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# Assessing the Efficient Cost of Sustaining Britain's Rail Network

## Perspectives based on Zonal Comparisons

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**Abstract**

The objective of this paper is to inform the debate on how efficiency targets for Network Rail (formerly Railtrack) should be set during the 2002/03 Interim Review and beyond. Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, we propose an internal benchmarking approach, drawing on data for seven geographical zones within Railtrack. Our approach mirrors the yardstick competition method used in other UK regulated industries. Two efficiency measurement techniques are applied to this data. Our results suggest that Railtrack (as a whole) delivered substantial real unit cost reductions in the early years after privatisation, although these savings were largely offset by the post-Hatfield cost increases. However, looking forward, zonal efficiency differences suggest that the company could make significant savings in future years by applying best practice consistently across the network.

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# 1. Introduction

The 2000 Periodic Review of Railtrack's[1] access charges saw considerable debate about the scope for the company to deliver efficiency savings during the second regulatory control period.[2] To inform the debate, comparisons were made with a number of external benchmarks (international railway companies and other UK privatised industries). However, none of these comparisons proved completely satisfactory. NERA (2000) found a lack of international railway (infrastructure) data to make meaningful comparisons with Railtrack. At the same time, the experience of privatised industries in the UK produced a wide range of potential efficiency targets for the company, and there was disagreement over which industry was most comparable with the railways.

The two years following the Periodic Review conclusions (October 2000) have seen considerable change in the industry. Just as the Periodic Review conclusions were being finalised, a train derailment at Hatfield,[3] resulting from defective track, set off a chain of events which resulted in Railtrack being placed into administration roughly one year later (October 2001). The derailment heightened concerns over the condition of Britain's rail infrastructure, and Railtrack management responded by imposing speed restrictions across the network. Maintenance and renewal activity was also stepped up, leading to a sharp increase in costs.

The Hatfield accident precipitated a major financial crisis at Railtrack. In addition to higher maintenance and renewal costs, in 2000/01 Railtrack also had to pay more than £500m in compensation to train operators[4] for the resulting disruption to the network (caused by speed restrictions and unplanned maintenance and renewal work). At the same time, the company was facing large cost overruns on the West Coast Mainline upgrade project,[5] where the cost of the work had grown from an initial estimate of £2.3 billion in 1996, to £5.8 billion in 2000 (in 1998/99 prices).[6]

In October 2002, a new company, Network Rail, emerged as the owner and operator of Britain's rail network, having agreed to purchase Railtrack PLC (in administration) from the parent company.[7] Network Rail is a

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[1] Britain's rail infrastructure provider (April 1994 to October 2002). See Section 2.

[2] Covering the period 2001/02 to 2005/06.

[3] In October 2000.

[4] Under Schedule 4 (possessions regime) and Schedule 8 (performance regime) of the track access agreements.

[5] The renewal and enhancement of Britain's West Coast Main Line (linking London and Glasgow).

[6] Source: Office of Rail Regulator, 2000. Higher estimates have been made since 2000. See Pollitt and Smith (2002) for further analysis of the reasons for the cost overrun.

[7] In administration from October 2001. Railtrack Group PLC was the parent company.

company limited by guarantee, owned by members, rather than shareholders. However, despite the change in ownership structure, the question of efficiency remains of central importance in the regulation of the new

**Figure 1**
*Map of Zone Areas (1995/96 to 2001/02)*

company. In September 2002, the Office of the Rail Regulator (ORR) announced an (interim) review of Network Rail's access charges[8] (to be completed by December 2003); and stated the need, during that review, to consider the scope for realistic but challenging efficiency improvements.

The objective of this paper is to inform the debate on how efficiency targets for Network Rail should be set at the 2002/03 Interim Review of the company's access charges, and beyond. Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, we propose an internal benchmarking approach, drawing on data for seven geographical zones (see Figure 1) within Railtrack (over the period 1995/96 to 2001/02). Our approach mirrors the yardstick competition method used in other UK regulated industries.[9] Of course, such analysis does not address the wider question of the company's efficiency relative to international or other external comparators. However, it does indicate the potential for Network Rail to reduce costs by applying (its own) best practice consistently across the network.

The period of our analysis, 1995/96 to 2001/02, captures the initial efficiency gains achieved after privatisation (see Pollitt and Smith, 2002); the sharp increase in costs between 1999/00 and 2001/02; and the deterioration and subsequent recovery of some of the output and quality measures since the Hatfield accident. The analysis predates the acquisition of Railtrack PLC by Network Rail, but is intended to illustrate the possibilities for zonal yardstick comparisons going forward.[10] The paper is arranged in six sections. Section 2 provides some background to Railtrack's organisation structure, and the efficiency debate that took place during the 2000 Periodic Review. Section 3 details the methodology. Section 4 describes the data and model specifications used in the empirical analysis. Section 5 presents the results and Section 6 offers some conclusions.

## 2. Background

### 2.1. The structure of Railtrack

The separation of infrastructure management from train operation was one of the most significant, and controversial, elements of Britain's rail privatisation programme. In 1994, the fixed railway infrastructure assets were transferred to a new company, Railtrack, separate from British Rail

[8] This announcement was made on September 25, a few days before Network Rail actually took over from Railtrack. See ORR (September 2002).

[9] See Section 2.2 below. See also Shleifer, 1985.

[10] Or, more generally, comparisons at business unit level (since it is possible that Network Rail may change the organisational structure).

(BR), but still wholly-owned by Government. The company was sold by public offer in 1996. Contracts were put in place between Railtrack and BR (and later the privatised passenger and freight operators), governing the charges for (and general terms of) access to the rail infrastructure.

At the same time, it was also decided that the infrastructure maintenance and renewal activities, previously undertaken by BR, would not be transferred to Railtrack; instead, these activities were reorganised into separate infrastructure maintenance companies (IMCs) and track renewal companies (TRCs), and privatised by trade sale. These companies provided maintenance and renewal services to Railtrack based on medium term contracts. The initial maintenance contracts were output-based, and were set to decline each year by RPI-3%; these contracts have recently been re-negotiated (a process that was largely completed by the end of 2002). Track renewals were to be negotiated on a case-by-case basis.[11]

At privatisation (1996) the organisation structure of Railtrack was based around seven[12] geographical zones (see Figure 1), with a corporate centre. This structure has been continued under Network Rail. The functions of the corporate centre include strategy, financial control, safety assurance, procurement, and R&D. The zones are responsible for managing the maintenance/renewal contracts within their area, subject to direction from the centre.[13] Expenditure plans are formulated at the zonal level, although financial and other targets are determined centrally.

### 2.2. Previous studies of Railtrack's efficiency

As a monopoly provider of rail infrastructure, it was clear from the outset that Railtrack's charges (to train operators) for access to the network would need to be regulated. The original level of "access charges" was determined by the Department of Transport. These charges were later reduced by the ORR, to reflect the expectation that Railtrack would be able to achieve significant efficiency savings over the first regulatory control period (covering the period 1995/96 to 2000/01). Railtrack therefore became subject to the "RPI-X" incentive-regulation used for other privatised utilities.

[11] However, Railtrack retained the option to (periodically) tender for renewals in order to test the market.

[12] On formation, in 1994, the company was arranged into ten zones. The ten zones included (in addition to the seven shown in Figure 1): West Coast, East Coast, and South West. West Coast was divided into Scotland, Midlands, and North West zone. East Coast was divided into LNE and Scotland zones. South West was combined with Southern zone. This process started on 26 June 1995, when the number of zones was reduced to eight. See Railtrack Annual Report 1994/95. Railtrack data on a seven-zonal basis are available from 1995/96 (financial year) onwards.

[13] Each maintenance contract area was contained within the boundary of a single zone.

In December 1997 the ORR started consultation on the appropriate level of efficiency targets for the company over the second control period (covering the period 2001/02 to 2005/06). The ORR's assessment of the scope for future efficiencies was based on evidence from a range of different sources[14] and was supported by four consultant reports: Booz-Allen and Hamilton (1999 and 2000); NERA (2000); Europe Economics (2000); and Horton 4 Consulting (2000); described in turn below. It should be noted that the academic literature provided little evidence on this question, since most studies had focused on comparing the efficiency of railway systems, rather than rail infrastructure provision. We have identified only one academic study which considered rail infrastructure efficiency (Chapin and Schmidt, 1999), although their paper is concerned with the impact of mergers on efficiency (US Class I railroads), rather than on international comparison.

Booz-Allen and Hamilton (1999; 2000) adopted a "bottom-up" approach to assessing the potential for efficiency gains. They reviewed each of Railtrack's asset areas and functions, and identified specific efficiency opportunities in each area. At the overall level, Booz-Allen and Hamiliton's work suggested efficiency targets of approximately 4 per cent per annum. However, the ORR noted that this approach — by definition — did not take account of the potential for savings from (as yet) unspecified efficiency initiatives.

The remaining three consultant reports were based on "top-down" methodologies. NERA (2000) examined the international evidence on rail infrastructure costs. They compared productivity levels across a number of countries (US, Canada, Japan, Australia, and Europe), and also analysed productivity trends (US Class I railroads). In respect of productivity levels, NERA found that there was insufficient evidence in the public domain to draw meaningful conclusions. However, their trend analysis revealed that the US Class I railroads had achieved annual productivity growth (infrastructure only) of between 3.3 and 3.9 per cent over the period 1986 to 1998. NERA argued that this benchmark provided a realistic long-run target for Railtrack, though recognised that it did not say anything about the scope for Railtrack to achieve the (expected) "catch-up"[15] savings resulting from privatisation.

[14]This assessment is set out in ORR (October 2000), ORR (July 2000), and ORR (December 1999).

[15]That is, catch-up to private sector best practice, following the change from public to private ownership. NERA acknowledged that their US calculations excluded the sharp improvements in productivity that occurred immediately after deregulation in 1980. NERA also recognised the problems of comparing a predominantly passenger railway (Britain) with a freight dominated railway (US).

NERA also reviewed a study by LEK (2000), prepared for English, Welsh, and Scottish Railways, but largely dismissed the LEK findings. The LEK study (of US Class I railroads) reported rail infrastructure productivity gains of 6.7 per cent per annum between 1980 and 1998, although NERA argued that the study failed to adjust for scale and density effects. LEK also showed Railtrack's freight access charges to be considerably higher than the infrastructure costs of the largest five US Class I railroads; however, this finding was based on comparing Railtrack prices with US costs, and also focused on a single (partial) productivity measure.

Europe Economics (1999) argued that the experience of other UK privatised network businesses offered the best means of assessing the scope for Railtrack efficiency improvements (the industries chosen were water, sewerage, electricity transmission and distribution, and gas transportation). In particular, each of these industries had, like Railtrack, been transferred from public to private ownership, and therefore provided useful evidence concerning the scope for "catch-up" savings following privatisation. Based on this evidence, Europe Economics suggested that Railtrack's efficiency target should be in the region of 3 to 5 per cent per annum (in real terms). Horton 4 Consulting (2000) supported the conclusions of the Europe Economics report, although they did not present any new evidence.[16]

In the event, Railtrack's efficiency target was eventually set at 3.6 per cent per annum,[17] close to the lower end of the range suggested by Europe Economics. Railtrack commissioned its own consultants (OXERA, 2000), who argued for a target closer to 2 per cent per annum. In essence, the dispute centred on the comparability of the benchmark information: for example, in terms of the scope for technical change; the extent of capital substitution; differences in volume growth and scale effects; and real wage inflation differentials.[18]

Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, the objective of this paper is to explore the use of internal (zonal) benchmarking to inform the debate on future efficiency targets for Network Rail. Compared to external comparisons, our approach has a number of advantages. First of all, the data is consistent across zones, and our analysis does not therefore suffer

[16]See ORR (July 2000) page 48.

[17]See ORR (October 2000), page 36. This is the underlying efficiency improvement on controllable costs, and is based on a simple average.

[18]But note that the ORR adjusted Railtrack's efficiency targets to take account of this last factor in the final conclusions.

from the problems often experienced in international studies. Furthermore, differences in scale, technology, or other environmental factors, which usually affect efficiency comparisons, are likely to be relatively small. Finally, we expect the analysis of comparable, internal business units to provide clearer guidance on how savings can be achieved in practice.

The internal benchmarking approach, based on sub-company data, also has strong precedents. In the water sector, OFWAT has used sub-company regional data in its econometric analysis for the sewerage business (in order to increase the number of observations; see OFWAT, April 1998). Furthermore, the Competition Commission has recently suggested that OFWAT consider extending this approach to cover the water business during the 2004 periodic review.[19] OFGEM has also recently announced proposals for separate price controls for each of the eight regional gas distribution areas (see OFGEM, June 2003). In the academic literature, Burns and Weyman-Jones (1998) used sub-company data — from twelve British Gas regions — to estimate a cost function for the gas supply business (1990/91 to 1992/93).

Of course, internal benchmarking does not address the wider question of a regulated company's efficiency position, relative to international or other external comparators. As a result, economic regulators in the UK have tended to use a range of internal and external comparisons to inform their efficiency determinations. In the present context we consider that the internal (zonal) benchmarking approach offers a useful additional methodology for the ORR in determining efficiency targets for Network Rail going forward. In this regard, we note that the ORR and Network Rail have commissioned an additional zonal benchmarking study as part of the current interim review of Network Rail's finances (see ORR, September 2002), building on the analysis outlined here in Sections 3 to 6 below.

## 3. Methodology

In this paper we apply two parametric techniques to assess the relative efficiency of Railtrack's zones over the period 1995/96 to 2001/02: corrected ordinary least squares (COLS); and stochastic frontier analysis

[19] In its report on the proposed acquisition of First Aqua (JVCo) Limited by Vivendi Water UK PLC (2002).

(SFA). Parametric efficiency measurement techniques have been widely applied to the study of productivity and efficiency measurement in the railway industry (see Affuso, Angeriz and Pollitt, 2002, for a review of this literature). We note that the use of more than one approach (COLS and SFA) enables the results of alternative methodologies to be compared. This section briefly describes the methodologies used in the subsequent analysis. The model specifications used in our empirical analysis are described in Section 4 below.

In conducting parametric efficiency analysis there is a choice to be made regarding the function (or frontier) to be estimated. We follow Coelli and Perelman (1999) and estimate an input distance function (using both the COLS and SFA techniques). Coelli and Perelman find that distance function estimation offers a convenient way of handling multiple inputs and outputs without the need to impose restrictive behavioural assumptions. They applied this method to the study of seventeen European railways over the period 1988–1993. We consider that this approach is applicable to the question under analysis here (as explained in Section 4.2 below). Coelli and Perelman (1999) define the (translog) input distance function for $M$ outputs and $K$ inputs as:[20]

$$\begin{aligned} \ln D_{Ii} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mi} + 1/2 \sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} \ln y_{mi} \ln y_{ni} + \sum_{k=1}^{K} \beta_k \ln x_{ki} \\ + 1/2 \sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} \ln x_{ki} \ln y_{mi} \\ i = 1, 2, \ldots N, \end{aligned} \tag{1}$$

where $i$ denotes the $i$th firm in the sample, the $y_i$ and $x_i$ are the $M$ outputs and $K$ inputs respectively, $D_{Ii}$ represents the input distance function, and $\alpha$, $\beta$, and $\delta$ are parameters to be estimated. Coelli and Perelman impose homogeneity of degree one in inputs by dividing through by one of the inputs (arbitrarily chosen). After this transformation, equation (1) becomes:

$$\ln(D_{Ii}/x_{Ki}) = TL(x_i/x_{Ki}, y_i, \alpha, \beta, \delta), \qquad i = 1, 2, \ldots n, \tag{2}$$

where $TL$ represents the translog function. Equation (2) can be re-arranged to give:

$$-\ln(x_{Ki}) = TL(x_i/x_{Ki}, y_i, \alpha, \beta, \delta) - \ln(D_{Ii}), \qquad i = 1, 2, \ldots n. \tag{3}$$

[20]See Coelli and Perelman (1999), page 329.

Equation (3) now shows the log of the $K$th input as a function of the outputs, and the ratios of the other inputs (to the $K$th input). The $\ln(D_{Ii})$ term is interpreted as the one-sided inefficiency term.

Equation (3) may be estimated using COLS or, with some alteration, SFA (see below). The COLS method, developed by Greene (1980)[21] proceeds by estimating equation (3) using OLS, and then adjusting the intercept by adding the largest positive residual. Efficiency scores are then calculated as the exponential of the adjusted residuals. The COLS method makes no allowance for noise, and assumes that all deviations from the frontier result from inefficiency (deterministic model). To overcome this problem, we also apply the SFA technique, developed (independently) by Aigner, Lovell, and Schmidt (1977) and Meeusen and van Den Broeck (1977), to our data set. The stochastic frontier method adds an additional random error ($v_i$) to the deterministic frontier model in equation (3), and can be written as:

$$-\ln(x_{Ki}) = TL(x_i/x_{Ki}, y_i\alpha, \beta, \delta) + v_i - u_i, \qquad i = 1, 2, \ldots N, \qquad (4)$$

where the $v_i$ term represents random noise, and is assumed to be identically and independently distributed as $N(0, \sigma_v^2)$; the notation $\ln(D_{Ii})$ is changed to $u_i$, where the $u_i$ term reflects inefficiency, and is therefore constrained to be non-negative. The $u_i$ is assumed to be distributed independently of $v_i$ and the regressors, and is usually assumed to be drawn from a $N(0, \sigma_u^2)$ half-normal distribution.

The stochastic frontier approach applies maximum likelihood estimation to equation (4), and the efficiency scores are then calculated from the residuals using the procedure developed by Jondrow, Lovell, Materov, and Schmidt (1982). The SFA technique has now been automated on many statistical packages, including FRONTIER and LIMDEP (both used in our analysis). The ordinary least squares regressions were carried out using the statistical package MICROFIT. Our parametric model specifications are described in Section 4.2 below.

## 4. Data and Model Specifications

This section describes our data set, as well as the model specifications used in the analysis presented in Section 5.

[21] Building on the work of Aigner and Chu (1968), Afriat (1972), and Richmond (1974).

### 4.1. Data description

The data set used in this study covers seven zones over the period 1995/96 to 2001/02, and was collected through fieldwork at Railtrack between February and August 2002. The data is shown in Table 1 (period averages), and includes:

- maintenance costs (*MAIN*);
- total costs (*TOTC*), which is the sum of maintenance and track renewal costs (*REN*);
- passenger train miles (*PTM*);
- passenger tonne miles (*PTON*);
- freight gross tonne miles (*FTON*);
- track miles (*TRAC*);
- Railtrack-caused delays (*DELS*); and
- broken rails (*BRLS*).

The cost variables, maintenance (*MAIN*) and track renewal costs (*REN*), accounted for £1.7bn, or roughly 45 per cent of Railtrack's total cash expenditure in 2001/02.[22] The variables *PTM*, *PTON*, *FTON*, and *TRAC* are all measures of volume and are commonly used in railway efficiency and productivity studies (see Section 4.2 below). The *DELS* variable can be viewed as a measure of asset performance, while the inclusion of *BRLS* in the data set provides a measure of asset condition

**Table 1**

*Inputs and Outputs (averages 1995/96 to 2001/02)*

| | *Inputs (costs)* | | | *Inputs (quality)* | | | *Outputs* | | |
|---|---|---|---|---|---|---|---|---|---|
| *2000/01 £m** | *MAIN £m* | *REN £m* | *TOTC £m* | *DELS 000 min* | *BRLS Number* | *PTM Million* | *PTON Million* | *FTON Million* | *TRAC Miles* |
| East Anglia | 76.2 | 38.4 | 114.6 | 882 | 68 | 24.5 | 5,093 | 1,155 | 1,414 |
| Great Western | 108.3 | 57.3 | 165.6 | 1,671 | 90 | 32.0 | 6,903 | 4,452 | 3,136 |
| LNE | 114.4 | 63.4 | 177.7 | 1,958 | 213 | 37.3 | 8,114 | 6,169 | 3,448 |
| Midlands | 137.4 | 126.0 | 263.4 | 2,599 | 132 | 43.5 | 9,662 | 5,154 | 3,096 |
| North West | 94.7 | 50.2 | 144.9 | 1,425 | 95 | 29.0 | 4,115 | 2,564 | 2,638 |
| Scotland | 83.6 | 39.6 | 123.2 | 794 | 62 | 24.6 | 4,269 | 2,288 | 2,541 |
| Southern | 149.7 | 57.2 | 206.8 | 2,113 | 104 | 64.4 | 15,100 | 1,617 | 3,017 |
| **Network** | **764.3** | **432.1** | **1,196.4** | **11,442** | **763** | **255.1** | **53,255** | **23,398** | **19,290** |

*Where monetary values are used.

[22] Defined as: (maintenance and track renewal expenditure) divided by (operating costs less asset maintenance plan (AMP) charge and depreciation plus total renewal expenditure). The remaining 55 per cent comprises non-track renewal costs, signalling operations, traction costs and overheads.

(and, in turn, safety). Further details about the data and sources are provided in Appendix 1.

It should be noted that the cost measures (*MAIN*, *REN*, and *TOTC*) are based largely on payments made by Railtrack to its contractors. It is therefore possible that contract payments might have diverged from underlying costs over the period. In particular, in the early years after privatisation, the contractors might have cut costs faster than the cost reductions implied by the contract prices. On the other hand, Railtrack's suppliers might not have been fully compensated for increased costs resulting from traffic growth following privatisation. In respect of the latter point, however, we note that there have been some (confidential) volume-related payments made to contractors; and the data shows considerable variation in contract cost trends across zones in the early years.

Of course, the problem raised by the use of contractors is shared with comparative benchmarking studies conducted in other UK regulated sectors — for example, the water and sewerage industry, where many activities are outsourced, or provided by another company within the same group — and does not therefore invalidate our approach. Indeed, in the case of Welsh Water (where all operations are outsourced), OFWAT has indicated its intention to continue to benchmark the company in the same way as the remaining companies in the sector. We further note that, between 1999/00 and 2001/02, the majority of Railtrack's contracts were renegotiated (therefore realigning costs with payments); and we were not able to find any systematic relationship between contract renegotiation and relative efficiency performance (see Section 5.2.3).

## 4.2. Model specifications

Before describing the model specifications used to measure relative efficiency for Railtrack's seven zones, we first outline our treatment of general changes in real unit costs (frontier shifts) that have occurred since privatisation (Hatfield and time trend effects). Note that for estimation purposes the data is pooled, to create 49 observations (seven zones over seven years). The sample size is therefore acceptable from an econometric perspective and will increase, over time, as additional observations (years) become available.

### *4.2.1. Modelling frontier shifts (Hatfield and time trend effects)*

As noted in Section 1, the cost of Railtrack's maintenance and renewal activities increased sharply following the Hatfield accident in October 2000 (see Figure 2 below). To reflect this structural break in the data, we have divided the analysis in Section 5 into two parts: (1) the period 1995/96 to

1999/00; and (2), the full seven–year period from 1995/96 to 2001/02. In respect of the latter we have included a Hatfield dummy variable in the model specifications (see Table 2). For the total cost models this dummy takes the value 0.5 in 2000/01; unity in 2001/02; and zero elsewhere (the Hatfield accident took place midway through the financial year 2000/01). For the maintenance cost models, the dummy variable takes the value unity in 2001/02; and zero elsewhere (since unit maintenance costs did not start to rise sharply until 2001/02).

We also include a time trend variable (see below) in all our models in order to test for the existence of a general reduction in real unit costs (across all zones) over time.[23] As our results show, real unit costs did fall considerably in the early years after privatisation, before rising sharply in the years following the Hatfield accident (see Section 5). The latter effect is captured by the Hatfield dummy variable.

#### *4.2.2. Parametric model specifications*

In seeking to analyse the relative efficiency of Railtrack's zones — and the overall unit cost performance of the company — it is important to take account of changes in quality that have occurred over the period, and across zones. In this way, genuine efficiency/real unit cost improvements may be distinguished from cost reductions achieved simply by allowing quality measures to deteriorate. As noted in Section 4.1 our analysis contains two quality variables: Railtrack-caused delays (*DELS*), which can

**Table 2**
*Parametric Models (COLS and SFA)*

| | *Model 1* | *Model 2* |
|---|---|---|
| Inputs* | *MAIN* | *TOTC* |
| Input ratios | *DELS/MAIN* | *DELS/TOTC* |
| | *BRLS/MAIN* | *BRLS/TOTC* |
| Outputs** | *TRAC* | *TRAC* |
| | *PTMD* | *PTMD* |
| | *FTOND* | *FTOND* |
| Other variables | *TIME* | *TIME* |
| | *DUMMY* | *DUMMY* |

*Arbitrarily chosen as the dependent variable.
**Traffic volume measures expressed as densities (per track mile).

[23]This specification achieves the best fit with the data.

be thought of as a measure of asset reliability; and the number of broken rails (*BRLS*), which can be regarded as an indicator of asset condition.

As described in Section 3, our modelling approach follows that of Coelli and Perelman (1999), who used distance function estimation in their comparison of European railway systems. The specifications for our (input) distance function models are shown in Table 2. We consider that the input distance function application is appropriate in the present context. Under this interpretation, the quality variables (delays and broken rails) described above are treated as inputs. Railtrack zones are then assumed to minimise inputs (costs, delays, and broken rails) for a given level of (exogenously determined) output (track miles and traffic volume).[24] The potential trade-off between cost and quality is therefore explicitly recognised in the distance function specification (since increased maintenance and renewal of assets — which in turn leads to improved asset performance and condition — involves higher cost, and vice versa). We note that previous studies of international railway efficiency have been unable to adjust for quality differences due to the lack of comparable data.

The delays and broken rail variables included in our analysis are highly relevant quality measures that have been the subject of considerable discussion between the ORR and Railtrack.[25] Furthermore, it is clear that management action (or inaction), combined with changes in traffic volumes and mix, can have a significant impact on these measures within a short period of time. For example, at the national level, the number of broken rails fell by more than 40 per cent over just two years (1999/00 to 2001/02), following the imposition of regulatory targets and focused management attention. At the micro-level, discussions with Railtrack engineers suggest that increases in heavy freight traffic on lines previously maintained for light regional passenger traffic (such as the Settle–Carlisle route), can quickly translate into deteriorating asset condition. We also note that the *DELS* and *BRLS* measures vary considerably across zones and over time.

We therefore conclude that management is able to exert considerable influence on the *DELS* and *BRLS* variables (for a given level and mix of traffic), even over short time periods; and that the inclusion of these

[24]Regarding the question of potential regressor endogeneity — caused by the inclusion of the input ratios on the right hand side of the distance function regression equations — Coelli and Perelman (1996) argue that these can be regarded as exogenous, since the distance function is defined for radial reductions in all inputs, for given output levels.

[25]Over the period of our analysis, the company was strongly encouraged to reduce delays through the combined incentives of the performance regime and the additional regulatory target set by the ORR in 1999. The Regulator also set targets for broken rails following the sharp increase in 1998/99 and 1999/00 (see ORR, 1999).

quality variables in our zonal efficiency analysis is therefore valid. While we accept that there are other factors affecting the cost/quality trade-off — as measured by our analysis — such as asset age, and other measures of quality (for example, track geometry), we were unable to obtain zonal data on these factors for the full seven-year period. We return to this point in Section 5.3.3 below.

The output variables shown in Table 2 are derived from the alternative specifications used in the railway efficiency and productivity literature. The majority of previous studies include measures of passenger and freight volumes as railway outputs.[26] We use freight tonne miles (*FTON*) to represent freight traffic volumes. For passenger traffic we have used passenger train miles (*PTM*).[27] In line with previous studies, the traffic volume variables are expressed as densities (*PTMD* and *FTOND*) and combined with the track miles variable (*TRAC*) in order to distinguish between economics of scale and density,[28] while avoiding potential multicollinearity problems.[29]

We estimate the models in Table 2 based on the log-linear functional form. This decision reflects the degrees of freedom and multicollinearity problems arising in the translog case, given the relatively small sample size (35 and 49 observations for the pre- and post-Hatfield regressions respectively). Morrison (1999) notes the particular problems (of using the translog) with small data sets when the number of cross-section observations is limited, as in our case (seven zones).[30] Technical progress is introduced in the form of a simple time trend ($TIME = 1, 2, 3, 4, 5, 6, 7$ for the full seven-year regressions). This treatment of the time trend therefore assumes Hicks-neutral technical change. For the full seven-year regressions, a "Hatfield" dummy variable is also included. Since we are

[26] See, for example, Caves, Christensen, and Swanson (1980).

[27] We also considered the use of passenger tonne miles (*PTON*) to represent passenger volumes. However, the regression equations perform better (in terms of overall fit and significance of the variables) when passenger train miles is used to represent passenger output. The results based on *PTON* are not reported in the paper.

[28] See, for example, Caves, Christensen, Tretheway, and Windle (1985).

[29] This may occur when *TRAC, PTM*, and *FTON* are included together as independent variables.

[30] We also tested the log-linear restriction against the translog for the two models (for both the pre- and post-Hatfield sample). The restriction could not be rejected for the maintenance cost regressions. For the total cost regressions the null hypothesis was rejected (in favour of the translog). However, the total cost translog model (over seven years) produced counterintuitive output elasticities for some of the zones in the sample. In addition, the translog produces large standard errors, and only three of the variables (two first-order terms and one second-order term) were significant at the 5 per cent level. The tests used were the *F* test for the OLS regressions, and the likelihood ratio test for the SFA models (although we note that the latter is a large sample test, and may not be a good approximation in the current case).

estimating a distance function, the derived efficiency scores are technical efficiency measures.[31].

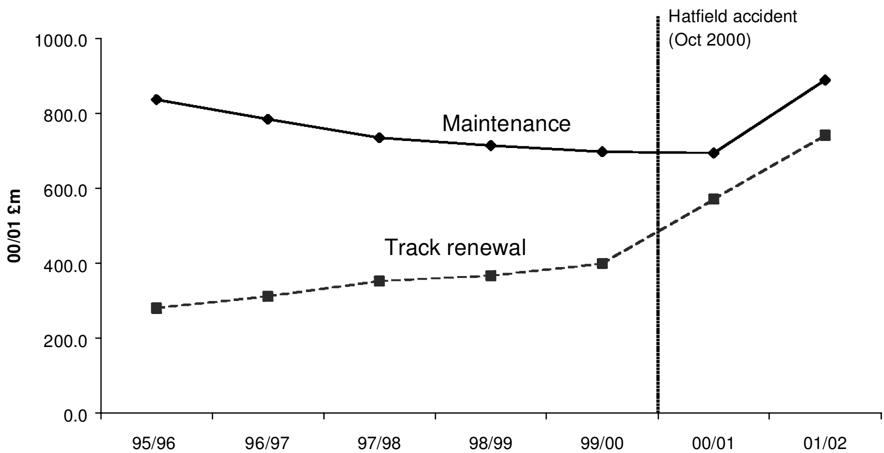
# 5. Results

This section is divided into three sub-sections. Section 5.1 shows the trends in the input, output, and partial productivity measures (at the network level) over the period 1995/96 to 2001/02. Section 5.2 presents the results of our efficiency analysis for the period before the Hatfield accident (1995/96 to 1999/00). Finally, Section 5.3 looks at how the post-Hatfield environment has impacted on absolute unit cost levels and the relative efficiency positions of the seven Railtrack zones.

## 5.1. Network level trend analysis

Figures 2 to 5 outline the trends in inputs, outputs and partial productivity measures (network level) over the period 1995/96 to 2001/02.[32] The quality

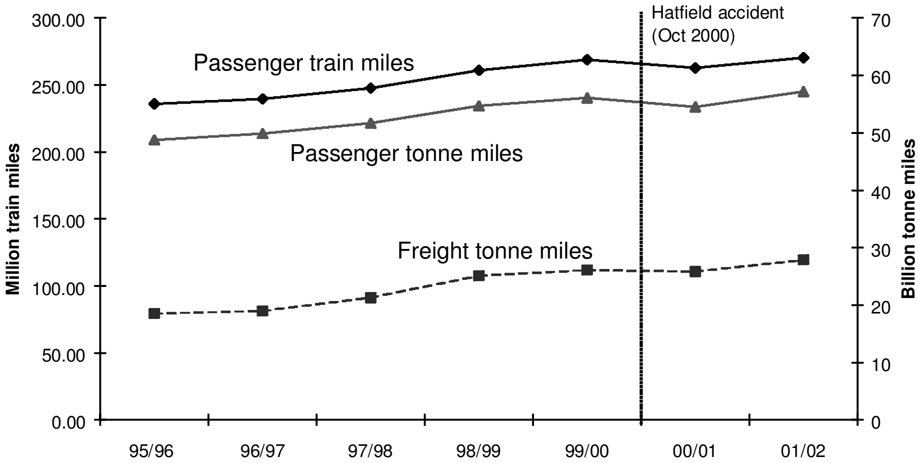
**Figure 2**
*Inputs: Maintenance and Track Renewal Costs*




[31]These scores take account of the technical relationship between cost and quality inputs (for example, the cost of reducing the number of broken rails). However, the scores do not consider whether a particular zone has achieved an optimal balance between the cost and quality inputs (given the price society may be prepared to pay, for example, to reduce the number of broken rails further). Of course, since information is not available on input prices (in the more traditional sense, for example, labour costs), these technical efficiency measures also subsume within them any differences in wage rates across the zones.

[32]Note that the track miles variable is not shown since it has remained broadly constant over the period.

**Figure 3**
*Outputs: Passenger Train Miles, Passenger Tonne Miles and Freight Tonne Miles*




measures are shown on a normalised basis (per train mile). Figure 2 shows that maintenance costs have fallen steadily over the period to 2000/01. However, in the aftermath of the Hatfield accident, maintenance and track renewal costs have risen sharply. Figure 3 illustrates the now familiar growth in passenger and freight traffic, partially halted in 2000/01, as a result of the speed restrictions imposed post-Hatfield.

**Figure 4**
*Quality (inputs): Delays and Broken Rails Per Train Mile*

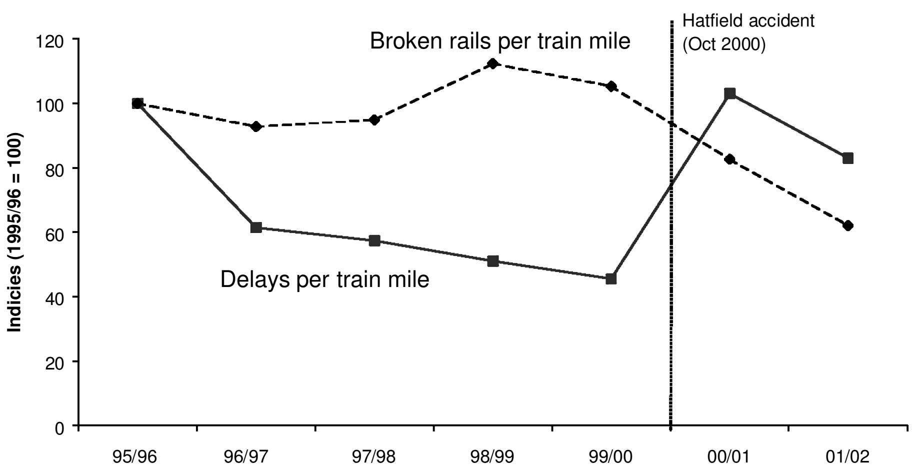


**Figure 5**
*Productivity Indices: Unit Maintenance and Total Cost (per tonne mile)*

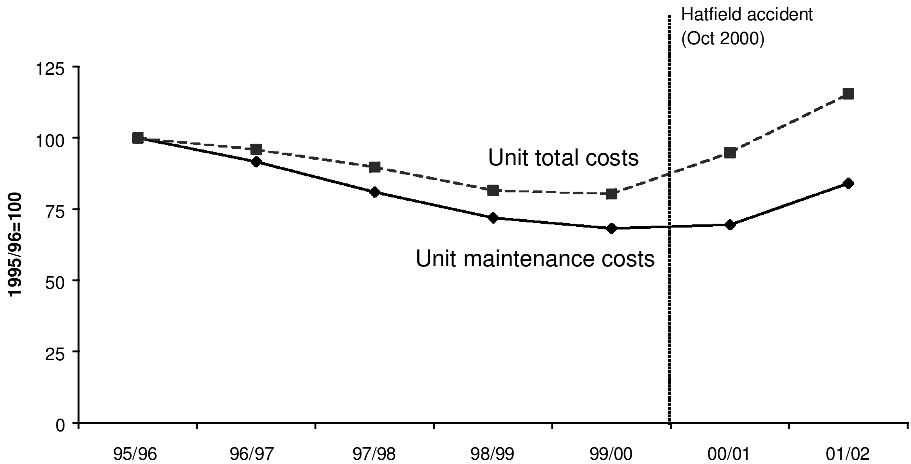



Figure 4 shows the significant reduction in delays achieved over the period to 1999/00. Delays have now resumed a downward path, following the sharp increase in 2000/01, though remain high. Figure 4 also shows that broken rails have fallen significantly over the period since privatisation, following an initial increase during the early years prior to 1999/00. Taking account of both cost and volume changes, Figure 5 shows that unit maintenance and total costs (per total tonne mile) fell significantly after privatisation, before rising again post-Hatfield.

Figures 2 to 5 show a clear structural break in the data after the Hatfield accident in October 2000. Maintenance and renewal costs have since increased sharply, along with Railtrack-caused delays. Passenger and freight volume growth was also partially interrupted by the Hatfield accident; and broken rails fell sharply over the period 1999/00 to 2001/02 (though the fall in broken rails began one year earlier). The remainder of the analysis in this paper is therefore split into two time periods; before and after Hatfield.

### 5.2. Efficiency results (pre-Hatfield)

Below we present the results of our efficiency analysis covering the pre-Hatfield period (1995/96 to 1999/00).

#### *5.2.1. COLS results*

In Section 4.2 we identified two models to be estimated, based on the literature. The OLS estimates for these models are shown in Table 3

**Table 3**
*OLS Input Distance Function Regressions (log-linear; t ratios in brackets)**

| *Input*** | *COLS1* *MAIN* | *COLS2* *TOTC* |
|---|---|---|
| Constant | 2.571 (6.44) | 1.028 (2.05) |
| *TIME* | −0.079 (−8.73) | −0.068 (−5.05) |
| *TRAC* | 0.787 (19.41) | 0.867 (15.67) |
| *PTMD* | 0.692 (16.23) | 0.768 (13.20) |
| *FTOND* | 0.200 (5.35) | 0.364 (8.13) |
| *DELS* (ratio) | −0.053 (−1.17) | −0.134 (−2.20) |
| *BRLS* (ratio) | −0.121 (−3.92) | −0.217 (−5.49) |
| Adjusted $R^2$ | 0.959 | 0.936 |

*Positive coefficient indicates positive relationship.
**Arbitrary choice of dependent variable.

below. Owing to the relatively small sample size we report only the results based on the log-linear functional form (see Section 4.2.2 above).

Note that in Table 3 the signs of the coefficients have been changed (compared to equation (3) above) for ease of interpretation, so that a positive coefficient indicates a positive relationship between cost and the other variables. We note that all the coefficients in Table 3 have the expected sign (positive relationship between cost and outputs; negative relationship between cost and quality; and negative relationship between cost and time, indicating firm-wide unit cost reductions over time). All the coefficients are also statistically significant (except the delays input ratio in COLS1). These results give us confidence in the efficiency rankings derived from the (adjusted) OLS residuals, shown in Table 4.

It is perhaps surprising that the total cost models (including annual renewal costs) are well behaved given the (potentially) lumpy nature of track renewal activity. Our results therefore suggest that some of this potential variation is smoothed out across the zonal route portfolios.

### *5.2.2. SFA results*

Table 5 shows the efficiency scores based on the SFA technique. The one-sided generalised likelihood ratio test shows that the average response function is not an adequate representation of the data in this case (the test statistics in Table 5 exceed the critical value at the 5 per cent level).[33]

[33]See Coelli, Rao, and Battese (1998), Chapter 8, for more on this test.

**Table 4**
*Summary of COLS efficiency scores**

| | | *COLS1 (MAIN)*** | | *COLS2 (TOTC)*** | |
|---|---|---|---|---|---|
| 95/96 | East Anglia | 0.907 | [4] | 0.914 | [3] |
| 95/96 | Great Western | 0.997 | [1] | 0.996 | [1] |
| 95/96 | London North Eastern | 0.878 | [7] | 0.842 | [6] |
| 95/96 | Midlands | 0.881 | [6] | 0.872 | [5] |
| 95/96 | North West | 0.932 | [3] | 0.916 | [2] |
| 95/96 | Scotland | 0.886 | [5] | 0.838 | [7] |
| 95/96 | Southern | 0.947 | [2] | 0.874 | [4] |
| | **Average** | **0.918** | | **0.893** | |
| 99/00 | East Anglia | 0.959 | [3] | 0.954 | [3] |
| 99/00 | Great Western | 0.895 | [4] | 0.902 | [5] |
| 99/00 | London North Eastern | 0.988 | [1] | 0.994 | [1] |
| 99/00 | Midlands | 0.884 | [5] | 0.737 | [7] |
| 99/00 | North West | 0.854 | [7] | 0.852 | [6] |
| 99/00 | Scotland | 0.970 | [2] | 0.970 | [2] |
| 99/00 | Southern | 0.881 | [6] | 0.923 | [4] |
| | **Average** | **0.919** | | **0.905** | |

*Relative rankings (within each year) shown in square brackets.
**Scores based on maintenance (MAIN) and total cost (TOTC) regressions.

**Table 5**
*Summary of SFA efficiency scores**

| | | *SFA1 (MAIN)*** | | *SFA2 (TOTC)*** | |
|---|---|---|---|---|---|
| 95/96 | East Anglia | 0.948 | [3] | 0.946 | [3] |
| 95/96 | Great Western | 0.989 | [1] | 0.988 | [1] |
| 95/96 | London North Eastern | 0.861 | [7] | 0.872 | [6] |
| 95/96 | Midlands | 0.869 | [6] | 0.893 | [5] |
| 95/96 | North West | 0.908 | [4] | 0.949 | [2] |
| 95/96 | Scotland | 0.900 | [5] | 0.863 | [7] |
| 95/96 | Southern | 0.954 | [2] | 0.925 | [4] |
| | **Average** | **0.918** | | **0.919** | |
| 99/00 | East Anglia | 0.975 | [3] | 0.967 | [4] |
| 99/00 | Great Western | 0.882 | [4] | 0.912 | [5] |
| 99/00 | London North Eastern | 0.975 | [2] | 0.985 | [1] |
| 99/00 | Midlands | 0.873 | [6] | 0.745 | [7] |
| 99/00 | North West | 0.846 | [7] | 0.873 | [6] |
| 99/00 | Scotland | 0.979 | [1] | 0.974 | [2] |
| 99/00 | Southern | 0.874 | [5] | 0.968 | [3] |
| | **Average** | **0.915** | | **0.918** | |
| | Gamma value | 1.000 | | 0.956 | |
| | Likelihood ratio statistic ($H_0$: Gamma = 0) | 6.501 | | 6.503 | |

*Relative rankings (within each year) shown in square brackets.
**Scores based on maintenance (MAIN) and total cost (TOTC) regressions respectively.

Furthermore, the high gamma values[34] for both models indicate that the stochastic frontier model is not significantly different from the deterministic frontier (COLS) model. As a result, it is unsurprising that the SFA results produce virtually identical rankings to those generated by the COLS method; and that the average efficiency scores are also similar. We note that Coelli and Perelman (1996) also reported extreme gamma values (either zero or greater than 0.99) in their analysis of European railways.

*5.2.3. Discussion of results*

From the parametric models we are inclined to accept the deterministic (COLS) results, based on the high gamma scores from the SFA approach (as described above). We therefore use the COLS results to draw conclusions about the relative efficiency performance of Railtrack's zones over the period 1995/96 to 1999/00 (but we note the similarity of these results with their SFA counterparts).

Starting with *maintenance activity*, our (COLS) results show that, at a firm-wide level, Railtrack delivered substantial real unit cost reductions in the early years after privatisation (the time trend coefficient in Table 3 indicates an improvement of 7.9 per cent per annum). This calculation takes account of quality, scale and density effects, which are captured separately in the regression equation. These unit cost reductions compare favourably with the savings reported by other UK privatised industries (in the region of 5 per cent per annum); and with the gains reported for the US Class I railroads following de-regulation in the 1980s (between 3.3 and 6.7 per cent).

In terms of relative efficiency, Table 4 shows that Great Western, Southern, and North West were the most efficient zones in 1995/96 (COLS1). However, by 1999/00, the rankings had changed significantly. London North Eastern (LNE), Scotland, and East Anglia moved up into the top three positions, while Great Western, Southern, and North West fell back into 4th, 6th, and 7th positions respectively. Scotland and LNE achieved the largest real cost reduction over the period (26 per cent), while East Anglia improved its relative position due to strong improvements across all measures.

It was noted in Section 2 that between 1999 and 2002 Railtrack renegotiated and consolidated its (inherited) maintenance contracts. Contract re-negotiation would be expected to affect costs (either positively or negatively), and we therefore investigated the extent to which this process may have impacted on our reported efficiency scores. However, we

[34]Defined as $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$. See equation (4) above.

were unable to find any systematic relationship between contract renegotiation and changes in relative performance. Of the four zones that saw changes to some or all of their contracts, two saw their relative rankings improve (Scotland and Midlands), while two saw falls in their relative positions (Great Western and Southern). Of those zones that saw no contract renegotiation, two moved up the rank orderings (LNE and East Anglia), while the other (North West) fell back from 3rd to 7th position.

At the *total cost level* (maintenance and renewals) our results imply firm-wide real unit cost reductions of 6.8 per cent per annum; slightly lower than for maintenance-only activity. In 1995/96, the three most efficient zones (total costs) were Great Western, North West, and East Anglia. By 1999/00, LNE, Scotland, and East Anglia had emerged as the top performing zones, for maintenance activity. However, the slight difference in the rankings of the other zones (between maintenance and total efficiency scores) indicates some degree of substitution between maintenance and renewal activity. We note that the West Coast Main Line Project[35] appears to have had a significant impact on the performance of Midlands zone in 1999/00 (efficiency score reduced from 0.884 in COLS1 to 0.737 in COLS2).[36]

In addition to the changes in relative rankings noted above, the dispersion[37] of efficiency scores also increased between 1995/96 and 1999/00 (for both maintenance and total cost scores). In their study of UK and Japanese Electricity Distribution systems, Hattori, Jamasb, and Pollitt (2002) note a similar trend, and therefore question the effectiveness of incentive regulation in closing the efficiency gap among companies in the sector. However, in that case, the widening efficiency gap results from frontier firms increasing their lead over other companies. Our analysis suggests that the leading zones in 1995/96 were instead overtaken by (previously) less efficient zones.

### 5.3. Efficiency results (post-Hatfield)

As noted in Section 4, the cost of maintaining and renewing Britain's rail network has increased sharply in the last two years. In the post-Hatfield environment it has been argued that a permanent increase in maintenance

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[35]The renewal and enhancement of Britain's West Coast Main Line (linking London and Glasgow).

[36]This project included a large component of track renewals, which shows up as inefficiency in our analysis. However, this interpretation may be inappropriate to the extent that the renewals programme has been accelerated to capture scope economies between renewal and upgrade work. The project started in the financial year 1998/99.

[37]Measured by standard deviation.

and renewal activity is needed to sustain the network, given the substantial increase in passenger and freight traffic that has occurred since privatisation. This argument has not been fully accepted, and the 2002/03 interim review is aimed at assessing the funding required to maintain the network going forward. It is possible that part of the cost increase has resulted from a number of temporary factors that are reversible over time (see below). In this sub-section we evaluate the impact of the Hatfield accident (and responses to it) on absolute unit cost levels, and on the relative positions of the zones.

### *5.3.1. Efficiency scores*

The OLS estimates for the two models are shown in Table 6, based on the log-linear functional form. As for Table 3, the signs of the coefficients have been changed (compared to equation (3) above) for ease of interpretation, so that a positive coefficient indicates a positive relationship between cost and the other variables.

The resulting COLS efficiency scores are shown in Table 7, together with the SFA scores. We note that, as for the pre-Hatfield results, the SFA results produce high gamma values, indicating that there is little difference between the deterministic and stochastic models (the rankings are also virtually identical). The discussion below is therefore based on the COLS results. Appendix 2 shows the rank correlations between the scores produced by the two approaches.

**Table 6**
*OLS Input Distance Function Regressions*
*(log-linear; t ratios in brackets)**

| | *Maintenance Costs (MAIN)* | | *Total Costs (TOTC)* | |
|---|---|---|---|---|
| *Input*** | *Coefficient* | *t ratio* | *Coefficient* | *t ratio* |
| Constant | 2.881 | 6.12 | 1.015 | 1.890 |
| TIME | −0.059 | −7.92 | −0.064 | −4.801 |
| Hatfield dummy | 0.235 | 5.08 | 0.321 | 3.874 |
| TRAC | 0.782 | 17.92 | 0.803 | 14.109 |
| PTMD | 0.640 | 13.11 | 0.808 | 13.302 |
| FTOND | 0.154 | 3.55 | 0.409 | 9.100 |
| DELS (ratio) | 0.000 | 0.00 | −0.090 | −1.775 |
| BRLS (ratio) | −0.135 | −3.55 | −0.244 | −5.571 |
| Adjusted $R^2$ | 0.921 | | 0.917 | |

*Positive coefficient indicates positive relationship.
**Arbitrary choice of dependent variable.

**Table 7**
*Summary of COLS and SFA efficiency scores (2001/02)**

| | | *MAIN scores* | | | | *TOTC scores* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *COLS1* | | *SFA1* | | *COLS2* | | *SFA2* | |
| 01/02 | East Anglia | 0.808 | [5] | 0.813 | [5] | 0.820 | [6] | 0.832 | [6] |
| 01/02 | Great Western | 0.788 | [7] | 0.769 | [7] | 0.914 | [2] | 0.931 | [4] |
| 01/02 | London North Eastern | 0.967 | [3] | 0.962 | [3] | 0.912 | [4] | 0.947 | [3] |
| 01/02 | Midlands | 1.000 | [1] | 0.983 | [1] | 0.822 | [5] | 0.842 | [5] |
| 01/02 | North West | 0.830 | [4] | 0.841 | [4] | 0.760 | [7] | 0.796 | [7] |
| 01/02 | Scotland | 0.987 | [2] | 0.980 | [2] | 1.000 | [1] | 0.977 | [1] |
| 01/02 | Southern | 0.795 | [6] | 0.812 | [6] | 0.913 | [3] | 0.955 | [2] |
| | **Average** | **0.882** | | **0.880** | | **0.877** | | **0.897** | |
| | Gamma value | | | 1.000 | | | | 0.928 | |
| | Likelihood ratio statistic ($H_0$: Gamma = 0) | | | 14.16 | | | | 7.92 | |

*Rankings shown in brackets.

### *5.3.2. Discussion of results*

As for the OLS results presented earlier (Table 3), the regression equations in Table 6 perform well in terms of overall fit, and the signs and significance of the variables. However, the delays variable is not significant in either of the equations, which may reflect the fact that, in the short term, reduced renewal activity can actually result in lower delays, due to reduced need for access to the track (and vice versa, as experienced in the aftermath of Hatfield). The time trend coefficient is negative and significant in both equations, reflecting the general unit cost reductions that occurred in the early years after privatisation (the time trend coefficients in Table 6 are broadly in line with those reported in Table 3). However, the positive coefficient on the Hatfield dummy variable indicates that "Hatfield effects" have led to a sharp increase in unit costs over the last two years (26[38] and 38[39] per cent respectively for maintenance and total costs). The combined effect of the time trend and Hatfield dummies suggests that, on average in 2001/02, zonal unit costs remain just below their 1995/96 levels after taking account of volume and quality effects (by 12 and 7 per cent for maintenance and total costs respectively).

In addition to the increase in absolute unit cost levels since Hatfield, the relative positions of some of the zones have also changed compared to the 1999/00 results. Confining our discussion to the COLS results (see Section

[38]Calculated as the exponential of the Hatfield dummy minus one: exp (0.235) − 1.
[39]Calculated as the exponential of the Hatfield dummy minus one: exp(0.321) − 1.

5.3.1), for *maintenance activity*, Midlands, Scotland, and LNE emerge as the top three zones (compared to LNE, Scotland, and East Anglia in 1999/00). Midlands moved up from 5th position in 1999/00 (see Table 4) to first position in 2001/02, and was the only zone to reduce maintenance costs over this period, while the other zones saw increases of up to 48 per cent in real terms. At the *total cost level*, the three top performing zones in 2001/02 are shown to be Scotland, Great Western, and Southern (compared with LNE, Scotland, and East Anglia in 1999/00).

The changes to the zonal rankings since 1999/00 suggest that different zones have developed alternative responses to the Hatfield accident (or have been impacted to a greater or lesser extent).[40] Furthermore, comparison of the maintenance and total cost rankings, before and after Hatfield, suggests that the relationship between maintenance and renewal activity has also changed (the correlation between the COLS1 and COLS2 results was higher in 1999/00 than in 2001/02; see Tables 4 and 7). In particular, we note that the relative position of LNE, the zone containing the section of track at Hatfield, deteriorated considerably between 1999/00 and 2001/02 (from 1st position to 3rd and 4th respectively for maintenance and total costs).

To complete this sub-section, Table 8 shows the range of potential efficiency improvements[41] that less efficient zones might be expected to deliver, based on replicating the practices employed by the most efficient zone (derived from the scores in Table 7). Table 8 puts these potential improvements in the range of 1 to 21 per cent for maintenance activity, and 9 to 24 per cent for overall maintenance and renewal activity. These

**Table 8**
*Indicative Potential Efficiency Gains*

| | *Maintenance costs (%)* | *Total Costs (%)* |
|---|---|---|
| East Anglia | 19 | 18 |
| Great Western | 21 | 9 |
| London North Eastern | 3 | 9 |
| Midlands | – | 18 |
| North West | 17 | 24 |
| Scotland | 1 | – |
| Southern | 20 | 9 |
| **Company weighted average** | **13** | **13** |

[40] The dispersion of maintenance scores has also increased since Hatfield; though the dispersion of the total cost efficiency scores has remained virtually unchanged.
[41] Radial contraction of cost and quality inputs.

potential cost reductions translate into an overall, company-wide efficiency target of around 13 per cent for both maintenance and total costs (based on a weighted average). In particular, we note that Great Western is the least efficient zone according to the maintenance cost rankings. This result appears to be in line with the decision taken by Network Rail to bring maintenance activities in-house on the Great Western zone in 2003.[42]

It should be noted that, in our analysis, we have treated post-Hatfield cost increases as a frontier shift. In other words, we assume that these cost increases are permanent — resulting from new information about asset degradation — and that there is no prospect of returning to the unit cost levels recorded in earlier years. However, it is possible that part of the increase has resulted from a number of temporary factors that are reversible over time. Examples are capacity constraints amongst Railtrack's supplier base; over-reaction and inefficiency in the response to Hatfield, given the lack of knowledge about asset condition; and a general switch in focus away from efficiency considerations, towards simply getting the railways working again. Further savings, over and above those shown in Table 8, may therefore be possible over time.

### *5.3.3. Other factors possibly affecting 2001/02 efficiency scores*

The above analysis has taken account of a number of factors in arriving at efficiency scores. In this sub-section we consider whether the zonal efficiency rankings produced by our analysis can be explained by other operational factors: (1) track quality, measured by Level 2 Exceedences per track mile (L2Es);[43] (2) track temporary speed restrictions per track mile (TSRs);[44] (3) track category (where a high track category score indicates track that is capable of handling high train speeds and/or high tonnages);[45] and (4) track asset age.

We were unable to include these factors in the efficiency analysis detailed above, since a full seven-year time series was not available. As a result, we carried out simple correlation analysis between the efficiency scores generated earlier, and the values of the above variables (for 2001/02

[42] But we also note that Great Western performs better at the total cost level.

[43] Level 2 Exceedence is a measure of the difference in the actual rail position from its "ideal" position.

[44] Temporary speed restrictions (TSRs) is a combined measure of the length (track miles) and duration (time) of TSRs imposed on the network due to concerns over the quality of track.

[45] Track category relates to the ability of a section of track to handle the highest train speeds and/or tonnages (on a scale of 1A to 6). Our track category measure is calculated as the percentage of track miles (by zone) falling into the top four categories (1A to 3 inclusive); and a high percentage therefore indicates a high track category score.

only). Our null hypothesis is that these four operational factors can explain some of the efficiency differentials reported above. If this hypothesis is true, we would expect high efficiency scores to be associated with high L2Es (that is, low track quality); high TSRs; low track categorisation (low linespeeds/tonnage capability); and low average asset age (newer assets).

Although the results (shown in Table 9) cannot be regarded as statistically valid — being based on only a single year's data — they provide no evidence in support of the above hypothesis.[46] In other words, there is no evidence to suggest that the most efficient zones identified in our analysis have achieved their high scores at the expense of other quality measures (L2Es or temporary speed restrictions), or as a result of advantages in respect of asset age (newer assets), or the category of track operated in the zone (for example low speed/tonnage lines).

To complete this sub-section, it is also of interest to examine whether the 2001/02 efficiency rankings can be explained according to the maintenance contractor (or contractors) operating in each zone. Tables 10 and 11 compare maintenance and total cost efficiency rankings (most efficient zone listed first) against maintenance contractor. However, this information does not indicate any clear relationship between efficiency measure and contractor, though analysis of efficiency by contractor may be an interesting area for future research. In particular, such an analysis would increase the number of cross-sections, since at the time of writing there were approximately twenty maintenance contract areas within Network Rail.

We consider that the analysis presented in this paper has analysed the main factors that affect efficiency performance. In particular, we have

**Table 9**

*Correlation between 2001/02 Efficiency Scores*and Four Operational Factors*

| | *Level 2 Exceedences (L2Es)* | *Temporary Speed Restrictions (TSRs)* | *Track Category* | *Track Age* |
|---|---|---|---|---|
| Correlation coefficients | −0.814** | −0.423 | 0.135 | 0.153 |

*Total cost efficiency scores.
**Significant at the 5 per cent level.

[46]The only correlation that is statistically significant is that between efficiency and L2Es, but this coefficient is negative, indicating that firms with high efficiency also have low L2Es.

**Table 10**
*Maintenance Cost Efficiency Rankings Versus Maintenance Contractor**

| *Zone* | *Maintenance Contractors* |
|---|---|
| Midlands | SERCO; AMEY; Carillion |
| Scotland | First Engineering |
| London North Eastern | Jarvis |
| North West | First Engineering; Jarvis; Carillion |
| East Anglia | Balfour Beatty; AMEC |
| Southern | Balfour Beatty; AMEC |
| Great Western | AMEY; Carillion |

*Most efficient zone (in 2001/02) listed first (based on COLS scores: see Table 7).
*Source*: Data on contractor location provided by Railtrack.

**Table 11**
*Total Cost Efficiency Rankings Versus Maintenance Contractor**

| *Zone* | *Maintenance Contractor(s)* |
|---|---|
| Scotland | First Engineering |
| Great Western | AMEY; Carillion |
| Southern | Balfour Beatty; AMEC |
| London North Eastern | Jarvis |
| Midlands | SERCO; AMEY; Carillion |
| East Anglia | Balfour Beatty; AMEC |
| North West | First Engineering; Jarvis; Carillion |

*Most efficient zone (in 2001/02) listed first (based on COLS scores: see Table 7).
*Source*: Data on contractor location provided by Railtrack.

taken account of quality measures (delays, broken rails, track quality, TSRs), and other potential cost drivers (track category and asset age), as well as the standard cost and volume indicators. We have considered the relationship between efficiency rankings and maintenance contractor, and also the maintenance contract renewal process. However, we recognise that, as with any efficiency study, there may be other factors affecting our efficiency comparisons that have not been accounted for.

## 6. Conclusions

Given the difficulties with previous attempts to benchmark Railtrack's efficiency performance, the objective of this paper was to explore the use of internal benchmarking to inform the debate on future efficiency targets for Network Rail. Our approach mirrors the yardstick competition method adopted in other UK regulated industries. Cost, output, and quality data were collected on a consistent basis for seven geographical zones within Railtrack, over the seven-year period 1995/96 to 2001/02.

The results in Tables 3 and 6 show that Railtrack delivered substantial real unit cost reductions in the early years after privatisation (between 5.9 and 7.9 per cent for maintenance activity; and 6.4 to 6.8 per cent for overall maintenance and renewal activity). These cost reductions take account of quality, scale, and density effects, which are captured separately in the regression equations. However, these improvements were largely offset by the post-Hatfield cost increases, which resulted in unit cost increases of 26 and 38 per cent for maintenance and overall (maintenance and renewal) activity respectively.

In terms of relative efficiency, the most efficient zones in 2001/02 are identified as Midlands, Scotland, and LNE (maintenance only); and Scotland, Great Western and Southern (total costs). The post-Hatfield environment resulted in changes to the relative rankings, compared to 1999/00, indicating differing responses to Hatfield at the zonal level. We note that LNE (the zone containing the section of track at Hatfield) remains one of the more efficient zones according to our analysis, although its relative position deteriorated between 1999/00 and 2001/02.

Since the efficiency scores and rankings outlined in the paper take account of volume and quality measures, and cannot be explained away by zonal differences in other operation factors (track quality; TSRs; track category; and asset age; see Table 9) we consider these rankings to be robust given the available data, and the relatively small sample size. However, we recognise that, as with any efficiency study, there may be additional variables that have not been accounted for in our analysis.

The relative efficiency scores in 2001/02 suggest there is scope for less efficient zones to make cost reductions and/or quality improvements of up to 24 per cent if they can replicate the performance of the most efficient zones (see Table 8). These potential savings at zonal level translate into an overall company-wide (radial) efficiency target of 13 per cent for both maintenance and total costs. Further savings may also be possible to the extent that part of the post-Hatfield cost increases are temporary, and therefore potentially reversible in future years (although, as noted earlier, this cost increase may reflect a permanent change resulting from new information about asset degradation).

We consider that the method and results detailed in this paper demonstrate the scope for using zonal yardstick comparisons to set future efficiency targets for Network Rail. The analysis is based on a high quality, consistently-defined data set, which fits well with our parametric models. Furthermore, zonal differences in scale, technology, and other environmental factors are relatively small compared with external benchmarking studies. Our study identifies the most efficient zones and indicates a set of efficiency targets for less efficient parts of the network. Furthermore, these targets are calculated relative to performance levels already being achieved elsewhere within the company. As a result, we argue that our approach, based on internal benchmarking, provides clearer guidance on how efficiency gains can be achieved in practice. We note that the ORR and Network Rail have jointly commissioned an additional zonal benchmarking study as part of the 2002/03 interim review, building on the analysis outlined in the preceding sections.

## Appendix 1 Data Sources and Definitions

| *Data* | *Source* | *Comments* |
|---|---|---|
| Maintenance costs | Railtrack (Finance) | All financial data reconciles with Railtrack's Statutory Accounts. |
| Renewal costs | Railtrack (Finance) | Our renewals cost series includes track renewals only, since this measure was considered to be more comparable across zones (in contrast to other renewals, such as structures or signalling). We have used annual track renewal costs (which are capitalised), in place of a capital stock series, since it was not possible to access zonal renewal data prior to privatisation (and net book value is not an accurate measure of capital in this industry).[47] |
| Track Miles | Railtrack Network Management Statements | No significant changes to track miles over the period of our analysis. |

[47] Our parametric models perform well using this track renewal cost series, without the need, for example, to construct a moving average renewal cost series.

**Table 11** *continued*

| *Data* | *Source* | *Comments* |
|---|---|---|
| Passenger train miles | Railtrack TOPS System; Railtrack (Performance) | Accurate data was available by train service code (groups of services) between 1998/99 to 2001/02 (TOPS system). Railtrack provided a mapping of train service code onto zones for 1999/00 (based on samples of data taken from the summer and winter timetable). Given the stability of the relationship between train service code and zones, the same mapping has been used for 1999/00, 2000/01 and 2001/02. The data for the period 1995/96 to 1997/98 was constructed using TOC data (which has a very strong correlation with the zones in most cases), supported by additional information from Railtrack experts. |
| Passenger tonne miles | Railtrack (Regulation & Government) | The passenger tonne mile series was constructed using Railtrack data on average tonnage per train (by TOC). |
| Freight tonne miles | Railtrack (Freight) | The freight billing system data (1998/99 to 2001/02), was allocated from service group to zones using the Railtrack zone/service group mapping. 1995/96 to 1997/98 data were constructed using freight data by commodity. |
| Delays | Railtrack (Performance) | Includes Railtrack-caused delays only. |
| Broken rails | Railtrack (Regulation & Government) | |
| Level 2 exceedences | Railtrack Annual Return, 2001/02 | |
| Track TSRs | Railtrack Annual Return, 2001/02 | |
| Track category | Railtrack (Regulation & Government) | |
| Track age | Railtrack (Regulation & Government) | Track asset age is an average of the age of rail, sleepers, and ballast. |

# Appendix 2 Correlations of Efficiency Scores

*Rank Correlation Coefficients of Efficiency Scores*
*Pre-Hatfield period (1995/96 to 1999/00)*

| | *COLS1* | *SFA1* | *COLS2* | *SFA2* |
|---|---|---|---|---|
| COLS1 | 1.000 | | | |
| SFA1 | 0.959 | 1.000 | | |
| COLS2 | 0.883 | 0.880 | 1.000 | |
| SFA2 | 0.894 | 0.899 | 0.974 | 1.000 |

*Rank Correlation Coefficients of Efficiency Scores*
*Full Seven-Year period (1995/96 to 2001/02)*

| | *COLS1* | *SFA1* | *COLS2* | *SFA2* |
|---|---|---|---|---|
| COLS1 | 1.000 | | | |
| SFA1 | 0.970 | 1.000 | | |
| COLS2 | 0.774 | 0.717 | 1.000 | |
| SFA2 | 0.722 | 0.677 | 0.969 | 1.000 |

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