performance and sensitivity to input variability when applied to single streets and intersections. The most stringent test applied to operational modelling will be assessments of the ability of such simplified methods to reproduce the general level and variability of the road-user exposure measurements, and the extent to which this is attributable to faithful representation of the processes that DAPPLE identifies to be important in determining such exposure.

The need for enhancements and new modelling capabilities will thus be identified. Attention will be focussed on the concentration field at short range and in the immediate wakes of vehicles, the exchange of pollutants between streets at an intersection and the overall balance of flow and pollutant interchange from a section of a street network, all of which are hardly if ever considered at all in operational models. A scientific assessment will thus be completed of the likely capability of existing and enhanced operational models to predict the extent to which small-scale changes in traffic movement relative to roadside buildings can reduce the impact of emissions on exposure. Considering such stringent demands on an operational model will also provide the basis of an assessment, using the results of DAPPLE, of its likely performance for any other related application, including the dispersion of short-term releases. This phase of the research will benefit from collaboration with related work on street network modelling at the Ecole Centrale de Lyon. Modelling developments will be expressed in a generic manner and their performance assessed both in a stand-alone form and in conjunction with ADMS-Urban.

The process of integrating the results from the interrelated parts of DAPPLE thus leads to two pathways for exploitation and application of the project output. Deliverables in terms of potential and actual improvement of tools and methods for assessing the problem is the first pathway, and this is explored further in the following section. The second pathway is the application of the understanding gained in DAPPLE, directly to address the problem of how best to minimise air pollution exposure and the air pollution impact of activity in the urban environment. A range of short and long term applications of this nature are discussed in the Case for Support under "Relevance to EPSRC". The combination of CFD and emissions modelling, supported by the field and laboratory measurements and tested by comparison with operational modelling of exposure of moving road users, will identify for the first time what factors and processes have the greatest control on short-term and longer-term exposure to air pollution from outdoor sources in the urban environment. It will thus be possible to focus effort on these more important factors. Conversely, it will be possible to ignore supposed air pollution control benefits where we show the total effect to be small. The greatest inequities between the major emitters and exposed low-emissions road users will be identified, so that the greatest attention in future can be devoted to reducing these inequities to reward changes to less polluting behaviour and thus contribute to sustainable development. Identifying these linkages, and placing them on a much firmer foundation in relation to related policy and social science research than it is possible to develop in this proposal, will be a major activity of DAPPLE's fifth work-package. Combining this with the assessment and application of operational modelling tools and risk assessment procedures will provide a unique synthesis of the practical with the theoretical, applied science connected directly to the basic study of air flow, dispersion and traffic in the preceding work-packages. This will make DAPPLE a truly interdisciplinary project with the potential to have greater impact than a purely engineering or scientific approach would typically deliver.

A3. Deliverables

A prime aim of DAPPLE is to deliver the understanding required to carry out the vital task of scientific assessment of decision support tools and risk assessment methodologies and the relationship between this and their applicability and likely performance in given applications. Methods for transferring the scientific understanding developed in DAPPLE into practical tools will also emerge and be explored as the project progresses; e.g. DAPPLE's quantitative results will, in some instances, form a basis of improved parameterisation. Implementation of such improved parameterisation schemes and evaluation of the performance of the resulting improved model will be appropriate as a means of testing our understanding. This more empirical approach will form a secondary path by which DAPPLE can deliver recommendations concerning modelling tools and their suitability in various applications. A number of strands is envisaged at the outset though these will no doubt change during the course of the work.

Practical methods: The effectiveness of using box and integral models, whereby a street canyon model is linked to an intersection model, will be assessed. In this approach the intersection model provides the exchange of air flow and pollutant fluxes between the streets at the intersection (resting heavily on empiricism) and the street canyon model is modified to include flow along the street that is input at the intersection and output at the following intersection. The aim will be to investigate elements that can be assembled into real street networks and to identify exchanges between the 'below roof level' regime and the boundary layer above.

These approaches will allow improvement of the current street canyon parameterisation schemes in urban air quality decision support tools based on Gaussian-type atmospheric dispersion models, especially where DAPPLE indicates that important features are not resolved by the existing models, for example for the assessment of exposure. This kind of model also provides the source-receptor relationships required by the urban scale integrated assessment modelling in USIAM.

Intermediate methods: Modelling approaches that will be assessed include the use of distributed force modelling, making use of expertise at Reading and Cambridge, and array modelling and plume splitting procedures. The latter is a natural extension of present building effects models, with expertise from Cambridge and Surrey. We seek to collaborate with EC Lyon on the first and MOD/DSTL on the second approach.

These methods relate to operational decision support tools (and hence to integrated assessment modelling) at two levels: firstly where there is a semi-empirical model to resolve one or more individual buildings (although DAPPLE would need to provide some guidance as to when it is appropriate and necessary to invoke such a model, as current urban air quality assessments generally only consider street canyons, the single building models being usually reserved for industrial point sources) and secondly, where an operational model considers the effect of diffuse urban emissions in a grid-wise fashion at source-receptor distances greater than about 200 metres.

Advanced methods: This includes both CFD and wind tunnel procedures and in both our aims will be to establish and demonstrate best practice and the sensitivity of solution reliability in moving away from best practice. We will also establish procedures for integrating output from such methods into practical methods. The CFD work will involve collaboration with the ERCOFTAC Quality and Trust in CFD initiative, including the QNet project based at Surrey, and related work at EC Lyons and Hamburg.

Wider exploitation: Close interactions will be maintained with other projects and groups in the UK working on similar topics, in particular with LANTERN projects such as CUPT (Centre of Urban Pollution from Traffic), to enhance effectiveness for all concerned. With regard to LANTERN projects, DAPPLE will provide data from a central London site and in turn be able to use data from other sites where driving habits and traffic conditions are different. We will work with CUPT to ensure a consistent approach to data structure and access, and quality control and assurance procedures. A regular series of progress reports and project workshops is planned to keep stakeholders fully informed of plans and achievements and to ensure feedback on all aspects of the work. Reports, meeting proceedings etc. will all be available electronically.

Careful attention to quality assurance and data management will be essential to facilitate the wider exploitation of DAPPLE output. A project-wide quality plan will be established as a matter of priority during the initial stages of the project. An analysis of the data requirements of the DAPPLE project will be undertaken on the same time scale. Data dictionaries, data structures and/or data mark-ups that are aligned with CUPT will be defined to facilitate the upload of data into a common data-base.

A4. Deployment of resources

Significant travel and subsistence funding is requested by all the consortium partners (inevitably by some because of their deep involvement in field work in London) to ensure that there is a wide exchange of knowledge and expertise amongst all those involved. This is considered a key element of a consortium proposal and one that will be carefully managed during the DAPPLE project. A general description of the total resources requested for the project is given in the main Case for Support. Here, more detail of the responsibility of individual members of staff and other associated costs are given separately for each participating institution.

University of Bristol. A PDRA (100%) and Technician (at 20%) are requested for a one year period to support the tracer experiments in London. Travel and subsistence requirements are substantial in order to cover the two field campaigns, each of four weeks duration. Consumables, exceptional items and equipment are all required for the execution of the tracer studies.

University of Cambridge. A PDRA (100%) is requested for two years to contribute to the field tracer studies by direct collaboration with Bristol and by making fine particle concentration measurements (the equipment requirement is associated with this activity), and to support the work at Cambridge associated with the analysis and interpretation studies, in particular the expression of the knowledge gained in operational modelling.

Imperial College. A PDRA (Karl Ropkins named, following his successful work on UTMC air quality sensor deployment in London and with the REACH Consortium equipment) is requested full time for the first 16 months of the project to prepare the ground for the field campaigns and ensure all the measurements are accommodated. David Ames is to be employed part-time over the same period to take charge of the modification of our PM2.5 exposure samplers to extend their capability to measure and log CO concentration continuously. A full-time PDRA is requested for three years, receiving training in setting up a CFD model, and then carrying out original research interfacing this to time varying and spatially resolved modelling emissions data. No staff costs are needed for the related application of the operational modelling to exposure assessment, because an externally funded PhD student is already working on this topic. Tom Bentham will have been completing his NERC-funded PhD work on adaptive mesh LES modelling of street canyon intersections supported by wind tunnel studies which are closely related to but not included in DAPPLE; his experience at this interface between measurement and modelling will then be brought on to the latter years of the project, at which point it will be becoming clear in what areas the steady-state CFD solutions are missing some of the important time-resolved phenomena. One full-time PGRA is requested for the duration of the project starting in the seventh month to take primary responsibility for much of Work-package 5; the opportunity to precede this with an MSc dissertation project tied to DAPPLE will assist in recruiting one of the College's best Environmental Technology MSc graduates to this post, as such a person is likely to have exactly the interdisciplinary skills required, as well as being able to take some management responsibility for the exposure monitoring in the field campaigns. Additional funds are requested for casual labour to carry the exposure sampling equipment. The whole Imperial College effort is supported part-time by the Air Pollution Research Group's IT manager. Other costs at the College are for the field experiment, especially the exposure sampling, plus the networking and co-ordination that are discussed in the main Case for Support.

University of Leeds. The PGRA and PDRA requirements are for work on the traffic flow and emission model for the DAPPLE field site. This activity will draw heavily on work currently in hand and planned (under a separate but related project) at Leeds. Funding for purchase of equipment to contribute to the DAPPLE field studies is not required, this equipment already having been provided by the LANTERN JIF award.

University of Reading. The named PDRA (Dr Janet Barlow) is currently working on an NERC funded project concerning the structure of the urban boundary layer and exchange processes between the urban canopy and the boundary layer above. This expertise will transfer directly to DAPPLE where work at Reading will concentrate on wind field measurements at the field site and flow modelling using the distributed resistance approach. Such a model has been developed at Reading for application to built-up areas and DAPPLE will benefit from this activity and provide a critical examination of the method.

University of Surrey. Work will concentrate on wind tunnel modelling and computational model assessment and development. The named PDRA (Dr Hong Cheng) is currently working on wind tunnel studies of urban boundary layer structure in the EnFlo laboratory, as part of the NERC project described above, and will bring considerable and relevant expertise to the DAPPLE work. The amount of wind tunnel work to be conducted is substantial and a PGRA is requested to work with the PDRA. This will enable both to take part in the computational work, extending the skills of the PDRA and providing a wide range of experience for the PGRA. A equipment request is made for new photomultipliers to improve the performance of the laser Doppler anemometry (LDA) system to be used in the project and the pre-purchase of a laser-tube to ensure continuous availability of the LDA instrument throughout the project. Exceptional items cover electricity costs for running EnFlo wind tunnels (standing charge and power use charge) and contributions to the general facility maintenance and development costs (based on 200 days use). Funding is also requested towards the EnFlo Infrastructure PDRA post (Dr Paul Hayden, 25%) and an associated technician post (Mr Tom Lawton, 25%), these being essential posts to the successful operation and development of the wind tunnel facilities and instrumentation – enabling research to concentrate very time-effectively on their research. The remaining technician funding requested is for model manufacture and related work.

The staff effort and expenditure for each consortium member is tabulated below, followed by the breakdown of these figures between the five work-packages. As intended, the major effort and expenditure is associated with the computational work and in integration, interpretation and exploitation of the knowledge gained. The traffic monitoring and emissions prediction work is relatively small (but essential), this reflecting that the effort is associated with adapting work already completed or separately funded to the London site.

Staff Effort and Expenditure							
	Bristol	Cam-bridge	Read-ing	Leeds	IC	Surrey	**Totals**
RA months	12	24	36	18	140	72	**302**
Staff costs, £	33282	48435	85153	53967	319802	220835	**755513**
Travel etc., £	18000	10000	8700	12000	18100	12000	**75100**
Consumables, £	9450	27000	3000	13964	11870	22000	**87284**
Exceptional, £					50000	34500	**84500**
Equipment, £	12925	8120	4935		30043	25332	**96420**
Large capital, £							
Indirect costs, £	15310	22281	39170	24825	147108	101391	**347536**
Facilities etc., £	17500						**17500**
Totals, £	**106467**	**115836**	**140958**	**104756**	**576923**	**416251**	
Grand total							**£ 1 461 191**

Distribution of effort and expenditure between work-packages		
Work Package	Staff effort, %	Expenditure, %
Field campaigns and longer-term measurements	16	19
Laboratory studies	12	16
Computational fluid dynamics studies	36	30
Traffic monitoring and emissions predictions	4	5
Integration and wider exploitation	32	30

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