Institute for Transport Studies
FACULTY OF ENVIRONMENT

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Estimating Marginal Wear and Tear Costs: Econometric Methods and Evidence

Track Access Charges Summit

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ITS

A starting point – from an evidence based perspective

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- The **econometric evidence** from European case studies suggests that rail infrastructure maintenance and renewal costs vary substantially with traffic):
  - **Variability = high**

- **Engineering evidence (models)** underpinning <u>current</u> track access charges in Britain suggests costs are largely fixed:
  - **Variability = low**

- **Earlier engineering (judgement)** in Great Britain (2000; 2005) put variability somewhere in between:
  - **Variability = medium**

- **Can we better understand these differences?**

Approaches to estimating marginal cost

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- Three methods have been used in the literature to date to measure rail infrastructure marginal cost

- Method 1: engineering approach (**<u>model</u>**)
  - Simulate damage done by traffic (engineering model)
  - Determine action need to remedy damage (e.g. tamping)
  - Activity volume * Unit cost of activity = (marginal) Cost

Engineering approach: illustration

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Stage 1: Simulation (track section level)

Vehicles

Weight
Speed

Track type

Track

D1: Settlement

D2: Wear

D3: RCF

Damage mechanisms

Activities: tamping or grinding

Stage 2: Unit cost analysis

Δ (Volume of tamping)

x

Unit cost of tamping

ΔCost

Approaches to estimating marginal cost

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- Two methods have been used in the literature to date to measure rail infrastructure marginal cost

- Method 1: engineering approach (**model**)
  - Simulate damage done by traffic (engineering model)
  - Determine action need to remedy damage (e.g. tamping)
  - Activity volume * Unit cost of activity = (marginal) Cost

- Method 2: engineering approach (**judgement**) – or cost allocation approach
  - See next slide

Engineering (judgement) / Cost Allocation Approach

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Activity / asset class	Variability Proportion: 2000 Regulatory Review	Variability Proportion: 2008 Regulatory Review
Track - maintenance	30%	29%
Track – renewals (plain line)	36%	23%
Track – renewals (switches and crossings)	25%	17%
Signalling - maintenance	5%	5%
Civils – metallic underbridges	10%	8%
Civils – embankments	10%	5%

Source: ORR (2008)

Approaches to estimating marginal cost

- Two methods have been used in the literature to date to measure rail infrastructure marginal cost

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- Method 2: engineering approach (**<u>judgement</u>**) – or cost allocation approach

- Method 3: top down **<u>statistical / econometric</u>** approach
  - See next slide

Econometric approach – relate costs to traffic in statistical regression

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$$C_{it} = f(Y_{it}, P_{it}, N_{it}, \tau_t; \beta) + v_{it}$$

- C_{it} is the cost measure – say, maintenance and renewal costs
- i is the unit of observation (e.g. track section; maintenance unit; region; country); t is time period (year)
- Y_{it} - output measures (e.g. passenger tonne-km; freight tonne-km)
- β - parameters to be estimated – gives us % of cost variable with traffic and in turn, marginal cost

Notes: P_{it} - input prices (e.g. wage rate; price of materials); N_{it} - exogenous network characteristic variables (e.g. network length; linespeed capability; rail age; proportion of track in a curve; S&Cs); τ_{it} represent time variables capturing technical change over time

High level summary of econometric evidence

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- **Countries**: Britain, Sweden, France, Switzerland, Austria, plus pooled international samples (CATRIN; SUSTRAIL; NETIRAIL-INFRA)
- **Data**: sections, maintenance units / contract areas, regions, countries
- **Maintenance**: range of **mean** elasticities = **20-35%** (GB=25%)
- But the answer depends on density - range of **20-45%** (3-10m t-km/tr-km)
- **Renewal**: less evidence:
  - M&R studies from Switzerland and GB (CATRIN) – **28-35%**. M&R studies from Switzerland (SUSTRAIL) – **50%**
  - Renewal only for Sweden: **55%** (track) and **50%** (all)
  - M&R from GB Periodic Review international study (area) = **45%**
  - M&R from GB Periodic Review international study (country) = **51%**

Conclusions on the range

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- Overall evidence seems to suggest variability for M&R could be as high as **40-45%**
- The lower part of the range of estimates could suggest a possible range of closer to **25-35%**
- Some uncertainty but strong body of reasonably consistent evidence from multiple countries – similar methods
- Interesting recent evidence from **France** (econometric): **c. 20%** variable for M&R (with some models pointing to higher variability)
- Evidence does **not** support variability **below 20-25%** - so econometric evidence <u>out of line with current GB charges</u>

Engineering evidence and evolution of charges in GB

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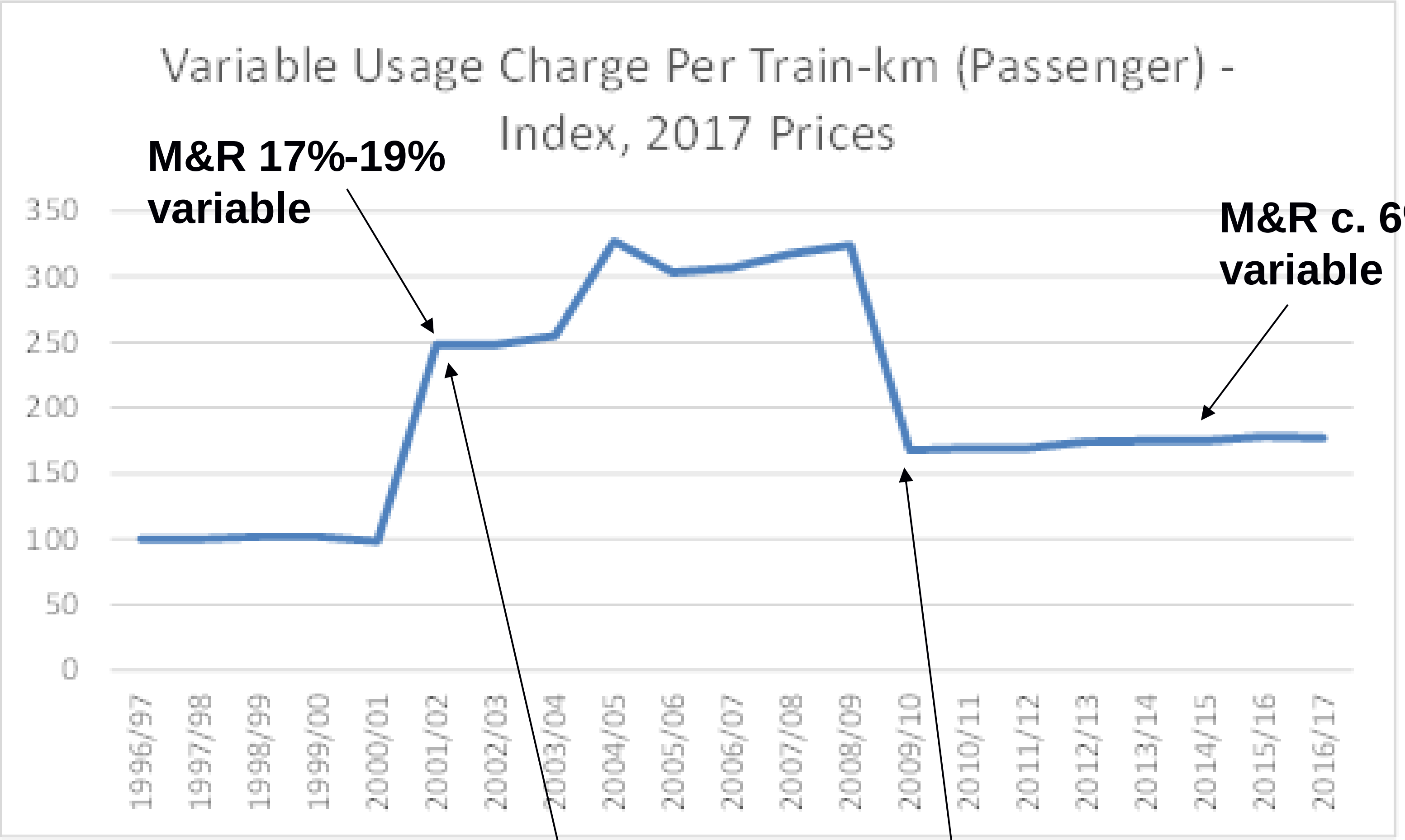

M&R 17%-19% variable

M&R c. 6% variable

PR2000: Engineering Judgement Approach

PR2008: Engineering Modelling Approach

- Why is the evidence so contradictory?
- Challenges in econometric estimation of marginal cost?
- Strengths and weakness of the two approaches

Challenges in econometric model of marginal cost [1]

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- Dealing with lumpy renewals costs?
  - **Two-part models**: decision to renew, then how much to renew (section level data); e.g. Andersson et. al. (2012) Odolinski and Nilsson, 2017
  - **Maintenance and renewal combined** together (many studies)
  - **Steady-state adjustments** to renewals prior to estimation (Smith, 2012)
  - **Dynamic models** that take account of M&R interactions and intertemporal effects (Odolinski and Wheat, 2017 – NETIRAIL-INFRA)
- Controlling for differences between sections/regions/countries?
  - **Extensive set of control variables**. E.g. Electrification, age of rail, linespeed, no. of S&Cs per track-km, proportion of track in a curve etc.
  - **Cross-sectional and panel data approaches taken**: different panel techniques applied (fixed and random effects; and frontier models)
  - Standardisation of approach to some extent

Challenges in econometric model of marginal cost [2]

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- Data types and coverage:
  - **Range of aggregations tried**: sections; maintenance units / contract areas; regions; countries; dual-level structures
  - **Data coverage**: co-ordinated research across EU research projects – suggests a generally <u>broad definition of M&R costs </u>(except stations)
  - **Scaled elasticities**: can be used where narrower definitions of costs are used (e.g. in GB, focus was on track – the most variable element)

- Functional form of the cost function
  - Wide range tried from CD and translog to Box-Cox and Box-Tidwell forms
  - Issue is about ensuring sensible variation in elasticities away from the sample mean
  - Again, standard methods applied across case studies in general

So why the differences with engineering methods?

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- Strong advantage of the econometric approach is that it is based on actual data – what actually happens on the ground
- Whereas engineering approach is based on a model of what “should” happen – though which is optimal?
- Engineering models: getting from simulated damage to cost?
  - Assumptions about unit costs and timing of remedial activity
- In GB the engineering approach:
  - Is based on a standard section – not an average based on all sections
  - Some calibration involved to reconcile to budgeted costs

But can these things explain the extent of the difference?

A final remark on cost base and disaggregation

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- With track-section disaggregation there may be a concern that the process of cost allocation to sections could distort results

- If a percentage mark-up on direct costs is used – in log models the elasticity will be unaffected – but the variability proportion **is then being applied to indirect costs as well**

- If allocated based on traffic the elasticity / variability proportion will be distorted

- **That said, the evidence from sections, areas, regions, countries is still fairly clear overall**

Conclusions

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- Overall, co-ordinated research has produced a wide body of fairly consistent evidence; using a range of approaches, different case studies, and different disaggregations

- There are issues and challenges and some uncertainty – however, It is hard though to disturb the basic conclusion – that M&R cost variability is **no lower than 20-25%** and **is probably higher**

- GB engineering evidence is much lower – there are some possible explanations but further research needed:
  - Lets open-up the “black box” on both approaches to obtain a clear finding on this important issue for charging levels

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- Thank-you for your kind attention

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References

- Odolinski, K. & Nilsson, J-E. (2017) Estimating the marginal maintenance cost of rail infrastructure usage in Sweden; does more data make a difference? Economics of Transportation, 10, 8-17.
- Andersson M; Wikberg T; Smith A; Wheat P (2012) Estimating the marginal cost of railway track renewals using corner solution models, *Transportation Research Part A: Policy and Practice*, 46, pp.954-964.
- Smith ASJ (2012) The application of stochastic frontier panel models in economic regulation: Experience from the European rail sector, *Transportation Research Part E: Logistics and Transportation Review*, 48, pp.503-515.
- Odolinski, K. and Wheat, P.E. NETIRAIL-INFRA Deliverable D1.7. Incentives Final Report - Annex 5 – Marginal wear and tear costs in Sweden using a 16 year panel.

- Additional slides not used

2017 Charges and Costs

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Costs	
Operations	554
Maintenance	1319
Renewals	2774

Revenue from track access charges	
Variable usage charge	224.2
Capacity charge	428.3
Fixed charges	410.8
Use of electrification assets	16.1
Stations and depots	353.0
TOTAL	1432.4

Implies:
M&R c. 6%
variable

Source: Network Rail (2017) Statement 1 (expenditure), Statement 6a (Analysis of Income) and Statement 6c (Analysis of Income by Operator).

Cost bases

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Maintenance (most studies)

- Permanent way
- Signalling and lineside telecoms
- Electrification and plant
- Other maintenance (including inspections and overheads)
- Most studies an "inclusive" definition (except GB)
- Stations, depots and lineside buildings generally excluded
- Structures maintenance – included in Sweden and Switzerland (not GB)

Maintenance & Renewal

- Sweden and Switzerland cases
- Track
- Signalling
- Electrification
- Telecoms
- Power supply equipment
- Crossings
- Platforms (some station costs)
- Fences
- Snow removal (Sweden)

Pros and cons of different approaches

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Engineering approach

- Requires multiple model runs
- Requires detailed model relating damage to remedial activity
- Unit costs hard to estimate, as vary depending on circumstances

Statistical approach

- Uses actual costs – powerful advantage of top-down benchmarking
- Based on expenditure rather than cost needed to rectify damage
- Differential impact of passenger and freight?