Econometric work underpinning the capacity charge

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25th September 2013

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Introduction

Introduction

Introduction
- Background
- Question
- Dataset

Background

- Network Rail (NR) introduced a capacity charge following Access Charges Review in 2001. The charge was updated as part of PR08 to take account of inflation.
- As part of PR13, NR undertook to recalibrate the capacity charge, and retained ARUP to carry out the recalibration work. As part of this recalibration work, ARUP contracted Imperial College London (ICL)to undertake an econometric analysis of the relationship between capacity utilisation (measured by the capacity utilisation index, CUI) and congestion-related reactionary delays (CRRD).
- In April 2013, NR published its Capacity Charge Consultation and Draft Pricelists, based on the findings in ARUP's draft report. ARUP's final report was published in May 2013.
- In June 2013, the Office of Rail Regulation (ORR) released its draft determinations for consultation. The draft determinations were that the capacity charge should remain fixed in in real terms in CP5, but for some limited corrections.

The question we addressed

- Arup's calculations are based on an estimate of the effect, in minutes, of an additional train on CRRD per train mile. This effect is called "*delta d*": ***is Arup's conclusion appropriate and evidence based?***

The answer is *Yes, the delta d used by Arup is conservative*

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Dataset

- We have extended the analysis of the relationship between CRRD and capacity utilisation (CUI) that was originally carried out by ICL, and on which ARUP based its calculations of *delta d*.
- We have used the same dataset as ICL, with one additional variable.
- We have estimated an econometric model.
- The dataset contains 154,920 observations in total, referring to 2012:
  - each observation relates to one of 6,455 distinct CTSs, in one of 24 separate timebands;
  - a timeband is a 3 hour time slot. There are 8 timebands on each day (0100-0400, 0400-0700, 0700-1000, 1000-1300, 1300-1600, 1600-1900, 1900-2200, and 2200-0100), and 3 days are included (Wednesday, Saturday, and Sunday);
  - each CTS is observed over the same days and timebands.
- For each CTS, data is available on CRRD, CUI, and various characteristics of the CTS:
  - the number of train miles in a year in the given CTS and time band;
  - whether the CTS is at the beginning or at the end of the SSR; and,
  - CRRD in downstream contiguous CTSs.

Summary of findings

Summary of findings

- Our model shows that on average, holding all other explanatory variables constant:
  - if CUI increases by 1 percentage point (e.g. from 40% to 41%), observed CRRD minutes increase by approximately 0.75%;
  - if annual train miles increase by 1% (e.g. from 40 miles to 40.4 miles), observed CRRD minutes increase by approximately 0.42%;
  - the first and last CTSs on an SRS, tend to have approximately 15% more observed CRRD minutes than internal CTSs; and,
  - if total CRRD minutes on contiguous downstream CTSs increase by 1%, this increases observed CRRD on the current CTS by 0.59%.
- Based on our results, we have then calculated the average predicted **impact on *CRRD per train mile*, of running an additional service** (i.e. adding an additional average train); the ***delta d***:
  - ignoring spillover effects, our *delta d* is **0.00074** minutes per train mile, **8%** higher than ARUP's;
  - when spillover effects are taken into account, the effect on CRRD per train mile of running an additional service across **the entire network** (rather than just on the CTS of interest), is up to **0.00200** minutes per train miles. This *spillover delta d* is **193%** higher than ARUP's *delta d*.
- We also find that **the effect of an additional train is almost 3 times as pronounced on a weekday than on a Sunday**, and spillovers magnify this effect by more on weekdays and Saturday, than they do on Sunday.
- Finally, we find that **the presence of a large number of observations with abnormal and unexpected values in the dataset has an impact on the model estimates**. The effect of an additional train on CRRD per train mile, is **twice as strong** when the outliers are dropped.

Model results

Overview

Model results
- Overview
- Results tables

- The results tables on the following three slides present the regression estimates for the following seven models:

1.our preferred model ;

2.ICL's preferred model;

3.The ICL model. In the tables and graphs, we refer to this as ARUP's preferred model, since this is the model that ARUP chose to calculate *delta d*;

- For each model, the tables report:
  - the estimated regression coefficients;
  - P-values of these estimates (in parenthesis); note that a P-value smaller than 0.05 indicates that the coefficient is statistically significant at least at the 5% significance level;
  - estimates of *delta d*, the average change in CRRD/train mile, when an additional train is added to the current CTS; and,
  - estimates of "*spillover delta d*", the average change in CRRD/train mile, when an additional train is added to the entire network

The results are explained, interpreted, and discussed in the next section.

Results tables – comparison to ICL/ARUP's preferred models

Model results
Overview
Results tables

Model number	1	2	3
Description	**Preferred model**	ICL's favoured model *	ARUP's preferred model **
Zero delays included?	**Yes**	Yes	No
Explanatory variables:			
CUI	**0.00746**	0.000423	0.000255
	(0.000)	(0.000)	(0.000)
Log(annual train miles)	**0.416**		
	(0.000)		
Dummy(start or end CTS in an SRS)	**0.142**		
	(0.000)		
Log(total CRRD in downstream contiguous CTSs)	**0.589**		
	(0.000)		
Sample size	**121247**	121194	88763
"Delta d"	**0.0007412**	0.00115658	0.000683558
"Spillover delta d"	**0.0020015**		

***** *ARUP, May 2013, Recalibrating the Capacity Charge for CP5, Appendix B: ICL Statistical Modelling Report and Technical Appendix, pg 15, Table 2: One-way parametric models, Exponential FE.*

****** *ARUP, May 2013, Recalibrating the Capacity Charge for CP5, pg 29. ICL's estimate of this model is in Appendix B: ICL Statistical Modelling Report and Technical Appendix, pg 23, Table 6: One-way parametric models without CRRD=0, Exponential FE.*

Discussion of results

Interpretation of results

Discussion of results
- Interpretation of results
- Effect of adding an additional train
- Comparison to alternative models

Interpretation

Explanatory variable	Interpretation of marginal effect coefficient
CUI	Effect on CRRD of increasing CUI whilst holding annual train miles, CTS position, and delays in contiguous CTSs constant. This could be thought of as **making less efficient use of the network** by, for example, reducing the speed at which trains travel, or increasing the headway between each train.
Annual train miles	Effect on CRRD of increasing annual train miles whilst holding CUI, CTS position and delays in contiguous CTSs constant. This could be achieved by **adding an additional train, but increasing train speed or reducing headway, such that CUI remains unchanged**.
CRRD in downstream contiguous CTSs	Effect on CRRD in the current CTS, of delays further down the track, whilst holding CUI, annual train miles, and CTS position constant.
Dummy variable for CTSs at the start or end of an SRS	Average difference in CRRD between CTSs at the start or end of an SRS, and internal CTSs.

Estimated effects on CRRD

- On average, holding all other variables constant:
  - if CUI increases by 1% point (e.g. from 40% to 41%), observed CRRD minutes increase by approximately 0.75%.;
  - if annual train miles increase by 1% (e.g. from 40 miles to 40.4 miles), observed CRRD minutes increase by approximately 0.42%;
  - the first and last CTSs on an SRS, tend to have approximately 15% more observed CRRD minutes than internal CTSs; and,
  - if total CRRD minutes on contiguous downstream CTSs increase by 1%, this increases observed CRRD on the current CTS by 0.59%.

Effect of adding an additional train

Discussion of results
- Interpretation of preferred regression results
- Effect of adding an additional train
- Comparison to alternative models

Effect of an additional train – ignoring spillover effects between CTSs

- ARUP's *delta d* for each CTS and time band, is **0.00068** minutes per train mile.
- Our average *delta d* is **0.00074** minutes per train mile, **8% higher than ARUP's**.

Effect of an additional train – including spillover effects between CTSs

- The effect of an additional train, given that the train does not just travel on one CTS, is likely to be higher than this.
- An additional train is likely to travel across multiple CTSs: delays, including CRRDS, are likely to increase in each CTS that it travels across. Some CRRDs spill over from one CTS to the next and need to be taken into account to assess how CRRD spread to the network
- Our model suggests that the "*spillover delta d*", the effect on CRRD/train mile of running an additional service across **the entire network** (rather than just on the CTS of interest), is up to **0.0020** minutes per train miles.
- This *spillover delta d* is **193%** higher than the *delta d* from ARUP, and **170%** from the *delta d* using ICL's approach.

Comparison to alternative models

Discussion of results
- Interpretation of preferred regression results
- Effect of adding an additional train
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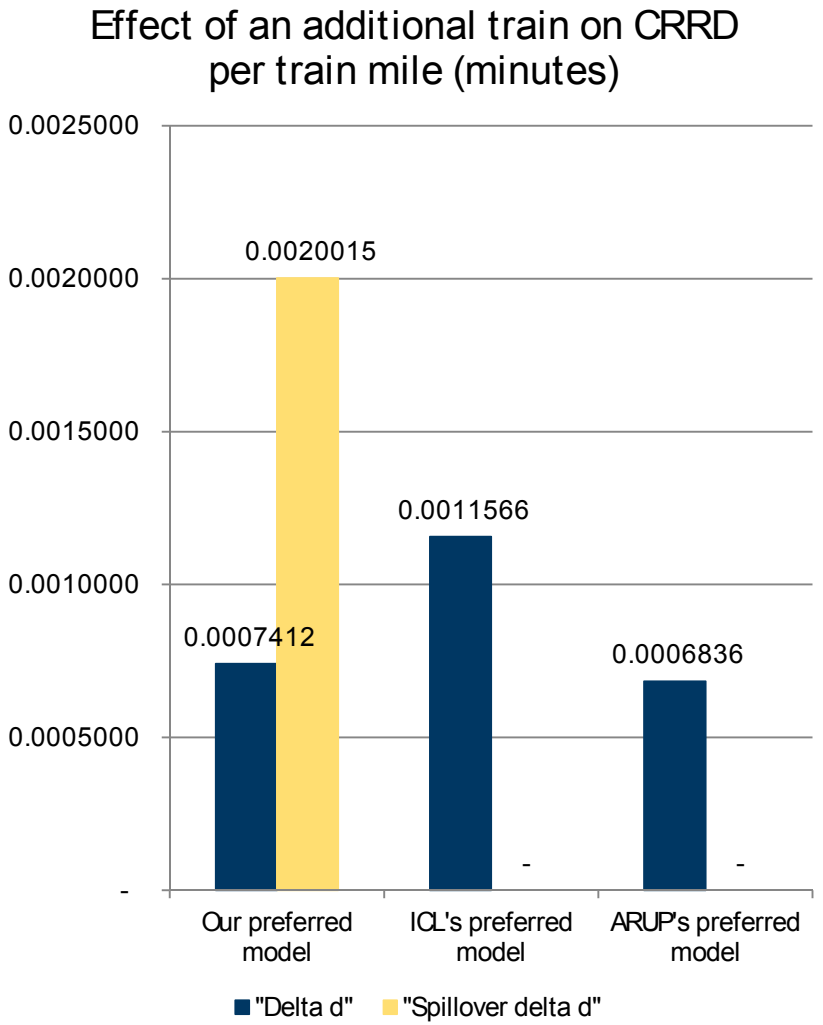
Comparing our model to ARUP/ICL models

- The average *delta d* from our preferred model is:
  - 8% higher than the *delta d* from ARUP's preferred model; and,
  - 36% lower than the *delta d* from ICL's preferred model.
- It is not possible to calculate a *spillover delta d* for the ICL and ARUP models, because those model specifications do not take account of spillover effects.



Sensitivity analysis

Overview

Sensitivity analysis
- Overview
- Outliers
- Days

- We have examined the sensitivity of the results from our preferred model, to changes in the dataset and model specification.
- This section summarises our findings, in relation to:
  - outliers – the effect of dropping u*nexpectedly abnormal observations* ('outliers') on the model estimates;
  - days – the effect of estimating the model separately for weekdays, Saturday, and Sunday.
- In brief, we have found that
  - the results are sensitive to the removal of possible outliers;
  - the effect of an additional train on CRRD per train mile, is almost 3 times as pronounced on a weekday as it is on a Sunday; and,
  - With the current dataset, it is not possible to determine precisely how the relationship differs by time band, although there are indications that the effect of an additional train is larger for the peak time bands (0400 – 1000, and 1600 – 2200) than for the off peak timebands, late at night, or very early in the morning.

Outliers

Sensitivity analysis
- Overview
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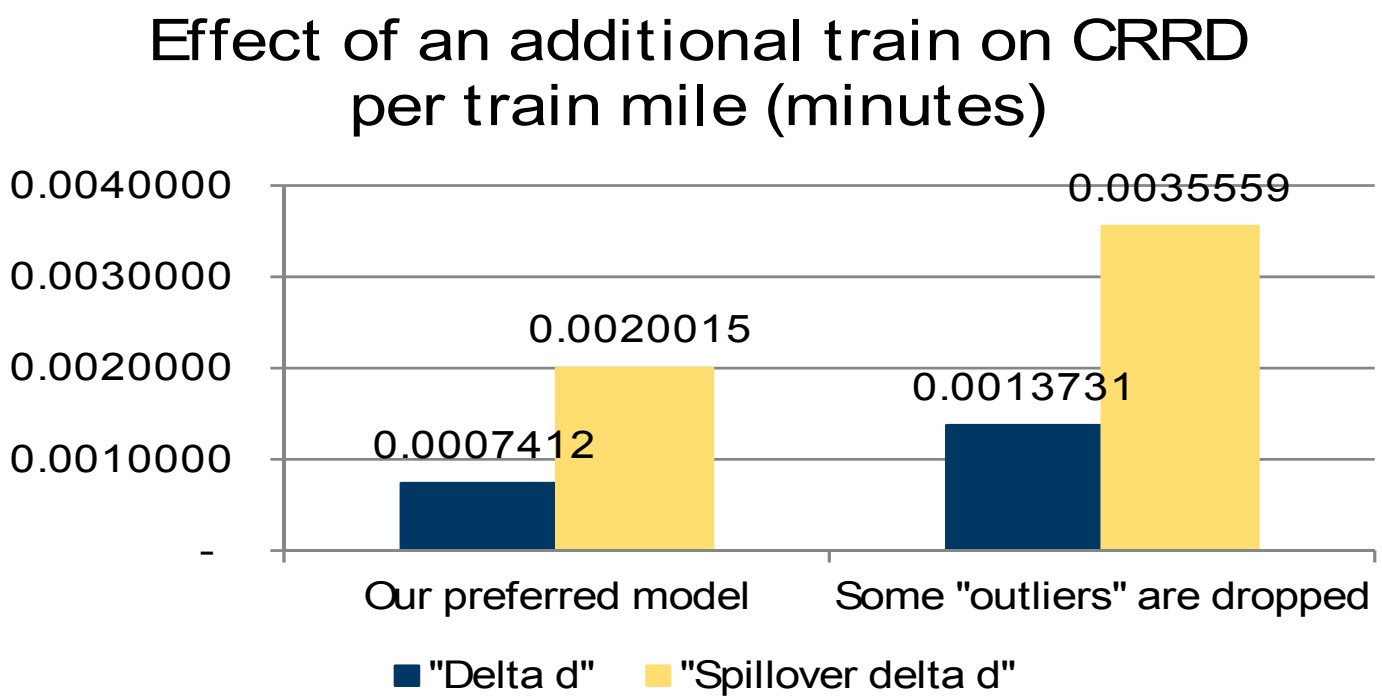
- We have used a basic method to 'identify' the effect of potential outliers:
  - CTSs with very high CUI and very low CRRD, *or* very low CUI and very high CRRD; and,
  - we exclude these observations, and re-run our preferred model.
- The results are for illustration only. They suggest that outliers have an impact on the model:
  - the effect of an additional train on CRRD per train mile, is **twice as strong** when the 'outliers' are dropped.

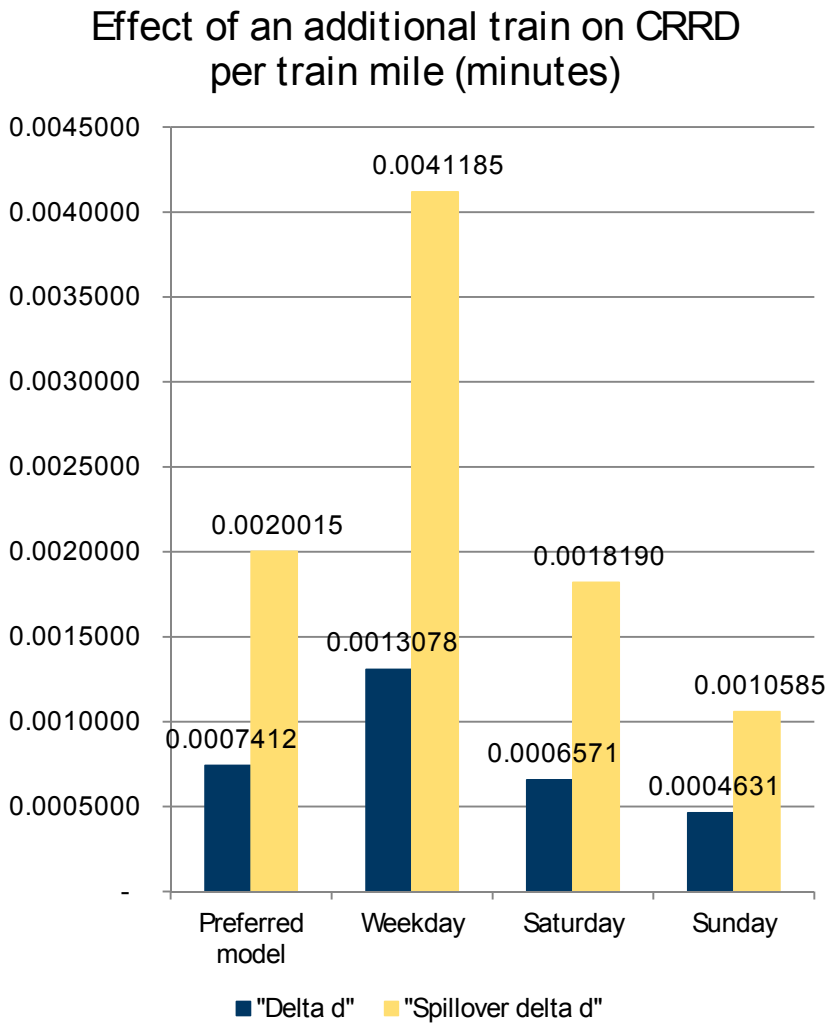
Going forward, it is important to develop and extend the dataset and analysis, to include additional explanatory variables, to reduce the influence of outliers



Days

Sensitivity analysis
- Overview
- Outliers
- Days

- We also estimate the model, separately for:
  - weekdays;
  - Saturday; and,
  - Sunday.
- The estimates differ:
  - CUI and annual train miles have a greater effect on weekdays than on the weekend; and,
  - spillover effects between CTSs, are less pronounced on Sunday, than on weekdays or on Saturday
- Using the estimates, we estimate the *delta d* for each day:
  - **the effect of an additional train is almost 3 times as pronounced on a weekday** (*delta d* of 0.0013) **than on a Sunday** (*delta d* of 0.00046);
  - the average *delta d* from the model the that pools the days together, is within this range; and,
  - **spillovers magnify this effect by more on weekdays** and Saturday, than they do on Sunday.



Conclusions

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- Our model shows that on average, holding all other explanatory variables constant:
  - if CUI increases by 1% point (e.g. from 40% to 41%), CRRD minutes increase by approx. 0.75%;
  - if annual train miles increase by 1% (e.g. from 40 miles to 40.4 miles), CRRD minutes increase by approx 0.42%;
  - the first and last CTSs on an SRS, have approx 15% more CRRD minutes than internal CTSs; and,
  - if total CRRD minutes on contiguous downstream CTSs increase by 1%, this increases CRRD on the current CTS by 0.59%.
- Based on our results, we have then calculated the **average predicted impact on *CRRD per train mile*, of running an additional service** (i.e. adding an additional average train); the *delta d*:
  - ignoring spillover effects, our *delta d* is **0.00074** minutes per train mile, **8%** higher than ARUP's;
  - when spillover effects are taken into account, the effect on CRRD per train mile of running an additional service across **the entire network** (rather than just on the CTS of interest), is up to **0.0020** minutes per train miles. This *spillover delta d* is **193%** higher than ARUP's *delta d*.
- We have also performed sensitivity analysis on our results:
  - **the effect of an additional train on CRRD per train mile, is twice as strong when the outliers are dropped**. This suggests that going forward, it is important to understand what these outliers represent, and to develop and extend the dataset and analysis, to include additional explanatory variables, to reduce their influence; and,
  - second, we have assessed whether model coefficients, and the ensuing *delta ds*, differ by day of the week: **the effect of an additional train is almost 3 times as pronounced on a weekday than on a Sunday**, and spillovers magnify this effect by more on weekdays and Saturday, than they do on Sunday.

We conclude that ARUP's estimates were conservative.

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