IMPACT OF NEW TECHNOLOGY ON RAILWAY COST-EFFECTIVENESS

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Introduction

A sound technological base for railways is essential if they are to have a secure and important role in future transport. The impact of new technology must be to secure traffic against competition from other modes by offering an attractive level of service at an acceptable cost.

Thus new technology must offer:

- the means of generating new traffic by introducing novel or significantly improved equipment or methods of operation;
- improved equipment in terms of reliability and cost of ownership;
- improved operational techniques maximising useful utilisation of resources, minimising the provision of infrastructure and enhancing quality of service.

It follows that both performance and cost-effectiveness are important. For example in the U.K. the growth of private car ownership, improvement in the Motorway network, and impact of internal air routes have all forced enormous competition on the railways both in respect of performance (average journey speed, for example) and in respect of cost (fares and freight rates).

A further dimension in discussion of technological objectives is concerned with the level of application of new technology. There is an urgent need for better technology at the sub-system or component level (with improved detailed design, materials and manufacturing processes) but there is also the need for radical change in system design, as exemplified by new high-speed systems and by innovative rapid transit systems.

Control, Communications and Computers

Major developments are taking place in the field of signalling. For example, the development of high integrity micro-computers for interlocking will replace the existing systems using electro-mechanical relays by solid-state devices. Algorithms for automatic route setting combined with interactive video display units allow the optimisation of complex traffic flows to a uniformly high standard. The combined use of solid-state interlocking and track to train radio provides a safe way of operating low density routes efficiently.

These developments, and others of a similar kind, reduce operating and equipment costs within the framework of the existing signalling system. This is an important objective in itself, but in fact these developments pave the way to more significant system improvements.

The presence of substantial computing power within a control centre and the availability of both fixed (timetable) and real time data presents the operator with the opportunity to have an integrated electronic control centre. This would embrace not only signalling, but resource management, maintenance of both vehicles and track, control of electrification, passenger information and so on. This is a broader concept than signalling as it would be an inherent part of the management of a particular area of the railway.

Communications are an essential part of the control of the system. Whilst fibre-optical techniques are now being exploited widely, communication via satellites will provide a cost-effective alternative for many applications.

These technological developments will create a very different approach to the way in which the railway is controlled and managed in the future. Operating practices will have to change, and management organisation will come to have far fewer levels in the hierarchy. Railways will have to be much sharper in the way information is handled and acted upon.

Clearly, to fully exploit the potential of these developments, a piece-meal approach must be avoided. Simply applying better technology within the existing framework of signalling practice, whilst useful in proving the new technology, will not be an adequate method of exploitation. It will be essential to develop a systems approach in which there is an overall vision of the future control system within which these various developments can fit as mutually compatible building blocks.

Track

The long life of track components tends to emphasise the importance of reducing costs of maintenance and renewal of track. There are three major thrusts in improving the technology available:

- measurement and analysis of track geometry and key lineside features to be carried out rapidly and on a large scale;

- computation of the deployment of resources to carry out the maintenance that is actually necessary;

- development of machinery and techniques, based on the mechanics of track behaviour, with longer lasting effects.

Examples of improved technology of measurement are high speed track recording cars, and structure gauging vehicles. These vehicles, which measure track geometry and the gauge clearances through which vehicles must pass, replace earlier, much more laborious means of achieving the same result. The results of operating these vehicles are processed by centralised and computerised data processing systems. It is clear that further measurements are desirable (for example, the transverse profile of rails and the stiffness of track) so that an overall assessment of the state of the route can be carried out.

An improved understanding of the mechanics of the deterioration of track under the loading imposed by traffic has suggested that much greater emphasis needs to be placed on the initial accuracy with which the track is laid. Moreover, it has been found that the levelling achieved by tamping does not endure for long under traffic. Consequently, a new approach in which stone is injected under sleepers at low points in the track so as to level the track with minimum disturbance of the roadbed has been developed. The resulting machine, the stoneblower, carries on-board measuring and computing systems in order to optimise the maintenance task. It is expected that after treatment track will last four times as long as it would if maintained by a conventional tamping machine.

Vehicles

There are two main lines of improvement in railway vehicle technology:

- new materials and a more scientific approach to design can lead to more cost-effective and lighter vehicles;
- the application of electronics to suspension and drives is leading to better ride, improved traction and improved braking.

Significant improvements in vehicle design can be made by reducing weight and aerodynamic drag. Even with conventional structural materials, large percentage reductions in weight are made possible by a quantitative approach to design (stringent weight targets and control throughout the vehicle), better methods of structural analysis and more realistic design cases, such as those concerned with crashworthiness. Moreover, the weight of many items of equipment (such as power and brakes) follow the decrease in overall specified weight. The cumulative effect on both performance and cost is likely to be dramatic.

The wide acceptance of solid-state techniques in power electronics is being exploited in the development of versatile or multirole locomotives, which could reduce the number of different types of locomotives required by an operator. Built-in diagnostic systems will allow more efficient maintenance. Active suspensions will have a major effect on vehicle design and could contribute in a major way to the desirable trend of reducing overall vehicle weight, as already referred to.

The Railway as a System

The technological developments outlined above are, of course, paralleled by similar developments by the railways' competitors. The two main thrusts are common to all branches of technology:

- incorporation of computing power within machines and systems on an increasing scale;
- a more numerate approach to engineering and decision-making.

In years to come railways will be very different because most of the components - signalling and control, vehicles and track will have changed to a more cost-effective technology. Signalling will be simpler, track maintenance costs will be lower and there will be more effective resource management.

However, since the railways operate in a competitive environment, will these developments be enough to meet the challenge of competition in a changing market? There seems little doubt that in order to maximise the benefits of new technology, it is important to get the systems engineering right and in many cases this means new railway systems. In this context systems engineering means examining the trade-offs between the component parts and arriving at a system which will meet a commercial need at the right price.

It might be useful, at this stage, to define what a railway system is. It has:

- a dedicated right of way;
- vehicles constrained to run under lateral guidance and longitudinal control on the track;
- vehicles coupled into high capacity trains with high safety levels, and the possibility of automatic operation.

Consequently, railways have expensive infrastructure and therefore their economic operation depends on high volume to achieve low unit costs. Thus the three key characteristics of railways are high speed, high frequency and high capacity. Railways are at a disadvantage when traffic volumes are small, when journey times are longer than by road or air or when only an infrequent service can be justified.

It is in this light that some of the principal system innovations can be viewed. They include:

- high speed rail systems on new or improved infrastructure, with speeds of up to 300 km/h using the steel wheel on steel rail, or up to 500 km/h employing magnetic levitation;

- automated urban systems in which separate small vehicles operate at high frequency to provide both high capacity and high quality of service;

- on a much longer timescale, the automated highway in which traffic is automatically controlled thus representing a final convergence of road and rail technology.

Of the first two types of system there are a significant number in use or under development, and the prospects for wide application are worth discussion. As for the automated highway this seems to be a very distant prospect.

Market and Competition

In developed countries there have been significant changes in the transport market in recent decades, with social and economic changes in population density which tend to work against fixed route systems. Though these trends vary from country to country, there has been a move away from urban cores of the major cities to the outer suburbs; growth has tended to be concentrated in satellite communities and small towns in outlying areas surrounding the main employment centres. Because of these changes the population is being spread more evenly over a larger area.

Moreover, the decline of traditional manufacturing industries in developed countries reflects the emergency of post-industrial society. There is less concentration of manufacturing industry and its associated populations. Ways of distribution of manufactured goods have changed and improvements in communications and the advent of the electronic office may well mean that increasing numbers of professional people will not need to be located near big cities or commute at all.

Above all, there is intense competition from other transport modes. Improved roads enable buses to compete with rail on many inter-city routes both in journey time and in quality of service. Airlines have long had a virtual monopoly of longer routes by virtue of journey time. However, the significant reductions in operating costs of new types of aircraft are allowing airlines to compete with railways in fare level over much shorter distances than in the past - a result of intensive utilisation of their equipment and full exploitation of technological possibilities.

There is now virtually no task in ground transport in which the railways will be free from effective competition from other modes of transport in the absence of protective regulation. It is essential, therefore, that railways concentrate their research and development efforts into those areas where the inherent advantages of railways are exploited. These advantages are most prominent in high speed inter-city passenger transport, mass transit within conurbations and bulk freight.

Research and Development for New Systems

In the case of high speed inter-city operation there are various ways in which the technology is likely to develop. There are three main approaches to the use of steel wheel on steel rail technology.

Firstly, a totally new railway can be built using a new right of way and new trains on new track not connected with the existing rail network. The major example of this is, of course, the Shin Kansen in Japan which required large investment but which fully maximised the technology available.

The second approach, as exemplified by TGV in France, is to upgrade existing lines, and build high speed connection lines which are better aligned but which are compatible with existing routes. A similar approach is being followed in Germany, though the infrastructure requirements are quite different. Because existing routes can be used for entry to city centres, construction costs can be mininised.

Thirdly, there is the approach which concentrates on using the potential of existing infrastructure to a maximum. In Britain, for example, a comprehensive network of high speed trains has been established making maximum use of existing assets. This approach is relevant when the rail network is extensive - perhaps radiating from a central metropolitan area - or perhaps is under-used due to over-investment in the last century. In these circumstances it is difficult to justify investment on one route alone and this approach using HST, APT and IC225 means that the capital costs involved in providing this significantly better service is principally that of the trains themselves.

All three options are likely to be pursued vigorously in the future, with applications being made as appropriate to the level of traffic.

The limits of steel wheel on steel rail technology are economic in that as speeds increase, both vehicle and track maintenance costs rise quite sharply. A major research task is to reduce the costs of speed by employing more effective technology. These limitations have encouraged research and development into new guidance and propulsion technology exploiting magnetic levitation capable of achieving speeds of 500 km/h and more.

The first regular commercial passenger carrying service using magnetic levitation was inaugurated in 1984 connecting the new Birmingham Airport terminal with British Rail's Birmingham International Station. For an automated low speed short distance shuttle, magnetic levitation coupled with linear motor drive has advantages over wheeled vehicles in that positional control is very accurate and the system has ability to penetrate buildings without environmental problems. These factors are likely to be more important in future with the continuation of the trend towards large shopping centres and business parks under one roof. Thus, even for low speed systems, magnetic levitation has distinct and valuable advantages over wheeled systems.

For high speed systems, the potential advantages of magnetic levitation become even more marked. The elimination of unsprung mass, the positive retention of the vehicle on the track (as opposed to the dependence on gravity for retention of the railway vehicle) and the ease with which the vehicle suspension can exploit digital control, immediately yield advantages in dynamic performance at high speeds. Moreover, maglev technology is on a growth curve of improvement. New magnetic materials, lighter electrical components, lower structural weights and other improvements in the mainstream of technology, are leading to lighter vehicles and lighter and hence cheaper guidways.

So, magnetic levitation is at the foot of a growth curve of improvement, whereas it could be said that steel wheel on steel rail technology, though capable of much improvement, is constrained to a much higher degree. It would not be unreasonable to suggest that if magnetic levitation development is sustained over the next few decades, it will overtake steel wheel on steel rail technology.

The rate at which this new technology can be applied is mainly dependent on one issue. This is the question of how the very high infrastructure cost of a new system can be recovered in terms of revenue from tickets. Three points need to be made in this respect. Firstly, operating costs are dominated by the cost of the capital. Secondly, the capital cost itself is dominated by the cost of the infrastructure and particularly by the acquisition of land and the cost of the guideway or track. Thirdly, the total cost is relatively insensitive to the particular support, guidance and propulsion technology used. Because of these points, it is necessary for any new high speed system to attract and cope with, very large flows of passengers indeed.

Over the period considered here it is quite possible that future attitudes to major capital investment on infrastructure might be quite different to those current now. A more favourable environment for investment in infrastructure might well stimulate radical changes in transport systems.

Turning to freight, the challenge in general merchandise freight is severe and rail's position is weaker. So what is the answer? The technological contribution to freight systems has appeared to consist of a series of incremental advances and refinements which have helped defend the railways market share. Looking to future competitive threats the question has to be asked whether this is adequate. While railways are apparently in a strong position in the transport of steel, iron, stone aggregate, and coal, when it comes to the transport of oil and other liquids the amount is small compared with the throughput of pipelines. Recent experiences in Britain have demonstrated dramatically that road trucks can compete with rail even in the haulage of coal and there are prospects for much larger road vehicles.

What seems certain is that the classical railway freight operation of trains made up in, operated between, and broken down in, large marshalling yards has no future at all in its present form, because equipment utilisation and quality of service are extremely poor and totally inadequate in a competitive situation.

In the case of mass transit, urban railways have traditionally thrived on providing a service from many suburbs to a central business district and the trend in decentralisation that I have already mentioned is likely to be a major problem for urban railways in the long term.

One development that could have a significant impact in improving the quality of service in both freight and mass transit is automation. That the technical questions of feasibility in fully automating a guided system have been overcome has been demonstrated by systems at Morgantown, Dallas-Fort Worth and the VAL system at Lille.

The outstanding significance of automation is that it makes it possible to have a dramatic increase in service frequency without an increase in labour costs, so matching more closely in a public service the key attributes of the road vehicle - that of immediate availability.

In addition, the vehicles or trains can be matched more closely to traffic requirements. The service can be maintained over longer periods of the day with less regard to the growing reluctance of staff to work long and unsociable hours. The conflicting requirements of volume and frequency can be resolved in an economic way.

Strategy

The preceding discussion indicates some of the striking opportunities for improving the technology used by the railways both at component or sub-system level and at transport system level. If this technological promise is to be realised, then the way in which technology is applied by the railways needs to be considered.

The exploitation of technology by the railways can take place on two levels, as already mentioned. The improvement of engineering within the existing system is a continuous process looked at with an historical perspective; though each significant innovation successfully applied is invariably the result of a battle with existing techniques. The inception of significant change in the system itself is a much more difficult process, involving a very large investment in new infrastructure often when the market response is largely unpredictable. In these cases a very long view must be taken which requires vision and faith and this can often only be done at government level.

That railway technology is in need of change there can be no doubt. Perhaps the railways' most fundamental problem is that they are both labour intensive and capital intensive. For example, in European railways, labour costs are typically about two-thirds of total operating costs. This is not because the use of labour is generally inefficient, but because the technology employed is not appropriate to the task.

How can the application of new technology to the railways be hastened? Compared with their major competitors, railways are slow in adopting new techniques. Partly, this is because infrastructure can only be changed over a long period of time. But in the vehicle field, this reason is not valid. By fostering technological change and designing for short and cost-effective life, the railways' competitors are able to replace their vehicles on a five to ten year cycle. Typically a railway train will still be in service when road and air competitors are introducing their third generation of new equipment - improved in both image and performance.

The answer to this is to continually develop specifications, in partnership with manufacturers, so that enhancement of commercial performance is the main reason for investment, rather than because equipment has become life-expired.

A second obstacle to rapid application of new technology is the structure of the industry. The industrial base of the railways is narrow, relying on a large number of relatively small companies, often with slender technical resources. This is no doubt partly owing to an equipment market which is highly cyclic and often lacks a stable and consistent ordering pattern, which if it existed would enable the industry to invest in facilities and, more importantly, technical teams, which are necessary to carry out steady technical development at a more rapid rate. Moreover, the industry is fragmented internationally, and if arrangements similar to those in the aircraft and car industries could be set up, the industrial and technological base of the railways could be enormously strengthened. A further deterrent to technical progress is the variation in national technical standards.

Even if policies such as these are adopted with the necessary strategic content which is essential for technical progress, commercial success is still not guaranteed. The system must meet the market need of the future. That there are doubts about the railways' ability in this respect lies behind some of the new systems mentioned above.

Conclusions

Thorough exploitation of the technological possibilities in view could transform the railway balance sheet. Exciting opportunities exist with new technologies and their successful application is very dependent on the way in which these new technologies are managed by the railways. If a business and managerial environment is provided which fosters more rapid change and more rapid application of appropriate technology, then the future role of railways in the transport system can be made secure.