# Lancaster University
## Engineering Department

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# Acknowledgements


- MIT, USA
  - Prof. M.E. Ben-Akiva
  - T. Toledo and J.R. Scariza
- Lancaster University, UK
  - Prof. P.C. Young
  - P.G. McKenna, A. Chotai, P. Kontoroupis
  - J. Whittaker

HIGHWAYS AGENCY

# Contents

- Ramp Metering Pilot Scheme
- Lancaster Project (M27)
- Research on Queue Regulation

# Ramp Metering Pilot Scheme

- M3/M27, M6 ...
- Highways Agency
- Atkins, TRG, TUC ...
- RMCS, MIDAS data ...

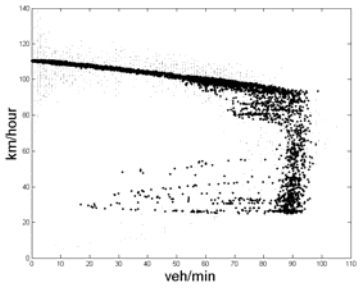
# Ramp Metering Pilot Scheme

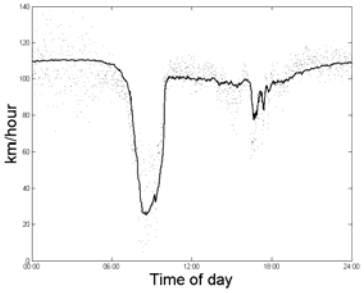

# Lancaster Project

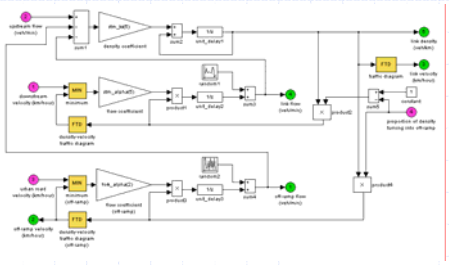
- Existing Algorithm
- Calibrate simulations
  - Macroscopic (Lancaster)
  - Microscopic (MIT)
- Linked-NMSS algorithm

# Macroscopic Simulation

- Statistical Traffic Model (STM)
- Monitoring and prediction of motorway networks
- DYNA & DACCORD projects

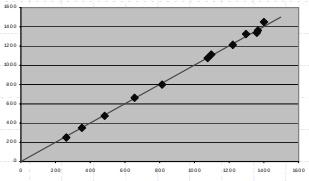


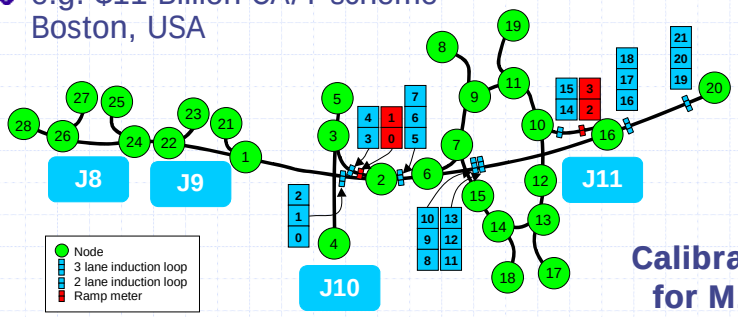



# Microscopic Simulation

- MITSIMLab (Prof. Ben-Akiva)
- Represents behaviour of individual vehicles as they accelerate, change lanes ...
- e.g. $11 Billion CA/T scheme Boston, USA

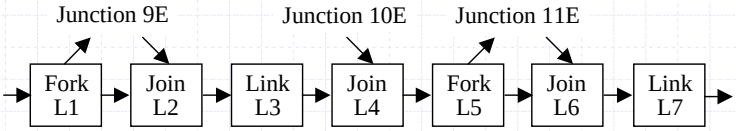




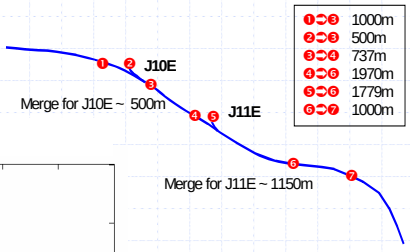

**Calibrated for M27**

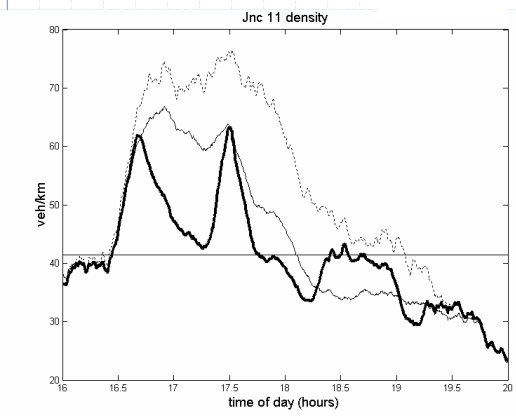
# Linked-NMSS Algorithm

- Linked or coordinated to use all available data
- Reduced order models, identified and recursively estimated directly from measured data (adaptive where necessary)
- Non-Minimal State Space (NMSS) form
- Optimal control weighting matrices selected using multi-objective optimisation




# Simulation Experiment

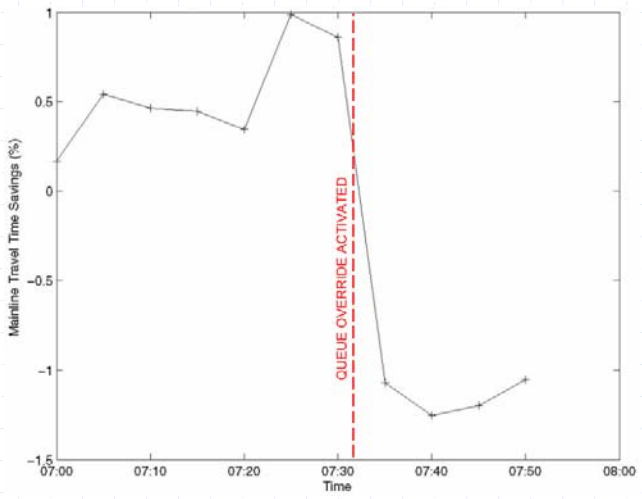


# Results

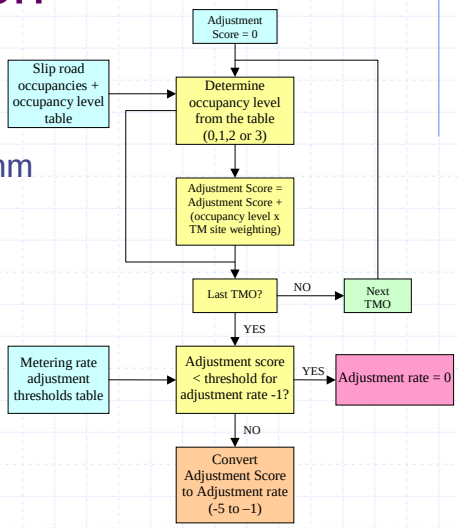
- Existing Algorithm (measured data)
- Macroscopic / Microscopic simulations calibrated
- Linked-NMSS yields travel time savings (5~10%)
- Benefits over local control depend on scenario
- Linked-NMSS yields lowest or second lowest overall travel times in 13 of 16 scenarios (4 controllers)
- Linked-NMSS works particularly well under conditions of high demand on the main carriageway
- But all 4 controllers have queue override problems

# Queue Regulation



# Queue Regulation

- Initial Linked-NMSS based on same *ad hoc* approach as Local algorithm
  - Queue adjustment
  - Queue override
- Potential adaptations to linked-NMSS
  - Tune diagonal elements of weighting matrix
  - Introduce queue state into the state vector




# Linked-NMSS (details)

**Control model (for one location):**

$$y_{j,k} = \frac{bz^{-1}}{1+az^{-1}} y_{j-1,k} + \frac{cz^{-1}}{1+az^{-1}} y_{j+1,k} + \frac{dz^{-1}}{1+az^{-1}} u_{j,k}$$

**State equation: (all locations)**

$$\boldsymbol{x}_k = \boldsymbol{A}\boldsymbol{x}_{k-1} + \boldsymbol{B}\boldsymbol{u}_{k-1} + \boldsymbol{D}\boldsymbol{y}_{\boldsymbol{d}_{k-1}}$$

**State vector:**

$$\boldsymbol{x}_k = \begin{bmatrix} y_{1,k} & y_{2,k} & y_{3,k} & y_{4,k} & y_{5,k} & z_{2,k} & z_{4,k} \end{bmatrix}^T$$

**Control Law:**

$$\boldsymbol{u}_k = -\boldsymbol{k}^T \boldsymbol{x}_k^T$$

# Linked-NMSS-Queue

Solution 1: Multiple-Objective Optimisation

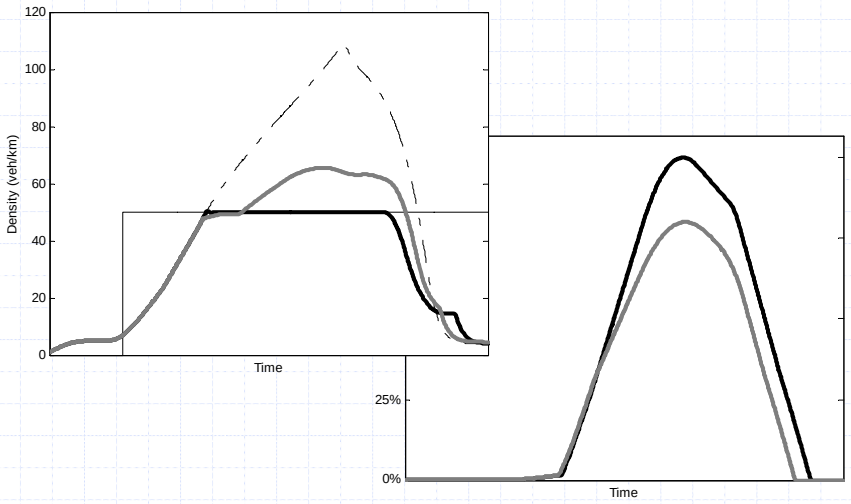
$$J = \sum_{k=1}^{\infty} \left\{ \boldsymbol{x}_k{}^T \boldsymbol{Q} \boldsymbol{x}_k + \boldsymbol{R} \boldsymbol{u}_k{}^2 \right\}$$

Solution 2: Additional States

Solution 3: Modified Cost Function

(Or combine all three)

# Linked-NMSS-Queue



# Conclusions

- Local and Linked RM can reduce travel times for M3/M27 pilot scheme (real data and simulation)
- For some scenarios, Local and Linked RM can unfortunately increase travel times
- Research on Linked-NMSS-Queue control improves overall travel times and reduces queue problems (simulation study only)
- Further research required