RESEARCH AT THE CENTRE FOR TRANSPORT STUDIES IMPERIAL COLLEGE LONDON 2002-2003

Prof. John Polak

This section reports the research activities of staff and students of the Centre for Transport Studies at Imperial College. The Centre includes the Railway Technology Strategy Centre and the Imperial College Engineering Geomatics Group. Further information on current research is available from the Centre's website (www.cts.cv.ic.ac.uk).

TRANSPORT ECONOMICS, POLICY AND REGULATION

Road traffic demand elasticities. *D.J. Graham and S. Glaister*
This project, which is being undertaken on behalf of the UK Department for Transport, is concerned with road traffic related demand elasticities. Elasticities play a key role in many aspects of modelling and policy, but there is a lack of consistency in their definition, estimation and use in policy studies. The aim of this project was to provide a critical review of the estimation and use of elasticities. Particular attention was paid to the effects of different modelling assumptions on results.
Graham and Glaister (2002c,e,f)

Pricing, investment and taxation of transport. *S. Glaister and D.J. Graham*
Transport prices are often set on the basis of historical precedent or political expediency and their use as tools of transport management has received insufficient attention. In this report we explore what would be the effect if all transport users were to be charged a "full price". The research reviews the literature to determine the relevant elasticities, values of time, incremental costs etc. We then develop a model to indicate the economic, social and environmental consequences of changing transport prices and investment, and evaluate transport policies within this model.
Graham and Glaister (2002a)

Urban metros: cost structures and productivity. *D.J. Graham, S. Glaister, and A. Couto.*
The research identifies factors that give rise to variation in output growth, in labour productivity and in total factor productivity in urban metro operations. A methodology is developed which decomposes metro output change into contributions made by constant returns input growth, non-constant returns to network size and density, and technology. Results reveal constant returns to scale but increasing returns to density. Total factor productivity change, due both to non-constant returns and technological change, has been of great importance in differentiating the output performance of metros.
Graham, Couto, Adeney and Glaister (2002)

Innovative Public Transport. *B.J. Condry, W.E. Adeney and W.Y. Ochieng.*
This research was undertaken for the Department for Transport to evaluate the economic performance of existing and emerging public transport technologies. The study was based on a theoretical transport corridor, with costs of providing the service and the resulting capacity estimated for each mode. This enabled comparisons to be made between existing conventional modes, such as light rail and bus, and selected innovative modes. The innovative modes were the ULTra personalised transport system and the rail-based Parry

People Mover vehicles. The results from the study will assist public transport policy, technology development and planning studies.
Condry, Adeney and Ochieng (2002)

Lloyd's Register - Asset Management. *W.E. Adeney, R.A. Cochrane and M. Berman.*
This project comprises two interconnected studies. Stage One was the development of a guide to asset management practice in industries employing safety and performance critical assets. This study identified what previous work had been undertaken in the development of generic approaches to asset management and associated standards. Stage Two consisted of a series of interviews with companies in a range of industries (oil & gas, bulk chemical, electricity distribution and urban mass transit), which had previously been identified as best practice in their corporate approach to asset management. The approach to asset management in each of these organisations was compared and contrasted, and identified important common elements that appear to exist in all effective systems.
Adeney Cochrane and Berman (2002,3)

An analysis of issues affecting the demand for Thames Riverboat Services. *R.J. Anderson, M.A. Quddus and J.W. Polak.*
This research, which was funded by the Corporation of London., involved a study into the potential demand for high-quality commuter river services along the Thames between Wandsworth, Central London, Canary Wharf and Masthouse Terrace on the Isle of Dogs. The objective of the study was to investigate the scale and nature of the demand for a range of possible commuter river services. The work was carried out in three distinct phases. Phase 1 comprised a catchment analysis and Phase 2 involved qualitative research with potential users of riverboat commuting services. The results from the first two phases provided the input for Phase 3, the assessment of the scale and nature of demand for river service.
Anderson, Quddus and Polak. (2003)

MTR Corporation Ltd., Hong Kong – Metro pricing and financing. *R. J. Anderson, D.J. Graham and S. Glaister*.
This research was undertaken as part of the CoMET metro benchmarking work. Increasing metro fares provides additional revenue for investment in the system, but also reduces demand. MTRC finance capital investment from fares, and the aim of this work was to assess the . An analysis of the fare models used by each of the metros in the CoMET group was carried out, as well as an assessment of the relative fare levels, their relationship to affordability in each of the cities and the associated elasticity to demand. Consideration was also given to the opportunities for increasing fares during periods of inflation and deflation.

Pricing acceptability in the transport sector (PATS). *J.W. Polak and A. Majumdar in association with various European collaborators*
The objective of this project, which is supported by the European Commission, is to investigate the acceptability of various types of pricing measures and to identify the key characteristics of pricing packages and implementation strategies capable of commanding support widespread support. The work carried out this year has focussed drawing conclusions from extensive survey work carried out with citizens and key decision makers in nine European countries. The results of this analysis indicate that the acceptability of pricing measures is critically influenced by perceptions of fairness, value and transparency (especially in the use of revenues).
Link and Polak (2002)

TRANSPORT AND THE ENVIRONMENT

Natural gas bus conversions and transport emissions in developing countries. *R. North (supervisors: W.Y. Ochieng and J.W. Polak)*
　　　　Local air pollution is a serious and growing problem in many cities in less developed countries. The trend of extremely rapid motorisation rates observed in these cities over recent years is predicted to continue in line with their economic development. The consequent need for increased mobility must be satisfied whilst simultaneously improving the local air quality. This research investigates the role of vehicle maintenance regimes in the cost-effective control of emissions from the in-use fleet. Current maintenance practices in both developed and developing countries will be assessed, and a framework will be developed in order to define optimal maintenance procedures adapted to local conditions of use. These procedures will then be tested to evaluate their potential contribution to the control of mobile source emissions.

A model of aviation air space, emissions, and the impact on climate change. *R.B. Noland, R. Toumi, and V. Williams*
　　　　This project, which is fiunded under the EPSRC Future Integrated Transport initaive, uses the RAMS airspace simulation model and existing databases of aircraft engine emissions to develop a model of the temporal and spatial output of aircraft emissions. This is used to examine potential changes in emissions and contrail formation. Different aviation demand growth scenarios as well as various policy options to minimize contrail formation have been examined.
Williams, Noland and Toumi (2002a,b)

Development and demonstration of a real time vehicle performance and emissions monitoring system (VPEMS). *W.Y. Ochieng, J.W. Polak, R.B. Noland, J-Y Park, L. Zhao, P. Elliott, D. Briggs and J. Gulliver in association with Sira Technologies Ltd and Saturn Technologies Ltd*
　　　　The objective of this three-year project (awarded under the Foresight Vehicle LINK scheme) is to develop and demonstrate a real time vehicle performance monitoring system (VPEMS). The VPEMS will be fitted within vehicles to monitor driver/vehicle performance and the level of emissions internal and external to the vehicle. Potential applications of VPEMS include; monitoring of environmental compliance, identification of polluters and effective management and maintenance of vehicles, provision of real-time pollution maps, promotion of the development of in-cabin anti-pollution measures, real-time route guidance and fleet management incorporating vehicle emission data. Trials of the system are currently being carried out.
Ochieng, Polak, Noland, Park, Zhao, Briggs, Crookell, Evans, Walker and Randolph (2003a,b)

Monitoring air pollution and health in Indian cities. *J.W. Polak, W.Y. Ochieng, R.B. Noland and D. Briggs*
　　　　The objective of this research, which is supported by the UK Department of Trade and Industry, is to provide an overview of the current air quality situation in Indian cities with a view to identifying the key requirements for the establishment of appropriate monitoring and assessment networks. Particular attention will be paid to the potential contribution of appropriate existing and emerging traffic system and vehicle technologies.

Microscopic modelling of air pollution from road traffic. *J.Y. Park in collaboration with Kent County Council (supervisor: J.W. Polak)*

The objective of this study is to develop a microscopic approach to the modelling of air pollution from road traffic. A stochastic microscopic traffic flow simulation model (VISSIM) is linked to a speed-based microscopic emission inventory model (MODEM). The output of the linked VISSIM-MODEM model is then used as input to a Gaussian dispersion model, which predicts pollution concentrations over an area. The combined model reproduces well conventional macroscopic relationships between average speed and emission. Detailed validation has been carried out using data collected over 2 weeks from small area of Maidstone controlled by the SCOOT system.

TRANSPORT SAFETY

Child pedestrian casualties. *D.J. Graham, R.J. Anderson and S. Glaister.*

This research analyses child pedestrian casualties in England, focusing on the influence of socio-economic deprivation. It develops an area-based model and presents estimates of the model at the level of the 8414 wards. The results detect an association between increased deprivation and higher numbers of pedestrian casualties across England. The deprivation effect is strong both for all child casualties and for children killed or seriously injured. Estimates for adult casualties also reveal a positive and significant association with increasing deprivation, but the magnitude of the effect is smaller than for children. The strength of the relationship increases as the level of deprivation increases and it is particularly large in London. Separate effects are established for each of the six components that constitute the Index of Multiple Deprivation.
Graham, Glaister and Anderson (2002), Grayling, Hallam, Graham, Anderson and Glaister (2002)

Analysis of road fatalities as a function of infrastructure and county-level socio-demographics. *R.B. Noland and L. Oh.*

Detailed time-series of road accident statistics and infrastructure expansions of selected US States were made available by the US Highway Safety Information System (HSIS). The road fatalities and reported accidents were analysed for the State of Illinois using a fixed effect negative binomial model. Independent variables included changes in road network infrastructure and geometric design and socio-demographic changes over the corresponding time periods. Specific geometric design factors such as the lane widths, shoulder widths and medians were analysed.
Noland and Oh (2002)

The influence of transport infrastructure and medical technology on traffic fatalities. *R.B. Noland and M.A. Quddus*

This newly funded project will evaluate the relative contribution of transport infrastructure elements and medical technology in reducing transport related fatalities. This follows on from previous research conducted that evaluated these effects using US data. Results demonstrated that medical technology, demographic changes, and increased seatbelt use have been the primary factors reducing traffic fatalities over time. Various infrastructure improvements, normally associated with improving safety, were found to increase fatalities and injuries. A similar analysis will be conducted using GIS data to extract infrastructure elements using UK data.
Noland and Quddus (2002a,b)

An analyses of trends in traffic fatalities in developed countries. *R.B. Noland*

This study uses the International Road and Traffic Database and OECD Health data to examine trends in traffic fatalities in developed industrialised countries. The fatality data are linked to various measures of medical technology improvements and the findings strongly suggest that improvements in medical technology over time have significantly reduced traffic-related fatalities.

The effects of speed limit enforcement cameras. *S. Hess and J.W. Polak*

Speed Limit Enforcement Cameras (SLEC) have been in operation in Great Britain since 1991. The aim of this research was to analyse the effects of SLECs on accident rates in Cambridgeshire, UK, using time series data collected over a 10 year period. A time series analysis of the accident data revealed the presence of both trend and seasonality components. A method was developed to remove the influence of these two components from the data and compare mean accident levels before and after installation of the camera. The method was also constructed in such a way that it would be able to distinguish between the actual effects of the camera installation and the effects of regression to mean. This analysis indicated that the introduction of a SLEC is associated with decrease in injury accidents by 31.26%.
Hess and Polak (2003c)

Cost-Benefit analysis of road safety improvements. *R.B. Noland in association with ICF Consulting*

This study seeks to analyze and document the benefits and costs of implementing various proposed European Commission directives to improve road safety. The analyses presented provides an estimate of the costs and benefits for the proposed initiatives. These are improving enforcement with respect to three important contributors to fatalities in road accidents - drunk driving, speeding and non-use of seat belts, and improving enforcement of existing EC road safety laws relating to commercial road transport. Analyses suggests that implementation of these measures will provide a positive benefit-cost ratio.

An analysis of motorcycle injury and vehicle damage severity using ordered probit models. *R.B. Noland and M.A. Quddus*

Motorcycles constitute about 19% of all motorized vehicles in Singapore but account for 40% of total fatalities. In this project, an ordered probit model is used to examine factors that affect the injury severity of motorcycle accidents and the severity of damage to the vehicle. Nine years of motorcycle accident data was obtained for Singapore based on police reports and analysed using ordered probit models. Several rider, vehicle and situational factors are significantly associated with injury severity and the severity of damage to the vehicle. In addition, it was also found that both injury severity and vehicle damage severity levels are decreasing over time.
Quddus, Noland and Chin (2002)

A spatial analysis of seat-belt usage and seat-belt laws. *R.B. Noland, W.Y. Ochieng and A. Majumdar*

Seat-belt usage has increased significantly in the US since the introduction of mandatory seat-belt usage laws in the 1980's. This paper analyses the impact of these laws on increasing seat-belt usage while controlling for other state-specific variables. Spatial analyses techniques are employed to further explain these effects. Spatial autocorrelation is found in the data but diminishes over time. Spatial correlation also exhibits a clear east-west direction. Results show that both secondary and primary seat-belt laws have been effective at increasing

seat-belt usage. In addition, these effects cross state boundaries, implying an even larger level of effectiveness than direct measurement would suggest.
Majumdar, Noland and Ochieng (2002)

Fatal train accidents on Britain's main line railways. *A.W. Evans*
Andrew Evans continued to work on the statistical analysis of fatal train accidents on the British main line railway network. He produced his regular update of estimates of train accident risk, based on fatal accident data in 1967-2001. He reviewed the question of whether risks are increasing after the accident at Potters Bar in May, and concluded that the evidence is that they are not.
Evans (2002a,b,c)

Intermodal transport risk comparisons. *A W Evans*
Evans conducted two studies of accident risks across the modes, in both cases focusing on fatalities and fatal accidents. The first was a contribution on transport risks to a special issue of the Journal of the Royal Statistical Society on the communication of risk. The second was the production and review for the HSE of empirical FN-curves of transport fatal accidents, based on data for road, rail and aviation in 1967 to 2001. FN-curves plot the frequency of accidents with N or more fatalities against N; they are a means of presenting information on the frequency and severity of accidents.
Evans (2003a,b)

Train protection. *A W Evans*
In April the railway industry published a report on the European Rail Traffic Management System (ERTMS) in Britain, proposing slower implementation than had been recommended by the Uff/Cullen inquiry into train protection systems. This is partly to take advantage of technical developments that are in prospect but not yet operational, and partly to avoid the need for premature resignalling. The HSE commissioned a review of economic aspects of that work, led by consultants NERA, to which Evans was a major contributor. The HSC and the government have now agreed that a slower timetable is sensible.
NERA (2003)

Long term fatal railway accident data. *A W Evans and A Kinoshita-Bashforth*
This project for Railway Safety involves the retrieval of complete and accurate sets of data on fatal train accidents and on multiple-fatality railway accidents in Britain since 1946. The data will provide a basis for long-term accident analysis, and a context for the current railway safety performance. The project will be completed during 2003.

Interactions between rail and road safety. *A W Evans*
Evans was awarded a grant under the Future Integrated Transport programme to study interactions between rail and road safety, concentrating particularly on the safety consequences of inter-modal shifts between rail and road, and on the contributions to overall risk of different stages of multi-modal journeys. The work begins in earnest in 2003.

TRAVEL BEHAVIOUR AND DEMAND MODELLING

Scoping a model travel behaviour dataset programme to address research and policy needs in transport. *J.W. Polak, J-D. Schmoecker and M.R. Wigan, J. Cooper (Napier University)*

The aim of this project, which is supported by the EPSRC, is to undertake a scoping study to identify key areas where data limitations have held back needed behavioural research and to define how best, in the light of current trends in data collection methods, these limitations can be addressed. The project involves extensive collaboration with the academic community, Government and the private sector.

Polak, Wigan, Schmoecker and Cooper (2003)

The implications of income, taste and substitution effects for the assessment of user benefits using discrete choice models. *J.W. Polak*

Recent developments in mixed multinomial logit (MMNL) and generalised extreme value (GEV) models of travel choice have raised a number of important issues regarding the calculation of welfare measures. In particular, in many cases, the simple log-sum measure of welfare will no longer of appropriate and alternative measures should be used. There is also evidence to suggest that welfare estimates can be extremely sensitive to the subtle details of model specification. The objectives of this project are (a) to develop recommendations regarding how welfare assessment should be carried out under different MMNL and GEV model forms and utility specifications and (b) to investigate the extent to which heterogeneity of tastes, complex substitution patterns and income effects would, if present and detected by such models, affect the appraisal of transport policy measures (relative to current MNL/NL approaches).

Optimising personal logistics: Improving the efficiency of travel by improved household activity scheduling. *J.W. Polak, W.Y. Ochieng and M.G.H. Bell and in association with PTV AG and Saturn Technologies Ltd.*

A wide range of conventional traveller information systems are available to support travellers' trip planning and re-planning behaviour. However, existing systems focus on he planning of individual trips rather than the broader (and more relevant) problem of scheduling activity patterns. Moreover, few systems exploit the growing opportunity to exploit positioning and navigation technologies to offer planning support that takes account of a travellers current spatio-temporal location. The overall aims of this project are to develop a Personal Scheduling Assistant (PSA) function to support individuals and households in their activity scheduling behaviour and to develop, field test and evaluate a prototype device delivering the PSA function in a portable handheld device with position capability.

Short and potential long-term travel behaviour responses to fuel shortages. *J.W. Polak, R.B. Noland, M.G.H. Bell and N. Thorpe (University of Newcastle), Diana Wofinden (STRS)*

The aim of this project, which is supported jointly by Transport for London and the Commission for Integrated Transport, is to study the behavioural adaptation stemming from the fuel crisis of September 2000. Focus groups and a telephone survey are used to explore the adaptations made in response to restrictions in fuel availability. The results indicate that households were generally able to cope with temporary interruptions in fuel supply, but that prolonged restrictions would cause hardship, especially amongst those dependent on cars. The impacts are influenced by physical and informational factors, and by life cycle, gender and activity-specific considerations.

Noland, Polak, Bell and Thorpe (2003); Thorpe, Bell, Polak and Noland (2002)

Generalised discrete choice models of departure time choice. *J. W. Polak and S. Athanassiou (Steer Davies Gleave)*

Conventional multinomial and hierarchical logit models are not well suited to time period choice. The aim of this research is to develop and test a number of generalised discrete choice model structures and to evaluate the extent to which they offer significant advantages compared to conventional logit-based approaches, both in terms of calibration performance and in typical policy analysis applications. The models examined include the ordered generalised extreme value models and various formulations of mixed logit model.

Day-to-day dynamics and traveller leaning. *A. Jotisankasa (supervisor: J.W. Polak)*

Day to day variations in travel behaviour arise from a number of sources, including the gradual learning by travellers of uncertain network conditions. The objective of this research is to develop and validate an individual level model of day-to-day adaptation and traveller learning and to integrate this model into a microscopic traffic simulator. As a first step, current work is concerned with investigating the influence of a variety of different learning mechanisms on the dynamic evolution of route and departure time choice in a simple Vickrey-style congested system.
Jotisankasa (2002,3)

The scheduling of commuter tours in congested networks with pricing. *J.W. Polak and B. G. Heydecker (UCL)*

An extensive literature exists on the equilibrium scheduling of peak period trips in idealised networks and the welfare impacts of alternative forms of pricing. Such models are useful in that they provide insights into the underlying structure of more complex systems. However, they are limited because they consider the scheduling only of single trips, rather than complete tours. The aim of this project is to extend these existing models to accommodate tours and to explore the welfare impact of alternative pricing regimes.

The integration of multi-modal reliability in the assessment of transport schemes. *J.W. Polak, R.B. Noland, X-L. Han, J.J. Bates in association with P.M. Jones (University of Westminster) and AEA Technologies (with Railtrack, the Association of Train Operating Companies, iTIS Holdings., Highways Agency and Department for Transport)*

The aims of this project are to develop improved methods for the assessment and evaluation of multi-modal transport schemes and improved models and software for the operational and strategic monitoring and reporting of reliability in multi-modal systems. This work extends earlier research undertaken by the project team, which has focused on the reliability of individual modes. The work involves the development of new theoretical models and algorithms and the collection and consolidation of network monitoring data from relevant road and rail operators and managers.

A model of airport competition in the London area. *S. Hess (supervisor: J.W. Polak)*

The aim of this project is to develop a model for airport competition in the London area. Such a model can be used to predict the decision of a (departing) traveller faced with a choice of different airports, all of which are offering flights (either direct or with a stop-over) to his chosen destination and different access modes. Such multi-dimensional choice situations are complex and require development and extension of existing discrete choice models and associated estimation technology.
Hess (2002,3); Hess and Polak (2002, 2003a,b,c,d); Hess, Polak and Daly (2003)

Activity duration decisions in activity-based scheduling behaviour. *L Oh (supervisor: J.W. Polak)*

The objective of this research is to model individuals' time allocation and scheduling behaviour. The research makes use of data from a detailed 7-day activity-travel diary and from several waves of the UK National Travel Survey. The single level duration model is extended to a multilevel formulation in which the hierarchical structure of individuals within households is incorporated. A typology of activity duration behaviour is produced which it is suggested can be serve as a useful guideline for the general use of activity duration decision stages in activity scheduling models. The nature and magnitude of the interactions between household members depending on their duty allocation and household relations are quantified and influence of inter-personal constraints on daily time-use behaviour is explored. The models developed are applied to predict the likely impacts of socio-economic changes and policy measures to daily time use and travel
Oh and Polak (2002,3)

Access to activities and services in urban Canada: Behavioural processes that condition equity and sustainability. *J.W. Polak, M. Lee-Gosselin (University of Laval) and S. Doherty (Imperial College and Wilfred Laurier University)*

Imperial College is an external collaborator in this major 5-year research programme supported by the Social Science and Humanities Research Council of Canada. The objectives of this programme (which involves collaboration between 5 Canadian Universities - Laval, Québec, Toronto Calgary and Wilfred Laurier) is to make fundamental advances in the understanding and modelling of urban travel behaviour. Imperial College is contributing to a number of the research themes including the dynamics of household car ownership, longitudinal studies of activities, travel and urban form and alternative frameworks for modelling individual behavioural response.

An informatics grid for e-science at Imperial College. *J.W. Polak with J. Darlington (Department of Computing), S. Richardson, J. Scott, C. Higgens and B. Robertson (Medical School)*

The aim of this project, which is supported under the Research Council's Joint Research Infrastructure Initiative, is to provide facilities for the storage and analysis of very large scale datasets, of the sort that arise in many scientific, engineering and medical disciplines. The Centre for Transport Studies will use the facility to undertake the analysis of a range of very large spatio-temporal datasets arising in a number of areas of its activity, including data from instrumented vehicle fleets, the simulation traces of highly detailed microsimulation models of traffic systems and large Monte Carlo simulation work.

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NETWORK FLOW AND CONTROL

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Capacity constraint transit assignment. *M.G.H. Bell and J-D. Schmoecker*

This research proposes a new approach to solving the transit network loading problem using absorbing Markov Chains. The approach handles congested transit networks, where some passengers will not be able to board a given line because of insufficient space on board. It is assumed that passengers coming from different origins and travelling to different destinations mingle on platforms, so that the OD-composition of boarders does not vary over a time-interval. The network loading method becomes a transit assignment method when route choice behaviour is added. It is shown how risk-averse route choice behaviour can influence the equilibrium transit assignment. Future research will look at the common line

problem under congestion and develop a software implementation for congested transit assignment.

Bell and Schmoecker (2002); Bell, Schmoecker, Iida and Lam (2002), Schmoecker, Bell and Lee (2002)

Application of fuzzy logic to traffic assignment in developing countries. *Didik Rudjito (supervisor: M.G.H. Bell)*

The problem of traffic assignment in less developed countries has received relatively little attention. Traffic in developing countries tends to be more heterogeneous, necessitating a multi-class approach to assignment. The objective of this research is to apply fuzzy logic to multi-class traffic assignment to suit the characteristics of developing countries. Smooth speed-flow functions, which are difficult to establish, are replaced by look-up tables based on data collected in Bandung City, Indonesia, during March to April 2002.

Travel time variability. *J.W. Polak, R.B. Noland and X-L. Han in association with D. Watling (University of Leeds), Mott McDonald and the Transport Research Laboratory*

The objective of this work, which is being undertaken on behalf of the UK Department for Transport, is to develop procedures to enable the influence of travel time variability to be incorporated into highway modelling and appraisal procedures. Particular attention is focused on incorporating a treatment of incident-induced variability into traffic assignment procedures. Work has focused on both updating the stand alone INCIBEN model and on implementing various developments within CONTRAM.

Performance of the SCOOT Traffic Control System in an Indian Context. *J-D, Schmoecker in association with F. Crouch and S.D. Wright (Newcastle University)*

The aim of this project was to assess the performance of the SCOOT traffic control system in the context of an Indian city. A range of performance data were collected from the SCOOT installation in New Delhi and used to assess the performance of the system with respect to the expectations for similarly sized systems in a Western city. Recommendations regarding future application in mixed traffic conditions are made.

Crouch, Schmoecker, and Wright (2003)

Modelling travel time variability with applications to the monitoring of transport network performance. *S. Robinson (supervisor: J.W. Polak)*

A major issue for urban network managers is the monitoring of travel time and travel time variability. The aim of this research is to develop methods to enable the measurement of travel time and travel time variability in urban contexts using data from Inductive Loop Detectors. Three models are proposed for the determination of travel time. The first is an explicit model of traffic states based on regression analysis. The second is based on Artificial Neural Networks, ANN, and the third on correlation techniques. Building on this, link travel time data are used to model the factors causing travel time variability. This research is being carried out in conjunction with Transport for London who are collaborating with Imperial College London to construct an archive of raw ILD data obtained from the London SCOOT system.

Measures of road traffic congestion. *J.W. Polak, W.Y. Ochieng, X.L. Han, S. Robinson, M.A. Quddus and in association with Mouchel and John Bates Services*

The overall aim of this project, which is supported by the UK Department for Transport, is to assess the scope that exists for improvements in the measurement of road traffic congestion as a result of the availability of a range of potential new data sources

including both fixed and mobile sensor systems. The first stage of the project involved a detailed appraisal of the potential sources and suppliers. The second stage involved the development of a theoretical framework for the use of disparate data sources (linked to the analysis of selected sample data). The third stage involves the planning and design of majot follow up studies.

Secondary road network traffic management strategies (SENSOR). *M.G.H. Bell with R. Bird, P. Blythe, S. Grosso and J. Nelson. (Newcastle University) and various European collaborators*

The aim of this new project is to develop appropriate tools and strategies for the collection of real time traffic data on secondary roads. The project will consider what data are needed and how they can be most effectively collected. Imperial College will have an advisory role in number aspects of the project.

Network reliability. *M.G.H. Bell and J-D* Schmoecker

Ongoing work in this area is concerned with the development of game-theoretic and related methods to characterise concepts of network reliability, taking into account topological, performance and behavioural consideration. A variety of applications of these methods have been developed.
Bell (2003); Schmoecker and Bell (2002)

TRANSPORT PLANNING METHODS

Optimising the use of partial information in urban and regional systems (OPUS). *J.W. Polak, M. Collop (Transport for London), H. Neffendorf (Katalysis), M. Logie (Minnerva) and A. Westlake (SSC) and various European partners.*

The aim of this project, which is supported by EUROSTAT, is to develop a generic statistical framework for the optimal combination of complex spatial and temporal data from survey, census, real-time and telematic sources. The framework will be sufficiently general to be applicable to a wide range of potential socio-economic domains, but will be specifically applied in the context of transport applications in London and Zurich. The project will also undertake feasibility studies of the applicability of the methods to a number of related transport and health domains.

Estimation of the use of smartcards by concessionary travellers. *J.W. Polak and L. Oh in association with John Bates Services.*

Bus operators issue smartcards to specified groups of concessionary passengers. For the transport authority to compensate the bus operators, the frequency of concessionary trips must be estimated. However, the smartcard records only the entry point of a journey and not the exit. A proposal has been made to estimate the Average Equivalent Single Fare (AESF) for concessionary passengers by matching the boarding point of a journey with a feasible alighting point of the previously recorded journey using 10-year metropolitan bus trip records from the UK National Travel Survey. The concessionary groups are characterised by their tour formation, trip chains and bus trip profiles in support of the estimation.

A D2D Travel Budget Scheme for London. *M.G.H. Bell, J.W. Polak, Schmöcker, J.-D., F. Kurauchi*

The objective of this project is to assess the viability of travel budgets with specific reference to the Accessible Transport Pilot Project in the London Borough of Newham. It is proposed to assess the potential viability of allocating subsidy to users of door-to-door

services according to two criteria; the specific mobility needs of the user determined by mobility assessment, and the range of transport choices available to the user. This needs-based fares assessment would allow for resources in terms of subsidy per trip and transport availability to be targeted to those most in need. Part of the project will be to develop a desktop simulation to model the effects of changes to the current travel budget concept in Newham.

Bell, Polak, Schmoecker and Kurauchi (2003)

London orbital multi-modal studies (ORBIT). *J.W. Polak and S.Glaister in association with Brown and Root. Marcel Enchenique and Partners, Kennedy and Donkin, Chris Blanford and Associates, Bell-Pottinger and Accent Marketing and Research.*

The objective of this ongoing project, which is being undertaken on behalf of the Government Office for the South East, is to develop a long-term multi-modal strategy for the sustainable management of the M25 orbital motorway and more generally for the transport corridor around London. The project involves extensive analysis and modelling work, linked to public consultation with a range of individual and collective interests. Imperial College is advising on a range issues concerned with the modelling of travel demand and the development of appropriate evaluation frameworks.

Modelling the effects of transport on social inclusion. *J.W. Polak, R.B. Noland, B. Morton in association with F. Hodgson (University of Leeds) and Mott McDonald*

The objective of this project, which is being carried out on behalf of the UK Department of Transport Local Government and the Regions is to identify how best to incorporate the impacts of transport policy on social inclusion into current transport modelling and appraisal methodology, including the current NATA framework. The work involved a review of conceptual, measurement and modelling issues (covering both UK and US practice) leading to recommendations regarding suitable development in modelling techniques. A case study application of some of the developments advocated is undertaken in the West Midlands.

Polak, Noland, van Vuren, Hodgson, and Morton, (2002)

Modelling accessibility to and by public transport. *O. Ashiru in association with Surrey County Council (supervisors: J.W. Polak and R.B. Noland)*

The aim of this research is to develop improved methods of modelling public transport accessibility and to integrate these methods into the planning and management of public transport service provision at a local level. Three key areas have been identified for study; (i) conceptual and theoretical issues related to different notions of accessibility (particularly, accessibility to public transport and accessibility by means of public transport to desired destinations), (ii) the treatment of public transport service reliability and information effects and (iii) treatment of multi-modal trips. An initial application of a model including temporal aspects of accessibility has been undertaken.

Ashiru (2003); Ashiru, Polak and Noland (2002, 2003a,b)

Analysis of factors affecting the volume of bicycle traffic in London. *J.W. Polak and X.L. Han*

The Mayor's transport strategy for London includes explicit targets to increrase the amount of cycling in London. Monitoring the attainment to these targets is especially difficult in the case of cycling, since it is significantly affected a range of exogenous factors. The aim of this project was to quantify the effect of temperature, rainfall, time of day, day of week and season on the magnitude of bicycle traffic. The project made use of link count data from 54 locations over the London area collected during 2000 and 2001. The results of a time series

analysis indicate that bicycle traffic is significantly affected by temperature, rainfall, day of week and season. However, the relationships are not straightforward, with evidence of non-linearities in the response to temperature and threshold effects in the response to rainfall.
Polak, Han and Smith (2003)

Expert-system based prediction of demand for international transport in Europe (EXPEDITE). *J.W. Polak, J-Y Park (with various European collaborators)*

The aim of this project, which is supported under the European Commission's 5th framework programme, are to produce a modelling system capable of generating multi-modal demand forecasts for the years 2005, 2010, 2015, 2020 for all travel in Europe, covering all distance bands for passenger and freight movements. The approach adopted involves combining information on the level and responsiveness of travel demand within the different market segments from a variety of different sources including existing regional, nation and international modelling systems. Current work focuses on estimating the sensitivity of intra-zonal flows, especially freight flows, to changes in the generalised cost of travel.

RAILWAY OPERATIONS AND MANAGEMENT

Metro Railway Benchmarking CoMET and Nova. *W.E. Adeney, G. Kwan, R.J. Anderson, D.J. Graham, N.G. Harris, R.C.d'A. Hirsch, T.M. Ridley and S. Glaister.*

The objectives of these two ongoing studies is to collate and disseminate best practice in a number of key aspects of urban rail operations and planning. The CoMET study undertaken on behalf of a consortium of nine of the world's largest urban rail operators (Berlin, Hong Kong MTRC, London, Mexico, Paris, New York, Sao Paulo, and Tokyo). The study, now in its ninth year, assists metro railways to identify and implement best practice through benchmarking comparisons and analytical case studies. The results of all CoMET studies have been made available to consortium members via the RTSC website. Nova has similar overall objectives to those of CoMET, but consists of a consortium of nine medium sized urban rail systems (Dublin DART, Glasgow, Hong Kong KCRC, Lisbon, Madrid, Montreal, Naples, Newcastle-upon-Tyne and Singapore).
Adeney, Kwan, Anderson, Graham, Harris, Hirsch, Ridley and Glaister.(2003a)

Improved tools for railway capacity and access management (IMPROVERAIL)
R.J. Anderson, W.E. Adeney and R.C.d'A. Hirsch in association with various European collaborators.

The objective of this EC 5th Framework research project is to develop improved modelling techniques for the management of railway infrastructure, including methods for capacity and access management. The research will be completed over a 2-year period, with many other European collaborators. In 2002, research has focussed on the development of specific benchmarking techniques for railway infrastructure companies. The research has shown that European railway infrastructure companies have carried out few benchmarking studies and therefore a methodological framework for benchmarking has been developed. The methodology has been tested in pilot projects with the support of industry partners, covering operational, commercial and managerial performance.
Adeney, Kwan, Anderson, Graham, Harris, Hirsch, Ridley and Glaister.(2003b)

Rail corridor portfolio management. *R.J. Anderson, K. Vitet in association with various European collaborators.*

The aim of this research was to produce a set of recommended procedures that allow railway infrastructure managers to take investment decisions in a sound and consistent

manner, taking into account as many relevant aspects as possible. The work involved identifying the discrete costs and revenues of selected network sections followed by the comparison of productivity indicators for the sections between the different railway networks. Consideration was also given to the routing of traffic over the network and the resulting implications for infrastructure and network performance.

Parametric approaches to benchmarking urban metros. *D.J. Graham, R.J. Anderson, W.E. Adeney, R.C.d'A. Hirsch.*

The efficiency and productivity of urban rail systems depends upon many factors. In the past benchmarking studies have tended to consider such factors independently, masking the effect of potentially significant interactions. The objectives of this research are to develop a methodology to enable the estimation of production and cost functions that take into account the simultaneous effect of several factors. These will be used for benchmarking the productivity of urban metros.

Benchmarking of Irish Railways: Iarnród Éireann Strategy Development Programme 2002/3. *R. J. Anderson, R.C.d'A.Hirsch and K. Vitet.*

This research was undertaken for Iarnród Éireann (Irish Rail) and involved the benchmarking of the Irish railway system against a number of other railway organisations in order to identify the critical success factors for the company, and a set of associated key performance indicators. The other organisations were mainly either the national railways of other European countries or UK train operating companies (TOCs). Data was obtained both from publicly available sources and by means of a questionnaire sent to the selected railway organisations.
Anderson, Hirsch and Vitet (2003)

Railway track access arrangements and charging. *W.E. Adeney, L. Ripley, N.G. Harris.*

This project was carried out on behalf of the Hellenic Railways Organisation (OSE) and the Attiko (Athens) Metro in conjunction with the National Technical University of Athens. It considers the reasons why the shared use of railway infrastructure might be considered beneficial, and the theoretical basis for the apportionment of joint costs between users. It explored the mechanisms by which the use of railway infrastructure by train operators is governed and charged for in Britain, with specific reference to the joint use of infrastructure by mainline (National Rail) and metro (London Underground) operators. It also looked at some of the technical and operational implications of adopting an infrastructure-sharing arrangement.
Adeney, Ripley and Harris.

CoMET Metro Reliability, Punctuality and Regularity. *J-D Schmoecker, W.E. Adeney & R.C.d'A. Hirsch.*

The study compares metros' operational performance: reliability, punctuality and regularity. It examines metros' response to service disruption, and looks to identify strategies for returning the service to schedule with the minimum impact on the passenger. This study analyses metro punctuality, regularity and train delays, and considers the characteristics of different systems, resulting in an evaluation of factors and strategies that lead to reliable service. The study will also identify effective service management strategies, through the analysis of both quantitative and qualitative data on the perceived efficacy of current recovery strategies.
Schmoecker, Adeney and Hirsch (2002)

GEOMATIC ENGINEERING

Earthquake risk assessment using remote sensing. *W.Y. Ochieng and j.J. Bommer in association with the NPA consortium*

A consortium consisting of Imperial College and European industry was awarded a contract by the European Space Agency (ESA) under the Long Term Development of Earth Observation Market initiative. The project is developing and validating the technique of Permanent Scatterer Interforemetry Synthetic Aperture Radar (PSInSAR) for the purpose of deriving high precision maps of ground displacements over time. GPS is to be used to validate the new PSInSAR concept.

Structural stability monitoring using satellite positioning systems and GIS. *W.Y. Ochieng, A. Elghazouli and D. Walsh (University of Leeds)*

The objective of this project is to specify and demonstrate a system architecture for structural deformation monitoring based on satellite positioning and geographical information systems technologies, and to develop methods for using this data to understand structural behaviour. The work requires a multi-disciplinary approach combining advanced satellite positioning and geographical information systems technologies with background in structural analysis and assessment as well as external input from practicing engineering firms. The project is being undertaken with the support of English Heritage.

Space-based dynamic positioning in built-up environments. *W.Y.Ochieng and L. Zhao.*

This is an ongoing project on high accuracy and high integrity dynamic positioning in urban areas to support road transport navigation. Part of this has been the contribution of Imperial College London to the review of the Countdown Bus Information System operated by Transport for London (TfL). The project assessed the capability of stand-alone and augmented navigation space-based systems to support the navigation functionality of the Countdown system. Currently, the system uses roadside beacons and distance information from odometer to determine the location of buses. Research is continuing to investigate data fusion techniques involving the integration of GNSS with low-cost MEMS technology sensors to enable required navigation performance in built-up areas.
Ochieng and Zhao (2002)

GPS performance characterisation in Greater London. *W.Y. Ochieng and L. Zhao*

The Countdown system provide real time information on bus services in London. It relies on beacon based Automatic Vehicle Location (AVL) technology to provide its positioning function. The advent of the GPS has provided an alternative to terrestrial based positioning systems such as microwave beacons. The objective of this project is to characterise the performance of GPS in the Greater London area to enable Transport for London to make an informed decision on whether GPS is a viable alternative technology to microwave beacons.

AIR TRANSPORT POLICY AND MANAGEMENT

Assessment of the impact of future air traffic management technologies and procedures on airspace capacity. *W.Y. Ochieng, J.W. Polak and A. Majumdar in association with Eurocontrol and QinetiQ*

This three-year project (funded by the EPSRC and the Royal Society) builds on existing research to study in detail the main parameters that affect airspace capacity and to develop mathematical models relating these parameters to capacity. The models will benefit

aviation authorities for the strategic planning of current and future airspace leading to increased capacity, reduced safety risks and costs associated with congestion.
Majumdar and Ochieng (2002)

GPS Integrity and potential impact on aviation safety. *W.Y. Ochieng*

This project studied the strengths and weaknesses of the global positioning system (GPS) of satellites as a navigation tool for civil aircraft. The study quantified the level of integrity (safety) afforded by GPS both at system and user levels, related this to civil aircraft navigation requirements and finally, proposed techniques for improving the performance of GPS to meet the requirements. The project was supported by the Civil Aviation Authority and contributed to the long-term programme on hazard analysis of navigation systems for civil aircraft.
Ochieng (2002), Ochieng *et al* (2003)

Hazard analysis of air traffic services. *W.Y. Ochieng.*
The objective of this project (on behalf of the UK Civil Aviation Authority) is to assess the level of safety of air traffic services (ATS). The initial phase of this has already been completed having identified the failure modes associated with the navigation component of ATS. The remaining phases are to be carried out in collaboration with the University of Leeds and Helios Technology Limited.
Ochieng (2002), Ochieng *et al* (2003)

A framework for modelling the capacity of Europe's airspace using a model of air traffic controller workload. *A. Majumdar (supervisor: J.W. Polak)*

This research uses a framework based upon a simulation model of the air traffic controller's workload to estimate airspace capacity. It does this by first considering the air traffic and airspace geometry factors that affect controller workload and then using the RAMS simulation model of controller workload (developed by EUROCONTROL) to make an estimate of airspace capacity. A series of simulation experiments covering continental European airspace, with both current and future air traffic demands, are undertaken using RAMS. The outputs of the simulations are analysed using a general linear modelling framework. The capacity estimates are then used to analyse airspace sector utilisation in Europe and identify bottlenecks.
Majumdar (2002)

Cross-sectional time-series analysis using simulated controller workload data. *W.Y. Ochieng and A. Majumdar*
This project was funded by Eurocontrol to carry out further research on understanding airspace capacity's dependence on controller workload. A cross-sectional time-series analysis using simulated controller workload data was carried out and a mathematical relationship between workload and capacity was developed.
Majumdar and Ochieng (2003)

FREIGHT TRANSPORT OPERATIONS AND PLANNING

Mixed Route Strategies for the Risk Averse Shipment of Hazardous Materials. *M.G.H Bell*

Previous work on the risk averse routing of hazardous materials has focussed on ways of finding the safest route between a pair of points. Incidents involving hazardous materials are generally low probability and high consequence. This research focuses on the case of

link-related incidents, unknown (but low) probabilities and repeated shipments. It is found that the safest strategy will in general be to use a mix of routes. In order to determine the safest set of routes and the safest share of traffic between these routes, a minimax programming problem is formulated. The properties of the optimality conditions are explored and a simple solution algorithm based on a shortest path procedure and the method of successive averages is proposed. Connections to game theory provide useful insights into the nature of the solution. The potential for improved solution algorithms is being investigated.

Modelling decision making in the UK contain industry. *J.W. Polak, S. Farrell, with J.D. Woods and J. N. Carter (Department of Earth Science and Engineering), J. Darlington, A. Field and Y. Guo (Department of Computing) and B. Hutton (Napier University)*

The aim of this project, which is jointly funded by DTI, EPSRC and a consortium of eight leading companies involved in various aspects of the container business under LINK Foresight scheme, is to develop a simulation model of UK container operations assess strategic infrastructure investment decisions in the UK container industry. The work involves two closely interrelated activities. The first is the identification of the principal actors, key information flows and essential decision making strategies that characterise the container transport market. The second activity is the translation of these understandings into a flexible and portable simulation tool that can be used by decision makers at various levels to explore the consequences of alternative business strategies.

Polak, Carter, Field, Marshall, Schumacher, Sinha-Ray, Song, Woods, and Zhang (2003)
Sinha-Ray, Carter, Field, Marshall, Polak, Schumacher, Song, Woods, and Zhang (2003)

UK freight modelling review. *J.W. Polak in association with Marcel Enchenique and Partners, RAND Europe, Parsons Brinckerhoff, MDS Transmodal, Katalysis, Oxford Systematics University of Leeds, University of Westminster*

The aim of this study, which is being undertaken on behalf of the UK Department of Transport, Local Government and the Regions, is to review current freight modelling techniques, and through assessing the suitability of the options potentially available, to make recommendations on the most appropriate techniques for use in Great Britain. The review will include road, rail and other freight modes and will also include the modelling of light goods vehicles.

UK freight panel. *J.W. Polak, S. Glaister, R.B. Noland, D.J. Graham and R.J. Anderson in association with WS Atkins Consultants*

The aim of this study, which is being undertaken on behalf of the Strategic Rail Authority, is to provide the SRA with advice on a broad range of policy and operational issues. The contribution of Imperial College will focus particularly on freight demand models, freight demand research and freight market structures.

UK Road Freight Statistics Quality Assurance Review. *J.W. Polak*

This project has involved service on the review board undertaking the periodic quality assurance review of road freight statistics, under the auspices of the Office of National Statistics. The review was wide ranging, covering the definition of data content, methods of processing, analysis and storage and presentation and reporting. The final report of the review will be published later this year.

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