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May 2-6, 2016 in Christchurch, New Zealand

Global Navigation Satellite Systems (GNSS) Equipped Public Transport Buses as Information Sentinels

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University of Leicester

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

CATAPULT Transport Systems

IMPETUS

East Midlands Intelligent Mobility Partnership

The aim of the University Partnership Programme is to develop a network of long term university partners with the Transport Systems Catapult (TSC). These select universities will serve as TSC's outreach to the wider UK science and technology academic community

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CATAPULT Transport Systems

The following slides detail some of the current IMPETUS placement projects . . .

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- **Integration of GIS, Open Source information and Pollution Measurements**
  - Dr Teresa Raventos, Air Quality Specialist, University of Leicester.
- **Mapping Obscuration of GNSS in Urban Landscapes (MOGUL)**
  - Dr Simon Roberts, Nottingham Geospatial Institute, University of Nottingham.
- **Twitter and Passenger Distruption (TaPD)**
  - Dr David Golightly, Human Factors, University of Nottingham.

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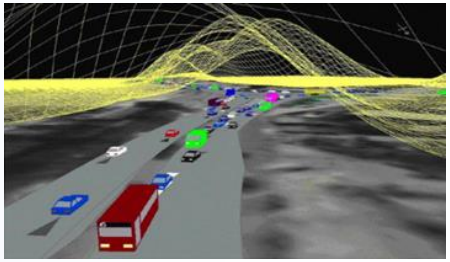
TfL Buses as Sentinels

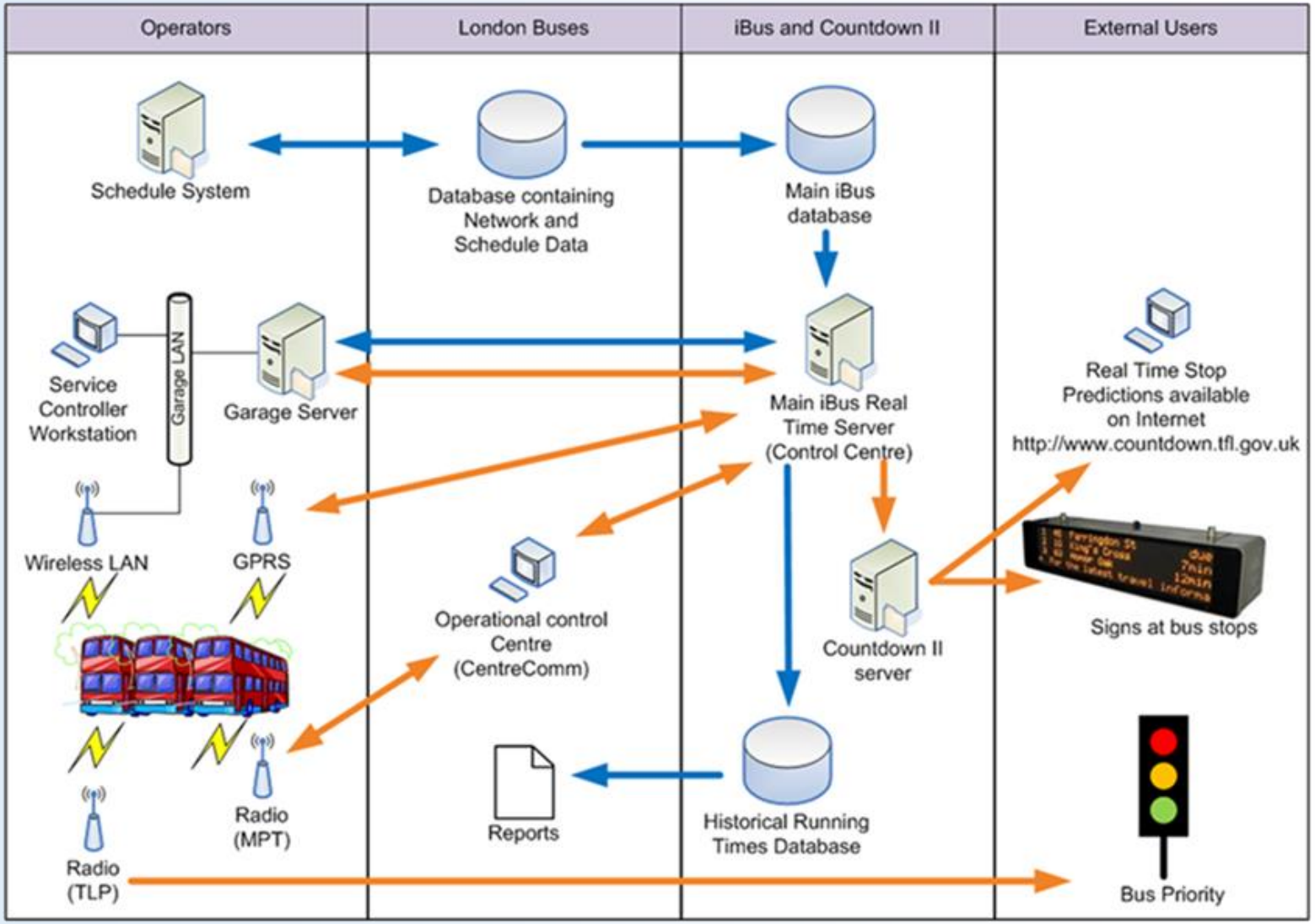
- The ability to predict, plan and prepare for the different usage patterns and traffic/road user load is very important to city transport planning, logistics & haulage industry, as well as emergency planning and other sectors.

- Increasingly around the world public transport buses are being equipped with GNSS receivers to help provide accurate timetable information to awaiting passengers

- The aim is to assess whether GPS data from the 8500+ London buses can be correlated with data about other events, in order to detect or assess the impact of the various driving forces affecting the city's traffic patterns. This can provide insight on traffic congestion, people movements and resource deployment.



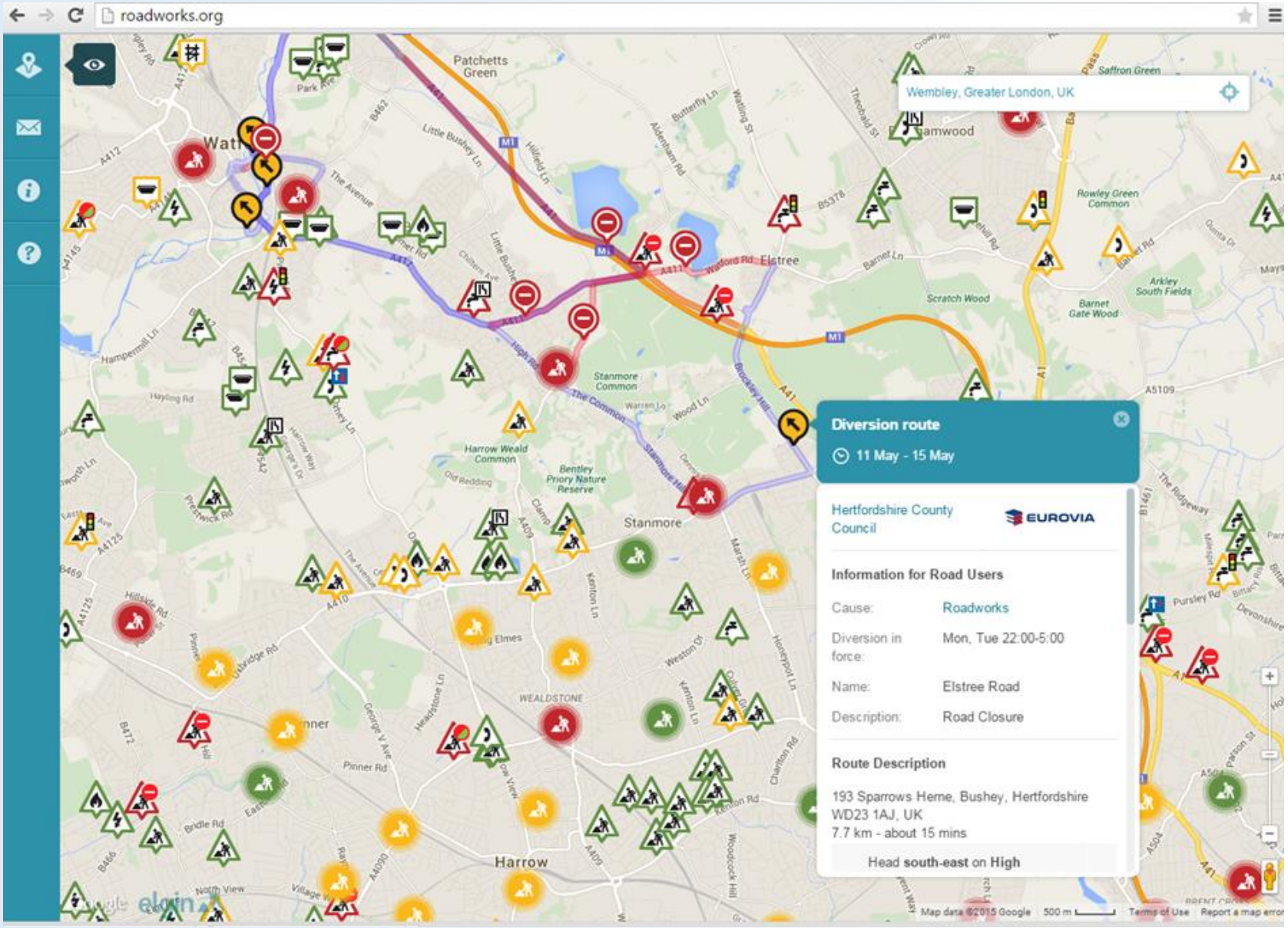
iBus System Architecture



Data

- Vast amount of data is collected daily by TFL's iBus system.
- Area of interest for this feasibility narrowed to Wembley.
- Data collected for the 1 week period, 2 wks before the FA cup final. 1 week period of the FA cup final.
- GPS data including position and velocity collected every 5secs.
- Door event data, which provided a timestamp and position when the bus door opened and closed.
- Complementary data on road works in the area also collected.

Road Works



roadworks.org
Wembley, Greater London, UK
Diversion route
11 May - 15 May
Hertfordshire County Council
EUROVIA
Information for Road Users
Cause: Roadworks
Diversion in force: Mon, Tue 22:00-5:00
Name: Elstree Road
Description: Road Closure
Route Description
193 Sparrows Herne, Bushey, Hertfordshire WD23 1AJ, UK
7.7 km - about 15 mins
Head south-east on High
Patchetts Green
Elstree
Stanmore
Harrow
Harrow Weald Common
Bentley Priory Nature Reserve
Stanmore Common
Scratch Wood
Barnet Gate Wood
Rowley Green Common
Arkley South Fields
Map data ©2015 Google
500 m
Terms of Use
Report a map error

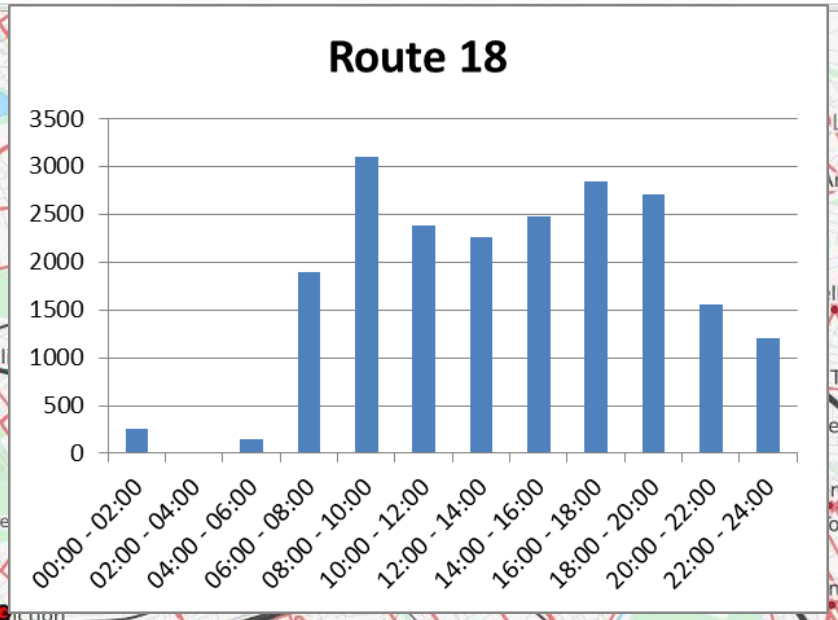
Methodology

- Data parsing
- Data cleaning
  - Anomaly or gross error detection
  - Data interpolation
  - Data smoothing
- Data analysis
  - Statistical analysis
  - Empirical analysis
  - Machine learning algorithms
- Data visualisation

Door Event Data – Friday 15th

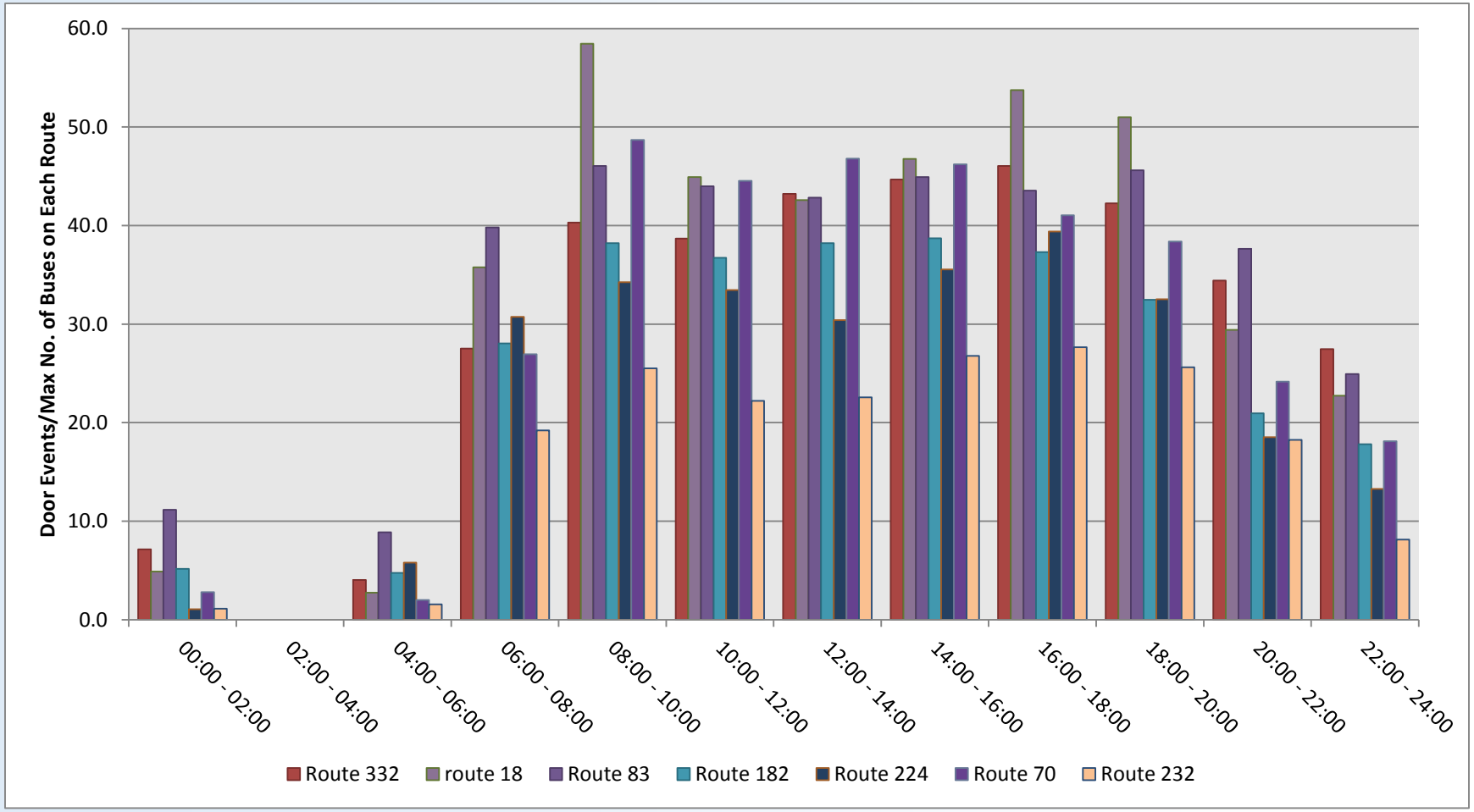
The University of Nottingham

raintimes.org.uk/map/london-buses/#18



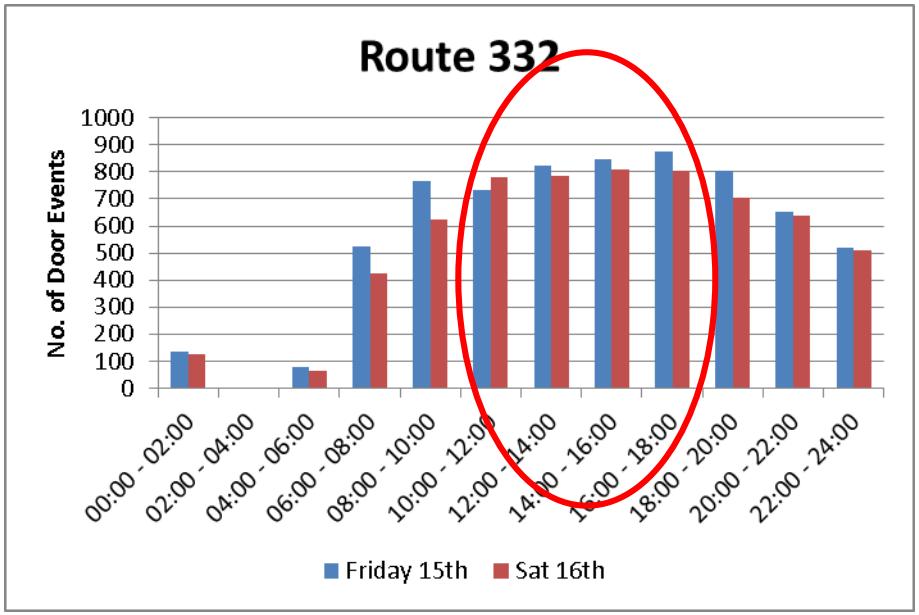
Route 18

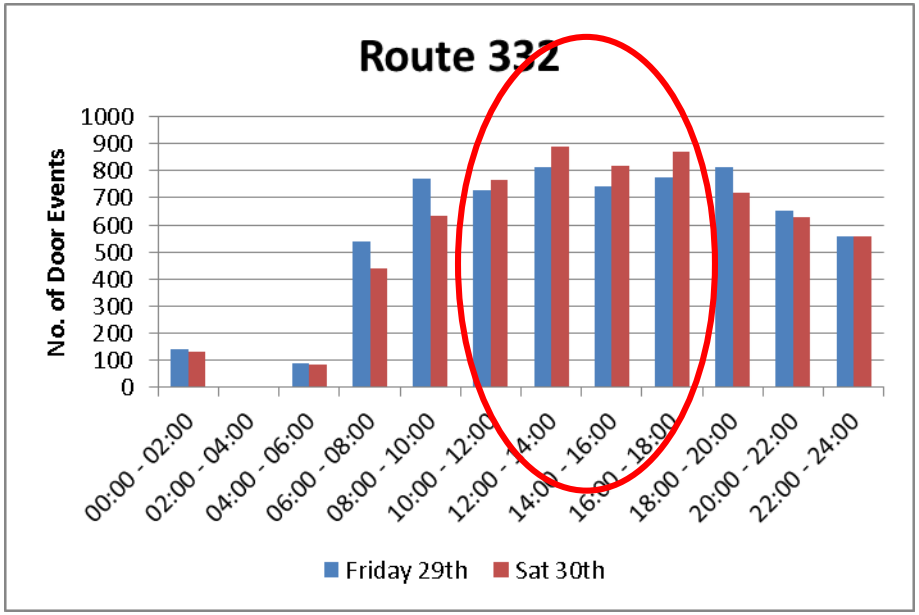
Door Events: 15th of May

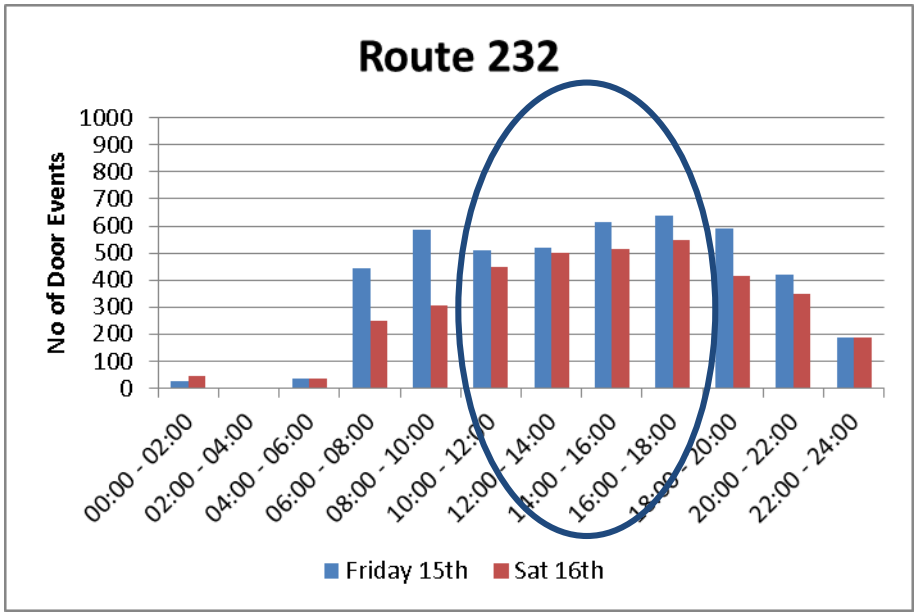


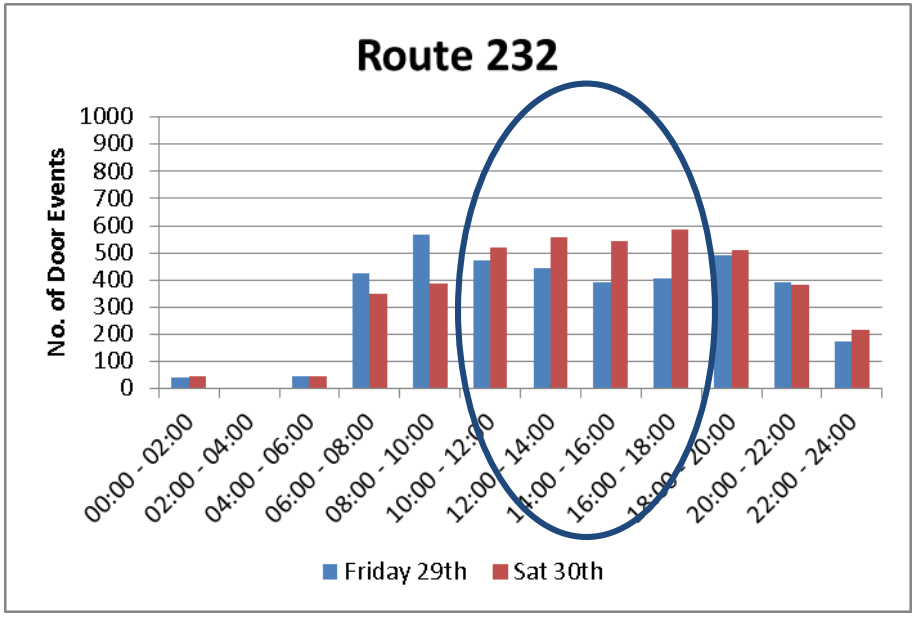
‘Normal’ Weekend

FA Cup Final Weekend









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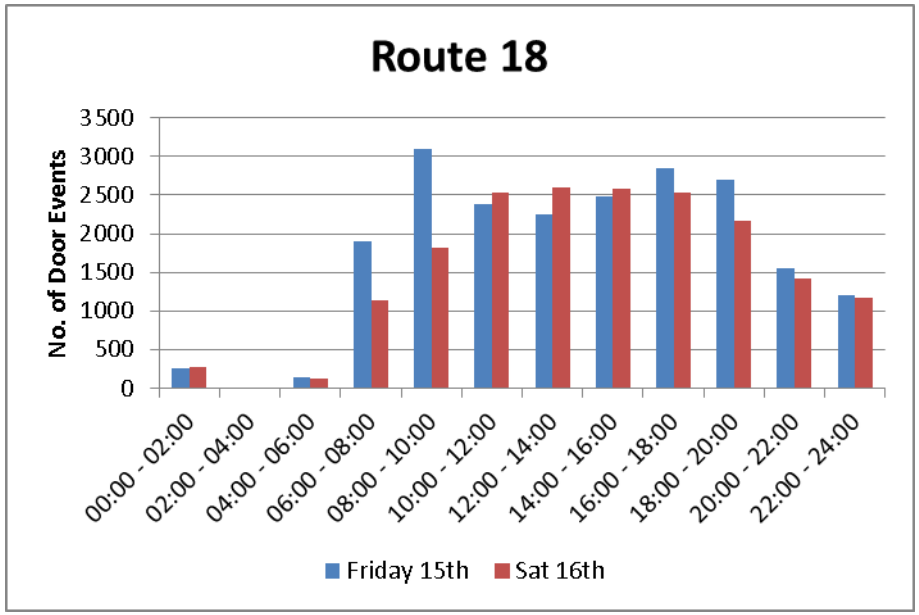
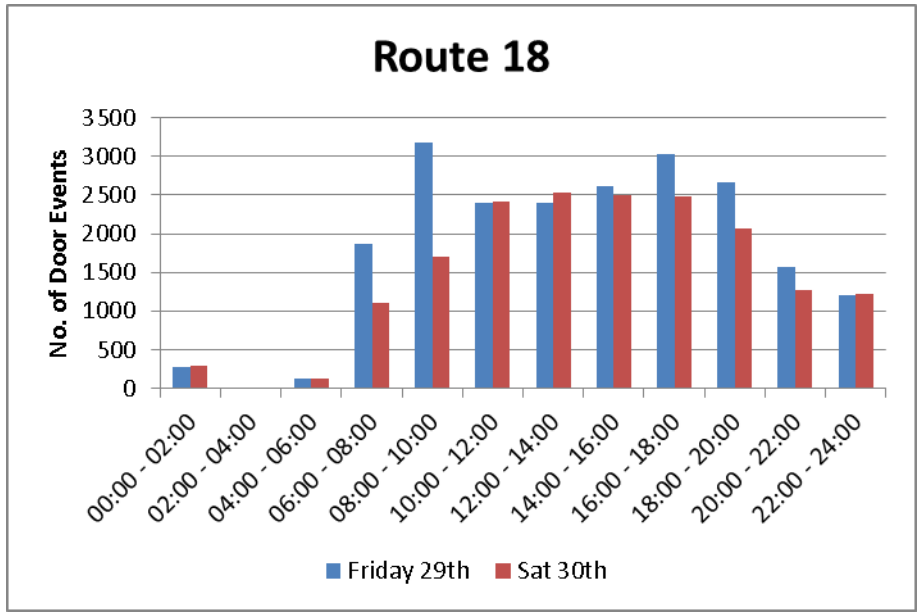
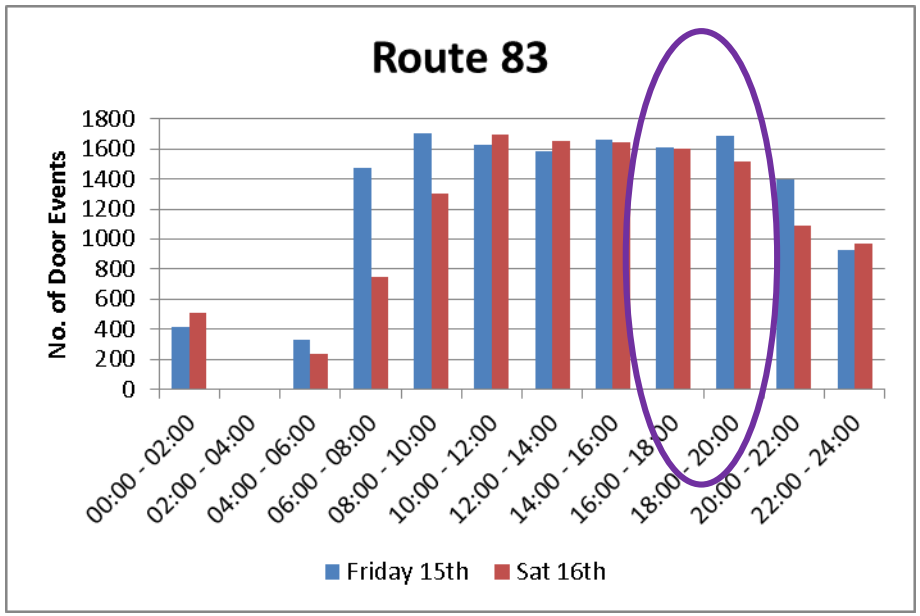
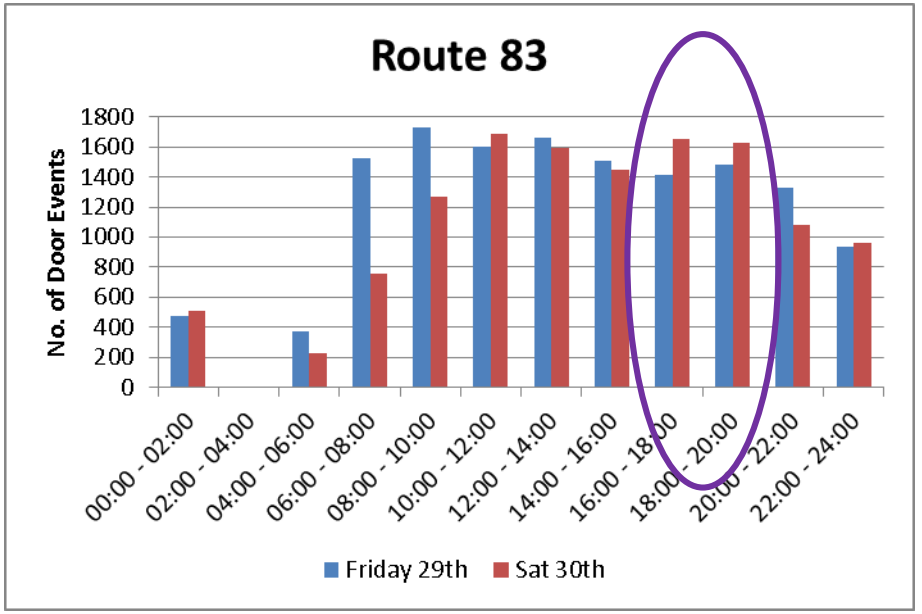


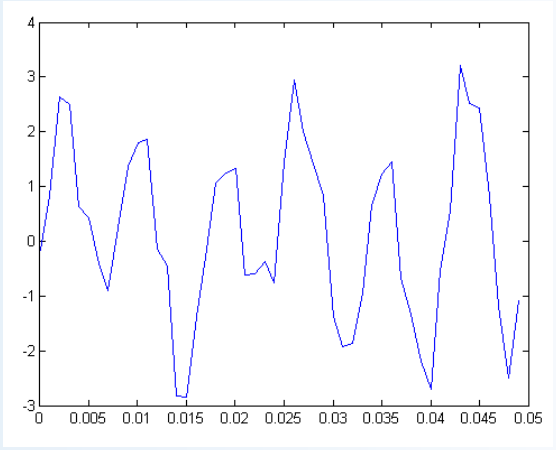


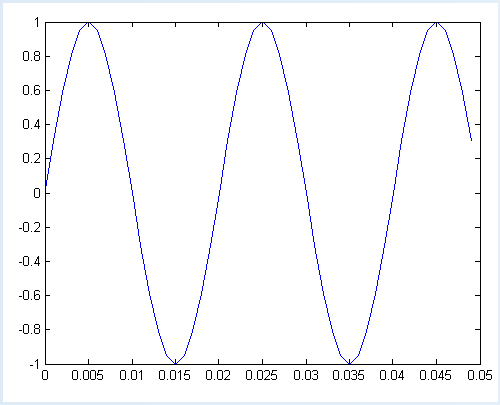


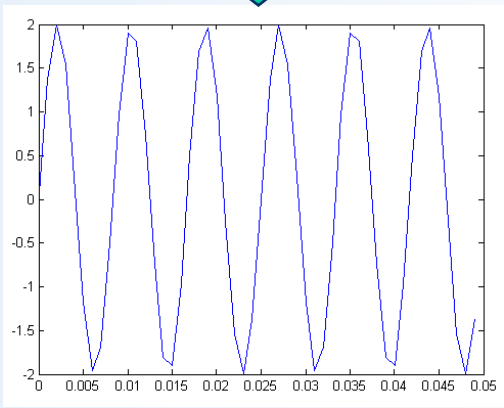


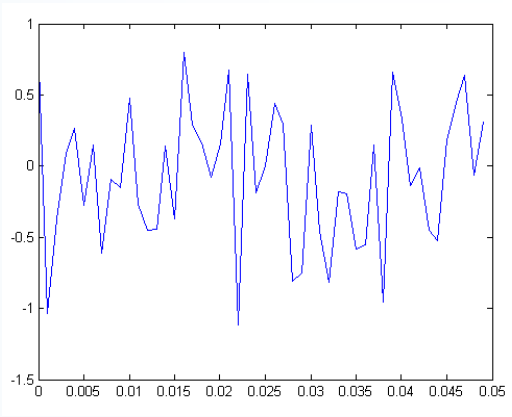
Modelling Using ICA

- Independent Component Analysis
  - Used for feature extraction and signal separation.





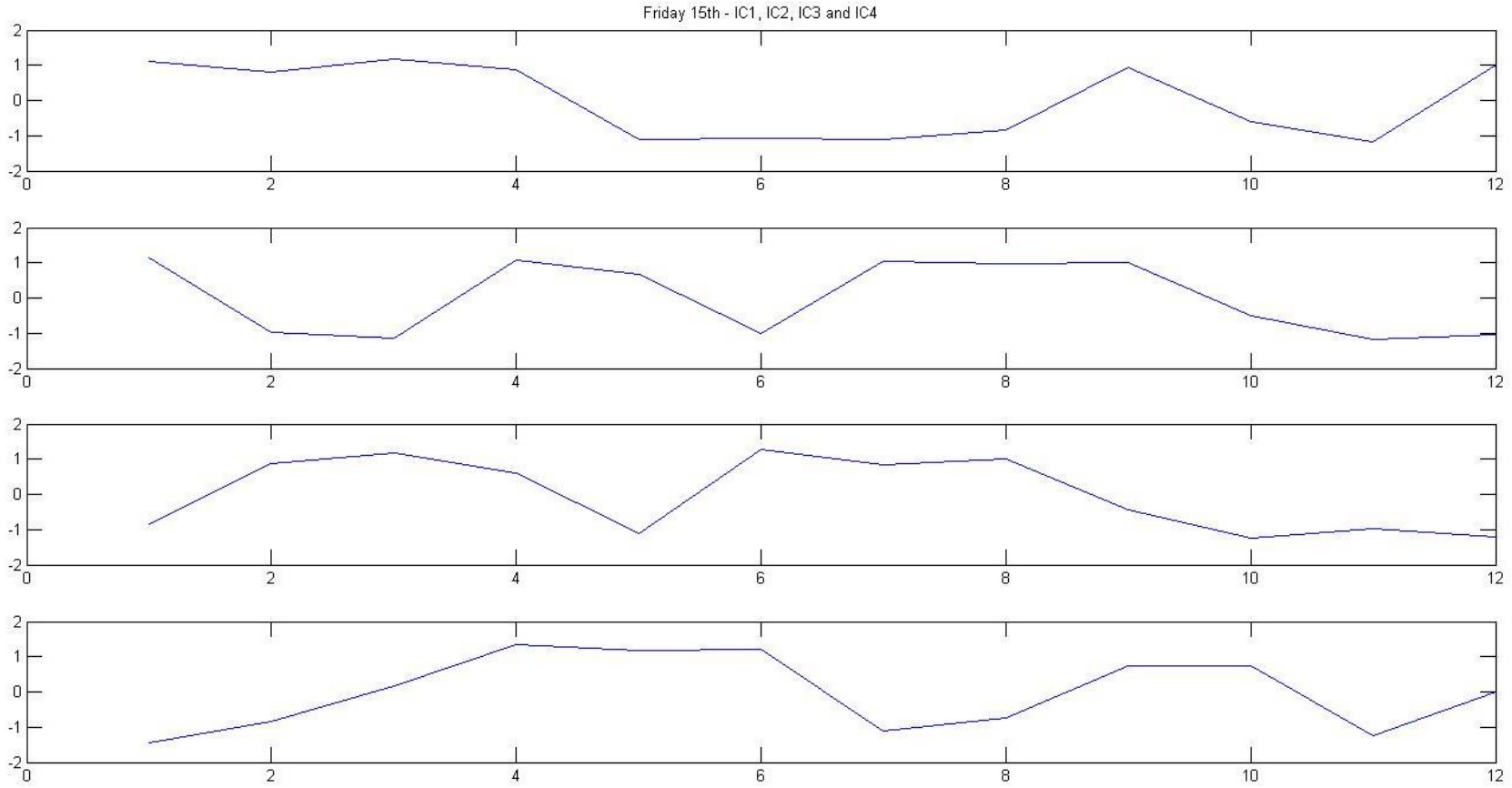




Modelling Using ICA

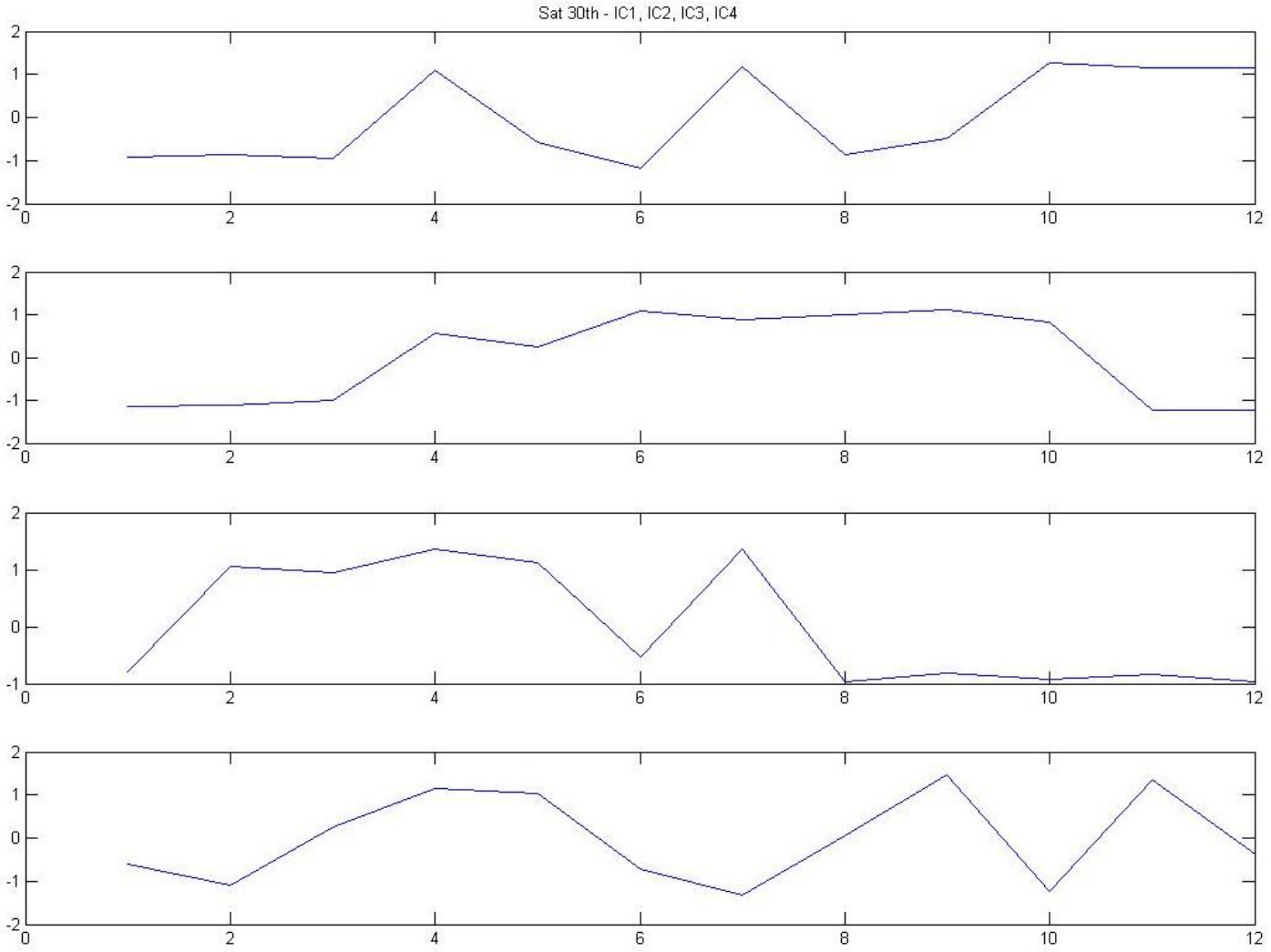
- Applications for ICA includes EEG analysis, structural deformation monitoring, financial analysis, etc.
- The aim for applying it to the bus data is to assess whether common key causative features can be extracted from the door event data of the different routes.
- This can then be used to model for future events – "Predict and Provide".
- The ICA model has two key ambiguities:
  - It is unable to determine the variances of the ICs. Also an IC can be multiplied by -1 without a model effect.
  - It is unable to determine the order of the ICs.

ICA Friday 15th – 7 Routes



- While it is difficult to ascribe each IC derived to an external feature, the peak trends and rush hour peaks can be seen.

ICA Sat 30th – 7 Routes



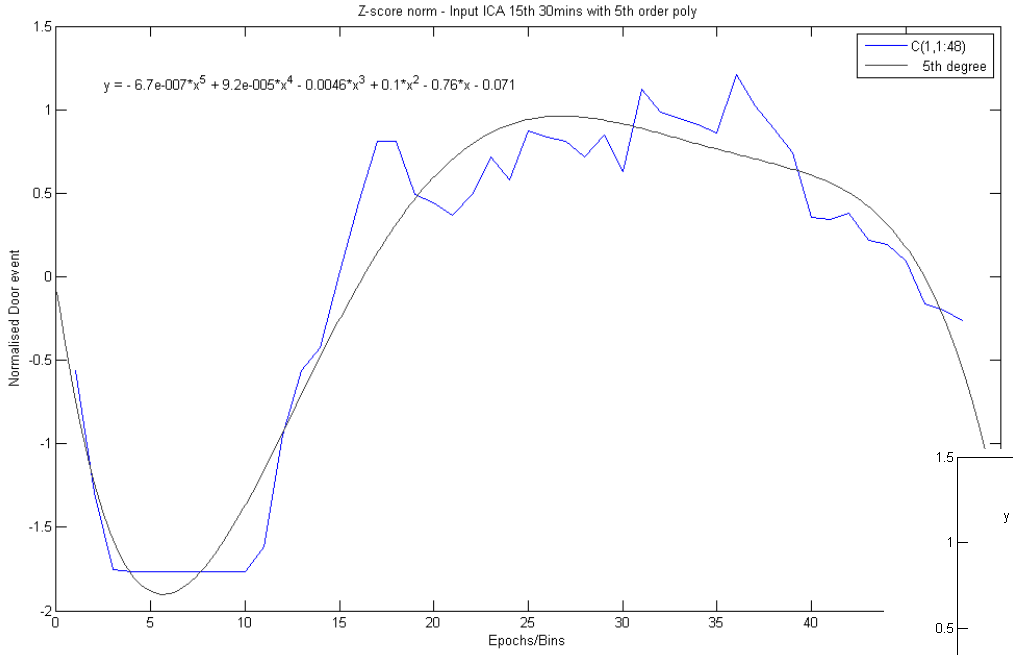
(02:00-04:00) (06:00-08:00) (10:00-12:00) (14:00-16:00) (18:00-20:00) (22:00-24:00)

ICA Analysis Sat 30th

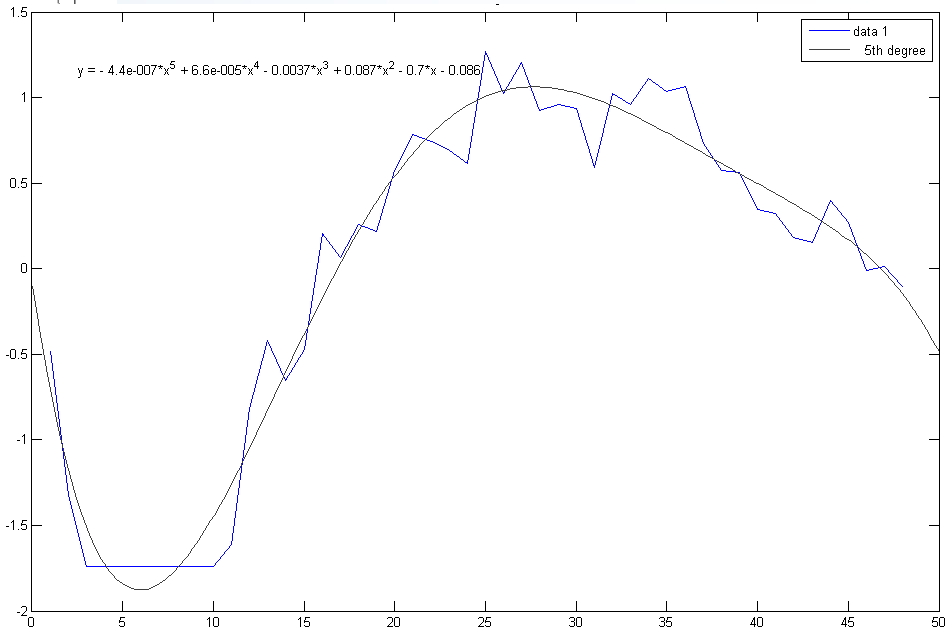
- IC1: Peak at 4 & 7= 6-8am & 12:00-14:00 resp. – Morning rush then midday shopping as well as some effects of people going to the football.
- IC2: Day time vs Night time effects.
- IC3: General morning activity and then peak for football start.
- IC4: Peak at 9 = 16:00 – 18:00 – last minute arrivals for FA; peak at 11=20:00 – 22:00 – going home.

Empirical Modelling

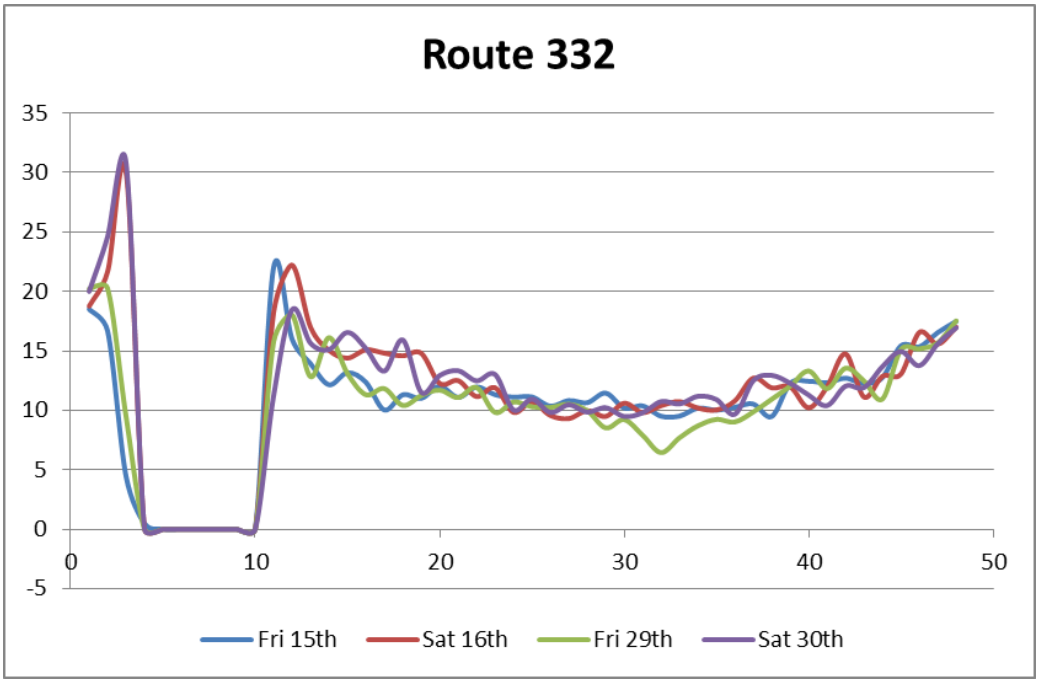
- Curve fitting using high order polynomials

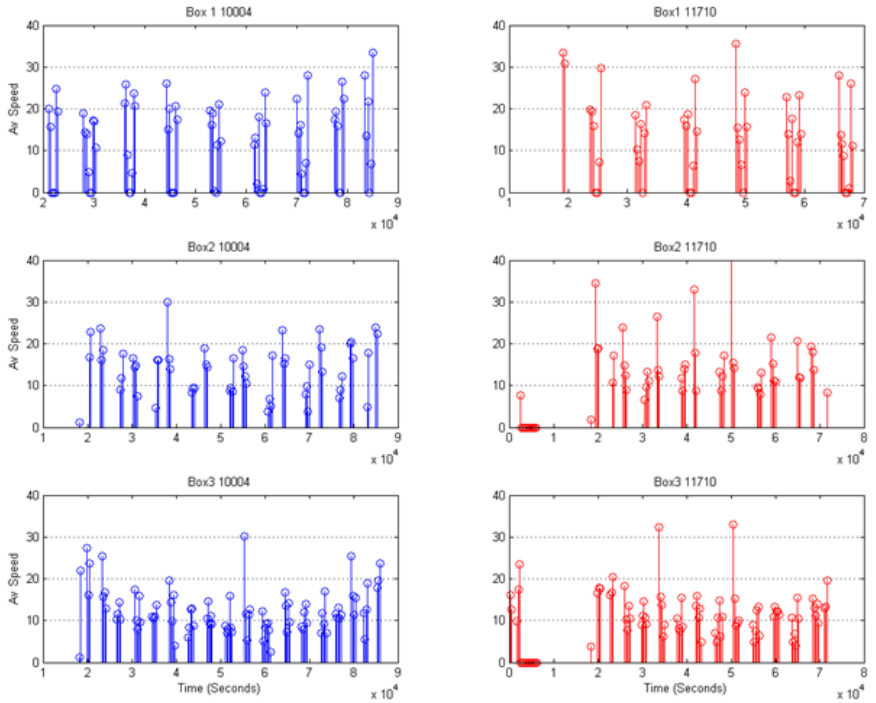


<- Friday 15th – z-score normalised door event data for signal 1 (route 332)



Sat 30th – z-score normalised data for signal 1 (route 332)





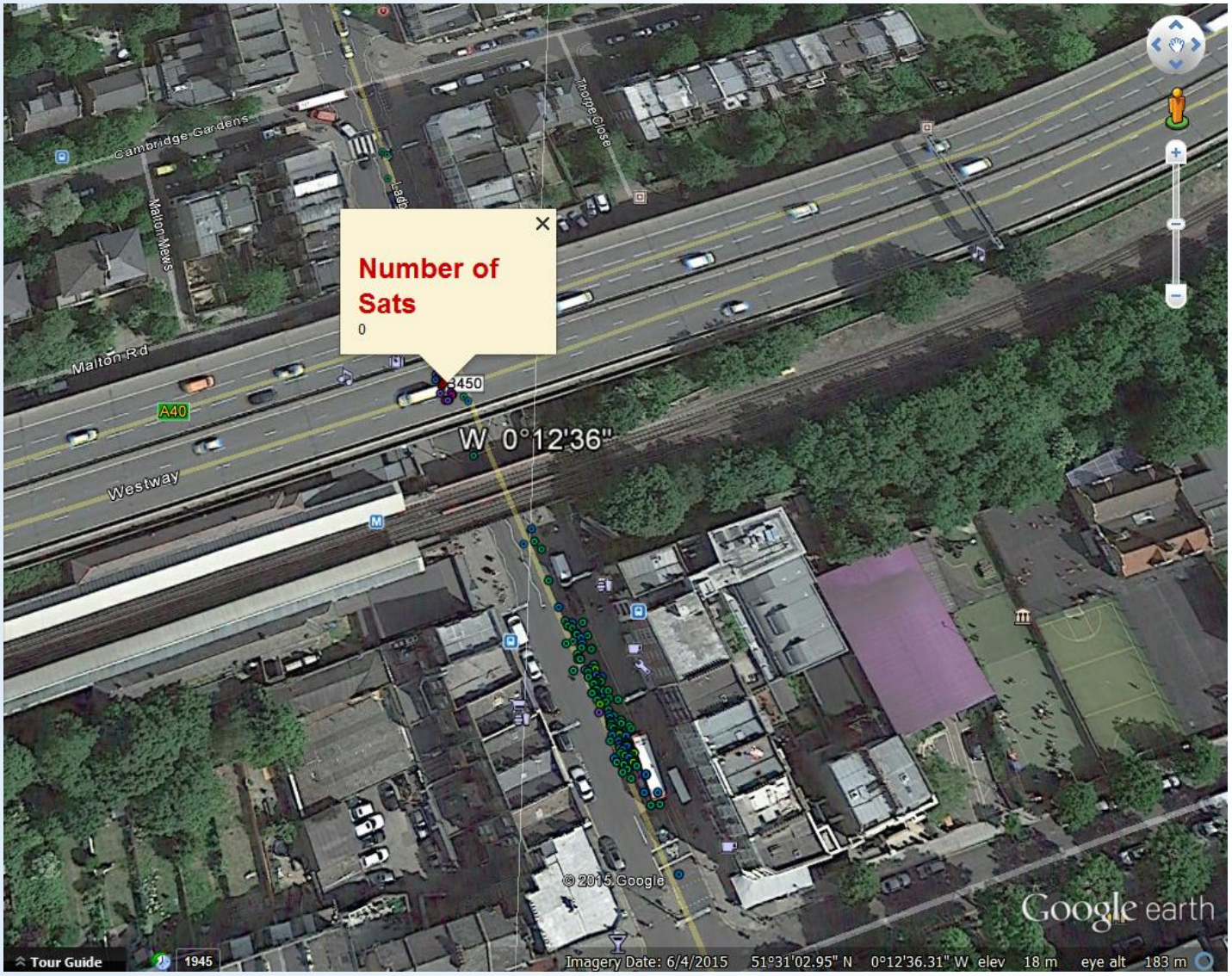
Vehicle Speed Analysis:

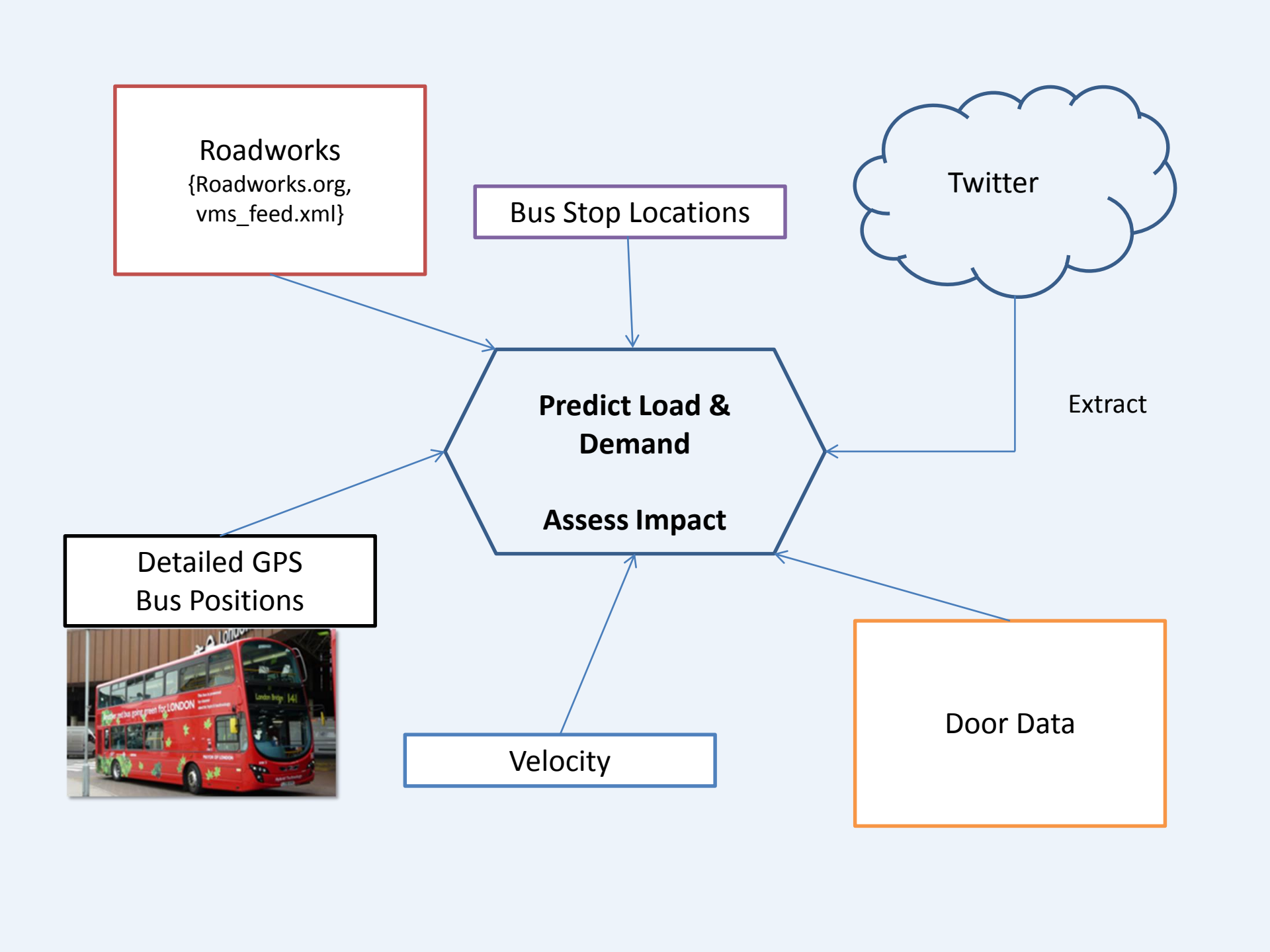
(a) Aggregated speed in 30minute bins for each route segment within a 10km radius of Wembley stadium

(b) Aggregated speed (5mins) for two specific buses on Route 332 passing through selected sub-zones (2km radius around certain bus stops) labelled ‘Box1’, ‘Box2’ and ‘Box3’.

This can be used to develop a pattern for what is normal for each sub-zone and thus a deviation from this trend can be used to identify an anomalous event.

Satellite Visibility




Roadworks
{Roadworks.org,
vms_feed.xml}
Bus Stop Locations
Twitter
Predict Load &
Demand
Assess Impact
Extract
Detailed GPS
Bus Positions
Velocity
Door Data

Conclusion

- Routes are complex and difficult to analyse.
- They are affected by a myriad of factors ranging from road works, closures, diversions, broken down vehicles, events, etc., as well as the day to day pattern of usage which is unique to each area.
- Trying to isolate cause and effect is difficult. Though this feasibility study shows that the data can give insights to enable prediction for adequate service provision.

Thank You!

I would like to acknowledge Mauro Manela and Simon Reed of TfL for providing access to the data used in this study