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The Financial Performance of Non-Urban Passenger Rail Services

Paul Amos and Richard Bullock

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THE FINANCIAL PERFORMANCE OF NON-URBAN PASSENGER RAIL SERVICES

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THE WORLD BANK
Washington, D.C.

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EXECUTIVE SUMMARY

Background

Passenger railways can perform a valuable economic and social role in dense inter-city corridors, for suburban transport in major cities, and in some rural regions where population density permits. In many cases these roles could only be transferred to road transport at a higher cost in road infrastructure, traffic congestion, vehicle emissions and traffic accidents.

In general, the Bank supports the role of cost-reflective prices in attaining efficient use of transport resources. It also recognizes the importance of market-based elements to recover those elements of fixed infrastructure costs that cannot be clearly attributed to specific user groups. In practice most pricing systems in the rail transport sector sensibly contain cost and market-based elements.

However, as is demonstrated in this Paper, it is also the case that the circumstances in which passenger train services actually can cover the costs of their infrastructure, even at reasonably efficient input cost levels, may be rather limited. Once a decision to provide passenger rail lines has been made, it may carry with it the need for long-term budgetary support for maintaining rail infrastructure (as is the case for most road infrastructure in developing countries). This does not make such a decision wrong, particularly if wider economic, environmental and social benefits may be gained. But it is clearly important to understand when and why this may be the case to avoid false expectations, to support appropriate rail management strategies to minimize the shortfall, and to develop appropriate long-term financing framework if long-term budgetary support of infrastructure is required

Structure of Paper

The Paper has three parts. It first summarizes the main factors that influence the costs and farebox cost recovery of rail passenger services, with illustrations from a range of different countries in which the Bank is involved in rail passenger operations. Second, it provides a generalized passenger service costing model, including indicative sets of input unit costs representing different levels of efficiency: this model is used for illustrative purposes in this paper but the structure can be readily applied by transport planners and policy-makers, with use of local parameters, in developing and transition countries. Third, it illustrates the cost drivers of services and the sensitivity of costs to different market and operational drivers.

Annexes provide more detailed information on cost allocation methodologies for both train operating and infrastructure costs.

Review of actual railway cost recovery

The paper examines the performance of ten railway systems in which the Bank has worked, which include low and middle income countries, and a variety of traffic levels and operating circumstances. Data from individual railways are not identified, as they are used to illustrate issues about passenger rail services in general rather than those of any particular country.

Four of the ten railways are able or nearly able to cover their above-rail working expenses. These are all railways with high revenues per carriage-km and high traffic density per route-km. The remaining railways typically cover about 50 percent of their above-rail working expenses and in one case rather less. When rollingstock capital is included, three railways can still just about also cover above rail costs, thus possibly justifying rollingstock renewal when due.

No railway of the ten is able to cover full infrastructure costs. The fares in most systems are essentially regulated. Nevertheless, many of the more poorly-performing systems would clearly be unable in aggregate to cover even above-rail working expenses even if they had full freedom to set their own tariffs, at least on a system-wide level.

The Paper shows however, that within any railway there are considerable variations in cost recovery between the different types of service and different routes. In many of the railways a proportion of the services performs much better than the average. The Paper draws particular attention to the importance of revenue yield in determining service viability. The distribution of revenue yield per carriage-km or seat-km shows much greater variation by service type than the distribution of cost, reflecting the importance of freedom of pricing to manage yield.

Passenger costing model

The Paper develops a passenger costing model to further to explore the relationships revealed by the specific examples. It is based on a functional classification of unit input costs that is used by many railways and that could be applied by a reasonably proficient transport economist or analyst.

From the range of experience, two indicative sets of unit input costs levels are developed, consistent with the lower (more efficient end) of the ranges found in two types of railway:

- a middle-income country (with railway labor costs of $3,500/employee p.a.)[1] which has reasonably high labor productivity (say 750,000 traffic units/employee;
- a low-income country (with railway labor costs of $1,000/employee p.a.) which has lower (but certainly not the lowest of the experience) productivity (say 200,000 traffic units /employee).

The Paper then uses the passenger costing model to apply the two sets of unit input costs to five typical service types: these five types are used to illustrate some of the main types of service found in the Bank's regions of operations. The model application thereby provides estimates of unit output costs for the five service types at the two input cost levels. The five service types are:

- Service 1: long-distance overnight train, with 18 carriages, probably operating daily (or at most twice daily);
- Service 2: medium-distance intercity service, with 10 carriages, probably operating 2-3 times daily;
- Service 3: branch-line train, with 4 carriages, probably operating about four or five times daily;
- Service 4: medium-distance intercity train, operated by multiple-unit on an interval timetable giving around 8-10 services daily;
- Service 5: higher-speed (160 km/h maximum-speed) intercity train, operated by multiple-unit on interval basis, giving around 6 services per day.

Results of the analysis

Full cost-recovery (covering both above and below-rail working expenses and asset capital charges) is achieved by the long-distance and intercity multiple-unit services under the more efficient (first) set of unit costs. The results critically depend on the reasonably high load-factors and fares assumed in the service specifications; if yields per seat-km are lower, either by regulation or by market forces (because the level of service is too poor to attract premium-paying customer, or because of very low ability to pay) then operators will fail to cover their above-rail operating costs.

The conventional medium-distance services, and particularly branch-line services, have particular problems in recovering costs. Even for at the more efficient unit input costs, yields only just cover above-rail working expenses and rollingstock renewal for the IC services and thus contribute nothing to infrastructure.

The multiple-unit services perform better than loco-hauled services for the medium-distance services, helped by 10 percent lower train operating costs, and a premium on the fare due to the typically higher speed and passenger amenity.

[1] All dollar amounts are U.S. dollar unless otherwise indicated.

Finally, even though the high-speed (160 km/h) services have higher unit operating costs (possibly up to 20 percent higher) compared to conventional multiple unit services, they have the potential to perform even better if their increased operating speed is reflected in the fares charged and they are operating in a market which can afford them.

In the examples illustrated, only the long-distance and multiple-unit trains contribute significantly to infrastructure costs. These examples indicate that well-loaded long-distance trains on dense corridors, should be able to cover more than two-thirds of fixed maintenance costs (and rather better on the better-performing railway systems) but would cover full costs only in a few instances. Higher-speed services can probably even make some contribution to the capital cost of the infrastructure upgrades required for their services to operate.

In all these cases yield/passenger and occupancy/carriage are critical in determining cost recovery. Costs per carriage-km for main-line services generally only vary over a relatively limited range –say +/- 30 percent but capital costs are similar for most railway systems which purchase on the international market and are only affected by utilization; fuel costs are similar in most railways and differences in wage rates are at least partially balanced by off-setting variations in labor productivity. However, variations in revenue per carriage-km, which is the product of revenue per passenger-km and passenger occupancy, are generally much greater and reflect the competitive environment, the level of service, the degree of management attention to train yields, and the degree of regulation.

Sensitivity analysis

This Report also addresses the sensitivity of cost to changes in key scenario assumptions. This shows that operating costs are minimized (but revenue not necessarily maximized) when operating speed is around 80 km/h. Above that speed, above-rail unit costs gradually increase as continuing reductions in time-related costs, principally rollingstock capital cost, are progressively offset by increased fuel consumption and equipment maintenance. Infrastructure maintenance costs also increase significantly with speed because of the need for higher-quality track.

Low commercial speeds, whether due to track condition or to lack of line capacity, also exert a significant cost penalty as unit costs related to elapsed time escalate and are up to 30 percent higher compared to the minimum at around 80 km/h.

Train size also has a significant impact on unit operating costs, particularly if the train is loco-hauled. Where there is no alternative use for a locomotive, as is the case with some branch-line services, the penalty is not so important; but where locomotives are used to haul trains well below their capacity, costs increase and a 5-car train costs about 30 percent more per seat-km than a 15-car train at the same commercial speed (assuming the 15-car train is still within the capacity of a single locomotive).

Multiple-unit trains provide a competitive alternative but this naturally diminishes as train size increases. This is especially true for small trains (4 cars), for which almost as much cost is typically incurred moving the locomotive as moving the carriages. As train size increases, the locomotive-related costs can be spread over a greater number of carriages. Even so, multiple units are likely to remain competitive with loco-hauled trains under most circumstances except for very big long-distance train services. However, these results are indicative only. Any comparison in real-life would also need to take into account the specific operational circumstances. In many cases the much faster turnarounds possible with multiple-units can allow higher overall capital utilization than locomotive haulage on a service-for-service basis.

Although it is not modeled in detail in this paper, electric traction is generally cheaper than diesel as long as demand is sufficiently large to enable the additional fixed costs associated with electricity supply to be balanced by the volume-related train benefits of (generally) cheaper power and motive power maintenance cost. In addition electric traction can, in more difficult terrain, allow better haulage and speed performance.

The analysis demonstrates the critical impact of occupancy on the output cost per passenger-km. The cost of a passenger train service of given consist is almost totally independent of the number of

passengers using it. Railway management should of course attempt to match the size of trains to the general level of demand offering and may change the consist at particular periods, but (unlike with a freight train) it must pre-plan that consist before the actual users materialize. Inevitable fluctuations in traffic within and between days of week and times of day mean that much unused capacity is provided even by efficient passenger managers, unless train capacity is so restricted as to create chronic crush loading and frequent inability to meet demand. Yield management to maximize the revenue from the planned 'normal' consist is therefore one of the major ways of improving financial performance; but is often constrained by fare regulatory policies.

Conclusions

The financial performance on any given railway will depend on its individual circumstances but there are some conclusions that seem generally applicable:

- If they are reasonably well-patronized and operated efficiently, mainline train services should be able to cover both their avoidable train working expenses and the cost of renewing the rollingstock as it falls due.
- The ability of passenger services to contribute to infrastructure costs depends on (a) the revenue earned per carriage-km because this determines the surplus over above-rail cost available to pay for infrastructure; and (b) the traffic density on the line, as this determines the proportion of fixed infrastructure costs allocated to the service. Full cost coverage can only be obtained by having a combination of relatively high earnings per carriage-km (at the upper end of experience, say $0.70 and above) and a high density of total traffic (say, 7500 trains p.a., or around 10 pairs per day). Achieving either of these targets is a major challenge in many developing countries, which in many cases would barely have 5 pairs on much of their network.
- Branchline trains can sometimes provide a valuable role in feeding traffic to mainline services, but will only rarely be able to cover even their above-rail working expenses, let alone make any contribution to rollingstock asset renewal or infrastructure costs. Bus feeder services can often (perhaps usually) be contracted to provide better service at lower costs.
- In general, the above rail cost of operating different types of train services at a given level of system efficiency varies less than revenue. The key factors in achieving reasonable levels of cost-recovery are through rollingstock utilization, carriage occupancy and passenger yield.
- Other things being equal, the difference in overall rail operating costs for a given type of service between an efficient railway in a developing country and an efficient railway in a high-income country is relatively small, say 2:1 (as the cost of many of the capital inputs, fuel and spare parts are the same in both cases). However, the difference in income per head which might be between 5:1 and 10:1 or more directly affects the affordability of fares. At similar passenger loading and line density standards, developing countries have an inherently greater challenge in achieving high cost recovery in passenger rail services implying a need to fund a greater share than high-income countries of infrastructure costs from some budgetary support (or less satisfactorily) from rail freight.
- Restricting capacity and subsequent crush loading of non-urban train services can help meet the above challenge on the revenue side, but low train service standards in general do not necessarily denote correspondingly low train operating costs. But they do certainly discourage use by higher income groups. Many governments that, despite rising country incomes, are pursuing policies of offering poor standards at a low fare (i.e. using rail as the default mode for the poor) are almost certainly damaging the long-term potential role of passenger rail. That role will increasingly depend on delivering the higher service benefits the technology can offer and pricing accordingly.

THE FINANCIAL PERFORMANCE OF NON-URBAN PASSENGER RAIL SERVICES

1 INTRODUCTION AND BACKGROUND

The Bank's Transport Business Strategy Update[2] recognizes that passenger railways can perform a valuable economic and social role in dense inter-city corridors, for suburban transport in major cities, and in some rural regions where population density permits. In many cases these roles could only be transferred to road transport at a higher cost in road infrastructure, traffic congestion, vehicle emissions and traffic accidents.

In general, the Bank supports the role of cost-reflective prices in attaining efficient use of transport resources. It also recognizes the importance of market-based elements to recover those elements of fixed infrastructure costs that cannot be clearly attributed to specific user groups. In practice most pricing systems in the rail transport sector sensibly contain cost and market-based elements.

Nevertheless, most countries in the world subsidize passenger public transport services to a lesser or greater extent. Some of the reasons are set out in the Transport Business Strategy Update. Beyond simply the political profile of such services, there is often a policy aim of transport 'equity': the idea that accessibility and the affordability of basic transport service (like health and education) is something that a government should ensure is available to the widest range of its citizens, including passengers who could not otherwise afford the full cost, those in remote or lower density areas, or those who need to travel in time periods when average costs of provision may be high. Some countries also choose through low prices to actively encourage public transport use as an alternative to private travel. In the particular case of railways, some countries are also persuaded by the economic case that recovery of the fixed costs elements from fares will lead to underutilization of sunk assets and may not maximize community economic benefit.

However, as is demonstrated in this report, it is also the case that the circumstances in which passenger train services actually can cover the costs of their infrastructure, even at reasonably efficient input cost levels, may be rather limited. Once a decision to provide passenger rail lines has been made, it may carry with it the need for long-term budgetary support for maintaining rail infrastructure, (as is the case for most road infrastructure in developing countries). This does not make such a decision wrong, particularly if wider economic, environmental and social benefits may be gained, but it is clearly important to understand when and why this may be the case to avoid false expectations, to support appropriate rail management strategies to minimize the shortfall, and to develop appropriate long-term financing framework if long-term budgetary support of infrastructure is required.

The World Bank is therefore frequently involved in issues regarding the financial performance and strategies for non-urban passenger railway services, both as part of policy dialogue on resource allocation in the transport sector, and in the context of specific projects. The range of circumstances varies from some of the world's busiest passenger lines to some that are very lightly used in Africa, South east Europe and elsewhere.

[2] Safe, clean and affordable: Transport for Development, World Bank (forthcoming, 2008).

The ability of services to recover their costs depends on market characteristics (in particular, density of demand and the passengers' ability to pay) and a range of supply-side variables (such as train size, staff productivity, rollingstock utilization etc). Both aspects can vary markedly within and between countries. These factors are further affected by the extent to which competitive alternatives are available.

This Transport Paper is intended to assist Bank staff and transport planners in developing countries to understand the financial drivers and characteristics of non-urban rail passenger operations, to illustrate the considerable challenge of recovering infrastructure costs from passenger fares, and to provide a model for costing passenger services that can used to improve decision-making.

The Paper:

- summarizes the main factors that influence the costs and farebox cost recovery of rail passenger services, with illustrations from a range of different countries in which the Bank is involved in rail passenger operations;
- provides a generalized passenger service costing model, including indicative sets of input unit costs representing different levels of efficiency – this model is used for illustrative purposes in this paper but the structure can be readily applied by transport planners and policy-makers, with use of local parameters, in developing and transition countries ;
- illustrates the cost drivers of services and the sensitivity of costs to different market and operational drivers.

This is a technical paper and its scope is specifically targeted at financial analysis and performance. The broader environmental and social issues that impinge upon the role of railways in national transport systems are not addressed. Data from individual railways are not identified, as they are used to illustrate issues about passenger rail services in general rather than those of any particular country.

The remainder of the Paper is in three sections. Section 2 overviews the current financial performance of non-urban rail services in a range of countries and discusses in general terms the reasons for the variations between railway systems. Section 3 develops the framework for a quantitative analysis of these variations: it describes the cost structure of rail passenger services, derives sets of unit operating and capital costs for different types of railway and defines typical services to which they can be applied. Section 4 then calculates the cost of providing each of these typical services and their sensitivity to variations in operating parameters (such as speed and size of train). It also gives some case studies showing examples from railways operating under a range of market and operating conditions.

Three annexes cover specific technical aspects. Annex A describes the cost structure of rail passenger services in more detail and provides the results of the costing model. Annex B discusses the main principles underpinning infrastructure cost allocation. Annex C summarizes the factors influencing track cost variability.

2 OVERVIEW

2.1 Introduction

This Section overviews the financial performance of non-urban passenger services in a range of countries and outlines the key determining factors. As with any other transport mode, the finances of non-urban passenger services depend on factors which affect both supply and demand. The key parameters on the revenue side are:

- Traffic density (passenger-km/route-km): this can vary from very heavy, as in China, India and Pakistan, which can all support several large (say 15-20 carriages) trains daily on the main corridors, to very low, where a train two or three times a week (or less) with three or four carriages is sufficient to meet demand;
- Carriage utilization: the average number of fare paying passengers per carriage-km;
- Revenue yields (revenue/passenger-km): these are typically influenced by income levels (hence ability to pay), level of service (hence willingness to pay), modal competition and fare regulations.

On the cost side, the key factors are:

- Operational characteristics: these include the pattern of services (several small trains each day or a few large trains, whether overnight services are operated, etc), technology[3] and travel time. These supply variables affect both the output cost (both absolutely and per seat-km) and the level of demand.[4]
- Unit input costs of the inputs required to operate the services: these are a function of wage rates, labor and capital productivity (themselves often a function of initial and succeeding investment) and management efficiency.

The remainder of this section discusses the financial performance of ten railway systems which operate in widely different technical and economic environments in the Bank's regions of operations. Sections 3 and 4 then develop a framework within which the individual influence of specific factors can be isolated.

2.2 System-wide Financial Performance

Table 2-1 summarizes the key operating parameters of ten national railway systems within which the World Bank (IBRD/IDA) operates. These cover a range of income levels (four low, four low-medium and two upper-medium) and labor productivity. This is measured in terms of thousands of traffic units (the sum of passenger-km and net tonne-km) per employee;[5] most European railways have productivities of around 1 million TU/employee (calculated over both train operations and infrastructure) while the large freight-only railways in North America, Australia and elsewhere are typically over 5 million TU/employee.

The density of passenger traffic (as measured by passenger-km per route-km over which passenger services operate) varies hugely, with the busiest carrying around fifty times as many passengers on average over each section of line as the most lightly laden. The very low traffic densities (say, 250,000

[3] The main technological factor is whether services are conventional or high-speed (200 km/h and above). All high-speed services are multiple-unit but conventional services can be either loco-hauled with carriages or multiple-unit (either diesel or electric).

[4] In particular, service frequency, particularly for medium-distance services, can have a substantial impact on demand, with low frequencies often causing a downward spiral in load factors by progressively driving demand to alternative modes such as minibuses, which can operate with much smaller unit loads at much higher frequencies.

[5] Although an imperfect measure in many ways (it generally, but not always, favors freight railways over passenger railways and also is affected by the level of out-sourcing), it is the single most commonly used measure and has the virtue of being easily calculated and understood

passenger-km/route-km p.a.) are typical of small railways with low service frequencies such as one return service daily on the main line. At the opposite end of the spectrum, average densities of 3 million passenger-km/route-km p.a. are broadly equivalent to Western Europe (e.g. Netherlands is 5 million whilst most of the larger countries, UK, Italy, France, Germany and Spain are 1.5 -3 million).[6]

The size and speed of services also varies significantly between the railways in Table 2-1, although none of them achieves a system-wide average speed greater than 60 km/h. Non-urban train formations are generally quite long on such systems; however, two of the higher-income countries have much smaller trains as they try to maintain service frequencies in the face of growing competition from long-distance buses and private cars. Average occupancies (as measured by passengers per carriage) again are higher in the lower-income countries, partly because of service frequency being primarily determined by volume, and partly because lower-income countries typically tolerate higher levels of crowding and capacity shortfalls. Average occupancy in Table 2-1 is based on recorded travel and in some countries where there is widespread fare evasion may significantly under-estimate actual loadings.

Revenue per passenger-km increases with average income, as might be expected. As a result, even for the upper-medium income countries, are an order of magnitude lower than Western Europe, where fares are typically in the $0.10–0.15 per passenger-km (in the United Kingdom which is privately operated, $0.20/km).

The financial performance of the ten systems consequently also shows considerable variation. Figure 2-1 shows costs and revenue per carriage-km.

Table 2-1. Key passenger service characteristics of selected systems

System	Income level(1)	Productivity (000 TU/empl.)	Pass density (mill) (2)	Average occupancy(3)	Average speed (km/h)	Cars/ train	Revenue/ pkm (USc)
A	Low	325	3.2	64	43	11.9	0.7
B	Low	149	1.1	41	26	9.1	0.9
C	Low	174	0.3	36	35	16.6	1.4
D	Low	309	0.1	26	28	11.4	1.2
E	Low medium	650	4.7	54	47	8.3	1.0
F	Low medium	1060	6.6	60	57	14.3	1.0
G	Low medium	605	2.3	34	42	10.4	0.4
H	Low medium	185	0.3	14	43	3.9	1.9
I	Upper-medium	922	0.2	19	50	9.0	1.9
J	Upper-medium	300	0.7	21	44	5.8	2.5

(1) As defined by World Bank in terms of GNI ($/head): Low below $875; Low-medium above $875 but below $3,645; Upper-medium above $3,645 but below $10,725
(2) passenger km/route-km
(3) Passengers per carriage

[6] For comparison, the Shinkansen (which concentrates on 2500 km of the more densely-travelled routes in Japan) has a density of over 30 million passenger-km/route-km, compared to about 15 million for the 27,000 km Japanese network as a whole

Figure 2-1. Unit cost and revenue per carriage-km – ten railway systems

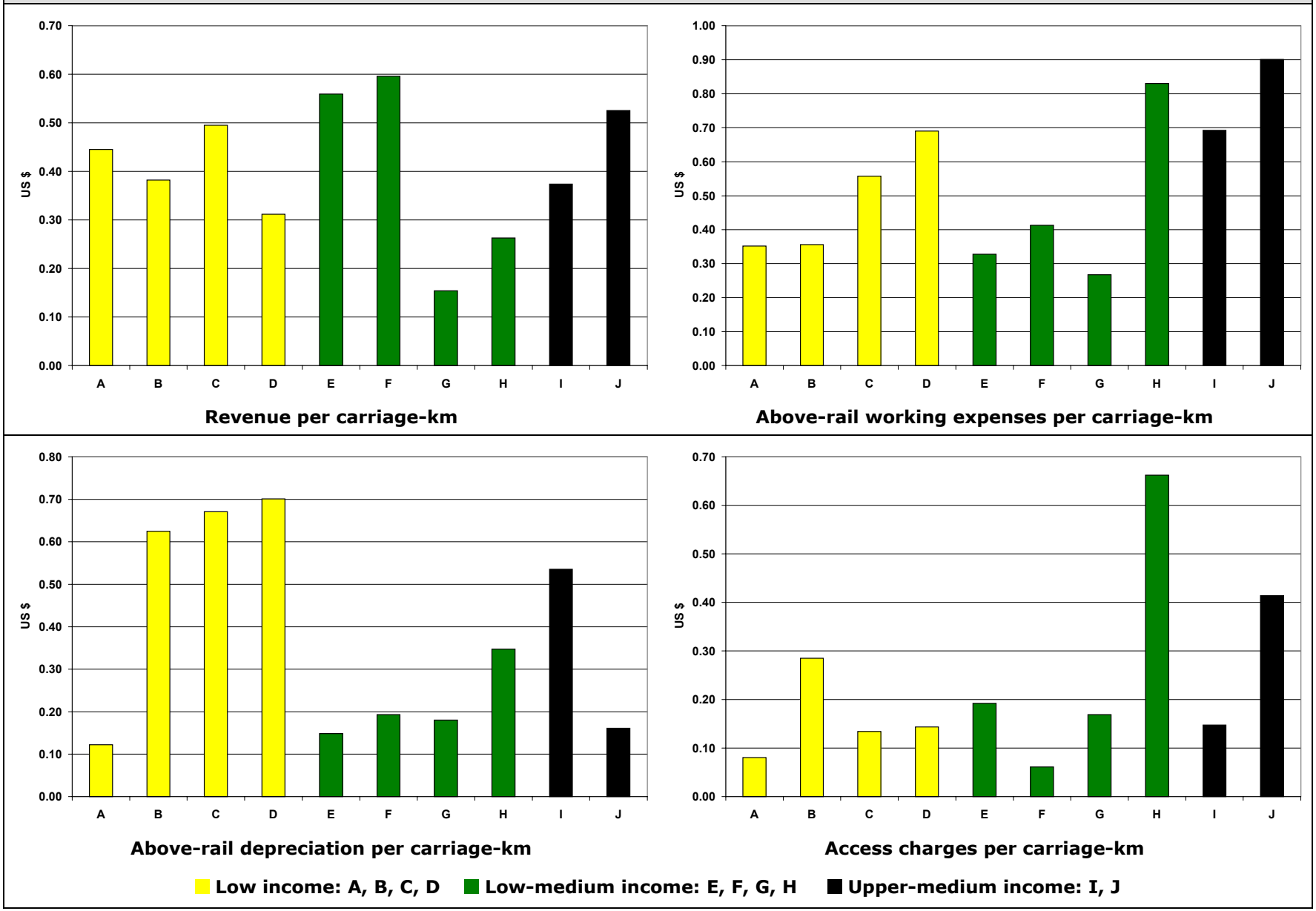


Figure 2-1 shows three components of cost:

- the avoidable costs of train operation, i.e. the costs which would be avoided if the services ceased operation. These can be conveniently[7] measured as the costs of train crew, rollingstock maintenance, fuel (or power) and passenger handling costs (ticket-selling/commission and some station staff).
- rollingstock capital renewal costs[8], which can be derived by converting the capital cost into an equivalent annual sum, based on the asset life and using a real discount rate.[9]
- an allocation of infrastructure operation and long-run maintenance costs (including rail and sleeper renewal), for convenience termed 'access charges' in this report. Although many different procedures have been devised for determining how much should be charged to the different types of service (see Annex B), for simplicity this paper uses the full-cost allocation method described in Annex B.

A final potential component (not shown in Figure 2-1) is the capital cost of infrastructure renewal in the cost base. This cost occurs very infrequently on most low-density railways (assuming routine maintenance has not been neglected). Only a few passenger services are ever able to make any contribution to this cost even though it is at least partly variable with usage.[10]

Examining the performance of the ten railway systems, the lower-income countries achieve as good, or better, revenues per carriage-km than the higher-income countries, in spite of usually having lower tariffs per passenger-km. This is because of their much higher occupancies (other than Railway D). Railway G is a special case, which charges negligible tariffs for passengers on local services, which make up about 60 percent of its non-urban services demand.

Above-rail working expenses fluctuate rather more than average revenues. Two of the low income countries (railways C and D) have relatively high average costs, partly because of low efficiency but also because of their comparatively low operating speed and low density of demand. The systems with higher traffic densities have the combined advantages of high service frequencies, low input costs and (with the exception of railway B) reasonable operating speeds. Although the higher-income systems (railways H, I and J) also have reasonable operating speeds, they operate smaller trains (thus incurring higher traction costs per carriage); they also have much higher labor costs which for two of them are not offset by corresponding improvements in labor productivity.

The rolling-stock renewal costs included in this paper (termed 'above-rail depreciation charges') have been calculated using a consistent framework based on the rollingstock assigned to passenger services on each system (excluding that which is obsolete and/or surplus) and estimated replacement costs. These costs are independent of labor productivity (and labor costs); instead they primarily depend on the average utilization of the rollingstock. This in turn depends on the average train operating speed, the intensity of services (so there are not long delays between consecutive train services) and the degree to which rollingstock is unserviceable because it is under repair in workshops and depots. Not surprisingly, railways with low operating speeds and low densities (such as B, C and D) have much higher depreciation charges than railways with the converse (such as A, E, F and G). Railway I has low service frequencies so, although the rollingstock moves reasonably fast when it is moving, it has long turnarounds between comparatively short services; it is also affected by poor locomotive availability.

The allocated share of infrastructure costs, termed 'access charges' in this paper, also varies widely. The approach adopted has two components, one related to train-km and one related to gross tonne-km (i.e. the weight of the train); railways operating small trains, as in railway H, will

[7] A proportion of infrastructure costs is also variable with usage and should strictly speaking be included. However, this is only significant for railways with relatively dense traffic and sophisticated signaling and for many of the more basic low-density railways the incremental impact of passenger services on infrastructure is relatively small. This is discussed further in Section 3 and Annex C.

[8] For convenience, these costs have been termed 'Above-rail depreciation' in the discussion that follows, assuming depreciation is calculated on the cost of renewing the assets rather than the historic cost. These costs as calculated appear in the accounts of very few railways.

[9] This report assumes a 4 percent real rate of return on capital

[10] Even fewer are able to make a contribution to the initial capital cost of construction (examples that did include the early– but not later – sections of the Japanese Shinkansen and French TGV networks; and the UK Heathrow Express spur line in London, reputedly the most expensive railway line in the world with a fare of around US$1.30/passenger-km (the Shinkansen, by comparison is about $0.25-0.30/passenger-km).

thus attract comparatively high charges per carriage-km. Because of the fixed component of infrastructure costs, the absolute level will also depend on the volume of freight traffic on the railway, and this is particularly marked for railways with relatively low volumes (unfortunately also the case for railway H). Conversely, railways with very high densities (such as railway F) have comparatively low infrastructure costs per carriage-km.

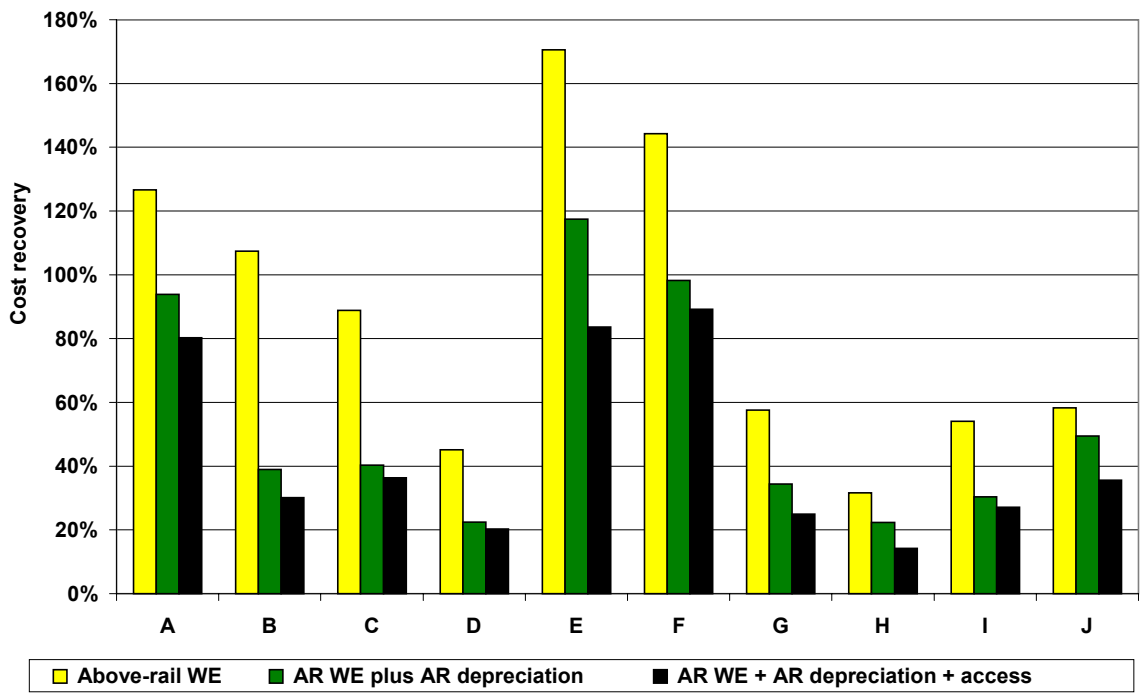
Figure 2-2 combines these costs and revenues to show three indicators of financial cost recovery:

- The most basic indicator of financial performance compares revenue with the avoidable costs of train operation; if the revenue only just covers the expense of the day-to-day operation of the train it can clearly not make any contribution towards rollingstock capital or infrastructure costs.
- The second indicator includes rolling-stock capital renewal costs in the cost base. If revenue also just covers this cost threshold then the service is able to cover replacement of its rollingstock when due, but this will still require someone else (either the taxpayer, or freight traffic) to pay for infrastructure.
- The third indicator includes the allocation of infrastructure operation and maintenance costs. This shows whether an operator would be able to operate without any contribution from third parties for infrastructure.

Several railways (A, B, E and F) are able to cover their above-rail working expenses. These are all railways with high revenues per carriage-km and traffic density. The only other railway to come close to 100 percent is railway C, which has high earnings per carriage-km but is also a low-density railway which is relatively inefficient. The remaining railways typically cover about 50 percent of their above-rail working expenses and in some cases (such as the railway H) rather less.

When rollingstock capital is included, railways A, E and F can still just about cover this cost, thus possibly justifying rollingstock renewal when due. However, all other systems perform poorly, even railway B, which performs reasonably well on working expenses, but which is severely handicapped by its low average operating speed.

Figure 2-2. Cost recovery – selected systems



None of the ten railways is able to cover full access charges (even without infrastructure renewal charges). The closest is railway F (at about 90 percent). Some of the tariffs in some railways (including those in railways A, B, C, F, G, H and J) are essentially regulated, and tariff-setting is done within a framework which only includes a subset of the costs included in Figure 2-2. (For example capital renewal cost is often financed by governments and ignored in pricing). Nevertheless, many of the more poorly-performing systems would clearly be unable in aggregate to cover even above-rail working expenses even if they had full freedom to set their own tariffs, at least on a system-wide level. However, the larger railways operate a range of services encompassing intercity expresses and branchline services, with differentiated pricing and there is thus normally a considerable variation within any railway in terms of the financial performance of individual service segments. This is now discussed in more detail, first at the business segment level and then at the level of individual services.

2.3 Financial Performance by Segment

Within any railway there are considerable variations in cost recovery between the different types of service. Figure 2-3 shows comparable results by segment for two of the railways (A and E) whose results were summarized in Figures 2-1 and 2-2.

Figure 2-3. Cost and revenue by segment

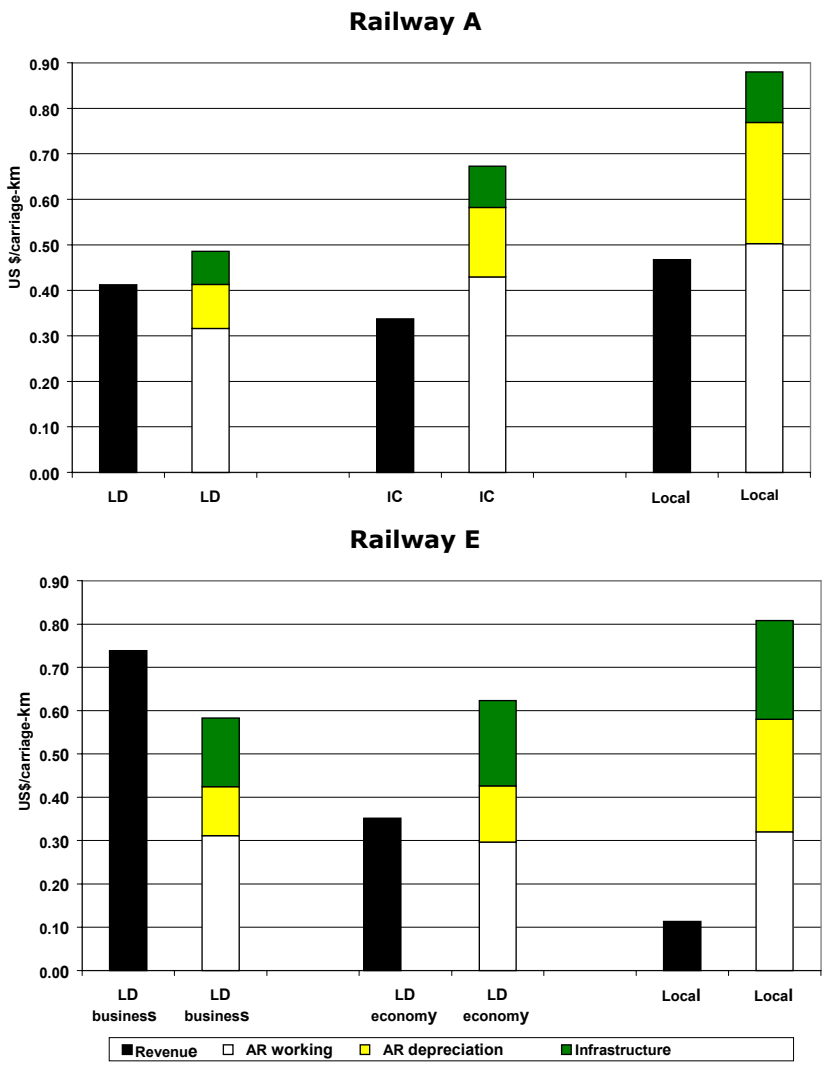


Figure 2-3 shows the importance of revenue yield in determining service viability. In Railway A, the long-distance (LD) services, most of which provide a mix of business and economy accommodation, cover their above-rail operating costs and depreciation. Intercity (IC) services are branded separately from long-distance and their revenue per carriage-km is lower (partly because of lower occupancies and partly because of a lower proportion of business passengers) but costs are a little higher, due to the smaller trains. Local trains have surprisingly high revenues per carriage-km but unit costs are much higher, because of smaller trains and slower speeds.

In Railway E, long-distance business (premium) services earn over twice as much revenue per carriage-km as the long-distance economy and local train services. Long-distance economy services (which are run as separate trains) are slightly more expensive on this railway; cheaper carriage maintenance costs in the economy segment are offset by the additional operating and capital costs caused by 20 percent slower running speeds. The fare-paying occupancy of local services is so much lower that the revenue per carriage-km is under a third of that for the long-distance economy services. Their working expense is similar to the other two segments although the allowance for above-rail depreciation is much greater because of the much slower operating speed (in practice, however, it is extremely unlikely that many of these services would receive any re-investment).

2.4 Financial Performance by Service

Within any given market segment, there are also variations in the performance of individual train services (the services offered on particular routes). Figure 2-4 gives the distributions by service of the revenue and costs per carriage-km of Railway A summarized in Figure 2-2. The distribution of revenue shows by far the greatest variation, reflecting the different levels of service provided and the impact of different levels of occupancy. Revenue on long-distance services ranges between $0.30 and $0.50/carriage-km, with a premium services earning up to $0.70/carriage-km. These services generally have a large number of carriages which can be fine-tuned to demand relatively easily. The medium-distance services have generally lower earnings per carriage-km (even though the basic fare scale is similar to the long-distance services), because many have more-or-less fixed formations which are operated whether they are fully-loaded or not. The branch-line services in this case earn surprisingly well, reflecting the policy of this particular railway of providing a minimum level of capacity and not attempting to cater for demand peaks on such services.

Costs show much less variation. Thus, in the second graph (above-rail working expenses) about 230 million carriage-km (about 70 percent of the total) cost $0.30 per kilometer, with the remainder (mostly medium-distance and local) costing up to $0.50 per kilometer. When above-rail capital renewal ('depreciation') is included, the distribution of costs broadens; and with access charges included, costs range between $0.40 and $1.00 per carriage –kilometer. In all cases, long-distance services are the cheapest to operate, followed by intercity and then local, mirroring the results shown in Figure 2-2. But there is a wide distribution of costs for each type of service and there are many long-distance services that are more expensive to operate than local services. Broadly:

- Long-distance services generally have above-rail working expenses in the range $0.30-0.40 carriage-km.
- Medium-distance services show a similar variation to long-distance services, although their average cost is about 20-30 percent higher
- Local and branch-line services are up to 100 percent more expensive, particularly when rollingstock costs and access charges are included (principally because locomotive depreciation and infrastructure costs are being spread over a smaller number of seats).

The revenue and cost distributions in Figure 2-4 can be combined to also provide a distribution of cost-recovery i.e. the extent to which the various cost thresholds are covered by revenue (Figure 2-5)

Figure 2-4. Distribution of costs and revenue by type of service

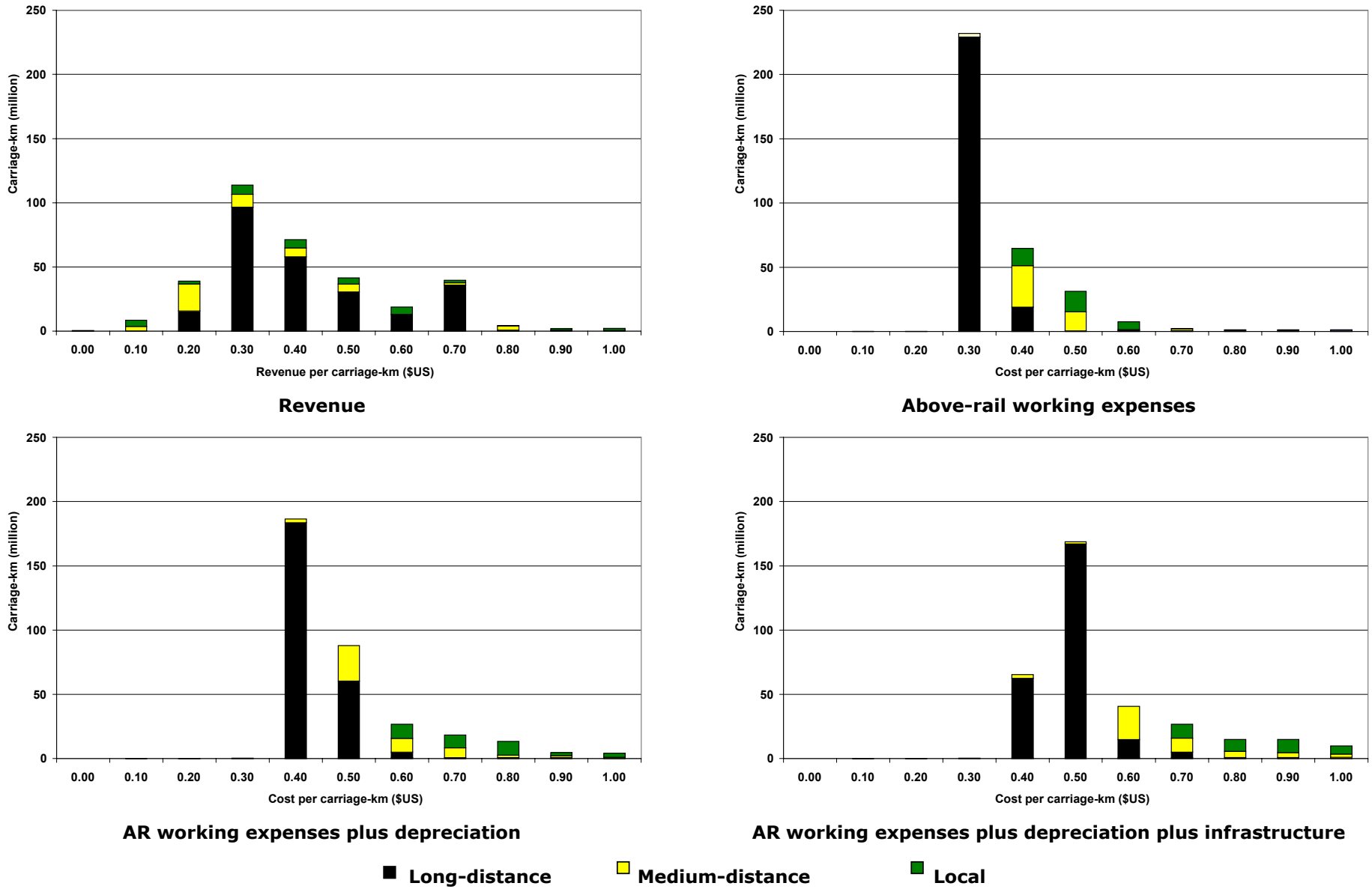
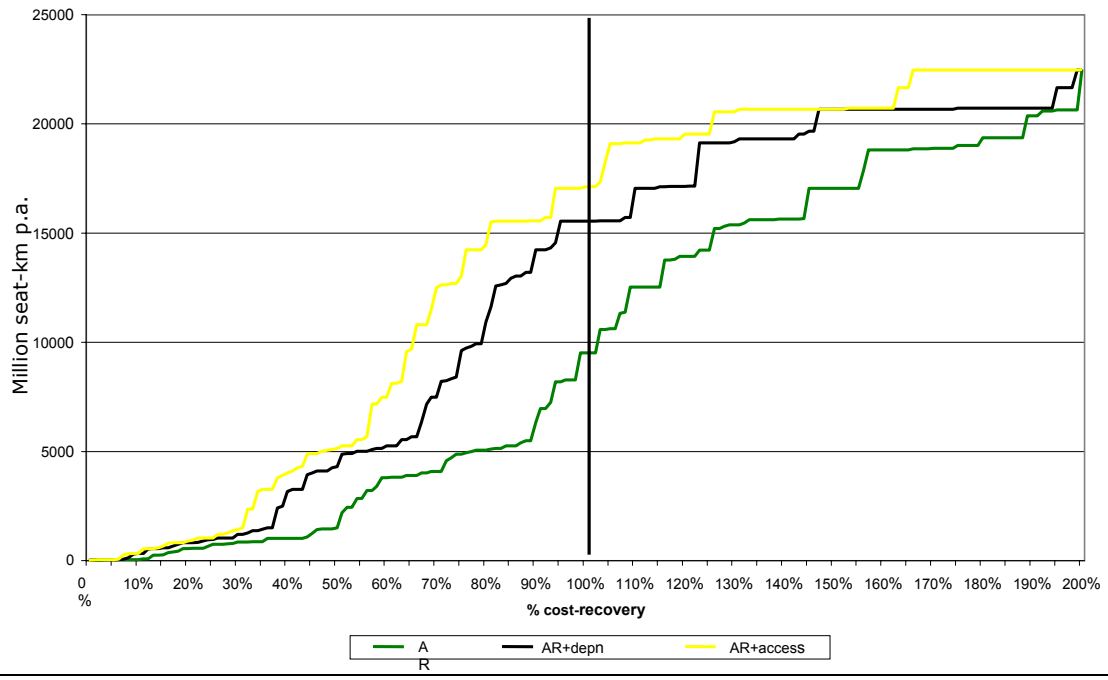


Figure 2-5. Cost-recovery across entire system



The green line shows the cumulative seat-km whose revenue achieves a given level of cost recovery compared to above-rail working expenses. Overall, this system covers 127 percent of its above-rail working expenses, but around 10 billion seat-km (approximately 25 percent of the total) achieve a cost recovery level of 100 percent or less. Conversely, about 5 billion seat-km achieve a cost recovery of above about 150 percent.

The black line shows the corresponding distribution when above-rail depreciation is included. The system only recovers 94 percent of these costs with 15 billion seat-km are achieve less than 100 percent cost recovery and no more than 2 billion are achieving 150 percent. Thus around 30 percent of seat-km are covering their above-rail costs (including depreciation), and are thus able (in principle at least) to fund rollingstock renewal as it falls due

Finally, the yellow line shows the corresponding distribution when infrastructure maintenance costs are also included. Overall cost recovery is now down to 80 percent and about 17 billion seat-km (75 percent of the total) are failing to cover this level of cost. On this system, the services are contributing nothing to infrastructure costs once they have covered their above-rail costs. This is discussed further in Section 4.5.

2.5 Summary

The financial performance of non-urban passenger services varies greatly, both between and within railways. This is for a wide variety of reasons: economic, technical, organizational and regulatory. This paper now turns to a demonstration of the impact of some of the key reasons (Sections 3 and 4).

3 COST STRUCTURE AND INPUT COSTS

3.1 Introduction

No railway to our knowledge automatically records the cost of individual train services through its general ledger system. However, most railways record (to a greater or lesser degree of detail) of each of the main technical functions from which train services are 'produced'. All use a fundamentally similar approach to deriving the cost of the passenger sector and of individual services. This approach is the basis for the generalized cost model for non-urban passenger services presented in this section.

In order to calculate the cost of any train service, or group of services, the resources identified in the model as the cost drivers need to be estimated and then valued using a corresponding set of unit costs. Two sets of these unit costs, corresponding to different technical and economic environments, are presented in this section, as well as five typical service types whose cost characteristics are then examined in more detail in Section 4.

3.2 Cost Structure

The reason for estimating specific service costs is to make decisions about those services. It is therefore important to use a cost structure which is related to the decisions which are to be made. At the tactical level these centre on the consequences of modifying the service characteristics (e.g. train consist[11] and commercial speed); the costing structure adopted should therefore be sensitive to these parameters. At the more strategic level, decisions are concerned with whether services should be expanded, contracted or withdrawn (or occasionally, whether sections of the network should be shut).

In all cases where contraction may be an option, the relevant costs are the avoidable costs, i.e. the costs that would be avoided if a course of action is adopted[12]. At the individual train service level, avoidable costs are often relatively small: if the train from A to B is cancelled but that from B to A remains, the avoidable cost is very small as the train-set generally still has to travel from A to B in order to operate the return service. If a train-set makes several return trips during a day, removing a pair of out-and-return services will save some of the operating costs but is unlikely to save any rollingstock capital costs unless the set can be redeployed elsewhere; and it may not even save any crew costs unless rosters are reworked. Therefore, in practical management accounting, the approach to cost allocation depends on the scale of the change under consideration and the timescale over which it is being calculated (this is discussed in more detail below). The costs presented in this Paper reflect the savings that would be made over the medium-term, in railway terms about two to three years, during which time operating staff have been redeployed and depots and workshops have adjusted their manning and procedures to reflect the change in workload; they also assume that the services can be costed on a stand-alone basis and that there are no inter-dependencies with other services (such as shared rollingstock or traincrew) which would reduce service cost variability.

Table 3-1 shows a functional classification of input costs that is in general use in railways. It provides sufficient detail for detailed passenger service costing. The majority of the costs have been categorized in two ways:

- in terms of whether they are directly variable with the volume of train operations or are fixed (at least until changes are made overall organizational scale or capacity);
- in terms of whether they are associated with train operations (sometimes called 'above-rail' costs) or whether they are associated with infrastructure maintenance and operations (sometimes called 'below-rail' costs).

[11] The make-up of the train - e.g. how many and what type of carriages
[12] The converse, for service expansion, is to use incremental costs

Table 3-1. Functional Cost Categories and Basis of Allocation to Services

Input Cost category	Basis of allocation
Variable costs	
Above-rail	
Fuel and energy	Gross tonne-km
Train crew (driver and assistant)	Train-hours
On-train crew (conductors, attendants)	Crew-hours (or weighted train-hours)
Passenger handling and station operations(1)	Passenger
Catering	Passenger-km
Rollingstock maintenance and servicing	Vehicle-km (with vehicle-hour component)
Rollingstock renewal capital	Vehicle-hour
Train planning	Train-km
Below-rail	
Traffic-related track maintenance	Gross tonne-km
Infrastructure renewal capital (traffic-related)	Gross tonne-km
Fixed costs	
Below-rail	
Traffic-unrelated track maintenance	Gross tonne-km
Structures maintenance	Gross tonne-km
Overhead line equipment maintenance	Gross tonne-km (electric-hauled)
Signals and communications maintenance	Train-km
Signaling operations, train despatching and control	Train-km
Infrastructure renewal capital (time-related)	Gross tonne-km
Administrative overheads	Percent mark-up
Non-renewable infrastructure capital	Omitted

(1) Includes ticket sales and customer service

Each of the input costs includes an administrative component (depot managers, crew supervisors etc). In addition there is generally a central administration function covering such areas as finance, personnel, legal and corporate management. Finally, many railways have capital charges associated with the initial construction of facilities which are unlikely to be renewed in the foreseeable future; these costs have been included for completeness but are independent of either current or future traffic volumes.[13]

[13] There are some activities not specifically identified which are distributed throughout the railway. For example, responsibility is normally distributed amongst rollingstock engineers, infrastructure management and the operating staff (included in 'signaling operations' in Table 3-1). Many railways nowadays also have a central safety manager, responsible for setting standards and monitoring the processes and performance of individual groups. The costs of these staff, which are generally quite small, are included in administrative overheads

The functional areas included under the heading 'variable' are largely the 'above rail' operating costs. Although in the very short term most of these costs (other than fuel) are fixed, all of these costs can be avoided in the medium term.[14]

However, the speed with which individual cost areas respond to changes in the level of activity naturally depends on management's ability to modify resource supply, which is as much a function of institutional arrangements as technical factors. Thus the cost of train crews, who can be redeployed to alternative services, generally responds faster than rollingstock maintenance costs, which have a substantial workshop component for overhauls which are only carried out at intervals of four years or more.

A large part of the costs of routine infrastructure maintenance are independent of the level of traffic and can be considered fixed, until traffic levels change drastically, or additions or subtractions are made to the network. Relative scale is always an important factor when considering the 'fixity' of any cost as the addition of a new traffic of sufficient volume requires additional infrastructure with its associated costs. Similarly, removing all traffic on a particular line, even if it is a comparatively small volume, would make all costs on that line avoidable if it were to facilitate closure.

The third group of costs are administration-related.[15] They are fixed in the sense that they are largely insensitive to the removal or addition of an individual train service but are more related to the overall scale of the railway. Even then, they generally react only sluggishly. A typical pattern is for these costs to remain more or less fixed (or slowly but steadily increasing) for several years punctuated by periodic 'restructurings' during which a chunk of the overhead is taken out. As long as operations continue at around an existing general level of activity, central administrative costs can generally be treated as independent of traffic volume, although there would be the ability to make a step reduction if passenger services more dramatically curtailed or withdrawn.

The treatment of capital costs also depends on the decisions to be made. The cost of operating an on-going service should include an allowance for renewable capital items such as rollingstock and track excluding only the non-renewable component of infrastructure capital costs.[16] However, an accounting income statement would include depreciation and interest charges for all assets, usually based on historical costs (and often of doubtful use). In general, for management accounting purposes, the avoidable capital cost is based on either the replacement cost of the asset, for an on-going service, or is zero where the service is unlikely to be replaced when the rollingstock becomes obsolete.

3.3 Operating Costs

There are significant variations between the costs recorded by different railway organizations in performing what are essentially the same tasks. Important factors in explaining this variation are the relative level of input costs (primarily wages and fuel) and the managerial efficiency of the enterprise.

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[14] Short-, medium- and long- term can be elusive concepts which mean different things to different people. In this paper, the long-run/long-term means that period of time during which both operations and capacity have adjusted to changes in demand, be it an increase or decrease. A long-run cost thus includes the capital cost or saving from the marginal change in capacity. Short-term, on the other hand, means the period of time before any such adjustments have been made; during this period, cost savings will generally only be those costs which are consumable (such as fuel) or the subject of short-term contracts. In railways, increases in infrastructure are often slow to eventuate and it is convenient to consider a third concept, the medium-term, during which adjustments have been made to operational capacity (crew, maintenance, and rollingstock capacity) but changes in the capacity of the infrastructure have not yet taken place. From a practical point of view, the short term for a railway is probably up to 18 months, while the long-term is rarely less than five years.

[15] These administration costs do not include **all** costs incurred at Divisions and HQ. The administrative costs of branches such as Engineering and Electrical are treated as overheads to the relevant direct costs, leaving only the accounting and general administration branches such as General Management and Finance.

[16] This assumes that the rollingstock can be redeployed elsewhere and that the renewable component of the infrastructure can be salvaged and re-used. The costs of the initial construction of the line, such as earthworks and some structures and buildings, are unlikely to be recovered and the associated capital charges generally continue to be incurred indefinitely until they are written off.

Operational efficiency affects the level of unit costs in two ways:

- Railways with poor management (or management heavily influenced by political constraint on employment policies) tend to be overmanned and have poor asset utilization because funds are used to pay excess staff rather than maintain and renew operating assets.
- Because such railways do not renew assets in a timely manner (or purchase assets that are unsuited to the task at hand) the equipment used is not technically efficient. Examples of such decisions include reluctance to purchase multiple-units for low and medium-volume services instead persisting with loco-hauled trains; or the purchase of higher-speed trains for routes where the track is not of the required standard to allow them to operate efficiently.

Input costs also vary with the quality of service being provided. For example, vehicles for main-line premium services will generally have a higher standard of interior fittings and maintenance than those used on the cheapest branch-line services; cheaper unit costs in the latter case therefore do not necessarily reflect greater efficiency.

Treatment of major periodic maintenance, both for rollingstock and infrastructure, can cause distortions. More financially robust railways such as in China and India routinely carry out such work and include the costs as part of operating expenses. However, many smaller railways with low traffic densities can often only do such work when they receive specific funds through loans and grants; in these cases, the work is almost always capitalized. Periodic maintenance can represent 50 percent or more of the long-run maintenance cost and its capitalization significantly deflates unit operating costs. The converse arises when rollingstock items, particularly locomotives, continue to be operated much longer than their normal lives as the railway does not want to (or cannot) purchase replacements; the life-expired locomotives can require extensive routine maintenance to keep them operating, leading to comparatively high unit operating costs.

The variations in ticket selling and terminal costs are partly a function of fare/ticketing systems and facilities (some railways have very basic passenger facilities or provide a low level of service for ticket-selling, with long queues) and partly a function of management. Some railways have out-sourced ticket sales on a commission basis (and others have set up special internal cost centres which effectively 'in-source' this activity); in such cases commissions generally range from 2–3 percent (for season tickets) to 7–10 percent for single-trip tickets.

Train control (signaling) and train-working costs are often difficult to establish with precision because station staff involved in this activity in many railways are generally carrying out multiple functions; these costs are also heavily influenced by policy decisions on station manning.

Even when a common methodology is adopted, infrastructure costs reflect different infrastructure standards on the different railways. The absolute cost of infrastructure maintenance increases as volume increases not only because of the costs associated with the incremental volume, but also because of the higher standards required to provide the required capacity. Higher traffic volumes also restrict the time available each day for access to the track, thus increasing the unit cost of maintenance activities.

The two sets of unit costs presented in Table 3-2 assume the same quality of output. They separately identify above-rail operating costs (rollingstock maintenance and operation, train crew, fuel and on-train and station services) and below-rail costs (infrastructure maintenance and operation), whether the latter are incurred by the train operator directly or by a track authority which then levies access charges. They represent indicative costs for two types of railway:

- A middle-income country (with railway labor costs of 3,500/employee p.a.) which has reasonably high labor productivity (say 750,000 traffic units/employee)
- A low-income country (with railway labor costs of $1,000/employee p.a.) which has low productivity (say 200,000 traffic units/employee).

Table 3-2. Unit operating costs by level of efficiency ($/unit cited)

Item	Variable with	High	Low
Diesel locomotive maintenance	Diesel loco-km	1.00	2.00
Electric loco. maintenance	Electric loco km	0.60	1.20
Carriage maintenance/cleaning	Carriage-km	0.10	0.20
Electric multiple-unit	Carriage-km	0.25	0.45
Diesel multiple-unit	Carriage-km	0.35	0.55
Train driving crew	Train-hrs	9.00	5.00
On-train crew(1)	Carriage-hrs	1.00	0.50
Diesel fuel – loco-hauled	000 diesel gtkm(2)	2.50	3.50
Diesel fuel – diesel multiple units	000 diesel gtkm	3.00	4.00
Electricity – loco-hauled	000 electric gtkm(3)	1.60	2.25
Electricity – Elec. multiple units	000 electric gtkm	1.90	2.55
Ticket selling/terminal	Passenger revenue	3%	9%
Corporate administration	Working expenses	9%	20%
Equivalent access charges			
Signal and trainworking	Train-km	0.20	0.60
S&C maintenance	Train-km	0.40	0.70
Electric OHLE	000 electric gtkm	0.50	0.90
Track and bridge (fixed)	000 gtkm	1.20	3.00
Track (variable)	000 gtkm	0.30	0.75

(1) Can vary widely between systems – includes guard/conductor/security only
(2) thousands of gross tonne-km of diesel loco-hauled trains
(3) thousands of gross tonne-km of electric loco -hauled trains

Both sets of costs assume the same level of fuel costs of $0.50/litre and electricity cost of $0.10 per kWh. The access charges have been developed for a main line carrying 5 million gross tonnes and 10,000 trains p.a. (see Section 4.5 for a fuller discussion of the impact of traffic density on these costs).

3.4 Capital Costs

The capital cost of rollingstock and infrastructure is reasonably consistent across all railways. Rollingstock manufactured in Europe is usually more expensive on a vehicle-for-vehicle basis but generally has more features and ancillary equipment e.g. air conditioning, more sophisticated toilets, centrally-operated doors etc. Given the purchase price and life of an asset, this can be converted into an equivalent annual cost, using an assumed real interest rate (Table 3-3). The capital cost per unit of use then depends on the asset utilization (Table 3-4); higher utilization, whether from the type of service being offered (e.g. long-distance overnight services or daytime medium-distance shuttle services) or from the efficiency of timetabling and operation, generates lower per unit capital costs.

The annualized capital cost of each asset class has been separated into two components:

- ‘Depreciation’ which represents the annualised cost of the purchase price over the life of the asset. This represents the amount a railway would have to invest each year if it were replacing its assets at a uniform rate and is thus similar to the accounting concept of current prices depreciation.

Table 3-3. Annualized capital costs

	Cost ($000)	Life Years	Annual cost ($000) Deprec(1)	ROI/Int(2)	Total
Locos	2000	25	80	92	172
Carriages	800	40	20	40	60
DMU	900	30	30	43	73
EMU	1000	40	25	50	75
Mainline track	400	40	10	20	30
Branchline track	100	40	2.5	5	7.5
High-speed upgrade	600	40	15	30	45

(1) Does not include any allowance for scrap value
(2) Based on 4 percent real interest rate

Table 3-4. Unit capital costs

	Unit of utilization	Cost ($000)	High-efficiency Utilization p.a.	Unit cost ($) Depr	ROI	Low-efficiency Utilization p.a.	Unit cost ($) Depr	ROI
Locos	Loco-hr	172	4500	18.00	20.00	2850	28.00	32.00
Carriages	Vehicle-hr	60	5000	4.00	8.00	2500	8.00	16.00
DMU	Hour	73	4000	7.50	10.75	2500	12.00	17.20
EMU	Hour	75	4000	6.25	12.50	2500	10.00	20.00
ML track	000 gtkm	30	10000	1.00	2.00	5000	2.00	4.00
BL track	000 gtkm	7.5	2500	1.00	2.00	5000	2.00	4.00
HS upgrade	000 gtkm	45	10000	1.50	3.00	5000	3.00	6.00

- 'ROI/interest' which represents the interest which would have to be paid on debt-funded investment or, equivalently, the dividend required if the investment is not debt-funded. It depends on the interest rate/target dividend rate, which has been taken as 4 percent real for the purposes of this paper.

Both sets of costs assume common fuel costs of $0.50/litre and electricity cost of $0.10/kWh.

The capital costs for track represents the cost per track-km of replacement of the superstructure when it is life-expired. They do not include the cost of initial construction of the formation or major reconstruction to a higher standard, with the exception of the 'HS upgrade' cost for increasing the nominal speed to 160 km/h.[17]

Although the capital cost of track has been expressed here as a cost per thousand gross tonne-km, in practice it is also a function of traffic density. The life of main-line track is principally a function of traffic volume, as measured by gross tonne-km, but is also subject to a maximum life of probably not more than 50 years (and rather less for wooden sleepers). For typical main-line track (54 kg/m or 60 kg/m rail on concrete sleepers) the life of rail was historically taken to be about 600 million gross tonnes of utilization for non-curved sections, but this can be extended by about 50 percent if rail grinding is done on a regular basis. These calculations are academic for moderate or lightly-used lines, for which track renewal is generally determined by sleeper life

[17] This figure will vary widely depending on terrain and the specific circumstances of each railway.

and technical obsolescence, and for which much of the material used is anyway often cascaded from main-lines.

3.5 Services Selected For Analysis

Railways operate a very large variety of non-urban passenger services, from the high-speed services of Japan, Korea, Europe and (very soon) China, through comparatively slow long-distance services to short-distance branch-line services in Eastern Europe. From this wide range of alternatives, five typical services have been developed which illustrate some of the main types. They are defined in terms of the following parameters:

- **Distance:** for non-urban services this can vary from around 100 km for inter-urban services to over 1,000 km (and more) for long-distance sleeper services. Trips of over 2,000 km are common in both Russia and China. Branch-line services typically range from 20 km to 150 km
- **Travel speed:** most loco-hauled services outside Western Europe travel at an average 'commercial speed' (i.e. including an allowance for en-route stops) of around 50–60 km/h. On certain main-line routes, faster speeds averaging up to 100 km/h are operated. On branch-lines, and on many main-lines in Africa, speeds are generally much lower, ranging from 20-40 km/h. Higher-speed services are gradually being introduced on some railways, generally aiming at commercial speeds of about 160 km/h unless new infrastructure is being purpose-built for very fast operation.
- **Train size:** where demand is heavy, passenger trains can be large, with up to 20 carriages relatively common in China, India, Russia and Pakistan. Such trains generally include dining facilities and sleeping cars in the train consist. Medium-distance day trains are more normally 10-12 cars of sitting accommodation. Interurban services are generally 4–8 cars. Branch-line services vary widely but are often no more than 2–3 cars.
- **Traction type:** the larger trains are generally locomotive-hauled but interurban services and branch-line trains are increasingly being operated by multiple units. Where main-lines are electrified, passenger services are also operated with electric traction, whether loco-hauled or multiple-unit.
- **Seating capacity:** capacity varies between types of coach, from around 20 for upper-class sleeping cars to 100 for economy sitting cars. In addition, on the longer trains, up to 3 or 4 cars are for non-passenger uses e.g. brake van, dining car, power van and parcels vans.
- **Passenger occupancy:** average occupancy varies widely between railways. On many railways, premium trains are planned to have an average occupancy of around 60–65 percent, while economy trains are planned on the basis of 80–90 percent (this average level is guaranteed to create peak capacity shortfalls/overcrowding on a regular basis).

Table 3-5 defines the five indicative services in terms of the above parameters:

- Service 1 (LD): long-distance overnight train, with 18 carriages, probably operating daily (or at most twice daily)
- Service 2 (IC): medium-distance intercity service, with 10 carriages, probably operating 2-3 times daily
- Service 3 (BL): branch-line train, with 4 carriages, probably operating about four or five times daily
- Service 4 (MU): medium-distance intercity train, operated by multiple-unit on an interval timetable giving around 8–10 services daily
- Service 5 (HSIC): higher-speed (160 km/h maximum-speed) intercity train, operated by multiple-unit on interval basis, giving around 6 services per day

Table 3-5. Definition of services

Service	1	2	3	4	5
Abbreviation	LD	IC	BL	MU	HSIC
Distance	1000	200	50	100	200
Commercial speed	60	60	40	80	140
Loco	1	1	1		
Carriages/train	18	10	4		
Multiple-unit vehicles				6	8
Passenger capacity	1280	750	320	480	520
Average occupancy (percent)					
High-efficiency	90	75	60	75	75
Low-efficiency	65	50	40	50	50
Traction type	E	D	D	E	E
Average revenue yield (c/pkm)					
High-efficiency	1.2	1.0	0.8	1.2	1.6
Low-efficiency	0.9	0.8	0.5	1.0	1.3

Table 3-5 includes an indicative yield (revenue per passenger-km). As was shown in Section 2, yields vary greatly both within and between railways. 'Premium' or 'business' services generally have yields two or three times those of 'lower-class' or 'economy' services and in some countries where 'economy' fares are regulated, railways have responded by restricting their capacity whilst introducing the higher-yielding 'business' services. While the level of 'economy' tariffs are also generally linked to income levels, so is the standard of accommodation (and associated maintenance cost). An 'economy' service in much of sub-Saharan Africa will often have limited, if any, lighting or other amenities; an 'economy' service in eastern Europe has padded seats, heating and lighting

4 SERVICE COSTS

4.1 Introduction

This section combines the unit costs of Tables 3-2 and 3-4 with the service parameters set out in Table 3-5 to produce output costs for the alternative input cost and services. Section 4.2 discusses the cost structure of the different services. Section 4.3 then shows how the costs of Scenario 2 vary with the service parameters.

4.2 Service Costs

Table 4-1 gives summary costs for the five services under each set of unit costs.[18]

Table 4-1. Cost-recovery by service

Service (see Table 3-5)	LD		IC		BL		MU		HSIC
Efficiency	High	Low	High	Low	High	Low	High	Low	High
Cumulative cost ($/car-km)									
Above-rail working	0.27	0.30	0.41	0.46	0.85	0.95	0.36	0.48	0.40
Variable infrastructure	0.29	0.37	0.44	0.56	0.92	1.15	0.41	0.61	0.44
Above-rail depreciation	0.38	0.54	0.55	0.76	1.22	1.67	0.50	0.76	0.51
Fixed infrastructure	0.49	0.77	0.65	0.98	1.39	2.03	0.63	1.01	0.63
Below-rail depreciation	0.54	0.87	0.70	1.08	1.45	2.15	0.66	1.08	0.68
Above-rail ROI	0.70	1.19	0.89	1.45	1.90	2.99	0.86	1.39	0.82
Below-rail ROI	0.80	1.39	0.99	1.65	2.02	3.23	0.93	1.53	1.05
Revenue/car-km ($)	0.77	0.42	0.56	0.30	0.38	0.16	0.72	0.40	0.78
Revenue/pass-km ($)	1.20	0.90	1.00	0.80	0.80	0.50	1.20	1.00	1.60
Cost recovery									
Above-rail working	288%	140%	138%	65%	45%	17%	199%	83%	195%
Variable infrastructure	262%	113%	127%	54%	42%	14%	178%	66%	178%
Above-rail depreciation	202%	77%	102%	39%	32%	10%	143%	53%	153%
Fixed infrastructure	157%	54%	86%	31%	28%	8%	115%	39%	123%
Below-rail depreciation	142%	48%	80%	28%	27%	7%	109%	37%	115%
Above-rail ROI	110%	35%	63%	21%	20%	5%	84%	29%	95%
Below-rail ROI	96%	30%	57%	18%	19%	5%	78%	26%	74%

For ease of comparison, the grey-shaded rows are the costs presented in the Chapter 2 analysis (e.g. Figures 2-2 and 2-3)

Full cost-recovery (covering both above and below--rail working expenses and asset capital charges) is almost achieved by long-distance (LD) and the intercity multiple-unit services (MU and HSIC) under the high-efficiency case. However, these results critically depend on the high load-factors and fares assumed in the service specifications; if yields per seat-km are lower, either by regulation or by market forces (because the level of service is too poor to attract premium-paying customers or because of very low ability to pay) then operators will often fail to cover their above-rail operating costs only; the services contribute nothing to infrastructure costs nor can they make any contribution towards renewing their rollingstock.

[18] Adjustments were made to the base costs to allow for the impact of the increased operating speed of Service 5 on track maintenance, fuel and rollingstock capital costs, as well as adjusting specific fuel consumption for the different train sizes. The HSIC service was not costed for the low-efficiency case.

Conventional medium-distance services (IC), and even more branch-line services (BL), have particular problems. Even for a high-efficiency railway, yields only just cover above-rail working expenses and rollingstock renewal for the IC services and thus contribute nothing to infrastructure.

The multiple-unit services (MU) perform better than loco-hauled for the medium-distance services, helped by a 10 percent reduction in operating costs and a premium on the fare due to the higher speed and, hopefully, a higher level of passenger amenity.

Finally, even though the high-speed (160 km/h) services (HS) have higher unit operating costs (possibly up to 20 percent higher) compared to conventional MU services, they have the potential to perform even better as long as their increased operating speed is reflected in the fares charged and they are operating in a market which can afford them.

Only the long-distance (LD) and multiple-unit (MU and HSIC) services contribute significantly to infrastructure costs. Well-loaded long-distance trains can cover about 80 percent of fixed maintenance costs (and rather better on the better-performing railway systems) but cannot cover full costs except in a few isolated instances. Higher-speed services can probably even make some contribution to the capital cost of the infrastructure upgrades required for their services to operate. In all these cases yield/passenger and occupancy/carriage are critical in determining cost recovery. Costs per carriage-km for main-line services generally only vary over a relatively limited range –say +/- 30 percent (see Sections 4.3 and 4.4), capital costs are the same for most railway systems which purchase on the international market and are only affected by utilization; fuel costs are similar in most railways and differences in wage rates are at least partially balanced by off-setting variations in labor productivity. However, variations in revenue per carriage-km, which is the product of revenue per passenger-km and passenger occupancy, are generally much greater (as shown in Figure 2-4) and reflect the competitive environment, the level of service, the degree of management attention to train yields, and the degree of regulation.

4.3 Sensitivity of Cost to Key Parameters

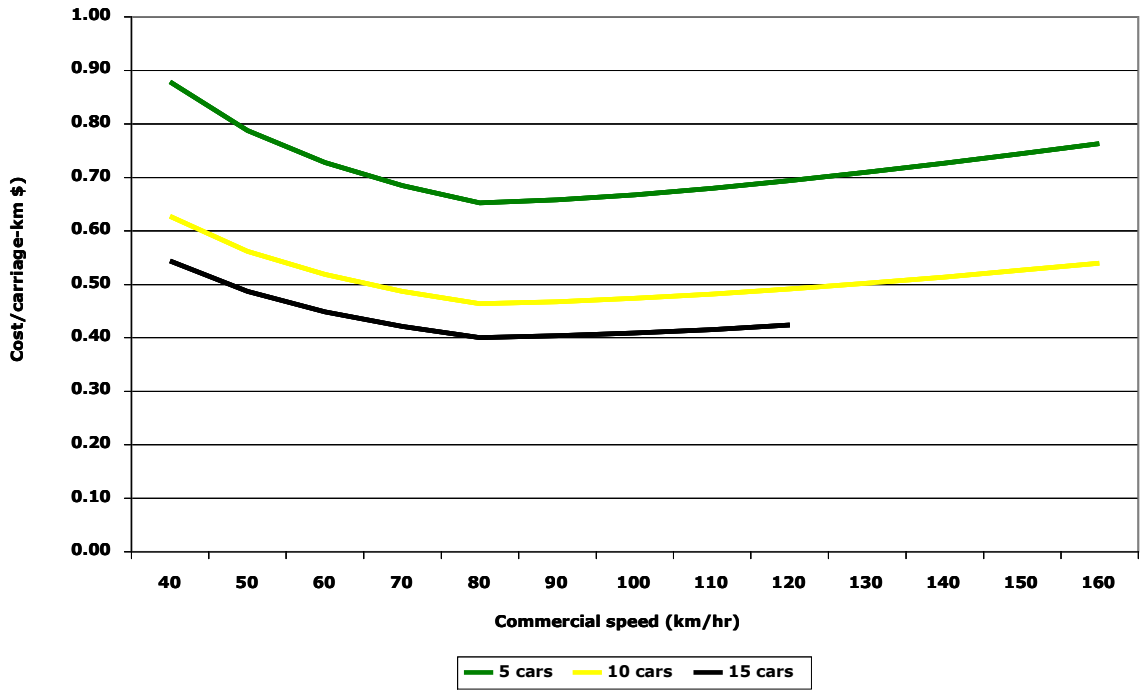
This section discusses the sensitivity of cost to changes in key scenario assumptions. Figure 4-1 shows the impact on above-rail operating cost (above-rail working expenses plus above-rail depreciation) of variations in commercial speed and train size for a diesel loco-hauled train over a distance of 400 km.

Operating costs are probably at a minimum when operating speed is around 80 km/h. Above that speed, above-rail unit costs gradually increase as continuing reductions in time-related costs, principally rollingstock capital cost, are progressively offset by increased fuel consumption and equipment maintenance. Infrastructure maintenance costs (not included in Figure 4-1) also increase significantly with speed because of the need for higher-quality track. Low commercial speeds,[19] whether due to track condition or to lack of line capacity, also exert a significant cost penalty as unit costs related to elapsed time escalate and are up to 30 percent higher compared to the minimum at around 80 km/h.

Train size also has a significant impact on unit operating costs, particularly if the train is loco-hauled. Where there is no alternative use for a locomotive, as is the case with some branch-line services, the penalty is not so significant but where locomotives are used to haul trains well below their capacity, unit costs increase and a 5-car train costs about 30 percent more per seat-km than a 15-car train at the same commercial speed, assuming the 15-car train is still within the capacity of a single locomotive.[20]

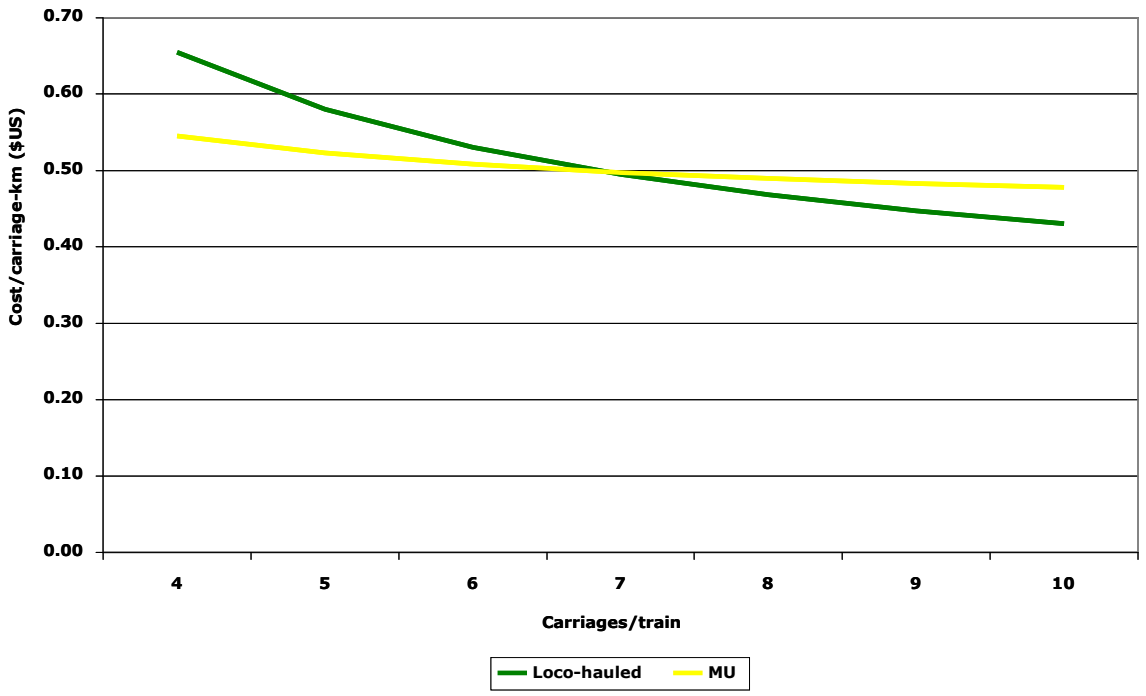
[19] Commercial speeds include en-route stops and are thus slower than operating speed but for most passenger services the difference is generally less than 10 percent.
[20] The 15 car train only goes to 120 km/h for that reason

Figure 4-1. Above-rail operating cost of loco-hauled trains per carriage-km as a function of cars/train and commercial speed



Multiple-unit trains provide a competitive alternative although this naturally diminishes as train size increases (Figure 4-2).

Figure 4-2. Above-rail operating cost per carriage-km – loco-hauled and multiple units



This is especially true for small trains (4 cars), for which almost as much cost is typically incurred moving the locomotive as moving the carriages. As train size increases, the locomotive-related costs can be spread over a greater number of carriages but, even so, multiple units are likely to remain competitive with loco-hauled trains under most circumstances except for major long-distance services. However, these results are indicative only; any comparison in real-life would also need to take into account the specific operational circumstances; in many cases the much faster turnrounds possible with multiple-units can allow much significantly more utilization compared to locomotive haulage on a service-for-service basis.

Although it is not modeled in detail in this paper, electric traction is generally cheaper than diesel as long as demand is sufficiently large to enable the additional fixed costs associated with electricity supply to be balanced by the volume-related train benefits of (generally) cheaper power and maintenance cost.

4.4 Comparison with Actual Costs

Tables 4-1 and 4-2 compare costs taken from actual railways with the costs generated by the cost model used in this paper. They include five of the railways analyzed in Figures 2-1 and 2-2 as well as an additional very low-density railway (Railway K). Three of these (Railways C, D and K) can be taken as 'low-efficiency' railways, not necessarily because of poor management efficiency and over-manning, although that is a factor in two of them, but principally because of the limited initial investment and resulting low technical standards. The costs in the table have been calculated on a consistent basis and represent the above-rail working expenses i.e. the cost of running and maintaining the train, of passenger handling at stations and the commercial aspects of the passenger railway business (ticket-selling, marketing and general management). As only one of these examples manages to cover even these costs, no analysis has been included covering rollingstock capital costs.

The actual costs per car-km vary significantly from those given in Table 4-1. Part of this variation can be traced to significant variations from both the service specifications assumed in Table 3-5, with the remainder due to differences between the assumed unit costs and those arising in practice (see Table A-1).

Table 4-2. Summary costs and revenues for passenger rail services

	Predominant type of service	Pass /train	Cars/ train	Speed[1] (km/h)	Cost ($)[2]		Revenue ($)	
					Veh-km ($)	Pass-km (c)	Veh-km ($)	Pass-km (c)
A	Long-distance	1040	14	46	0.32	0.42	0.41	0.55
C	Long-distance	490	16	35	0.56	1.83	0.60	1.96
D	Medium-distance	290	11	26	0.63	2.45	0.33	1.28
E	Long-distance	625	8	46	0.30	0.38	0.35	0.45
I	Medium-distance	175	9	50	0.44	2.26	0.31	1.59
K	Branch-line	340	8	13	0.88	2.05	0.40	0.93

(1) Commercial speed i.e. including en route stops
(2) Above-rail working expenses, excludes rollingstock capital costs

The differences from the model operating assumptions (commercial speed, traction type and size of train) are best illustrated by comparing the cost per carriage-km. The impact of the major variations around the model demand assumptions that arise in practice are then demonstrated by converting the cost per carriage-km to the equivalent cost per passenger-km.

Table 4-3. Comparison of modelled and actual above-rail working costs

	Cost/ carriage –km (US c)						Occupancy		Cost/pass-km	
	Base[1] Model	Adjusted model			Actual					
		Train size	Traction	Speed	Cost	% model	Model	Actual	Model[2]	Actual
A	0.27	0.28	0.36	0.39	0.32	82	60	74	0.65	0.42
C	0.30	0.31	0.38	0.45	0.56	124	46	31	0.98	1.83
D	0.46	0.44	-	0.59	0.63	107	38	26	1.55	2.45
E	0.27	0.34	0.45	0.49	0.30	61	60	78	0.82	0.38
I	0.41	0.43	-	0.45	0.44	98	56	19	0.80	2.26
K	0.95	0.63	-	1.04	0.88	85	32	43	3.25	2.05

(1) As given in Table 4-1
(2) Model cost after adjustment for size, traction type and speed

Table 4-3 shows a reasonable correspondence between the modelled and actual costs *per carriage-km*, ranging from 61 percent to 124 percent, with the residual difference being due to differences between the actual unit costs of individual railways and those adopted for the model. Some of these apparent differences are due not only to different levels of input costs (e.g. railway A is not only a reasonably efficient railway but also has by far the lowest wages cost) but also due to the coverage of working expenses; railway E, for example, funds a large proportion of its periodic overhauls of rollingstock through capital grants and if these were expensed (as most railways do) it would increase its costs per carriage-km by about 20–30 percent.

Table 4-3 also demonstrates the critical impact of occupancy on the derived cost *per passenger-km*. Unlike freight (for which extra traffic requires extra wagons, extra trains and extra cost), for passengers the costs of a train service for which the consist has been determined, is almost totally independent of the number of passengers using it. Railway management should of course attempt to match the size of trains to the demand offering; this is more easily done on the longer-distance loco-hauled trains, to which extra carriages can often be relatively easily added and removed. However, fluctuations in traffic by day of week (or by time of day) mean that there is usually much unused capacity even in very efficient operations. Conversely, occupancy rates over 70–80 percent will almost always create shortages of capacity on a regular basis. Yield management from fixed consist trains is therefore one of the major ways of improving financial performance, but is often constrained by fare regulatory policies.

4.5 Contribution to Infrastructure Costs

The estimation of what proportion of infrastructure-related costs should be attributed to passenger services, where both passenger and freight services use the same line, has been a problem for railway management for nearly two centuries.[21] What is universally agreed by all railway economists is that the share allocated to passenger (or any other) services should be at least the incremental cost imposed by these services but should not be any more than the cost of creating an equivalent stand-alone facility.

Converting these simple principles into a practical rule has never been easy. Even agreement on definitions of incremental/avoidable cost is far from universal Annex C gives a summary of what is generally known about track costs) and there is a significant difference between the avoidable cost of an additional passenger train, which is just the marginal track maintenance and renewal and the incremental signaling cost, and the cost imposed by the higher standards of ride quality and signaling generally required for passenger service operation in general.[22]

Even if these 'floor' and 'ceiling' costs can be derived, they often are of limited practical value, as they may range from, say, 10 percent to 80 percent of infrastructure costs (Figure 4-3), providing plenty of scope for creative allocations in countries with track access regimes.

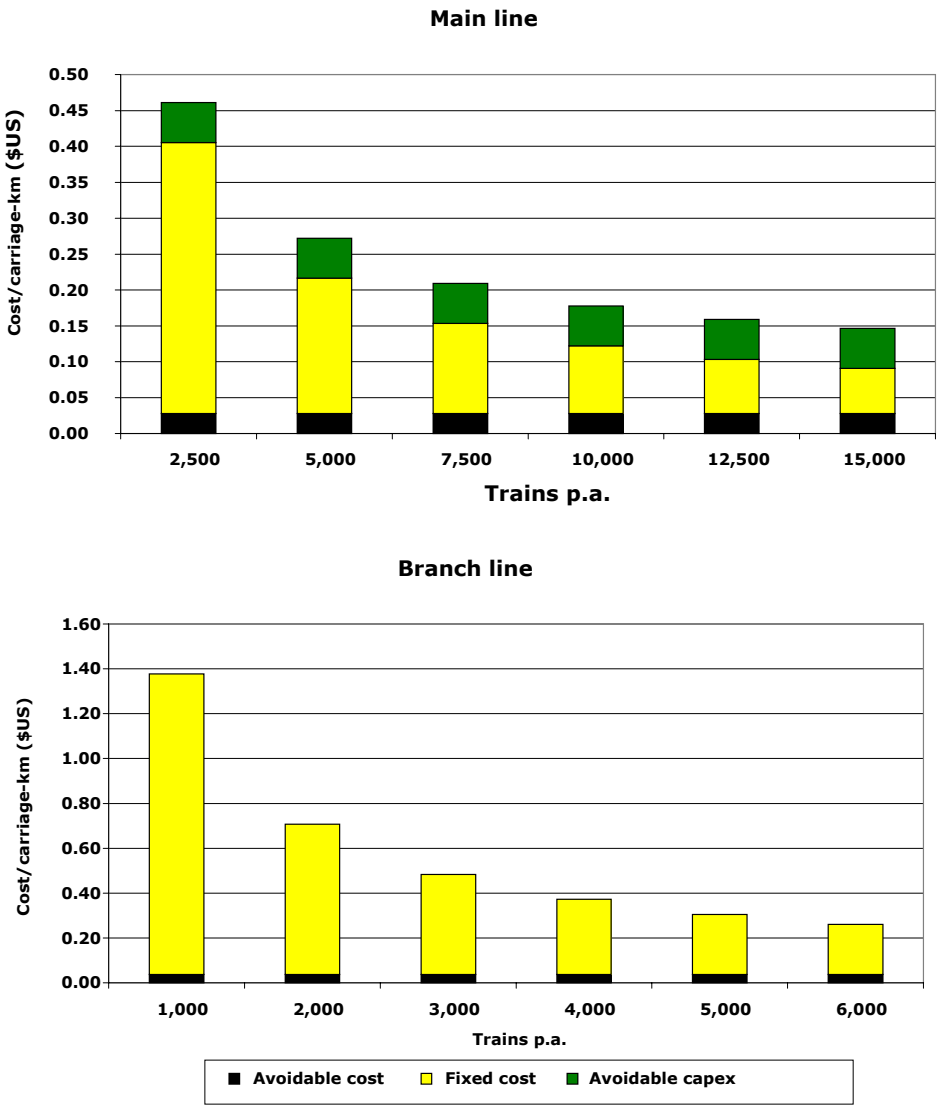
[21] A summary of the main methods adopted is in Annex B.
[22] Where passenger services are operated, it is common for them to dominate in terms of train-km (which broadly determines the capital and operating cost of signaling) but to be a much smaller proportion of tonne-km (which broadly determines the cost of track).

Figure 4-3 gives the infrastructure cost (excluding ROI) per carriage-km, which has been derived assuming:

- For main-lines (assumed to be single-line), a 50:50 mix of passenger trains of 500 gross[23] tonnes (9 carriages) and freight trains of 1,500 gross tonnes.
- For branch-lines, a 75:25 mix of passenger trains of 250 gross tonnes (4 carriages) and freight trains of 300 gross tonnes

The capital cost included only covers the depreciation element of track renewal. Given the relatively low proportion of maintenance cost that is avoidable, traffic density and the consequent allocation of fixed costs, thus plays the dominant role in determining the total cost per train-km.

Figure 4-3. Infrastructure cost per passenger train-km (excluding ROI)



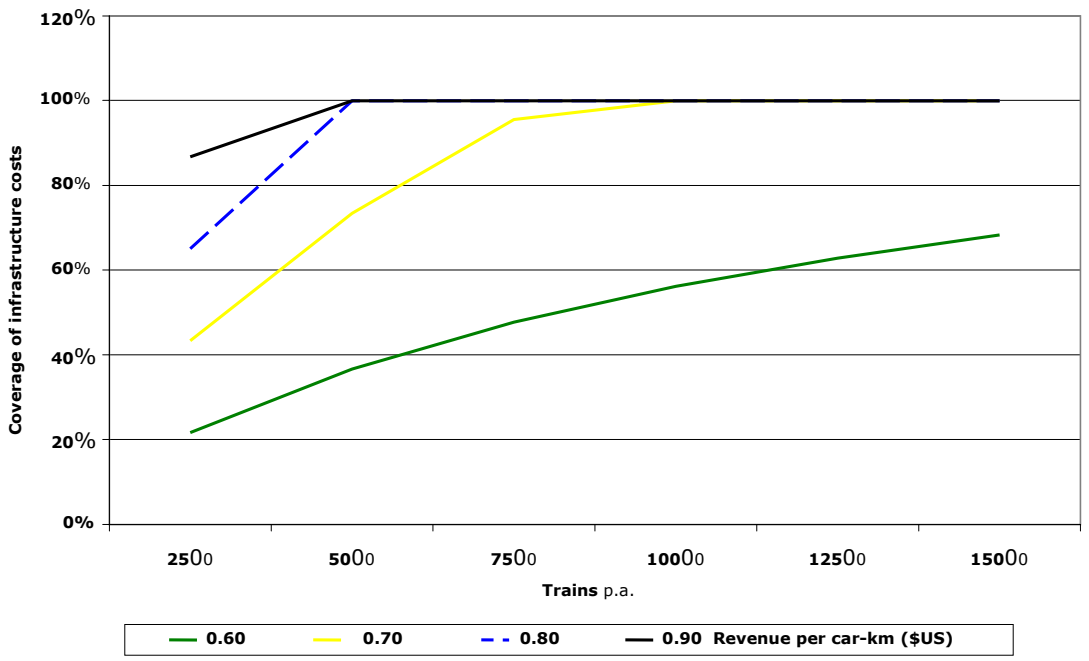
Branch-lines are generally of a lower standard (and hence often, but by no means always, cheaper to maintain in absolute terms) and this is reflected in the cost per train-km for lines of similar density. However, the typical branch-line also only carries a fraction of the traffic on a main-line and thus the infrastructure cost on a fully allocated basis is typically 2–3 times as high as for a main-line.

[23] The total weight of the train, including the locomotive

The ability of passenger services to contribute to infrastructure costs thus depends on the revenue earned per carriage-km (as this determines the surplus over above-rail cost available for infrastructure) and the traffic density, as this determines the fixed cost allocation.

Figure 4-4 shows the percentage coverage of infrastructure costs, as a function of revenue per carriage-km and traffic density, based on the intercity service (IC) costs in Table 4-1.

Figure 4-4. Coverage of infrastructure costs as function of traffic density and revenue per carriage-km (IC service – high efficiency)



4.6 Summary

The financial performance on any given railway will depend on its individual circumstances but there are some conclusions that seem generally applicable:

- If they are reasonably well-patronised and operated efficiently, mainline train services should be able to cover both their avoidable train working expenses and the cost of renewing the rollingstock as it falls due.
- The ability of passenger services to contribute to infrastructure costs depends on (a) the revenue earned per carriage-km because this determines the surplus over above-rail cost available to pay for infrastructure; and (b) the traffic density on the line, as this determines the proportion of fixed infrastructure costs allocated to the service. Full cost coverage can only be obtained by having a combination of relatively high earnings per carriage-km (at the upper end of experience, say $0.70 and above) and a high density of total traffic (say, 7,500 trains p.a., or around 10 pairs per day). Achieving either of these targets is a major challenge in many developing countries, which in many cases would barely have 5 pairs on much of their network.
- Branchline trains can sometimes provide a valuable role in feeding traffic to mainline services, but will only rarely be able to cover even their above-rail working expenses, let alone make any contribution to rollingstock asset renewal or infrastructure costs. Bus feeder services can often (perhaps usually) be contracted to provide better service at lower costs.
- In general, the above rail cost of operating different types of train services at a given level of system efficiency varies less than revenue. The key factors in achieving reasonable levels of cost-recovery are through rollingstock utilization, carriage occupancy and passenger yield.

- Other things being equal, the difference in overall rail operating costs for a given type of service between an efficient railway in a developing country and an efficient railway in a high-income country is relatively small, say 2:1 (as the cost of many of the capital inputs, fuel and spare parts are the same in both cases). However, the difference in income per head which might be between 5:1 and 10:1 or more directly affects the affordability of fares. At similar passenger loading and line density standards, developing countries have an inherently greater challenge in achieving high cost recovery in passenger rail services implying a need to fund a greater share than high-income countries of infrastructure costs from some budgetary support (or less satisfactorily) from rail freight.
- Restricting capacity and subsequent crush loading of non-urban train services can help meet the above challenge on the revenue side, but low train service standards in general do not necessarily denote correspondingly low train operating costs. But they do certainly discourage use by higher income groups. Many governments that, despite rising country incomes, are pursuing policies of offering poor standards at a low fare (i.e. using rail as the default mode for the poor) are almost certainly damaging the long-term potential role of passenger rail. That role will increasingly depend on delivering the higher service benefits the technology can offer and pricing accordingly.

ANNEX A: SERVICE COSTING AND TYPICAL UNIT COSTS

Cost allocation to services

The raw data available in the financial information available in most railways with conventional accounting systems is broadly consistent with the categorization of Table 3-1. However, the labor and materials on-costs and functional overhead accounts (supervision etc) generally need first to be re-allocated to obtain useable functional costs.

Labor on-costs are often included in general administration and need to be extracted and, in the absence of specific causal information, allocated to functional areas on the basis of wages and salaries.[24] Functional overheads can then be spread to their appropriate functional area. For example administrative costs relating to track maintenance (supervisors, district engineers etc) should be included in track related direct expenditure. Costs that are directly related to a function will then be allocated on the same basis as the direct expenditure, providing a better estimate of the true cost of the function.

General administration overheads, such as general and financial management, are not directly related to a particular function and remain separate.

The augmented functional costs, including the on-costs and overheads, can then be allocated to services, initially between the passenger and freight sectors[25] and subsequently between individual passenger services. The allocative mechanisms are based on the appropriate causal relationship for the functional costs which are 'variable'.

'Above-rail' costs (rollingstock maintenance and operation, fuel and passenger handling costs) are normally recorded separately in the accounts, albeit generally at a system-wide level, and can thus either be specifically identified or else allocated[26] using standard operating statistics, such as locomotive-km or gross tonne-km.

However, where the cost is 'fixed' no such relationships are available and instead costs were allocated using a variety of principles (Annex B). In recent years, the development of rail track access charges has seen these principles formalized, although there remains a wide variety of systems and levels of detail (Annex C). For the purposes of this report, 'below-rail' costs have been allocated to passenger services using a simple mechanism similar to that historically used by railways:

- All track-related expenditure is allocated on a gross tonne-kilometer[27] basis
- All expenditure associated with the distribution and supply of traction energy has been allocated on the basis of gross tonne-kilometers
- All expenditure associated with signaling and communications maintenance and with train despatching and control has been allocated on the basis of train-kilometers.[28]

The allocation bases used in this report for the non-infrastructure costs are summarized in Table 2-1. These are further commented on in the remainder of the section.

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[24] Many modern accounting systems allocate on-costs directly.

[25] Some functional costs will be directly attributable to passengers in general; these typically include multiple-unit maintenance, carriage maintenance, diesel fuel (generally maintained separately for multiple-units).

[26] However, many railways account for labor-related costs (pensions, retirement funds, staff facilities and benefits, workers' compensation and labor related taxes such as payroll tax) at an administrative level rather than at the level where the costs are consumed. These costs should instead be distributed to the direct expenditure areas as a labor on-cost prior to allocation as they represent a cost associated with direct labor.

[27] Including the weight of the locomotive – this is not done in all railways and there is a significant difference for many passenger services

[28] Train control and safe working/signaling costs are probably more closely related to train-hours but there is no access charging system to our knowledge that is based on train-hours

Fuel and Traction Electricity

Fuel and energy costs are normally booked to system-wide accounts but may sometimes then be allocated to passenger and freight based on estimated consumption rates. Very few railways have on-train meters. The simplest basis to distribute fuel and traction electricity costs to services is with gross tonne-kilometers; however, more accurate estimates are possible for individual routes if the average grade of the route, the speed of the train and the train size are taken into account.

Train Crew

On some railways, drivers are booked under separate accounts for freight and passenger work, and sometimes also for multiple-units and locomotives; on other railways all train crew is booked to a common account. Allocation to services is best done by train-hours; on railways where this statistic is not available, train-km is a second-best alternative. Adjustments need to be made for the number of train-crew used—some railways use single-manning for some types of locomotive and multiple-unit.

Guards now do not exist on all railways but where this is so, they are normally allocated on the basis of train-hours.

On-train crew

The cost of on-train crew varies sharply from railway to railway as well as by type of train. At one extreme are sleeper cars with one attendant per carriage on some railways; at the other is a single conductor/inspector – or maybe none at all. Some railways also have on-board security staff (or railway police), typically two or three per train. In the absence of detailed analysis, the only practical basis for allocation is to use weighted train-hours, with the train-hours weighted by the estimated number of on-board crew.

Passenger handling and station operations

These are often difficult costs to identify for the typical integrated railway. The major costs are labor-related and therefore can only be identified by analyzing (or using a management assessment) of the time spent by staff on passenger-related activities. Staff employed at stations for train dispatching and train-working should be included under signaling operations.

Station maintenance costs are generally only available in aggregate but can be allocated in proportion to staff numbers. Although the connection between station maintenance and staff numbers is more tenuous than for operations costs, the number of staff does give an indication of size and complexity and therefore expected level of maintenance effort.

The aggregate passenger-related costs are best allocated to services on a per passenger basis. In practice, the high-fare and long-distance passengers have higher costs than commuters and low-fare passengers and an acceptable alternative could be to distribute costs in proportion to revenue.

Catering

Catering costs should be directly available from the accounts. However, such costs generally only include the cost of food and catering staff; they exclude the costs associated with maintaining and hauling any restaurant and buffet cars. Catering revenue and expenditure should be allocated in the same manner; depending on the system, weighted passenger-kilometers is a reasonable basis, with weights reflecting the relative use of these facilities by the different classes of passengers.

Rollingstock Maintenance

Maintenance of passenger rollingstock is generally available by broad type (locomotive, carriages and multiple-units) but is rarely available by class of carriage and not always by type of locomotive. There are arguments for and against differentiating between classes of locomotive, as the locomotives used on any particular service often reflect policy rather than being based on specific technical characteristics; in addition, very often the most powerful locomotives are the newest and hence have the lowest unit maintenance costs. It is therefore often best to use a fleet average maintenance cost for locomotives; analysis has shown this can be allocated on the basis of locomotive-km and locomotive-hours, typically 50:50. Similar results hold true for multiple units, although here it is often worth distinguishing between modern 3 and 4-car sets used for main-line services and the life-expired one or two-car units often used for branch-line services. Carriage maintenance costs should also distinguish between the higher-class carriages, often with air-conditioning and generally with much higher interior standards, and the lower-class carriages, for which interior maintenance is minimal on many railways. A reasonable basis for allocating carriage maintenance costs between services is 70 percent on the basis of vehicle-km and 30 percent on the basis of vehicle-hours; however, if costs by class of carriage are available, vehicle-km alone can be a reasonable basis, as most trains with similar types of carriage operate at similar commercial speeds

Headquarters Administration

Analysis of these costs on different railways has shown that these costs are within a fairly close range (7–12 percent) of total working expenditure (i.e. excluding capital charges). In the long-run, therefore, they should move up and down in line with expenditure and can be included in service costs as a percentage mark-up.

Capital Costs

The appropriate approach to the measurement and allocation of capital costs depends upon the purpose for which it is being made. For the purposes of accounting statements, assets are generally valued using accounting standards which assume that the railway is a going concern, values are related to historic costs and that normal commercial relationships between risk and return prevail.

From an operating railway's perspective, many assets are impossible to value in the accepted commercial sense. Land for the permanent way may have a significant alternative use value but if it is unavailable for that alternative use, its value is a function of the level of income that it can generate. This report assumes the on-going operation of the railway and the only capital costs included are replacement costs for renewable items.

The capital costs are represented as an annual charge equivalent to the depreciation and interest costs that would be incurred if the replaceable assets were replaced at current new costs with a loan over the life of the asset. The interest rate used (i.e. the return to the investor) is set at 7 percent real (i.e. the return excluding the effects of inflation).

Rollingstock costs in this report are based on lives of 25 years (100,000 hours) for diesel locomotives, 30 years for diesel multiple-units and 40 years for electric locomotives, electric multiple units and hauled carriages.

The replacement costs of track in this report are calculated based on the estimated track life and component costs. On main-lines, the life is assumed as 600 million gross tonnes or 40 years (whichever is the earlier) with cost as a direct function of gross tonne-kilometers. Branch-lines are assumed to use cascaded materials and no replacement capital cost has been included.

The replaceable component of the overhead line equipment is the contact wire. This is assumed to have a life of 30 years. The costs are allocated to services according to Electric GTK.

Table A-1 presents typical sets of unit operating costs which have been developed from a range of different railways:

- Railways which are low/medium-wage but which have high technical skills and provide a medium level-of-service, such as some of the major Asian railways;
- Railways which are low-wage and which provide a relatively low level-of-service, such as some African railways;
- Railways which are medium-wage and provide a medium level-of-service, such as Eastern Europe.

Table A-1. Typical unit operating costs ($)

Item	Variable with	A	C	D	E	F	G	I	J	K
Rollingstock maintenance										
Diesel loco maintenance	Diesel loco-km	0.64	2.03	1.34	0.31	0.88	0.60	0.93	1.50	1.23
Electric loco maintenance	Electric loco km					0.56	0.23		0.75	
Carriage	Carriage-km	0.05	0.17	0.10	0.09	0.08	0.06	0.10	0.25	0.24
Electric multiple-unit	Car-km						0.08		0.31	
Diesel multiple-unit	Car-km				0.11		0.20			
Train crew	Train-hrs	2.88	7.46	14.20	7.89	8.90	9.85	37.09	17.25	9.47
On-train crew	Car-hrs	0.82	0.26	2.02	1.03	3.29	2.23		1.74	
Diesel fuel – loco-hauled	000 diesel gtkm	1.89	4.57	6.06	1.32	0.98	1.21	1.49		6.48
Diesel fuel – DMU	000 diesel gtkm				1.80		2.55			
Electricity - loco-hauled	000 electric gtkm	0.68				0.79	0.31		2.81	
Electricity – EMU	000 electric gtkm				2.20		0.64		4.51	
Ticket selling/terminal	Passenger	0.14	1.07	1.03	0.07	0.56	0.10	1.28		0.03
Signaling/train-working	Train-hr	4.18	14.54	4.02	14.73	15.12	8.54	10.91		3.32
Track and bridge mtce – fixed	Track-km	2149	3848	2383	6682	11493	5026	2165		962
Track and bridge mtce –	Gross tonne-km	0.18	0.51	0.42	0.36	0.22	0.43	0.18		
Overhead equipment	Electric track km	3613			1048	5886	3354			
Signaling & telecoms	Route-km	665	534	911	5681	8449	1511	809		
Corporate	Working expenses	14.8%	12.4%	13.4%	7.5%	11.8%	5.3%	28.5%	16.0%	15.4%
Equivalent access charges										
Signal and trainworking	Train-km	0.12	0.77	0.21	0.39	0.40	0.20	0.29		0.24
S&C maintenance	Train-km	0.13	0.42	0.88	0.28	0.29	0.23	0.48		
Electric OHLE	Electric gtk (000)	1.39			0.83	0.09	0.14			
Track and bridge (fixed)	Gtkm (000)	0.71	3.63	2.29	1.37	0.22	0.46	1.00		5.80
Labor productivity[1]	H (> 500), M, L	M	L	M	H	H	H	H	M	L
Income-level	See Table 2-1	L	L	L	LM	LM	LM	UM	UM	L

[1] As measured by thousands of traffic units (the sum of net tonne-km and passenger-km) per employee

ANNEX B: INFRASTRUCTURE COST ALLOCATION

Three approaches to allocating these costs have been proposed at various times:

- full-cost apportionment
- prime-user[29]
- sole-user

This annex briefly discusses these three alternative approaches, within the specific context of establishing a basis for the charging of infrastructure and train-control-related recurrent and capital costs.

Full-Cost Apportionment

The most common method of allocating infrastructure and other costs which cannot be attributed to a service on the basis of causality is by using full-cost apportionment. This is the approach historically adopted by most railways and essentially consists of defining a set of bases for allocating costs which are 'reasonable'. The typical bases in use around the world are:

- track- and infrastructure-related costs are distributed on the basis of gross tonne-kilometers
- signaling-related costs are distributed on the basis of train-kilometers
- electric traction infrastructure (catenary, substations etc) is distributed on the basis of electric gross tonne-kilometers
- general administration costs are distributed on the basis of gross tonne-kilometers, or as a percentage mark up on other allocated expenditure.

These factors, which have been in use for over a hundred years, have many advantages for a unitary administration trying to allocate expenditure to service groups at a strategic level. The calculations are relatively straightforward and use operating statistics which are readily available and unambiguous. In the short- and medium-term, the costs which are being allocated do not vary directly with the factors. However, as capacity is adjusted to throughput in the long-run, there is a much stronger relationship. Thus:

- only around 30-40 percent of track-related expenditure is directly variable with usage in the medium-term (and even less in the short-term) for the typical railway. However, in the long-term, as traffic volumes increase, more track capacity needs to be provided. This is done by increasing either or both of the number of tracks or the track standard. This long-run variability in practice of so-called 'fixed costs' with volume was recognized as long ago as 1890.
- signaling maintenance costs are generally time-based and hence invariant with traffic levels. Instead they are directly related to the installed signaling capacity. However, in the long run the capacity (and hence maintenance costs) varies with traffic density, as measured by the number of trains, for which train-kilometers is a good measure.
- signaling operating costs are similarly invariant in the short-run in practice but vary in proportion to traffic densities in the long-run. However, they are somewhat more variable than signaling maintenance costs, as intermediate boxes can be closed and control sections amalgamated when traffic volumes are low.
- general administrative costs are a function of the overall size of the railway, and typically represent between 8-12 percent of total operating costs. The best single indicator of the scale of a railway is gross tonne-kilometers and, although there is no direct causal link with general administrative costs, there is almost always a strong correlation in the long-term. Some railways use a cost mark up procedure, allocating administrative costs in proportion to the allocation of direct costs. The underlying assumption for this is that administrative resources are directed in proportion to the level of spending. In some instances, this

[29] These are essentially public-sector-oriented. The private sector either uses full-cost apportionment or the more informal method of just striking a charge by negotiation.

approach is modified by excluding energy costs as these are often a significant proportion of costs for which there is relatively little administrative effort.

The traditional full-cost apportionment procedures are thus acceptable indicators of long-term cost movements. At the sector level, as long as the network is reasonably dense, they also give a reasonable estimate of the cost impact of a major change such as the withdrawal of services from a whole sector. At the individual service level, however, or when the network is indivisible, (such as consisting of a single track), the results of such apportionments need to be treated with caution.

Prime-User Costing

Although full-cost apportionment is a satisfactory process for a unitary railway, it has some unfortunate characteristics when applied to a railway which has been restructured into a set of business units with individual financial targets. The first major integrated railway to restructure itself in this way was British Railways (BR) and it soon faced two problems:

- the 'fixed' infrastructure costs allocated to a business unit were a function not only of the its own activity but also of the activity of the other units using the infrastructure in question. As a result, a business unit's financial performance was partly outside its control.
- as the allocated costs included a capital component, it was difficult to reach agreement on the treatment of any new investment which was required by only one of the units using the infrastructure. For example, it was difficult to get local passenger services to pay towards projects to increase the maximum speed of intercity express trains on sections of track over which they both operated.

BR solved these problems[30] by introducing the concept of 'prime-user' in the early 1970's. Each item of infrastructure was allocated to one, and only one, of the four business units into which BR had been split. Each business unit was initially wholly responsible for all the maintenance and investment costs associated with that piece of infrastructure, and effectively defined the operating standard to which all other users had to conform. Under this arrangement, budgeting became a much more certain exercise, and investment proposals in theory could be more speedily implemented.

In the late 1970's, the system was modified so that each user using 'foreign' infrastructure paid its 'owner' the estimated marginal cost of using it. However, these costs were relatively small and did not represent a major change to the system.

Prime-user was an acceptable way of ensuring clear lines of responsibility within an integrated railway for the maintenance and operation of infrastructure where it was used by more than one business unit. However, from a commercial viewpoint, it represents an extreme case in which the secondary users contribute nothing other than their avoidable cost. This is clearly not sustainable in a commercial situation and, with the introduction of a track authority in UK, the prime-user approach has been abandoned and the new operating companies are now paying an approximation to full-cost apportionment on a per train and per gross tonne-km basis.

Sole-User Costing

As the management of business units developed, and as increasing pressure was put on them to meet ever more stringent financial targets, attention inevitably focussed on the cross-charges for infrastructure usage. Although most railways continued with full-cost apportionment, many marginal users complained that the relatively simple allocation procedures unfairly penalized them. For example, under full-cost allocation a freight user running over suburban tracks is often paying for the use of sophisticated signaling systems that would not be required if it was the only user.

[30] There was also a related problem associated with the method of calculating PSO grants, which were initially done on a marginal cost basis, leaving all the infrastructure costs to be met by the BR 'commercial' services. The allocation of specific items of infrastructure to PSO-funded services enabled the grant to be increased to cover the full costs of such services.

The concept of 'sole-user' was therefore developed, in which the cost of a stand-alone system for each user is calculated and used as a basis for allocating the costs of the actual system.

The concept was developed in response to the increasingly more competitive outlook of the individual business unit managers. However, it has never been rigorously applied in practice[31] although it has been used as the basis for negotiations and submissions to pricing tribunals where there is an open access regime. Its main weakness is that it requires inherently hypothetical calculations and is unlikely to be acceptable as the main methodology for calculating charges in a contractual or commercial situation.

Conclusions

Although the various options such as prime user and sole-user costing have strong intellectual appeal, the main reason they were invented, in the UK at least, was to overcome the difficulties faced in mimicking commercial behaviour whilst remaining under public sector ownership. Commercial operators would almost certainly have found a simpler approach. In the US, where this is a common problem, it is generally solved by commercial negotiation. This is a workable procedure as the different users are organizationally independent and (generally) have a common interest in rapidly reaching a 'reasonable' allocation. Many of the agreements for working over another company's tracks are in practice full-cost allocation, based on indicative operating statistics such as vehicle-kilometers. There seem to have been many more difficulties in reaching an acceptable allocation of costs in situations where the various users are all part of the same umbrella railway but have individual financial targets, such as in UK.

Full-cost apportionment therefore remains the simplest and most practical method of allocating infrastructure costs and the best starting point for any negotiations between interested parties. However, as much effort should be put into improving the accuracy and level of detail in which the basic expenditure is recorded, rather than developing more sophisticated allocation procedures to apply to aggregated base cost data.

[31] One Australian railway uses an approximation of sole-user costing to allocate infrastructure costs between suburban, freight and long distance passenger businesses. However the application is limited to specific areas and the decisions regarding the infrastructure requirements of individual businesses have been arrived at through negotiation, with the emphasis on arriving at a "fair" allocation rather than a precise modeling of the specific sole-user infrastructure requirements.

ANNEX C: VARIABILITY OF INFRASTRUCTURE MAINTENANCE COSTS WITH USAGE

Considerable work has been undertaken by railway authorities throughout the world on the relationship between infrastructure maintenance costs and the variables summarized in the previous section. The work includes:

- engineering-based analysis of asset degradation, such as the ORE work in Europe as well as the engineering work undertaken by AREA in the US and various railways in Australia and other countries;
- models of cost attribution and allocation, of which the best-known is probably Uniform Rail Costing System (URCS), developed by the Interstate Commerce Commission (ICC); such models combine historical experience, engineering assessments and econometric analysis.

A significant body of research into track behaviour and costs was undertaken by the ORE (Office for Research and Experiments) of the UIC during the 1980's, building on previous work undertaken by various European railways. This work, amongst other things, related track maintenance costs to track condition, speed, axleload and volume and showed[32] track costs vary at approximately 60-65 percent of the rate of change in both speed and axleload. The rate of change was also sensitive to track condition, with the increase generally being greater the poorer the quality of the track.

US rail engineers have been developing cost variabilities for over a century. One of the earliest authorities was Wellington in the late 19th century; he observed that the maintenance of way costs per train-mile, far from decreasing as traffic volumes increased, had been almost constant over a long time period. He attributed this to the continual upgrading of track quality as volume increased, and for the cost of this upgrading to itself to be an increasing function of quality. This was in spite of a large part of track-related expenses being in areas (sleepers, ballast, bridges etc) which were considered to primarily vary with network size. In hindsight, however, an alternative explanation could also be that the track engineers of the time spent as much as they were given, and denser railways had a larger surplus to spend on track after payment of above-rail operating costs.

The creation of the Interstate Commerce Commission (ICC) in 1887 and the introduction of mandatory financial reporting in a standard format generated a vast body of railway financial and operating statistics in the US which has proved a fertile source for railway economic analysis. A large amount of econometric analysis was undertaken over the years by both the ICC itself and by academic researchers who investigated the relationships between railway costs and usage.

The ICC used many of these relationships in its regulatory work. Its origins lay in a desire to control the widespread price discrimination that was practised by the rail industry at that time. Accordingly, it developed standard costing systems (known for several years as Rail Form A, replaced in 1980-1981 by the Uniform Railroad Costing System (URCS)) against which rate changes proposed by the railways were assessed. Guided by the Transportation Act of 1940,[33] the main emphasis of the ICC was probably as much on preventing rate decreases (which it saw as the possible prelude to 'destructive competition') as on controlling rate increases and it thus placed great emphasis on ensuring proposed rates covered costs. Its costing methodology thus tended towards long-term variable costs which implicitly included (in the case of track) the impact of quality and capacity changes in response to volume changes.

[32] ORE Committee 141

[33] This directed the ICC, inter alia, 'to encourage the establishment and maintenance of reasonable charges for transportation services, without unjust discriminations, undue preferences or advantages, or unfair or destructive competitive practices'

The cost relationships in URCS were developed by statistical analysis of the expenditure of the (then) 37 Class 1 US railways for the four years 1978 to 1981.[34] This analysis showed 'Running Track Maintenance'[35] and 'Track Maintenance – Overhead' to be 55 percent and 58 percent variable respectively with gross ton-miles.

Similar analyses, using substantially the same datasets, were undertaken by the Association of American Railroads (AAR).[36] Their statistical analysis assumed expenditure on buildings, facilities such as wharves and power plants and on signals is effectively independent of traffic volume but related the remaining 'way and structure' expenses to length of track, shunt locomotive-miles and gross ton-miles. It also developed 'engineering estimates' from professional experience. Both these approaches showed variabilities of about 60 percent for medium-high density lines (20 million tons). However, the commentary to the analysis included a number of caveats which continue to apply some 30 years later:

- the difficulties of establishing the traffic volume associated with the work carried out in any one year because of the cyclical nature of much of the work undertaken
- the impact of constrained budgets on the maintenance of way, which is generally the first item to be deferred when there is a shortage of funds. These deferred works will then be undertaken when traffic recovers. Simply relating annual expenditure to traffic volume in that year thus over-emphasises the purely physical impact of traffic volume on track maintenance
- while statistical procedures can be helpful in understanding the behaviour of infrastructure maintenance expenses, they must be applied with an understanding of the inherent deficiencies of the input data and the validity of the results should be tested by logic and engineering judgement based on experience.

Both the URCS and the AAR work was based on the cross-sectional analyses of railways of different sizes and densities and thus implicitly includes the longer-term effects of traffic volume on the quantity and capacity of infrastructure. The results should be used with caution as they will overestimate the variability of the cost of maintaining a fixed quantity of infrastructure as volume changes.

Another set of data is included in the AREA Manual for Railway Engineering, which provides a series of factors relating track maintenance costs to changes in tonnage, speed and construction materials used. These were last reviewed in 1994 and thus are more up-to-date than the ICC/URCS analyses, although they naturally reflect North American freight track characteristics, loading and maintenance practices. They are based on a substantial body of field research and controlled trials and show a variability with tonnage of between 30 percent and 40 percent, all other things being equal, more or less independently of track standard. The cost increase if passenger train speed increases from 100 to 150 km/h is estimated at 30 percent, equivalent to a variability of 60 percent. Increasing axleloads from 20 tonnes to 25 tonnes on track with a maximum speed of 150 km/h is estimated to increase maintenance costs by just over 10 percent, equivalent to a variability of 50 percent; variabilities for lower speed tracks are lower at around 35 percent.

In addition to these published sources, there have been many internal analyses by or for individual railways, either using engineering estimates or statistical analyses of past expenditure. These almost all produce results which consistently show track variabilities in the 30-60 percent range e.g. the Canadian Transport Commission[37] estimates 55 percent of track maintenance expenses are variable with gross ton-miles, with the remainder invariant with traffic. Other studies in Australia have found variabilities of 30-40 percent.

Infrastructure cost research on Russian and Chinese railways shows a high variability with tonnage. However, the average densities on these systems are so large (the average density on the Russian system was 40 million gross tonnes per annum in 1989 and even today is over 25 MGT pa) that they

[34] Uniform Railroad Costing System: 1980 Railroad Cost Study, ICC 1982
[35] 'Maintenance' in this context includes cyclic renewals.
[36] A guide to Railroad Cost Analysis Bureau of Railway Economics AAR 1964
[37] Railway Costing: A Review 1984

are towards the high end of the cost curve, where the fixed costs of maintenance are a small proportion of the total cost. One interesting feature of the Russian system is that the allocation of costs between passengers and freight for reporting purposes (but shortly to be also for access pricing as well) discounts passenger tonnage by 20 percent, presumably to reflect the generally lower axleloads (typically about 12-15 tonnes) and less damaging bogie characteristics of passenger vehicles.

In summary, the results of cost research on other railways demonstrates a uniform pattern, with the variability with volume of track-related expenditure being typically in the range 30-60 percent and with significant relationships between axleload and speed and maintenance activity.

Little published research has been undertaken anywhere on the variability of structures costs with traffic (although they are often included by default in the US analyses). The maintenance and renewal costs of fixed signal infrastructure are generally assumed to be constant and electrification-related costs are rarely addressed.[38]

[38] Although there will almost certainly be some material available in Russia and China.