Exposing the REAL infrastructure cost drivers

Why are life-cycle infrastructure costs five times lower in the USA than in the Netherlands, but are 50% to 200% higher in Japan and Hong Kong? Jan Swier* shows how these huge cost differences can be explained, allowing them to be predicted more accurately

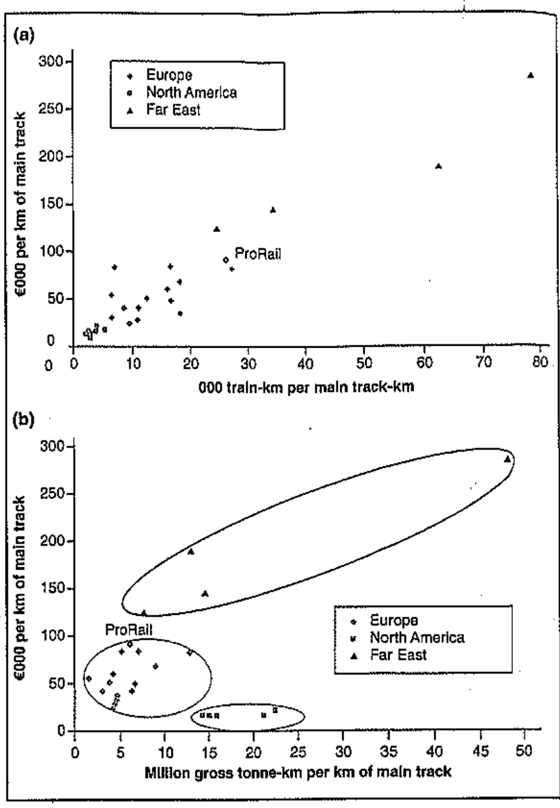

Fig 1: Plotting the annual life cycle cost of main track (a) per train-km and (b) per gross tonne-km exposes a very different relationship in the three continents

OVER THE LAST 10 years, Netherlands Railways has undergone a complete change. So far as infrastructure manager ProRail was concerned, there has been a shift of management focus from technology to contract management, from tasks to processes, from man-hours to costs, and from budgets to operational performance.

In the course of this change, ProRail gained valuable insights into the relationship between life-cycle infrastructure costs and operational performance, and why international benchmarking data proved so valuable in shedding new light on the drivers of those costs.

On the initiative of UIC, a benchmarking study was carried out to compare the costs of infrastructure maintenance, renewals and new projects. The reports published between 1996 and 2002 provided a wealth of information and results (RG 3.03 p130).

One of the most exciting analyses of this benchmarking data, which I implemented at the time, involved plotting the life-cycle costs of railways in some 25 countries spread across three continents against train-km and tonne-km.

Plotting LCC against train-km (Fig 1a) reveals a more or less proportional relationship. It is noteworthy that the three continents form three clearly distinguishable groups that lie more or less in a line. Note that 'Far East' refers to the densely populated and prosperous regions of Hong Kong and Japan where mass transport of passengers dominates. It does not apply to China as a whole, for example, where quite different results could be expected if the data were available.

Plotting the same LCC against gross tonne-km (Fig 1b) generates a totally different picture, and at first I saw no logical explanation. Engineers responsible for rail had always told me that deterioration of the superstructure is caused primarily by the axle load and gross tonnage each section carries.

From my own experience, I know that the rail infrastructure and traffic are very different in the three continents. But what always struck me during my visits was not so much the extent to which railways differed as how much they had in common. Everywhere I went I saw recognisable rail infrastructure, be it track, pointwork, signalling, bridges or tunnels. There were no differences in principle in the type of rail infrastructure. The explanation for the huge discrepancy in costs had to lie elsewhere.

A variance analysis of traffic that the railways in each continent typically carry offered the first clues. Combining this with information in the two graphs slowly but surely transformed speculation into knowledge. This process was further encouraged by a number of relevant questions from managers at ProRail.

Management paradigm

What really helped me stay on course in my search for infrastructure cost drivers was a generic management paradigm that I developed.

Every manager's task is to control time, scope, costs and conditions, and so long as they are under control he is in charge. The four elements contain a number of related variables:

Scope embraces functionality, performance and technical quality as well as reliability, availability, maintainability, safety, health and environment (RAMSHE);

Costs are determined by man-hours, materials and machines;

Time for developing and constructing an infrastructure component plus its service life;

Conditions and circumstances that affect the task but cannot be influenced by management.

The four elements comprise a cohesive management framework. If one element changes, its effect on the other three has to be investigated, and the consequences of that investigation accepted. This is a general management principle, and it certainly applies to rail infrastructure.

Management can be compared to keeping a pair of scales in balance, with one side containing money and the other side time, performance and limiting conditions. The manager is able to keep them in balance using two different but complementary methods.

The better known method, if he has

Table I. Variance analysis for the three continents

	USA	Europe	Far East
Principal traffic	Freight	Mixed	Mixed
Punctuality	15 min - 24 h	85% <3 min	98% <3 min
Daytime work	<90%	<70%	<25%
Train length *m*	≈2 500	50 to 350	50 to 350
Train weight *tonnes*	≥7 000	100 to 700	100 to 700
Trains/hour/direction	4	14	24
Points per track-km	0·3	1	1
Signal spacing *m*	±5 000	1 000	1 000
Traction	Diesel	Electric	Electric

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less money to spend, is to translate this into less availability, less functionality, lower pay, and so forth. However, there is an alternative policy which is to run the organisation more effectively, thus achieving greater results at less cost. This is possible if his employees perform their tasks better because of greatly improved process management and the use of powerful management tools.

The scales can be considered as a paradigm for management from which all the influences on costs can be derived. This provided me with a check-list, which I used for developing a cost model and the analysis of cost drivers. Thanks to this paradigm and the checklist I have maintained an overview, and remain confident that I have taken practically all the major effects on operational performance into consideration.

The QM4C cost model

On the basis of this insight, I developed the QM4C model for forecasting the LCC maintenance and renewal costs for new and existing lines. QM4C stands for: Q = Quality; M4 = Money, Man-hours, Material, Machines; 4C = Costs, Circumstances, Conditions, Complexity.

The model consists of six modules. The core is a cost template (Module 1) that is linked to a calculation model for running sensitivity analyses (Module 3). The other four modules include norm graphs for determining the service life, overhead costs and a method for determining effective working times, but these are less relevant for the purposes of this article.

Module 1: cost template

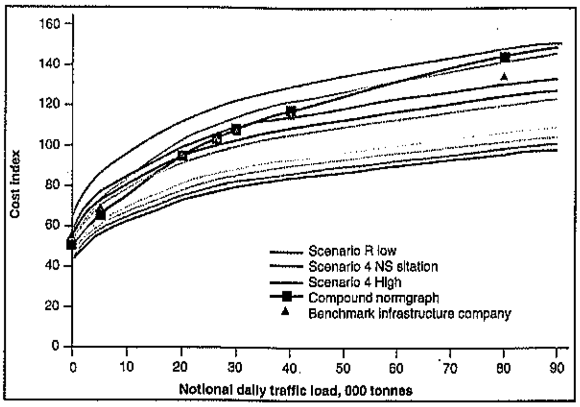
This contains infrastructure quantities and cost ratios for maintenance and renewal under average usage conditions on the Dutch rail infrastructure. These are assumed to be 27 000 gross tonnes/day passing over each track, 65% of maintenance carried out during the day, and an effective working time of 5 h during the day and 4 h at night.

Maintenance budgets are calculated by multiplying cost ratios by the infrastructure quantities. These budgets, when added together, should cover total expenditure for the year. The template is indexed for cost inflation and can be brought up to date every year. The cost ratios are therefore realistic and reliable, because they explain the actual maintenance costs in a given year.

The cost template is also used to forecast maintenance costs for existing or new lines. This can be done simply by replacing average quantities for the NS network with quantities for the line to be analysed. This yields a maintenance cost forecast based on the complexity of the line and the average usage circumstances of the NS network.

The cost template contains cost ratios for renewal as well as maintenance. Supporting evidence and historic calculations are available for all those ratios, as a result of which the calculated cost ratios are also realistic and reliable.

Fig 2. Two indicative extrapolation steps in Module 3 for usage and conditions



Module 3: sensitivity analysis

The output from Module 1 is the input for Module 3. Module 3 uses a norm graph that describes the relationship between maintenance costs and intensity of use. The norm graph has been compiled from eight subsidiary norm graphs, one for each system that makes up a railway line: track, trackbed, level crossings, civil engineering structures, power supplies, signalling, telecommunications and traffic control.

The norm graph is used as the basis for performing the sensitivity analyses. Module 3 contains a number of parameters with which the model can be calibrated for a specific situation. They can be adjusted to best describe a line, a contract area or an entire country. These parameters are:

- cost ratios for man-hours, material and machines;
- the proportion of day/night/weekend work;
- man-hour cost ratios for day/night/weekend work;
- effective working times.

The output from Module 3 is a graph which describes in the form of a number of scenario curves the relationship between maintenance costs, usage, and the influence of the effective working time on a specific ratio of day, night and weekend work over the year.

If usage increases, the conditions under which maintenance has to be carried out become increasingly unfavourable: more night work is required and the amount of effective time becomes shorter. If usage increases, costs switch to another scenario line at a higher level. This creates a new curve, which connects the different scenario curves to each other, and therefore describes the relationship between usage and the costs due to technical wear and tear *and* altered conditions (Fig 2).

This composite norm graph has been measured against international benchmark information, and has been shown to correspond surprising closely.

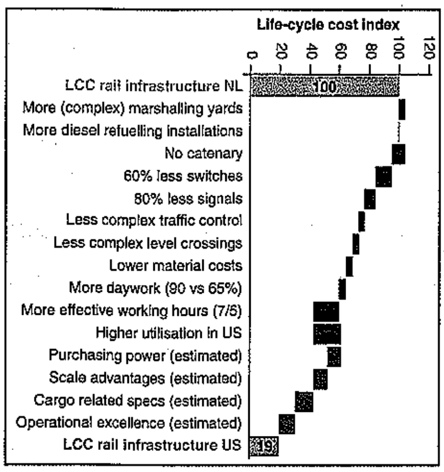
Changing network characteristics

The QM4C model was used to recalculate the Dutch railway as if it had network characteristics applicable to Far East (Hong Kong and Japan) and US railways. As a result, the scale of influences on costs due to the differences set out in Table 1 became increasingly clear.

Most differences were quantified using the QM4C model. The influences which do exist – according to the management paradigm and the checklist – but where there is no substantiated cost forecast were subsequently estimated.

The major influences explaining the fact that costs in the USA are about 80% lower than in the Netherlands, listed and quantified in Fig 3, are:

- less complex infrastructure; far fewer points, far greater signal spacing, no catenary;
- more favourable conditions; much



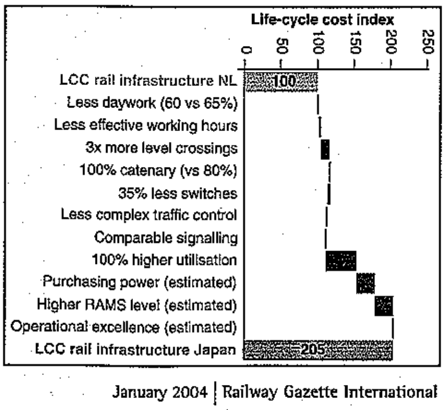


Fig 3 (above right) and Fig 4 (right) provide an indicative variance analysis of life-cycle costs between the Netherlands and the USA in one case and Japan in the other

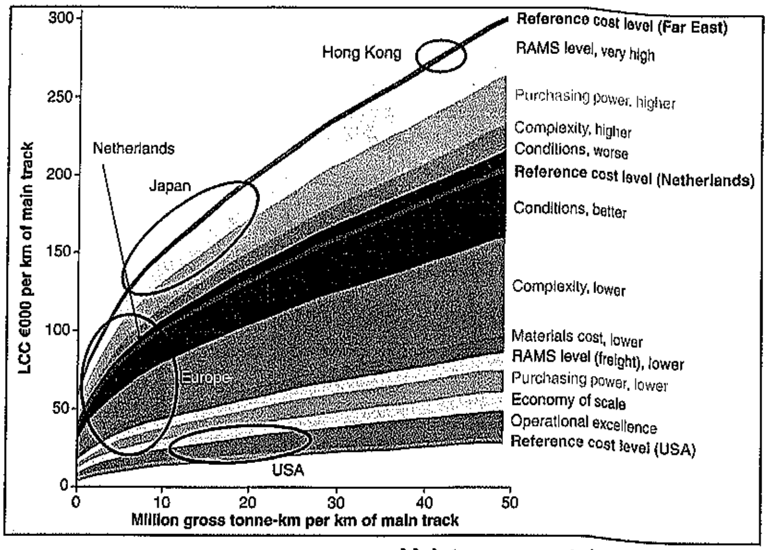


Fig 5. Indicative generic cost driver model showing the possibilities for reducing costs

longer train-free periods and much more work during the day;

- lower material costs;
- lower technical specifications; no passenger comfort level;
- differences in purchasing power;
- professionalism of management; measuring, analysis, modelling and improvement.

There are also cost-increasing effects:

- more hump shunting in yards;
- higher usage loads.

A similar analysis was performed to explain the 50% to 200% difference in costs between the Netherlands and the Far East. The most important cost drivers which explain the 105% cost difference between a specific Japanese company and the Netherlands are:

- higher utilisation;
- less favourable conditions, more night work;
- higher RAMS performance;
- differences in purchasing power.

Fig 4 illustrates and quantifies the most important influences explaining these cost differences with respect to Japan. A similar result is obtained for Hong Kong, the major difference being much higher track utilisation. But it is important to understand that producing and satisfactorily interpreting analyses of this kind is only possible in combination with local knowledge.

At first sight, there are more similarities than differences between the infrastructure in Japan and the Netherlands. However, closer inspection reveals that the Japanese network has fewer junctions; it consists mainly of trains running on separate lines. Each railway operates as a single entity, processes are well controlled, quality is continually measured and improved, much preventive maintenance is carried out, and renewal is carried out in good time.

High-quality infrastructure therefore costs more. This is explained not just by technology but also to a great extent by the processes and conditions.

Maintenance cost drivers

Using the QM4C model, norm graphs have been compiled for maintenance, renewal and overhead costs; these are the life cycle costs. The LCC graph curve was applied to the benchmark information, whereby LCC were plotted against gross tonne-km in Fig 1b.

The percentage influences for cost drivers derived from the cost variance analyses were then projected in the graph, resulting in a generic cost driver graph (Fig 5). This generic graph has been shown to explain the cost differences between the three continents accurately, and it sets out the package of possible influences that affect costs.

The narrow central red curve shows LCC trends in relation to usage for the Dutch situation. The scope for reducing LCC is quantified by the coloured graph areas, and the approximate extent of these effects is shown for each cost driver. Each cost driver has been tested against the checklist of influences to be managed, and has been shown to cover the entire spectrum.

It is clear that we in the Netherlands will never achieve the level of costs enjoyed in North America. This is due to the far higher comfort requirements imposed by passenger transport, the more complex rail infrastructure (more points, signals and catenary), the higher demands on availability, and the fact that far less work can be carried out during the day due to our intensive clockface timetable.

That said, real cost reductions are possible by learning from the effective management techniques in the USA, and by sourcing materials more cheaply. This analysis helps to provide a good quantitative estimate, as well as sound arguments, for the possibilities for cost reduction – and for their limitations.

The analysis does, of course, have limitations – it is not the ultimate truth. But it does provide a coherent indicative picture of reality. The cost drivers have been portrayed reasonably well, and have been quantified quite accurately. There may be a few percentage points of variation, but the underlying relationships give a realistic picture of the scope of the various cost drivers.

Obviously, infrastructure costs increase as use intensifies. When utilisation increases government and infrastructure managers must be particularly careful when factoring in possible savings. They are often unrealistic, because all too often the many negative effects on costs when more trains run are ignored. The important possibility, which can make this situation acceptable, is that the rise in LCC due to increased train traffic is less rapid than the rise in income.

Maintenance & renewal is a management-intensive field that involves a great deal of money, but has a direct influence on the financial and operational performance of railway companies. A range of very different cost drivers influences the LCC of rail infrastructure. Only by managing each of them in combination with the others is it possible to improve overall operational performance, as opposed to simply improving budgets. ■

Exposer les facteurs directeurs des coûts d'infrastructure

Aux Etats-Unis, les coûts de la durée de vie de l'infrastructure ferroviaire sont quelques 80% inférieurs à ceux des Pays-Bas, mais dans les zones densément peuplées des agglomérations prospères d'extrême-orient, telles que Hong Kong et le Japon, ils sont entre 50% et 200% plus élevés. Basés sur les informations de référence de l'UIC et les modèles de coûts analytiques, Jan Swier a identifié les facteurs directeurs expliquant ces divergences. Il s'avère que le niveau du trafic voyageurs ou fret, ainsi que la complexité et les circonstances sont les principaux facteurs

Die wirklichen Faktoren der Infrastrukturkosten

Lebenszykluskosten von Bahninfrastruktur sind in den USA rund 80% tiefer als in den Niederlanden, aber in dichtbesiedelten und prosperierenden Gegenden im Fernen Osten, wie Hong Kong oder Japan liegen sie zwischen 50% und 200% höher. Basierend auf UIC-Kennzahlen und analytischen Kostenmodellen hat Jan Swier die Kostenfaktoren identifiziert, welche diese Diskrepanzen erklären. Es zeigt sich, dass Personen- oder Güterverkehr, Komplexizität und Randbedingungen die wesentlichen Faktoren sind

Exponer el auténtico motor de los costes de la infraestructura

Los costes del ciclo de vida de la infraestructura ferroviaria en los Estados Unidos suponen un 80% menos que en Holanda, pero en prósperas comunidades del Lejano Oriente con una densa población como Hong Kong y Japón suponen entre un 50% y 200% más. En base a la información de referencia de la UIC y modelos de costes analíticos, Jan Swier ha identificado el motor de los costes que explica estas importantes discrepancias. Resulta que el nivel de tráfico de pasajeros y de cargas, la complejidad y las circunstancias son los factores máas importantes