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Pervasive Sensing and the Changing Transport Datascape

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Objectives

- To provide a brief overview of the role of sensor systems in transport systems analysis
- To describe some of the important current trends in the field
- To identify some key challenges and opportunities
- To give some examples of current work addressing these issues

Scope of transport systems analysis

- Transport systems analysis can be categorised into two broad areas:
  - Transport planning: Concerned with design and evaluation of major infrastructure and policy initiatives
  - Transport operations: Concerned with providing operational and tactical support for short term and real time management of transport networks
- Planning and operations models share certain common modelling concepts but typically differ in terms of methods, data and algorithms

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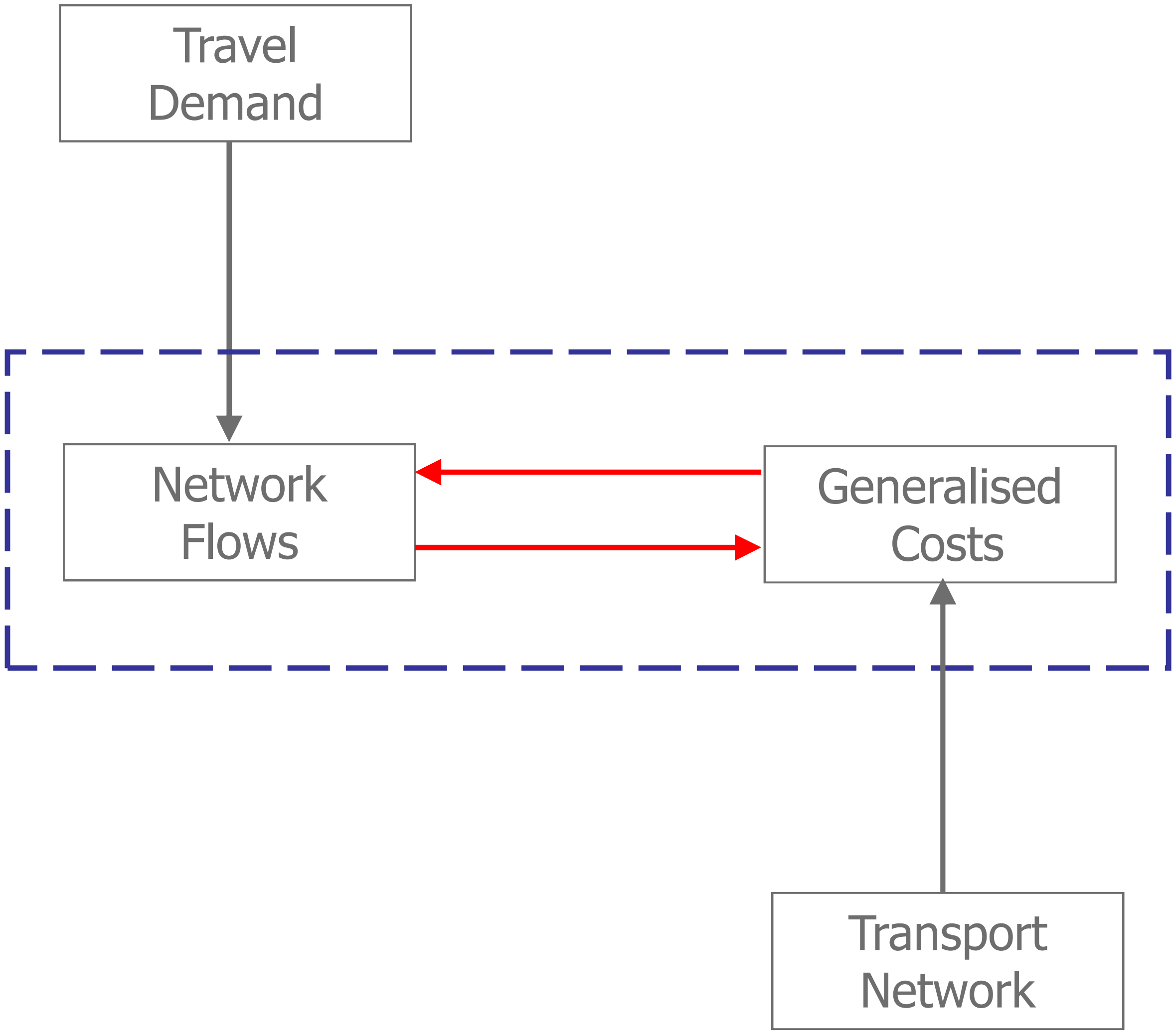
How transport researchers see the world



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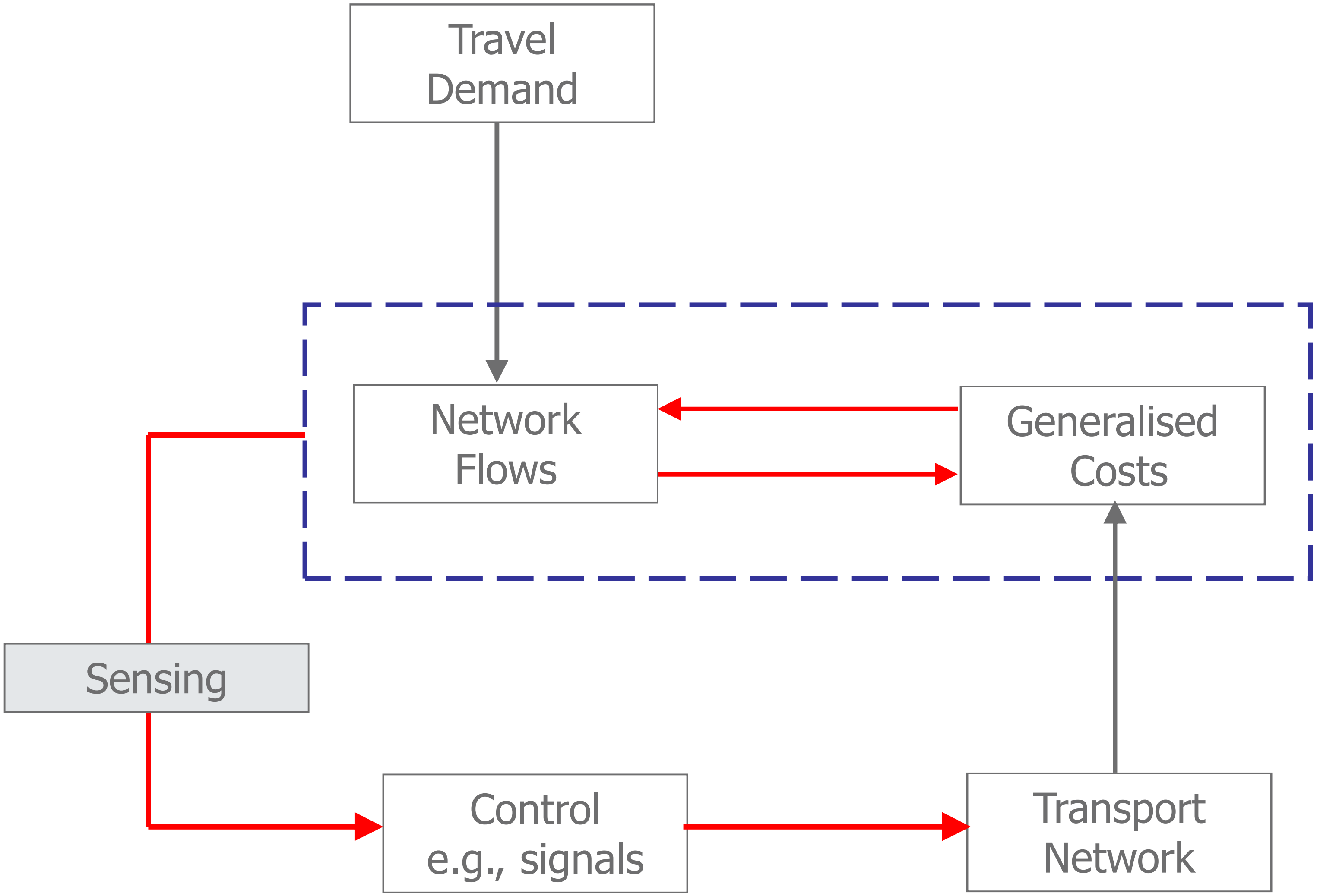

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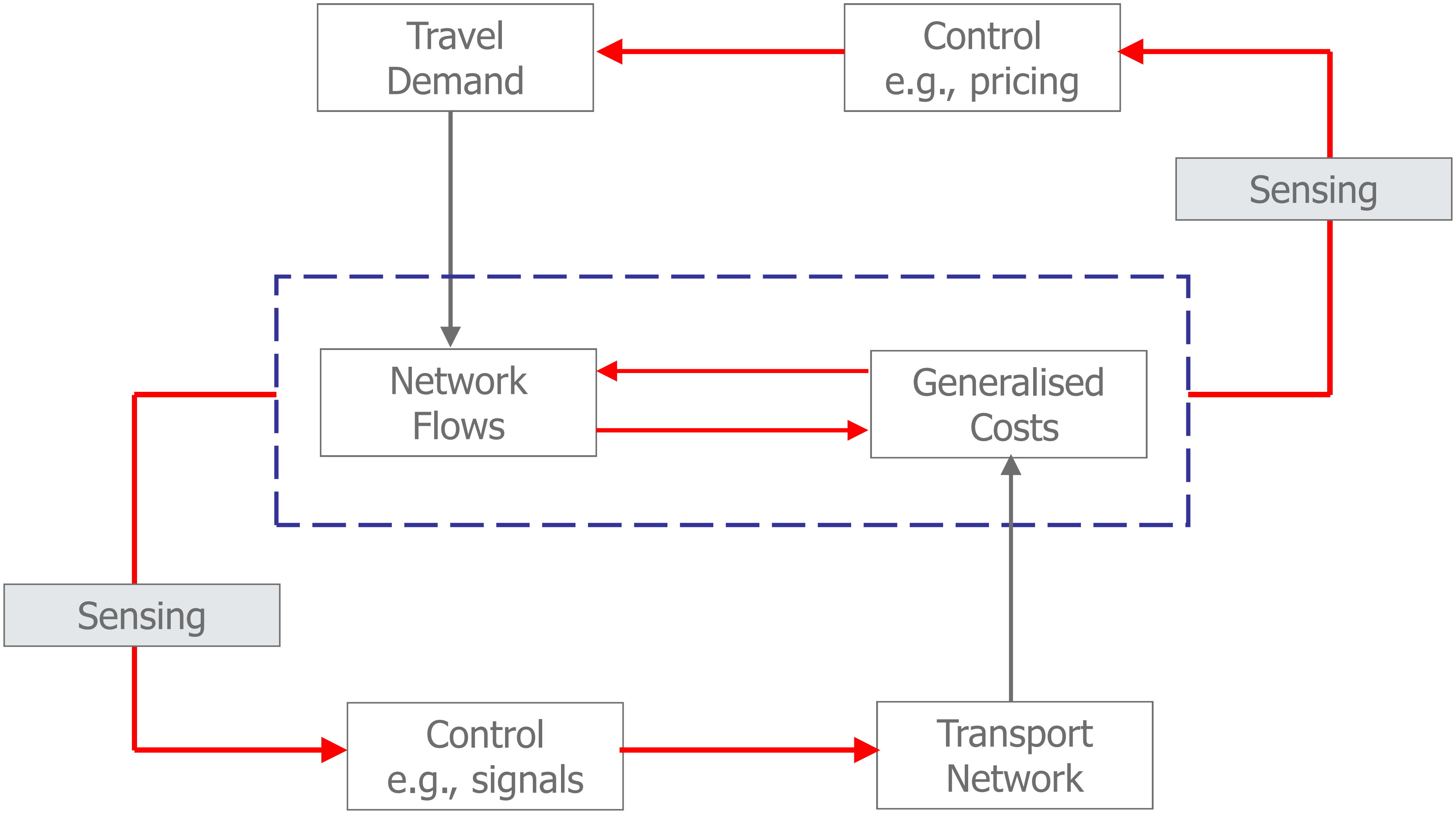

50 years of traffic control

- Traffic management and control has a long and largely successful history of application, especially in urban areas, e.g.:
  - 1960s: Isolated adaptive traffic signal control
  - 1970s: Area wide coordinated traffic signal control
  - 1980s: Fleet management systems
  - 1990s: Automatic payment systems
  - 2000s: Public transport information systems
  - 2010s: Personal navigation systems
- Developments in sensing capability have been fundamental to these developments

The transport datascape (1)

- Transport networks are already relatively densely sensed:
  - Inductive loop detectors
  - Automatic number plate recognition
  - CCTV
  - Floating vehicle data
- We are witnessing profound changes in the nature of data environment in transport, driven by:
  - Embedded sensing, pervasive positioning and ubiquitous communications for infrastructure, vehicles, people and artifacts
  - Penetration of the internet into all aspects of network activity
  - Massive data archival (e.g., of network flows and events, financial and information transactions, control interventions)

The transport datascape (2)

"Past" datascape

- Low volumes and rates
- Intermittent collection
- Explicit sampling & design
- Costly to collect
- Limited sectoral scope
- Collection is human led
- Centralised collection
- Data holdings fragmented
- Little commercial exploitation

"Future" datascape

- Very high volumes and rates
- Continuous collection
- Naturalistic sampling
- Low marginal collection cost
- Scope includes many sectors
- Mostly automated & passive
- Distributed collection
- Greater integration of data
- Significant commercial use

Opportunities (1)

- Radically better data offers enormous scope for new and improved traveller and network management services

- Digital economy; opportunities to valorise new and existing data streams
  - Enhanced probe vehicle
  - Real time estimation of risk, pollutants etc,

- Increasing scope for integration across sectors:
  - Transport
  - Automotive
  - Healthcare
  - Energy
  - Water and wastes
  - Retail

- And integration between elements of the transport system itself – infrastructure, vehicles, drive trains

Opportunities (2)

- Step change improvements in our ability to calibrate and validate various process and prediction models e.g.,
  - Vehicle following
  - Route and departure time choice
  - Pollutant dispersion
- Better understanding the dynamics of network behaviour at different scales; exploration of limits to control
- Integration of ‘intent’ information into prediction and control

Challenges

- Need significantly improved tools for
  - Data discovery
  - Data provenance and quality
  - Management of security and trust
- Need to evolve new forms of interpretive and predictive models that can:
  - Accommodate multiple data sources and scales and levels of behavioural richness
  - Support distributed architectures
  - Joint representation of multiple networked infrastructures e.g., transport, communications, energy etc.
- We also need to maintain the right balance between data, theory and modelling – big data but not mighty data

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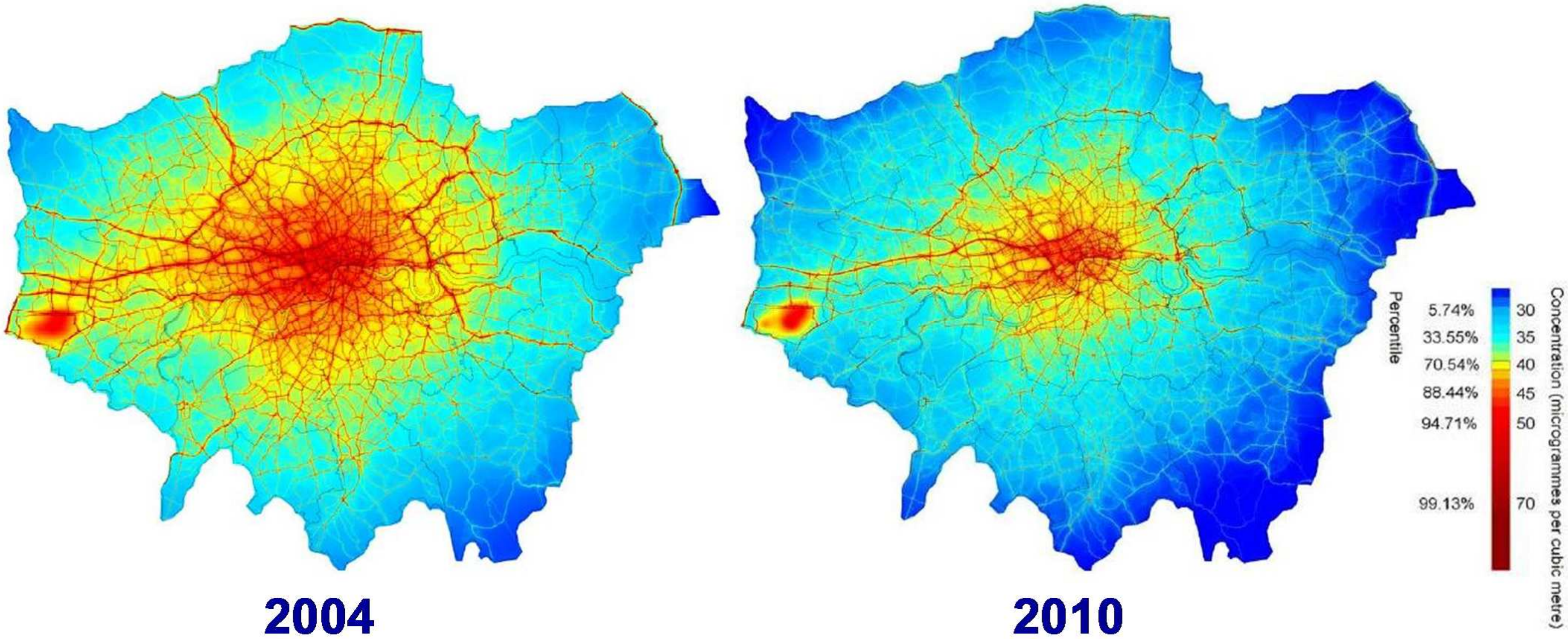
The MESSAGE Project

MESSAGE: Motivation

- Urban air quality is improving, but pollution 'hot spots' will remain a key problem. For example, NO2 in London…



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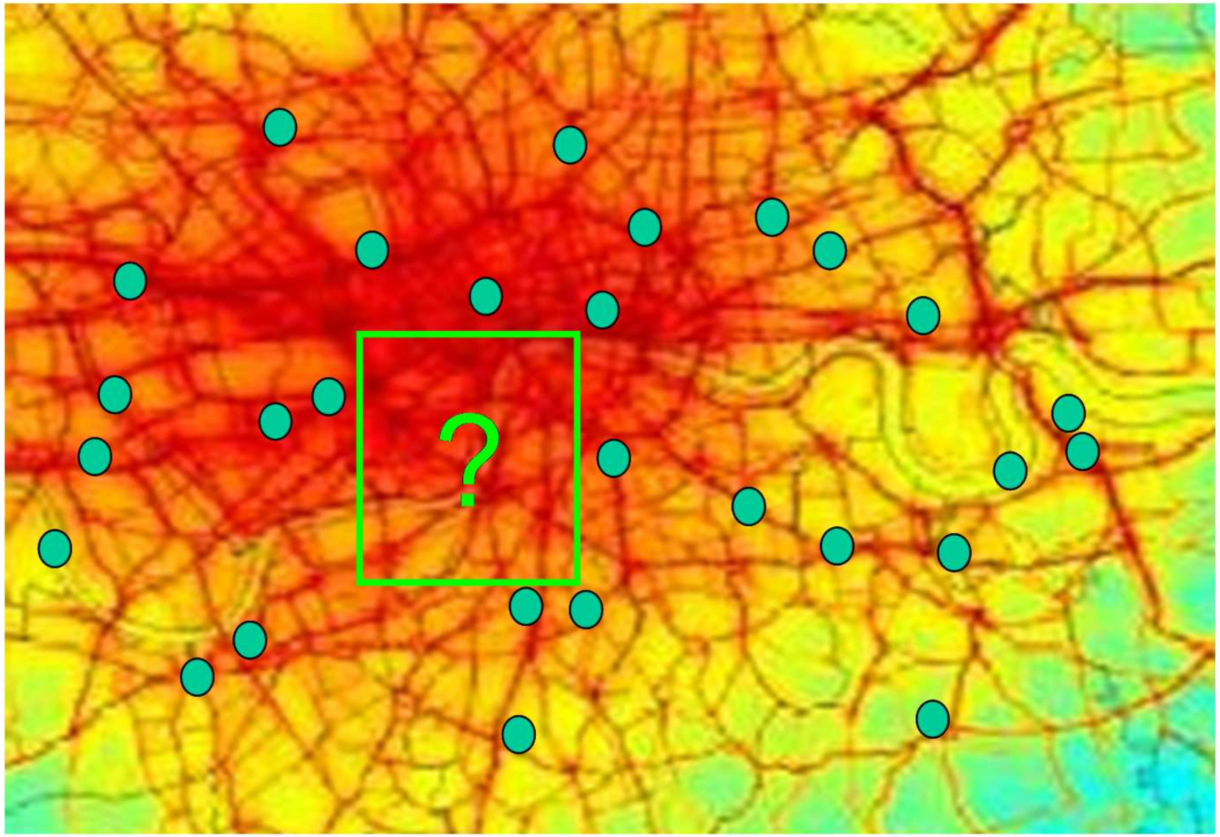
MESSAGE: Motivation

- By existing standards central London is relatively well monitored: ~30 fixed AQM sites. But this still leaves huge gaps…



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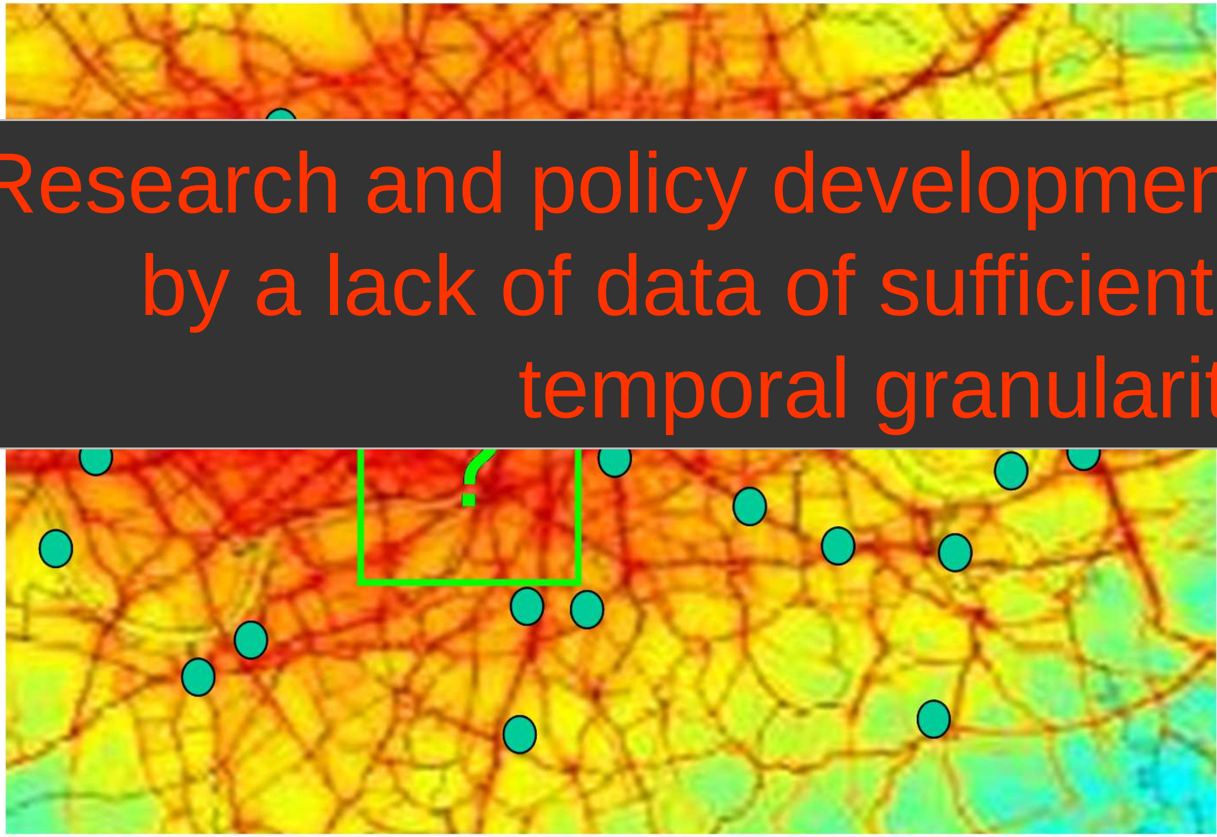
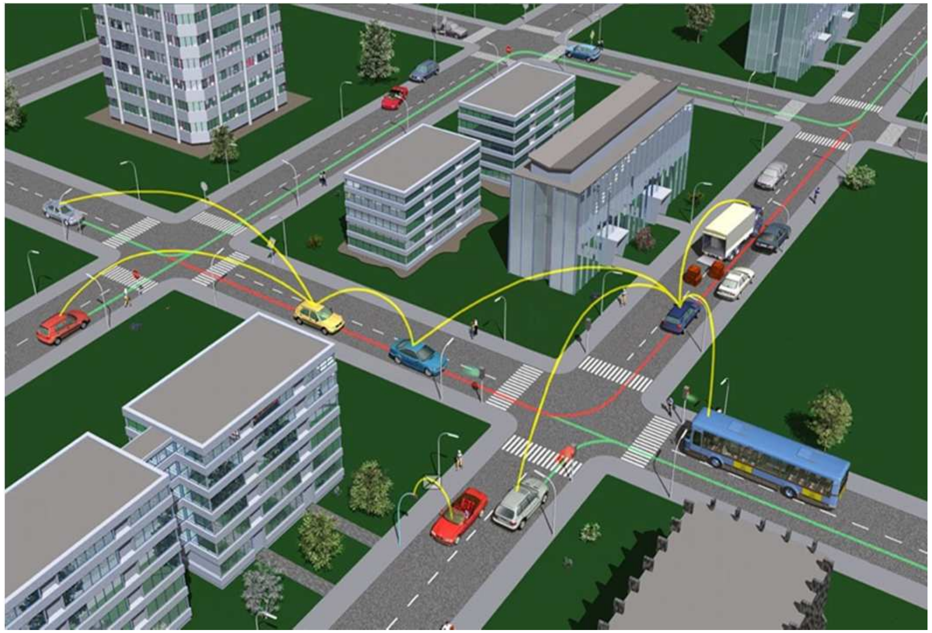


Research and policy development are hampered by a lack of data of sufficient spatial and temporal granularity

MESSASGE: Overview

- Network of heterogeneous fixed and mobile air quality sensors on infrastructure, vehicles and people
- Sensors communicate via wireless networks
- Positioning via GPS + wireless & cellular ranging
- Integration of processing along the data path
- Multiple application studies in different local contexts



Source: BMW Car 2 car project

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Engineering and Physical Sciences Research Council

Department for Transport

MESSAGE: Key research areas

- Sensor development
- Positioning via augmented GPS and WiFi ranging
- Communications via vehicle ad hoc networks
- Scalable e-Science architecture
- Utility computing platforms for transport and environment models
- Distributed data mining and visualisation
- Integrated modelling framework
- Application scenarios

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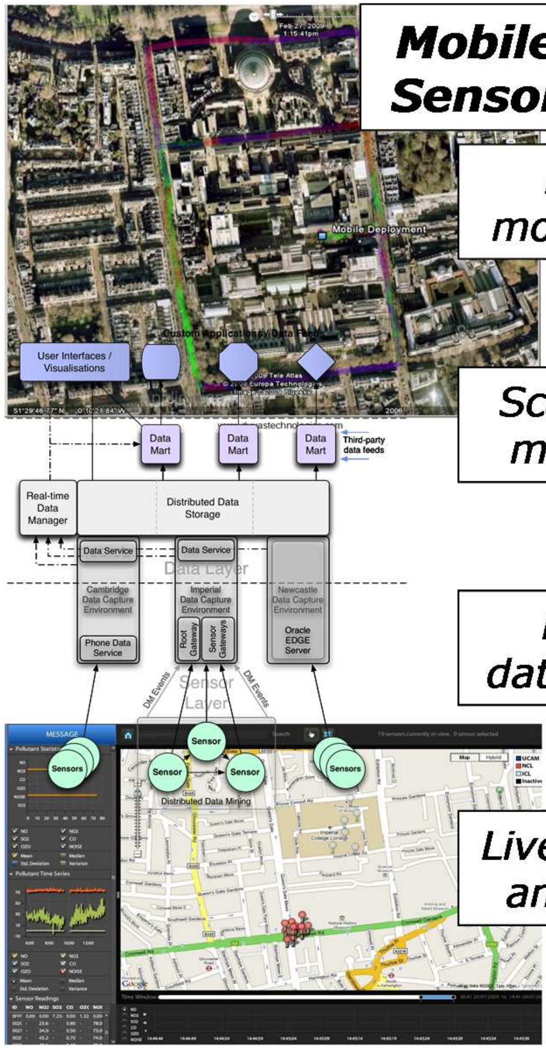
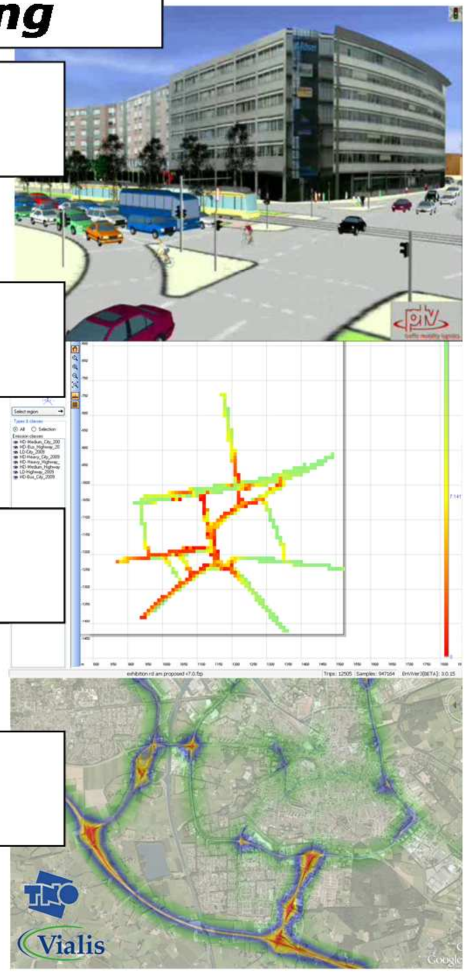
MESSAGE: Data and modelling framework



Mobile Wireless Sensor Network ⟷ **On-Demand Modelling**

Fixed and mobile sensors ↓ *Scalable data-management* ↓ *Federated database query* ↓ *Live display and analysis tools*

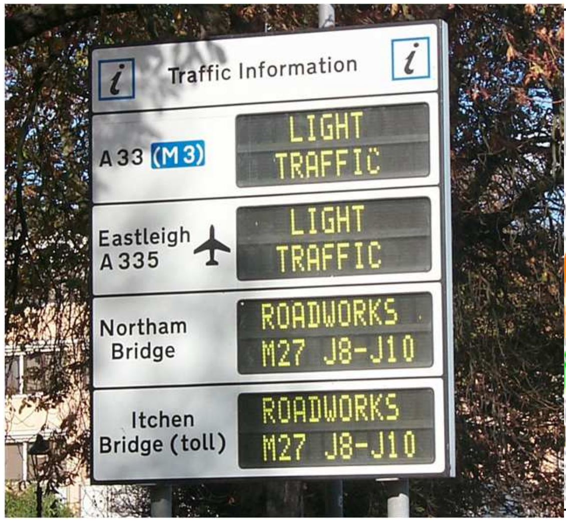
Scenario models ↓ *Pollutant Emissions* ↓ *Pollutant Dispersion* ↓ *Impact Analysis*

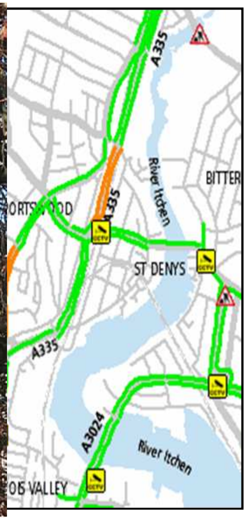


MESSAGE: Application sceanrios (1)

Traffic Management

- Inclusion of environmental objectives in UTC
- Resolution - reliability – cost tradeoffs
- Distributed processing of air quality projections





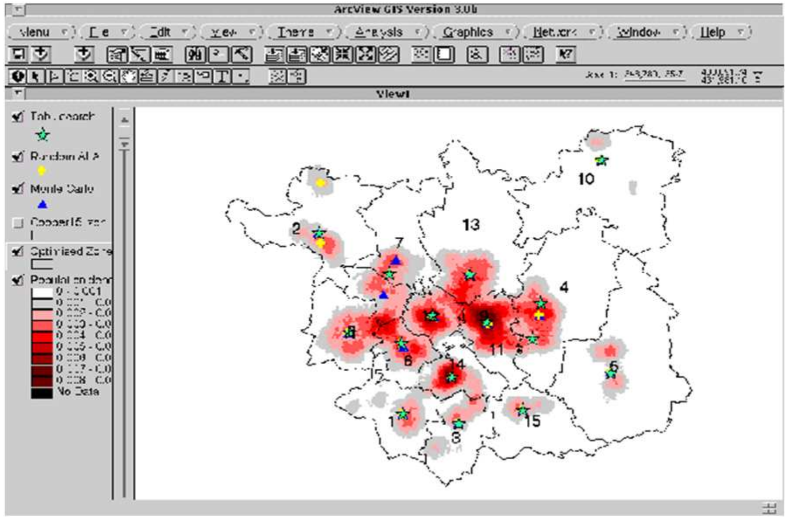
Traveller Information

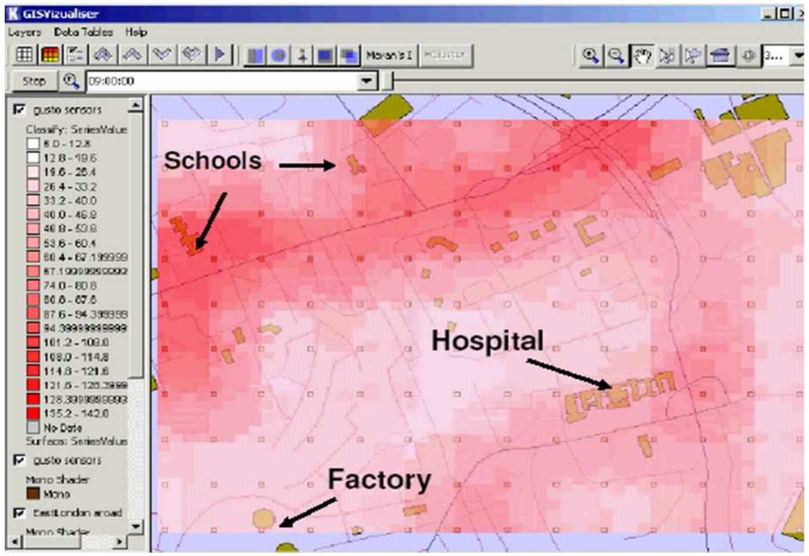
- Data aggregation across wide areas
- Visualisation of temporally varying data
- Interfacing with legacy applications

MESSAGE: Application sceanrios (2)

Health and Exposure

- High spatial resolution monitoring
- Distributed data buffering and processing
- Path based data aggregation





Pollution Modelling

- Real-time, archive and predicted analysis
- Resolution - reliability – cost tradeoffs
- Dynamic sensor resolutions

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The FREEFLOW Project

FREEFLOW: Motivation

- Rapid innovation in:
  - data sources (e.g., pervasive GPS and GSM, increasingly extensive CCTV)
  - network modelling tools
  - decision support technologies
  - channels of communication with individual travellers
- Provides enormous scope for innovation in network management and traveller information
- To meet new challenges in transport policy
- But existing strategies for network management do not fully exploit these capabilities, and remain largely reactive

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FREEFLOW: Overview

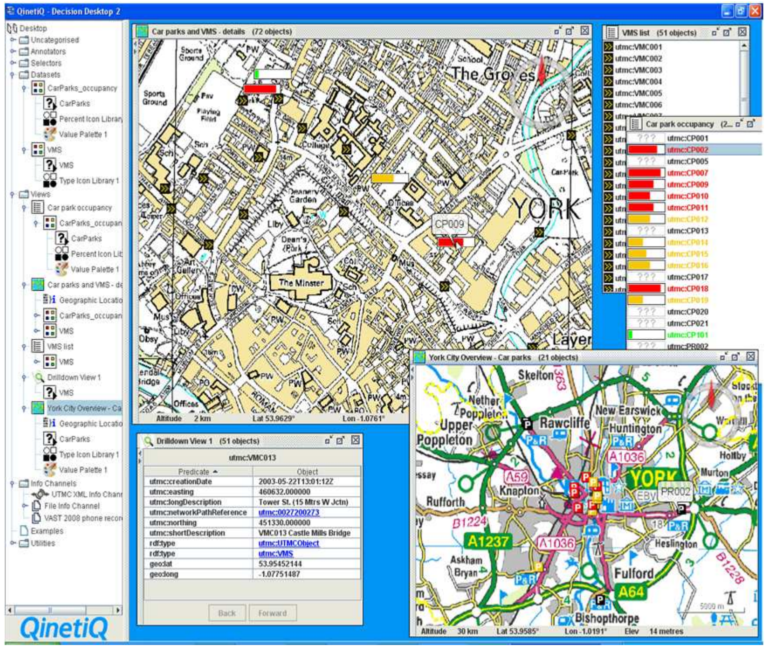
- Develop a flexible platform that integrates latest developments in data, models, decision support and dissemination technologies

- Modular, pick-n-mix. Not one size fits all

- Driven by explicit analysis of user requirements

- Build on, not duplicate, existing investments e.g., in the UK's UTMC architecture

- Develop services, tools and approaches that can be used in the UK and elsewhere



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FREEFLOW: Key research areas

- **Sensor processing** (e.g., enhanced signal processing of CCTV images)
- **Sensor data fusion** (e.g., combining ILD, GPS, ANPR data for network performance estimation)
- **Network state estimation and prediction** (e.g., where are the queues/incidents, are they growing or clearing?)
- **Strategy development and selection** (e.g., what should we do, what worked in the past, what does modelling tell us?)
- Tools for integration, **visualisation** and **decision support** (e.g., how do I get at and use all this information)?
- Enhanced **traveller information** for users as well as system managers (e.g., personalised travel alerts)

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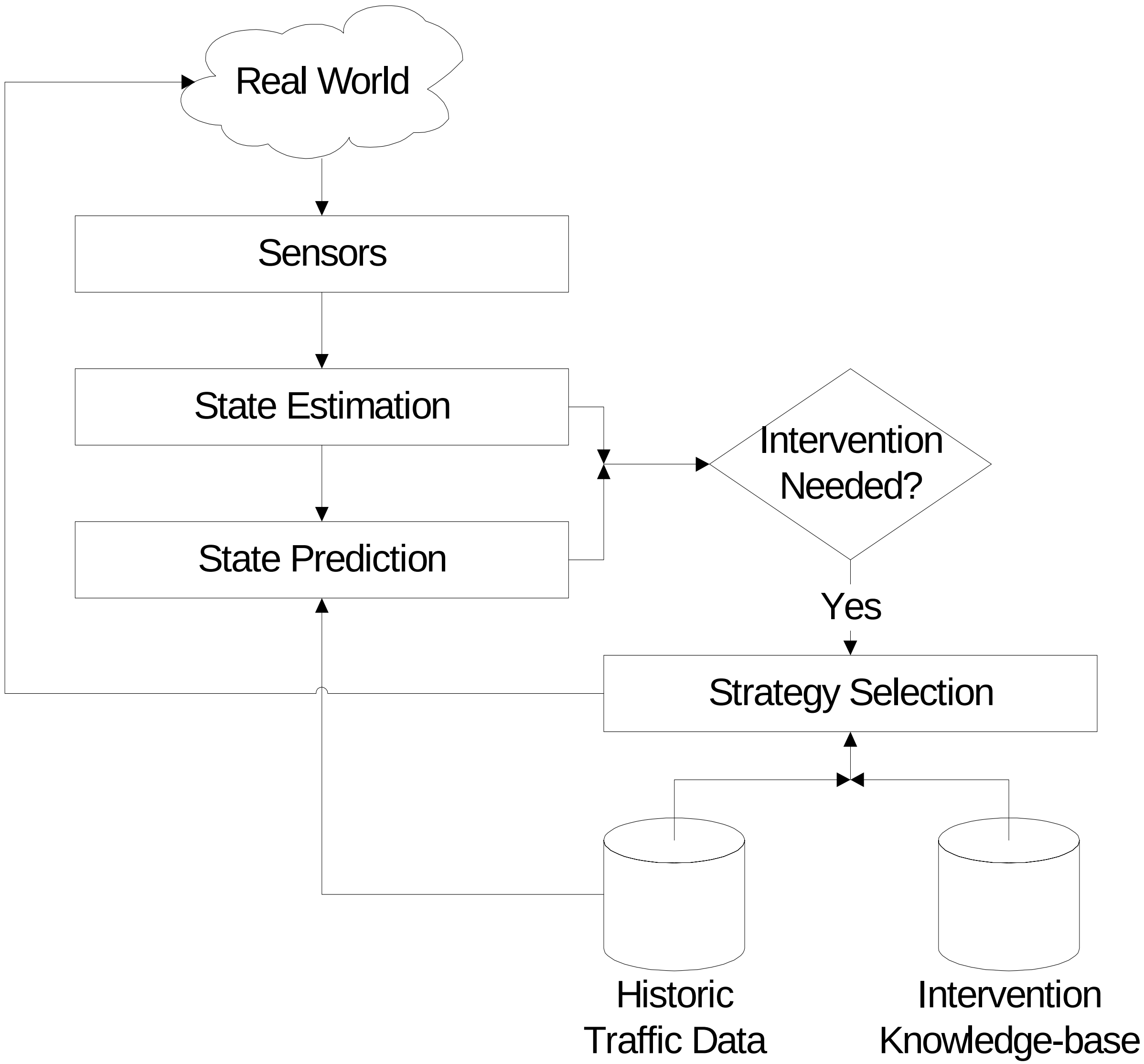
FREEFLOW: Intelligent decision support



FREEFLOW: Applications

- The FREEFLOW system is being demonstrated in three application areas in the UK
  - London: Control of traffic circulation at Hyde Park Corner in central London (one of the busiest urban traffic systems in the world)
  - Maidstone: Control of urban-interurban interactions during periods of acute congestion
  - York: Traffic gating in a historic town centre
- The next step is commercialisation

Conclusions

- The rapid development of sensor network systems has the potential to have a profound impact on transport network planning and operations
- Progress is being made in modernising modelling architectures and procedures
- But significant potential bottlenecks are associated with
  - Limitations in underlying sensor technologies themselves
  - Sensor data discovery and characterisation
- Although much attention is currently focused on cooperative technologies within the transport sector, large potential exists in integration across sectors.

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Thank you