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NEW INTER-MODAL FREIGHT TECHNOLOGY AND COST COMPARISONS

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1. Abstract.

Freight carried by rail has traditionally been mainly low value bulk commodities. As Western economies advance the market for such freight services is at best static, and forms a smaller proportion of the total demand for freight transport. There is thus an urgent need for British Rail and other rail systems to develop practical and cost effective inter-modal systems, which offer high quality services to consignors of consumer goods whose premises are not usually connected to the rail network.

The new developments are of two types. Either they involve transferring the body of a road vehicle from road to rail, or moving the complete semi-trailer of an articulated outfit by rail. Each system has disadvantages in terms of volume or tare weight when compared to road, but each system may attract different commodities.

Though the costs of inter-modal systems vary, their cost structures have similarities, consisting of collection and delivery costs, terminal, and rail movement elements. The break-even distance of each system depends on the extent to which low rail haulage charges offset the other costs incurred. However, traffic will only be attracted to inter-modal in sufficient quantities to enable viable services to be provided over a limited number of long distance routes. These services must also approach, if not equal the competition in terms of quality of service attributes, particularly reliability, if they are to overcome customer resistance.

To assess the distances over which these new inter-modal systems will be cost competitive a cost model has been developed. The paper decribes how the model works, and the sources from which data was obtained. A separate paper (Working Paper 276) reports on a study to find the value placed by shippers on quality of service attributes, and a third paper (Working Paper 286) brings the two together to reach conclusions on the future role of inter-modal systems.

2. Background.

Railway companies have been involved in the development of bi-modal systems for many years. In the U.K. small containers made of wood were first introduced in the last century, being transferred to horse drawn carts for final delivery to take place by road.

In more recent times, rail has had increasing difficulty remaining competitive with road haulage, particularly for the carriage of finished consumer goods. These form a large proportion of the total traffic moved, but the origin and destination points are unlikely to be on the rail system and can only be carried using some form of inter-modal system.

At the same time the production of consumer goods has expanded whilst the heavy industries, where rail has traditionally gained much of its freight traffic, have been in decline. The combination of these factors, together with increased road vehicle weights and dimensions, and an improved strategic road network on which the vehicles operate, has allowed road transport operators to increase productivity and improve their competitive position.

To be able to offer more flexible freight services, rail operators must develop intermodal services offering both speed and reliability for door to door time sensitive traffic moved in small quantities. The attempt to do so has produced advances in bi-modal technology which may allow rail to compete in a broader spectrum of the current freight transport market.

3. Gauging Problems.

The first consideration in the design of any combined road/rail system is the dimensions of the vehicles. A second consideration is their tare weights when compared with the equivalent road vehicle. The first consideration determines the volume of the goods which may be conveyed in a vehicle, while the second determines the payload.

Railway 'loading gauges' restrict the height of rail wagons, and anything that is carried on them. Because many of the bridges on the railway network are of arched construction, height restrictions tend to be more severe at the side of a wagon than in the centre. This gives the normal curve, or chamfered roof contour of railway equipment.

In the case of British Rail (B.R.), the general freight loading gauge is known as W5; this is compared with other European gauges in Figure 1. The B.R. gauge is one of the most restrictive found in Europe; even 8'6" high ISO containers on Freightliner wagons infringe the gauge. These containers are passed for carriage on a restricted network of routes where clearance for W5 with 'ears' has been achieved. A slight relaxation of the loading gauge is being allowed with the introduction of the W6 gauge.

In Europe, Berne gauge ~~is~~ the lowest common denominator. The German DB has larger clearances, while for the construction of

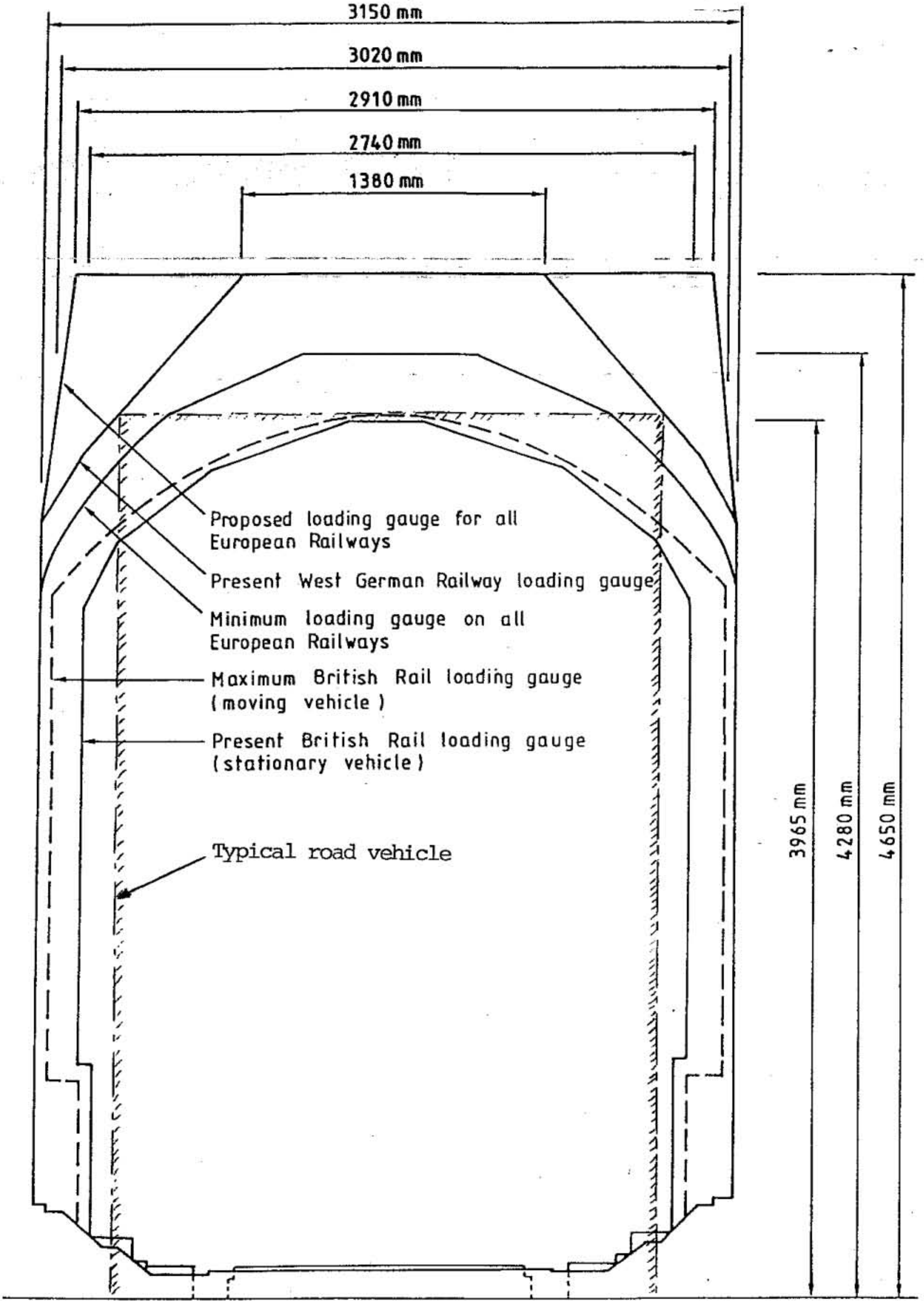


Figure 1.

LOADING GAUGES FOR BRITISH AND EUROPEAN RAILWAYS new lines the International Union of Railways (UIC) gauge is used, which gives a maximum height of 4.65 metres. If a road vehicle of maximum height (4.0 metres, or 4.2 metres in the U.K.) were parked on the rail track it would infringe all but the UIC gauge at the top corners, and this is before it is placed on a rail wagon. It must in any case be lifted clear of obstructions, such as signals, at rail level, which has the effect of limiting the available height within the gauge for bi-modal vehicles.

An alternative scenario is to leave the rubber wheels behind, and carry a demountable or swap-body. However, in the U.K. these may infringe the gauge at platform level when mounted on a rail wagon.

4. European Practice.

On the continent of Europe several bi-modal systems have been in operation for a number of years, with varying degrees of success. The most widespread is the use of ISO containers mounted on flat wagons, and this is currently the only form of inter-modal equipment in common use in Great Britain. However, this system has proved to be competitive mainly for the carriage of maritime traffic during the overland section of a movement because the standard container dimensions restrict the volume available when compared to a road vehicle, and the tare weight of the equipment is also greater. Other systems used tend to be restricted to a specific group of routes offered, in the main, by the operator who developed the system. Diagrams of the main systems are shown in Figure 2.

4.1 Demountables.

The basis of this system is to transfer the body of a road vehicle to a rail wagon, leaving the 'rubber' behind. In general it has the advantage that a greater volume can be offered per unit because, without the road wheels, the demountable body can be placed on a rail wagon which has a lower platform height than is possible if the whole semi-trailer is transferred. The cranes used for demountables are similar to those used for lo-lo trailers.

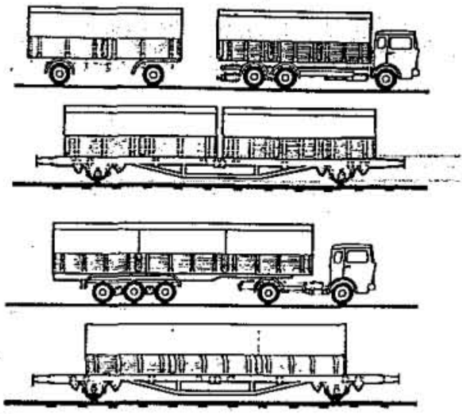
Various body lengths can be moved by this system, the most popular being 7.15 metres, 9.12 metres, and 12.2 metres (which is the same length as a forty foot container). The length of body can vary as long as the lifting and vehicle mounting points conform to standard dimensions and positions, though the mix of body lengths influences space utilisation of the rail wagons.

Demountable systems of various types are in use on most of the railway systems in Europe and Scandinavia. The experience in France has been that road operators who are attracted initially by the Kangaroo system often change to demountables when the advantages of greater volume per vehicle become apparent.

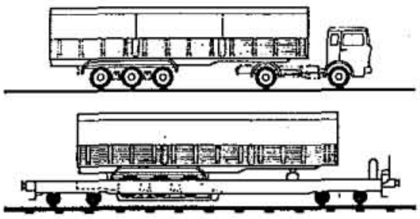
Figure 2

EUROPEAN PIGGY-BACK SYSTEMS.

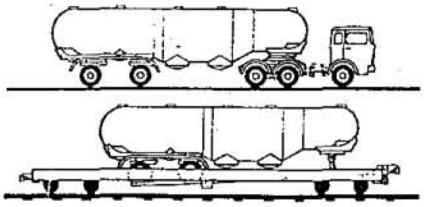
a) Demountables/Swop Bodies
(Lo-Lo)



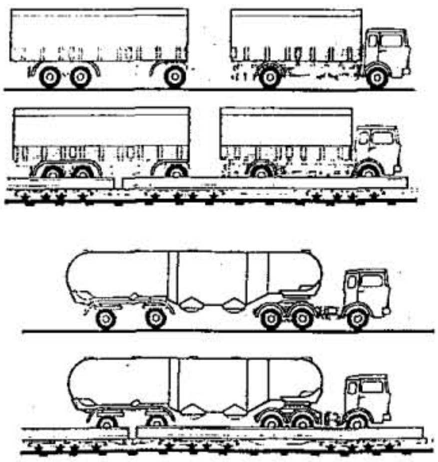
b) Semi-trailer on Well Wagon
(Lo-Lo)



c) "Kangaroo"
(Ro-Ro)



d) "Rollende Landstrasse"
(Ro-Ro)



4.2 Kangaroo and Lo-Lo.

The original concept of the French Kangaroo system was to use a tug, fitted with a lifting fifth wheel coupling, to push or pull semi-trailers along a train of rail wagons. The latter were fitted with a well or pouch, hence the name Kangaroo, into which the specially adapted tandem axle bogie of the road semi-trailer fitted. The vehicles are restricted in height, the bodies being chamferred at the top corners, and weigh about half a tonne more than a normal semi trailer.

One disadvantage of this system in operation was found to be the sequential loading and discharge of trailers at terminals. This proved to be time consuming, and the removal of a particular trailer in the middle of a train was difficult.

In order to improve the speed and flexibility of terminal operations, the system was developed to use lift-on lift-off techniques (lo-lo). Generally container style overhead cranes were used, fitted with grappling arms to lift the trailers by their frames. Obviously the trailers required some strengthening which adds about 0.5 tonnes to their tare weight. The lo-lo system does allow heavier trailers with tri-axle bogies to be carried by rail than was possible with the original Kangaroo system.

4.3 "Rollende Landstrasse".

In Germany, where the DB has the advantage of a more generous loading gauge, the 'rolling highway' system has been developed. It is also in use in Austria and Switzerland. The restrictions as to the height of road vehicles carried varies by route, the limit through the St. Goddard tunnel on the route from Basle to Chaisso in Italy has been increased to 3.7 metres, the Swiss Government having financed a SFr50 million operation to lower the rails through the tunnel.

An initial assessment may seem to indicate that this is the system which would answer the railways inter-modal dilemma. The rail wagons are fitted with small wheel bogies which allow a very low floor which is extended to join the next wagon. This allows complete road vehicles (including tractors) to be driven the length of the train in a roll-on roll-off operation (ro-ro).

Operational experience has shown that the small wheel bogies incur heavy maintenance costs. However, the main disadvantage is that the trains have a small payload in terms of goods conveyed relative to the trailing weight of the train. For example; the net payload of the road vehicles carried on a train of 1,100 tonnes gross weight would be only about 450 tonnes. The individual rail wagons cost £90,000 to convey a tractor and semi-trailer, which in turn carry a payload of 25 tonnes (Stone 1987). The system is therefore uneconomic.

None of the European intermodal systems have proved to be very profitable, or exceptionally attractive to road transport operators. They do carry moderate amounts of traffic, and have been most successful in countries where quantity restrictions on road freight transport exist, namely France and Germany, as well as for international movement of Italian traffic to overcome permit restrictions, and the weight limits imposed by Switzerland.

5. Inter-modal developments in the U.K.

The W5 loading gauge within Britain means that development of a practical, and commercially sound inter-modal system is even more difficult than for British Rail's continental contemporaries. Nevertheless, several new systems have been proposed in recent years, and three of these have now reached prototype testing stage. These encompass both demountable and piggyback systems within the B.R. gauge.

5.1 Minilink and Maxilink Demountables.

The two demountable systems being developed by B.R. (in conjunction with a Swedish manufacturer, Kalmar Lagab) are similar in that small and medium size containers are carried on road vehicles fitted with mechanical or hydraulic equipment which can transfer the demountable body to a rail wagon. The disadvantage of the system is that the tare weight of the road vehicle is increased by up to 1.5 tonnes, limiting the payload. This problem can be partially overcome by providing only a few vehicles with transfer equipment which are retained at the terminal. Most of the road collection and delivery fleet is then only fitted with the mounting system on which the demountable bodies rest when in transit.

British Rail is undertaking commercial trials with its demountable system under the brand name of Minilink, between London and Glasgow. It is aimed at the part vehicle load market, where the rates per tonne mile are relatively high, and the goods are currently transferred between road vehicles at depots, or delivered by a large vehicle on a multi-drop round. For this type of traffic, road operators cannot offer such a good service at low rates as they can for full loads over long distances. It is a part of the freight market where B.R. has not offered a service for a number of years, and is one where the rates could withstand the costs of terminal operations in changing modes.

5.2 Trailer Train.

It is over twenty years since the last British attempt at piggyback operation was abandoned with the demise of the Road Railer concept. The main disadvantage of that system was that it carried both road and rail wheels at all times, thus severely restricting the systems payload.

Trailer Train consists of a 12 metre semi-trailer fitted with a tri-axle bogie with air suspension for road operation. At the transfer terminal, only a level apron with rails flush with the road surface is required. The road tractor positions the rear of the semi-trailer over a special rail bogie, and then lifts the road wheels by exhausting the air suspension bags. The tractor then detaches from the trailer, having lowered its landing legs. Several semi-trailers can be combined at the terminal, each trailer sharing a rail bogie with the next, being pushed together by a road tractor to form a train.

The Trailer Train semi-trailers have some disadvantages. As they are built to act as the rail vehicles, they have to be capable of withstanding rail buffing loads and stresses. This results in the strength of the trailer being much greater than the equivalent road trailer, the tare weight of the prototype being 11.5 tonnes. Each unit has a capacity disadvantage compared to a 38 tonne GVW lorry. In terms of payload this amounts to two to three tonnes, though it is claimed that production units will have a capacity of 23 tonnes. However, the chamfered corners also restrict volume and ease of loading.

Nevertheless, the prototype vehicles are undergoing evaluation, and being assessed by potential users. There are also very similar designs being developed in both France and Italy. Hopefully, the three (or more) systems will be manufactured to compatible standards to allow operation through the Channel Tunnel.

5.3 Tiphook Rail.

The Tiphook system is based on a novel idea; the 'swing deck' rail wagon. This is a form of well wagon in which the well section is hinged so that one end can be moved sideways, which allows semi-trailers to be reversed into the well. The road tractor unit is removed, the swing deck then being returned to its position for rail travel. The prototype rail wagon was of a two axle design which would restrict payload capacity of the semi-trailers carried when operated on the continent. It is likely that production versions will be of a four axle bogie design, which can also be used for the carriage of containers so as to increase the flexibility and utilisation of the piggyback wagon fleet.

Although the semi-trailers used are not standard, the major difference is that a narrow track bogie is used. In terms of original cost and capacity they will be virtually the same as standard road equipment. It is intended that they can be used in direct road operations as part of the general road fleet to avoid loss of utilisation through having mode specific trailers.

Both the above piggyback systems reduce to a minimum the facilities required at terminals thereby reducing costs, though sophisticated rail equipment is required which may off-set some of these cost savings. Apart from the provision of a network of piggyback train routes, these vehicles will allow piggyback sections of ordinary freight trains to be forwarded by large consignors direct from their works destined for various customers not connected to the rail network.

5.4 Small Wheel Bogies.

The small wheel bogie is not in itself an intermodal system, and their main use will be to lower the floor level of general rail vehicles, increasing the volume available within the body. However, one type of rail vehicle which these permit has a low platform to carry demountable bodies, or possibly complete road vehicles, including new commercial vehicles being delivered from the manufacturer.

Railfreight Distribution are examining the possibilities of using such wagons to carry both containers and large demountable bodies, particularly in the context of traffic through the Channel Tunnel. Current plans are for units up to 9ft 6ins high, which may be of various lengths, including those greater in length than the maximum forty feet allowed at present.

6. Market for Bi-Modal Services.

Each of the bi-modal systems proposed for use in the U.K. is suitable for certain types of traffic, and each should allow B.R. to compete for traffic which it cannot gain at present. The success of the bi-modal system will depend largely on the operating costs of the production version rather than the prototypes currently under evaluation.

Until more cost information is available, it is not possible to estimate with precision the distance over which any of the proposed systems becomes competitive with direct road operations. In any case, part of the traffic may be carried over shorter distances on a marginal cost basis. For instance, the break-even distance for Freightliner operations is thought to be well in excess of 200 miles, though the service is operated over a few routes of less than this distance.

In calculating the distance over which inter-modal traffic becomes cheaper than road operation, there is a trade-off between the low trunk haulage costs rail can offer between terminals, and the costs involved in the transfer of vehicles between modes at these terminals, together with the collection and delivery operation. One aim of all the new bi-modal systems is to reduce the capital and operating costs of terminals when compared to those required by Freightliner.

Nevertheless, the competitive distance for many of these services may well prove to be of the order of 200 miles. Within the U.K. the proportion of traffic which is conveyed more than 200 miles is relatively low , some of this being in diverse flows only suited to movement by individual units or wagons. The major long distance freight flow in the U.K. is along the London-Birmingham-North West-Clyde Valley corridor and any network of rail services designated for inter-modal traffic will include this corridor as its main artery.

In order to explore the competitive position of inter-modal services, not only is it important to determine the distance at which a system can compete, but also to assess over which routes traffic of suitable commodities for inter-modal carriage is consigned and whether the volume is sufficient to support a regular service. Data on the movement of goods by road is published annually (DTp 1988) showing average length of haul for various commodities, and inter-regional flows. Additional information has been supplied by the Department to allow a more detailed assessment of the traffic between the South East and Scotland to be underatken.

This data, together with the valuation of quality of service attributes (Fowkes, Nash & Tweddle 1989) and the cost model, allows a case study of the most promising inter-modal route within the U.K. to be undertaken. The information regarding demand in terms of quality as well as quantity has been produced.

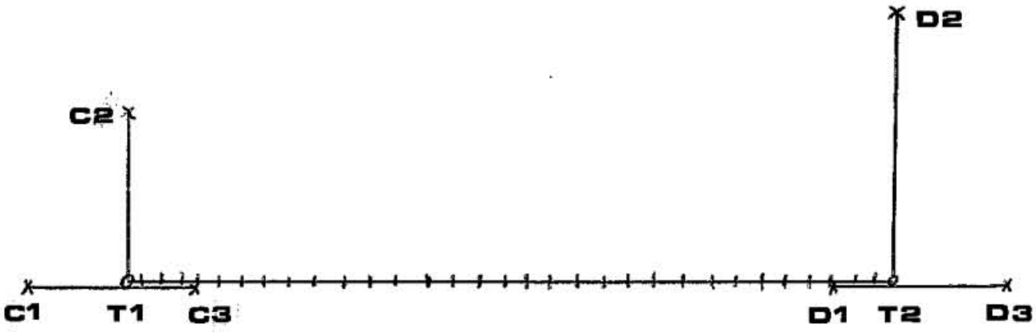
7. Development of a Computerised Cost Model.

In order to make cost comparisons between road and intermodal services, a program has been developed to calculate the distance between any two points, both direct (by road) and via an intermodal service, as shown in Figures 3 and 4. Here the distance between the intermodal terminals T1 and T2 can be varied, as can the distance from the terminals to collection and delivery points (C1-C3 and D1-D3). If account is taken of the distance and direction of the collection and delivery points from a terminal, then the distance from the collection point to delivery direct (taken as the direct road transport distance) can be calculated using trigonometrical equations, as described below.

7.1 Calculation of Distances in the Model.

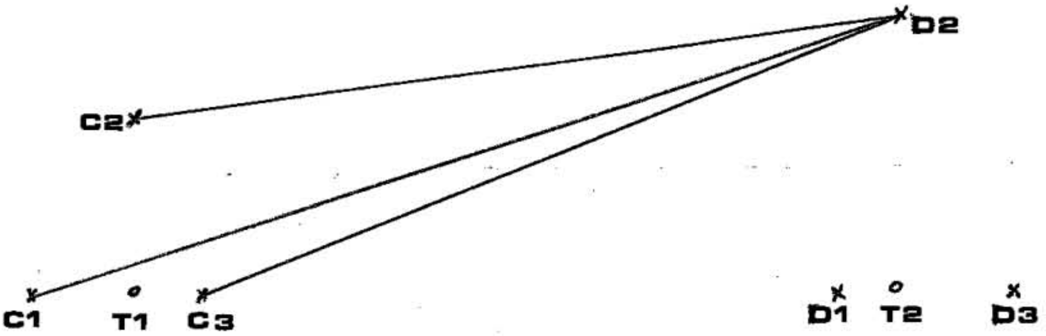
The model works on the basis that initially data on the intermodal movement to be tested is entered interactively. This consists of the distance between the inter-modal terminals (say 300 miles), the distance of the origin of the goods to the despatch terminal (say 20 miles), and the angle (A1) which this collection route forms to an imaginary reference line drawn between the two terminals.

Figure 3. Diagram of Intermodal Model.



The computer program has been designed to calculate the distance between each collection and delivery point direct. (See Figure 4). The distance from collection points (C1-C3) to D2 is calculated as a straight line, giving the shortest possible route by road.

Figure 4. Diagram of Road Transport Model.



The following trigonometrical expression is used to establish this distance (D1):

```
D1 = SQR(((D2*SIN(PI/180*A2))-(D3*SIN(PI/180*A1)))^2)+
     ((TT+D2*COS(PI/180*A2))-D3*COS(PI/180*A1))^2))
```

The components of this expression are shown in Figure 5.

7.2 Road Haulage Costs.

Road haulage rates are estimated from equations in the programme which have been calculated from rates data supplied mainly by the F.T.A. These rates can be adjusted interactively to take account of inflation, or differentials in the quality of service.

The distance is estimated for the direct road distance (as described above), and the haulage costs for that type of vehicle are calculated using the cost equations built into the program. The cost per vehicle is then converted in to a cost per unit of capacity, and compared to the intermodal cost.

In developing the costs of road transport to compare with various intermodal systems, three levels of cost are used. The first reflects the round trip cost, loaded both ways, giving a low cost per unit carried. A second high cost scenario where backloads are not available, and the average haulage rate for a journey of a given length is a third, making an allowance for travel to the point of collecting the return load. It is the latter cost which is normally used as the basis for the estimation of break even distances.

7.3 Costs of Inter-modal Transport.

Costs relating to the rail trunk movement, rental of the inter-modal unit or container, and terminal costs are entered

Fig.5 **Distance by Road**

Direct by Road

Unknown **D1** — — — — — —

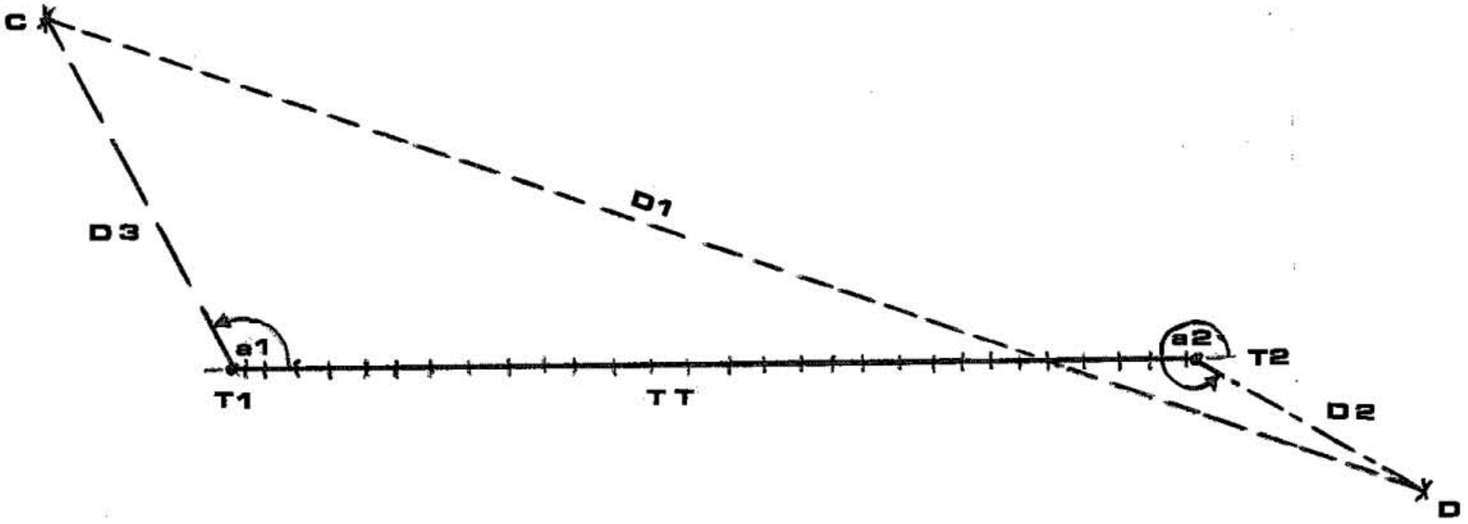
Inter-modal

Road collection **D3** ——— ——— ———

Rail trunk haul **T T** +++++++++++

Road delivery **D 2** —·—·—·—

Angles to base line **a1** **a2**



interactively. The type of inter-modal unit and road vehicle are also entered, together with their capacities in units of either weight or volume. Costs relating to the collection and delivery of inter-modal unit are built into the programme as data.

7.4 Determination of Terminal Catchment Areas.

The computer now has data on the location of the collection and a set of costs associated with that particular movement to the destination terminal. The object is to find the area around the receiving terminal in which the container can be delivered at a cost lower than road transport can offer for a direct delivery from origin to destination.

In order to accomplish this the computer first works out the cost of delivering the container 10 miles along the reference line away from despatch terminal. Thus the total distance would be from the collection point to the despatch terminal, the trunk haul (20 miles and 300 miles in this case), plus 10 miles for delivery. The costs for the operation consist of collection and delivery, trunk haul, terminal and unit rental costs, divided by the capacity of the unit. The result is a cost per tonne or cubic metre.

If the cost of inter-modal is less than that by road, ten miles is added to the delivery distance from the terminal as an iterative process, and the costs recalculated. This is repeated until inter-modal becomes more expensive than road haulage, and a distance ten miles less is flagged as the maximum competitive distance in that direction from the receiving terminal. The maximum distance from the terminal for delivery is set at 150 miles on the basis that, within the U.K., inter-modal terminals are unlikely to serve an area greater than this.

The program then looks at an alternative delivery to a point along a line 15 deg. from the imaginary base line between the terminals. The maximum distance at which inter-modal is cost competitive in this new direction is calculated as above, and the iterative process continued at 15 deg. intervals until an arc around the receiving terminal has been generated in which the inter-modal system being examined is cost competitive with road haulage.

7.5 Sources of Data.

Data used for the cost model has been obtained from a variety of sources. Road transport rates are calculated from semilog regression equations of the form:

$$\log(\text{rate}) = a + b \times \text{distance}$$

These were estimated using raw data supplied by the F.T.A. for various types of movements of over 95 miles, together with rates quoted during a recent survey of manufacturers undertaken as part of this study (Fowkes, Nash & Tweddle 1989). A semilog equation was thought to give a better representation of the changes in rates over distances between 100 and 500 miles than was obtained using a linear one. The rates quoted all applied during the period September 1988 to April 1989.

Turning to data for the intermodal system, Freightliner provided sample data for trunk haul costs, together with utilisation of train space and terminal handling costs. These costs applied to services offered in 1986. As the network has been rationalised to improve productivity since that date, and on advice from Freightliner the costs given were not adjusted for inflation, it being assumed that subsequent inflation had been exactly offset by real cost reductions. Collection and delivery costs using freightliner vehicles were known from a previous study in 1983, and a 15% increase was applied to these on the basis that haulage rates in general over the period rose at an average 2% p.a.

Information on the capacity of the various inter-modal systems was gathered from British Rail and Novotrans (the French based Inter-modal operator), as well as promotional material supplied by equipment manufacturers. The latter source was used for information about road transport equipment.

7.6 Application of the Model.

In applying the model, it is particularly important to consider the likely spread of exact locations of consignors and consignees. If on a particular route a large flow of suitable containerised traffic can be found whose collection and delivery points are close to the respective terminals, then such a route may become viable for inter-modal operation based on an individual flow. This is not the normal situation. In general it is likely that each terminal would require a hinterland extending as far as 30 miles in most directions from the terminal from which to gather sufficient traffic to support a viable service. Even this assumes that the hinterland contains transport using industry, and the terminal is located so that it is between the flow of traffic and its customer base to minimise over-haulage.

By developing a scenario in which the inter-modal terminals are set fixed distances apart, an indication of the breakeven distance for each of the inter-modal systems can be determined, as well as the geographic area of the terminals hinterland from which it will draw traffic. Even when the competitive distances have been calculated it should be remembered that Freightliner already has a significant cost advantage over long distances such as London- Glasgow (400 miles), but road transport predominates on the route. It is presumed that this is due either to the goods being volume constrained, or to differences in the quality of service (see Working Paper 276).

Of course mode choice decisions are not made entirely on the grounds of cost. To remain competitive rail services must offer in addition speed, frequency, and most important in the era of 'just in time' delivery, is a high level of reliability. In the case of traffic moving in full loads by 12 metre trailers, rail is in direct competition with road haulage. With less than full loads rail has the opportunity to offer a better service with the demountable Minilink system, where the consignor can load a small container with goods for delivery direct to the customer.

Another part of the project has therefore attempted to measure the value manufacturers of various types of goods place on quality of service in freight transport (Fowkes, Nash & Tweddle 1989). This demonstrated that the carriage of some commodities, notably manufactured goods, require a very high quality of service and the reduction in the freight rate to extend the transit time by half a day was over 25%. It is not conceivable that an inter-modal system for use within the U.K. could provide cost reductions of this magnitude. Such systems must, therefore, provide a quality of service equivalent to that offered by road transport if they are to capture such traffic.

So far only the carriage of internal U.K. trade has been considered. It is likely that with the completion of the Channel Tunnel rail will become much more competitive for traffic to other European countries, and this is a sizable and expanding market. In 1983, 35% of U.K. imports and exports used either container or un-accompanied ro-ro trailers as the method of transport. A further 16% travelled by driver accompanied vehicle (Mackie, Simon & Whiteing, 1987).

The U.K.-European market, in which inter-modal can share, already amounts to over two million ro-ro units per annum to the continent from the Britain. This can be expected to increase rapidly towards the end of the centuary. Continental traffic has an additional advantage for rail in that as distance increases, rail becomes more competitive in terms of speed. For distances of over 400 miles on the continent, even current rail wagonload services can be as fast as conventional road movement.

8. Conclusion.

The success of the bi-modal systems being developed depends not only on their technical ability to handle general merchandise traffic, but on their operating costs. If they can produce cost effective services, they will be attractive not only for a network of separate services, but also for large consignors dispatching units direct from production sites by wagon load Speedlink trains, for final delivery by road.

This paper has discussed the alternative technologies available, and developed a cost model for comparing the cost of inter-modal transport and road haulage. The results of applying the cost model, in the light of the study of the value of quality of service attributes in Working Paper 276, are described in Working Paper 286.

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