Data Sandbox+
Cross-projects meeting

16 January 2020
Project presentations
Round 1 winners

1. Real-time prediction and mitigation of disruption through personalised passenger communication

2. IntelliDwellTime

3. Data-Driven Robust Timetabling

4. Rail Performance Modelling for Strategic Decision Making
Using real-time prediction to influence passenger behaviour in order to improve the management of disruption on the railway
**Project team**

- Data platform - historic and real-time - rail + connected networks
- Commercially deployed personalised communications
- Door-to-door transport demand
- Real-time machine learning
- Leading the development of the predictive disruption model
- Experts in data-driven approaches to delay prediction
- Extensive history of relevant Innovate UK-, industry-, and EU-funded work
- Real-time machine learning
Aims and Objectives

- Enable better management of disruption
- Improve customer experience of rail travel
- Demonstrate potential of rail disruption management at human behavioural level
- Take a customer-focused approach and empower passengers
- Use real-time predictive capability based on Kx technology
- Test communication of predictions to customers and station staff
- Reroute customers and intelligently distribute load to mitigate effects of delay
Expected outcomes

- Demonstration of customer-centric, real-time predictive model of rail disruption using Kx technology

- Dynamic model based on extensive historic performance and environmental data, using methodologies proven in the rail domain

- Tested methods of passenger communications and delivery tools- initially trialled through established Messenger channel

- Analytics tools to measure impact and support commercial case
Benefits to industry

· Data-driven predictions designed to inform customers

· Dynamic approach based on exogenous data to contribute to disruption mitigation

· Communications model able to divert passengers and distribute load around issues (E.G. GWR Oct 2018)

· Positive impact on customer satisfaction, as seen already in existing commercial deployments
Methodology

- Definition of modelling objectives (through industry consultation)
- Data audit
- Aggregation of Zipabout platform historic data and new inputs from sandbox

Deliverables

- Full technical specification document
Methodology

- Prediction of service delays based on historic data
- Application of Random Forest methodology shown to be effective in this problem domain
- Continuous performance assessment and daily model refinement based on available data

Deliverables

- Technical report detailing:
  - Modelling approach
  - Validation method / results
  - Deployment of the model in / to new geographic areas
  - Mechanisms / processes for model update
WP3 - Triggers and customer engagement

**Methodology**

· Industry consultation and requirements gathering

· Identification of user stories, trial lines and key information

· Rules of engaging customers defined

**Deliverables**

· Logic document outlining parameters of trial, trigger rules and key information
WP 4 - Conversational flow development

**Methodology**

- Behavioural psychologist input
- Design of messaging treatments
- Validation in small-group testing
- Deployment of conversational flow and logic to internal Messenger testing channels

**Deliverables**

- Document outlining different message treatments and hypotheses
- Internal test document
WP5- Tech. rollout and benchmarking

Methodology

· Technology rollout planned and documented,

· Trial objectives fully documented

· Customer satisfaction and operational impact of delays benchmarked through literature reviews and surveys

Deliverables

· Confirmed trial timeframes and plan

· Benchmarking results for post-trial measurement
WP6 - Customer trial

Methodology

- Iterative rollout of technology to LNER Assistant Messenger bot
- Testing of different messaging treatments
- Later tests of information delivery for operational staff

Deliverables

- Full test document outlining results and process
WP7- Management and assessment

Methodology

· Targeted, in-channel surveys to measure effect of comms and rerouting against satisfaction benchmarks

· Validation of predictive model against operational data

· Business case development

Deliverables

· Draft business case with supporting evidence
Methodology

· Analytics measuring customer satisfaction and delay effect against other inputs

· TOC consultation for operational value

Deliverables

· Final report including:

  - Trial findings, success of model, effect on customer satisfaction

  - Data analytics, business case
Exploitation

- Immediate roll out of predictive model and communications into commercial product, including National Rail Enquiries
- Built on Kx technology supporting commercialisation
- API provision into existing information sources
- Customer-centric, real-time predictive model to supplement Darwin
- Analytical tools to inform disruption mitigation strategies delivered through personalised customer communications
Data Sandbox+ IntelliDwellTime (IDT)
Overview Presentation January 2020
The IntelliDwellTime (IDT) Team – and why we’re here…

ScotRail
End-User & Co-Sponsor

Project Lead & Principal Sponsor

ELASTA CLOUD
Commercial Product Development

porterbrokek

A Data Sandbox (Dwell) Feasibility Winner
Agenda:

1. Aim – what problem is IDT designed to tackle?
2. Approach and Methodology
3. Initial Findings
4. Challenges and Next Steps
5. Further Questions?
1. Aim – What are we trying to tackle? in a picture…
1. Aim – What are we trying to tackle?

- **< 3mins, Sub-threshold, suspected to be due to Dwell Issues**
  - 1 Million minutes per year, nationally (= 2yrs of time)

- **< 3mins, Sub-threshold, so do not have a known cause**
  - 28%

- **>3mins, Attributed, so have focus to determine cause**
  - 65%
1. Aim – What are we trying to tackle?

NR and TOCs: starting to focus on understanding sub-threshold delays as well as attributed

→ Utilising data science to establish root cause, so improvements be made

Dwell is a challenge: Difficult to link parameters to outcomes

e.g. staff practice and processes, seasonal conditions, capacity overall increase and daily fluctuations, technical failures etc.

IntelliDwellTime Project will demonstrate how data can be used to impact the

1 million dwell related delay minutes per year
Build on existing tools/methods to assist in establishing **target areas** for Dwell Improvement:

Gordon Stewart (Head of Performance): “But it’s really hard for human beings to detect underlying problems when there are probably a variety of issues at different times of day. NR has acknowledged to ORR that they need more data science. See below for our dwell time adherence by hour at Rosyth station, for example:”
2. Approach and Methodology

Focusing on **door operation on ScotRail Class 158’s**, we will:

**Aggregate Data**
- **TRUST, passenger counts, door sensors, OTMR, weather, staff, location, etc**

**Apply Analytics**, to assist in root cause
- Problem stations and under what conditions they struggle
- Problem doors/vehicles
- People/ training issues and opportunities (benchmarking, learning from the best)

**Quantify Benefits** of each to rank improvement plans

**Provide Baseline and Measure Impact**, to verify improvements and identify next priority issues
5. Initial Findings (month 2 of 7)

Started with a simplistic “Dwell Map”

A – Expected time between Wheel stop and door open
X – Additional Dwell time

B – Expected time between door open and door close
Y – Additional Dwell time

C – Expected time between door close and wheel move
Z – Additional Dwell time
5. Initial Findings (month 2 of 7)

Confirmed which feeds/events we need to develop this process map of the dwell process:

![Diagram of Station Dwell Remote Feeds]

- **A** – Expected time between wheel stop and door open
- **X** – Additional Dwell time
- **B** – Expected time between door open and door close
- **Y** – Additional Dwell time
- **C** – Expected time between door close and wheel move
- **Z** – Additional Dwell time
5. Initial Findings (month 2 of 7)

Working through which of the feeds we have, and understanding how they can be used:

1. Joined Nexala data with Working Time Table and unit allocation
2. Determined wheel stop and start
3. Looking at Door open/close feeds and accuracy of OTMR data for these timings
5. Challenges and Next Steps

Challenges:
1. Data has been challenging to get hold of…. and in formats that we were expecting
   → Believe we have enough data now to start evaluating overall Dwell

2. Local conductor cab door open / close cannot currently be determined from the OTMR data
   → Further work is being performed on the OTMR data to see if there are other opportunities

Next Steps:
1. Develop historic model to output the Dwell times for the CI158 routes

2. Looking at opportunities with Amey and the Quartz tool as a possible end-use target
6. Questions?

Welcome!
Data-Driven Robust Timetabling

Data Sandbox+ Cross-Project Meeting

John Preston, John Armstrong, Stephan Zieger
16 January 2020
Overview

• Project team and contributions
• Context - performance
• Preliminary review
• Objectives
• Case study
• Work packages (WPs 1-4)
• Overall industry benefits
• Project schedule
Project team, contributions

- TRG: previous timetable and performance research and other work for RSSB and Network Rail; knowledge and understanding of international research and methods
- RWTH Aachen: timetable applications of Big Data and Machine Learning; international knowledge and experience
- Network Rail: primary ‘research client’; data provision and guidance; knowledge and understanding of industry needs
- Bellvedi/Tracsis: ATTUne software and wider expertise
- WPA: in-depth industry knowledge, including timetabling process, its shortcomings and links with performance
Context – performance (1)

- Growing levels of traffic and secondary delay
  - 70% of attributed delay
Context – performance (2)

- Growing levels of secondary delay – 70% of attributed delay
- Unattributed sub-threshold (<3 minutes) delays
  - 35% of total (~67% for some TOCs); poorly understood
- Need for objective, quantitative measure(s) of predicted timetable performance quality – research hypotheses:
  1. TT quality issues reflected in sub-threshold delays – unlikely to cause larger delays
  2. TT-related delays related to incorrect allowances
  3. Amended allowances → TT quality ↑ (NB trade-offs)
Preliminary review (1)

- Timetable Quality definitions (from the ON-TIME project)
  
  - **Feasibility** – ability of trains to adhere to scheduled paths under normal operating conditions without delays or conflicts
  
  - **Robustness** – ability of timetable to absorb day-to-day operational variations and maintain planned schedule throughout (reflects distribution of allowances)
  
  - **Stability** – ability of timetable to recover from primary delays so that trains regain their scheduled paths (reflects size of allowances)
Introduction
Timetable quality trade-off

Competitive travel times
• Short running and dwell times
• Short passenger transfer times
• High frequencies

Reliable travel times
• Punctual arrival times (no late arrivals at destinations)
• Reliable transfers (no missed transfers)
• High availability (no cancellations)

No allowances
Much allowances

Robustness and allowances in timetabling
Objectives

- Overall objective:
  - Improved timetable quality
    - Feasibility, Robustness, Stability
    - Improved punctuality, performance; higher thresholds of reliable capacity
  - via

- Better understanding of causes, transmission of timetable-related/sub-threshold primary and secondary delay

- Ability to quantify timetable-related performance risks and thus compare alternative timetables using resulting metrics
Case study
WP1: Top-down Analysis (1)

- Mining of historic performance data for Wessex Route
  - Preliminary MATLAB, ML analysis of Dec 2017 – Dec 2018 data by Stephan Zieger

- Identification of locations, times and/or rolling stock/service types with recurring performance (i.e. punctuality) problems
  - Punctuality
  - Running and dwell time exceedances
WP1: Top-down Analysis (2)

- Initial Results – Punctuality

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<td>50.9%</td>
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![Histogram of Lateness Distribution](image)
WP1: Top-down Analysis (3)

- Running times
WP1: Top-down Analysis (4)

- Dwell times

![Graph showing number of entries vs. change in delay in minutes](image)
WP1: Top-down Analysis (6)

- Mining of historic performance data for Wessex Route
  - Preliminary MATLAB, ML analysis of Dec 2017 – Dec 2018 data by Stephan Zieger

- Identification of locations, times and/or rolling stock/service types with recurring performance (i.e. punctuality) problems
  - Punctuality
  - Running and dwell time exceedances

- Report

- Input to subsequent bottom-up analysis in WP3
WP2: International Review

- Review of alternative approaches - ongoing:
  - Methods of Schwanhausser, Hertel, etc. – analysis, prediction of performance, esp. secondary delays
  - Pros and cons

- Applicability to GB situation in current or modified form?

- Potential for replication (with modification as necessary) of aspects/elements in GB-specific methods and tools?

- Report of findings and recommendations
WP3: Bottom-up Analysis (1)

- Bottom-up performance analysis of locations/services identified in WP1 - ongoing
  - Detailed analysis of delays (changes in lateness) in relation to the planned timetable and underlying planning rules – \( \Delta \) lateness vs. net allowances
  - ‘Transverse’ (by location) and ‘longitudinal’ (by train/diagram, individually and in series) analyses
  - Identification of ‘reliable lower limits’ by location, time, service/stock type for SRTs, headways, dwell times, etc.
  - Calculation of ‘expected delays’ arising from different running and dwell time scenarios
WP3: Bottom-up Analysis (2)

- **Initial results – Barnes station**

- **Average delay probability for Barnes Station depending on time of day and dwell time filtered for weekdays**

- **Increasing the dwell time by 30 seconds (1 minute), may decrease the probability of being delayed from 58.7% to 8.0% (6.2%)**
WP4: Initial Implementation

- Implementation of findings
  - Preparation of ‘overlay rules’ to provide local and service type-specific adjustments to Timetable Planning Rules
  - Initial incorporation in ATTUne to indicate potential performance risks (analogous to existing planning rule violation and conflict warnings)
  - Development of quantitative indicators of likely timetable performance

- Report

- New and updated timetable assessment and planning tools
Overall industry benefits

• Improved understanding of timetable-related (and sub-threshold) delays
• Ability to quantify predicted timetable performance and compare alternatives
• Improved punctuality and performance
• Opportunity to maximise reliable capacity
• Potential impacts of further/follow-up work
## Project schedule

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Add picture of Brunstall, Fat Cat?
Rail Performance Modelling tools

Presented by Jonathan Hyde
The railway is a complex system

Complex systems:
• have many diverse, interacting components
• are non-linear and non-proportional interactions between the components
• have components that adapt/learn in response to change

Centre for the Evaluation of Complexity Across the Nexus
www.cecan.ac.uk
Aim of research and demonstration
Create practical tools to help improve performance

The problem:
• reactionary delays
• attributed delay data

The project:
• big data
• agent based modelling
• interactive visualisations

The outcomes:
• insight into what causes reactionary delay
• identify effective ways to improve performance
• measure the potential performance improvements available
  » lateness
  » passenger journey delay
  » financial penalties

Primary delay near Birmingham, impact spreads across network

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Collaboration partners

- RSSB
- Network Rail
- Greater Anglia
- City University of London
- Heriot-Watt University
- University of Southampton
- Steer
- Tracsis plc
- ScotRail
- Crossrail
Rail Performance Model and Interactive Visualisations

Using industry data to help TOCs and Network Rail improve service performance

Finding out where to focus effort so it really counts

Model the interaction of trains, and the reactionary delays resulting from conflicts,

Discover the root causes of poor performance by visualizing the complex interacting delays,

Model interventions designed to remove/reduce the effect of these root causes,

Quantify the benefits of the improved performance to establish the value for money of interventions.

Rail industry data

Rail Performance Model

Service performance results

Interactive visualisations

Rail Performance Model and
Interactive Visualisations

Using industry data to help TOCs and Network Rail improve service performance

Finding out where to focus effort so it really counts

Model the interaction of trains, and the reactionary delays resulting from conflicts,

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Rail industry data

Rail Performance Model

Service performance results

Interactive visualisations
Rail Performance Model - demonstration
Agent based model: 1,000 simulations of the same timetabled day, trains are agents, their interactions can change each model run
... exploring the range of the possible, including days that haven’t happened yet, the best / worst ...

Data driven: the model input data is configured to represent the real rail network
• A specific part of the network: incidents tailored to represent a TOC area, region, or route
• Any day(s) from the timetable: the CIF timetable is used as source data
• Incidents delaying trains from any periods of the year: autumn leaves, cold winter periods, hot summer periods

New scenarios: a proposed rail service or situation
• Changes to the timetable, and new timetables (e.g. GWR timetable analysis)
• Different primary incidents and delays: interventions to improve performance

A strategic modelling tool, not a micro simulation:
• Relatively quick and efficient to setup for new area
• Able to model a large area, with multiple routes, all operators (aiming at the whole national rail system)
• Easy to setup alternative situations, or scenarios, to test impact of changes on performance
Sandbox plus project

1. **Build on last Sandbox** to create a market ready set of tools:
   - Quick and easy to setup for any part of the UK
   - Include key dependencies causing reactionary delay (stock and crew)
   - Add passengers, and report passenger journey delays
   - Calculate and report likely financial penalties
   - Create new ways to explore results through visualisations to gain insights
     - Schematic map visualisations of results
     - Rail service capacity (timetabled and with incidents)

2. **Demonstrate the value of the tools:**
   - Case studies with GWR, Greater Anglia, Network Rail, other TOCs…

[Visual diagram of research tools and project stages]
Scaling up challenge
Modelled area (for testing), based on Sandbox plus GWR timetable project
Scaling up challenge
creating locations in modelled area… GWR example

Source data: BPLAN
For May 2019 timetable

164 locations in test route GWR Paddington to Bristol (orange)
  • 2,500 train services in a day

Consider larger modelled areas
e.g. 1,031 GWR locations (green)
  • XX train services in a day

6x size of Sandbox 1
Model area for case study demonstrations
e.g. all GWR routes

Station/depot/sidings
(size = platforms)

Available routes / track
Scaling up challenge
creating locations in modelled area

Source data: BPLAN
For May 2019 timetable

12,129 UK locations (stations, depots, sidings, junctions)

1,031 modelled locations in GWR routes (inside green shape) = a modelled area

1,205 actual TIPLOC (with duplicate locations)
Scaling up challenge
case study demonstrations

Four TOCs contributing (GWR, Greater Anglia, MTR CrossRail, ScotRail)
The model will be calibrated for each TOC:
• All locations (stations, sidings, depots)
• All routes
• All trains from all operators
• Any day from any timetable: all train journeys, all station stops

Note: model is data driven, any route can be characterised, any day of year, with specific incidents or situations
Model results
performance measures

RPM model results
EXISTING
EXISTING
NEW
NEW

Service delay
Service lateness
Passenger journey lateness
Financial impacts

Delay by type (primary, reactionary, subthreshold)
Lateness at station stops
Lateness at destination
£ penalties

Select measure to explore in visualisations

By attribution JPIP
By location
By service and service group
By time of day

Delay length
% on-time station stops
% of late station stops by (1, 3, 5 mins, etc)
% on-time journeys
% of journey lateness by (15, 30, 60 mins, etc)

Interactive visualisations

On time Late

OCTOBER
30
JANUARY
08

Delay by type
% on-time station stops
% of late station stops by (1, 3, 5 mins, etc)
% on-time journeys
% of journey lateness by (15, 30, 60 mins, etc)

Industry (Including TOC Franchise) Measures
Schedule 8 Payments
Delay Repay
Revenue impact

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Select measure to explore in visualisations

By attribution JPIP
By location
By service and service group
By time of day

Delay length
% on-time station stops
% of late station stops by (1, 3, 5 mins, etc)
% on-time journeys
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Interactive visualisations

On time Late

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Delay by type
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Industry (Including TOC Franchise) Measures
Schedule 8 Payments
Delay Repay
Revenue impact
Benefits to rail industry

Immediate benefits for GWR, Greater Anglia, MTR CrossRail, ScotRail, Network Rail:
- Knowledge of the underlying causes of service performance, to share with industry
- Performance improvement solutions (evidence Performance Improvement Plans)
- Champions, equipped to continue using tools to improve performance
- Stress testing capability for changes to timetables, stock and crew diagrams, passenger demand, infrastructure changes, temporary speed restrictions, …

Ongoing benefits to rail industry:
- A tested performance modelling solution
- With potential to deliver UK wide modelling
- A platform to develop further…

VALUE
Improve disruption management and rail performance through reducing, and/or better recovery from, reactionary delay.
Rail Performance Modelling

Potential further development

- **Alternative infrastructure:** test alternative rail network topology (impact of HS2 and other infrastructure investment)

- **AI goal seek:** Use AI to suggest the best interventions to reduce delays

- **Real-time:** use real time train movement data feeds to create a real time decision making aid

- **Real-time passenger information:** Provide predictions for through network journey timing
Q&A panel
Conclusions

1. Sharing project plans / findings (to date)
2. *For project teams*: start to identify potential synergies and future collaboration opportunities
3. *For industry partners*: gain early visibility of portfolio of work and provide advice / suggestions etc.
4. Network!
Could be of interest…

• 21 February, London - Innovate UK launch of FOAK2020

• 26 February, Birmingham – Destination Digitalisation

• Autumn 2020 – PERFORM / Data Sandbox+ dissemination
The End