Lorry transport: British experience

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SYNOPSIS: Developments in lorry transport in Great Britain over the last 30 years are briefly described with particular emphasis on aspects affected by Government action. These include regulations on vehicle weights and dimensions, safety, noise and emissions, rates of vehicle tax, and the provision of roads and bridges. National Traffic Forecasts for Great Britain indicate continued growth in lorry traffic around 50% over the next 25 years. Attention is drawn to the advantages of articulated vehicles with six axles and a maximum axle weight of nine tonnes.

1 INTRODUCTION

Most of the work of this Symposium will be devoted to discussion of the latest research findings about the interface between lorries and the road pavement.

This presentation is about lorry transport in a much wider context. How has the lorry, and the road system it uses, developed over the last 20 to 30 years, and what are the long term prospects? What follows is a summary of British experience and British perceptions. But the basic forces at work have been, and will be, similar in all industrialised countries.

2 LORRY TRANSPORT IN THE EARLY 1960S

Figure 1 depicts a typical lorry engaged in long distance haulage 30 years ago. The maximum permitted weight for an articulated vehicle was 24 tons, and the maximum length 33 feet. The vehicle would have a payload of 15 tons at most. Drawbar trailer combinations were permitted at 32 tons gross weight and a length up to 60 feet (18.3 metres), but they were subject to a 30 mph speed limit and regulations required two men in the cab, so they were not economic. Most freight moved small distances on two axle rigid vehicles. In total there were over 600,000 lorries in 1960 and they handled half Britain's freight (in ton miles) - the remaining half was shared about equally between the railways and coastal shipping.

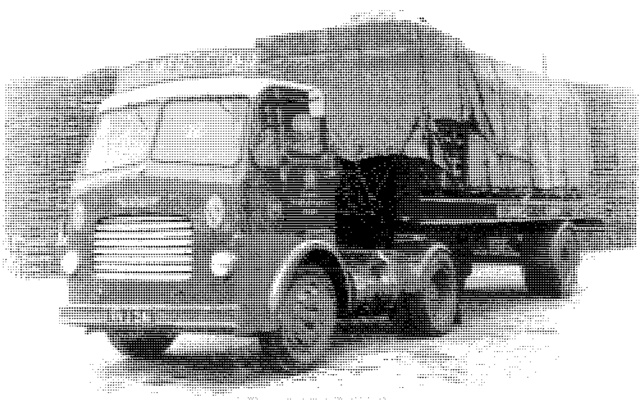


Figure 1 Old 3 axle articulated lorry

The speed limit on ordinary roads had recently been raised to 40 mph for articulated lorries, but there was no speed limit on the new M1 motorway from London to Birmingham. A survey in 1962 showed that lorries averaged 40 mph on this motorway. Lorry traffic on the non-motorway road system was perceived as a nuisance and hazard to car traffic; on any moderate up gradient it was a familiar experience to be trapped behind a lorry doing around 25 mph and emitting clouds of black smoke.

There have of course been enormous changes since that time. Lorries have got faster and cleaner. They have also got safer despite being bigger and heavier. They are more efficient and have replaced rail transport in all but some specialised sectors. The ingredients in this success story are familiar - vehicle technology, the development of motorways and other high quality roads, and the entrepreneurial skills of those engaged in road transport.

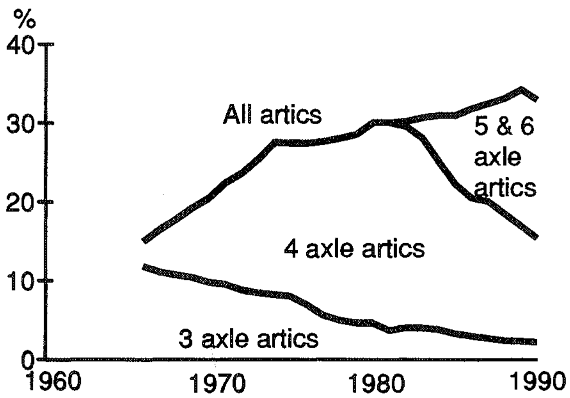
3 INCREASES IN LORRY WEIGHTS AND DIMENSIONS

Increases in size and weight of lorries have been crucial to the economic performance of road transport, and have also been at the heart of political debate about the lorry.

In this country very substantial increases were made in the 1960s. In 1964 the maximum gross weight of an articulated lorry was raised from 24 to 32 tons (32.5 tonnes) on 4 axles, and the maximum axle weight from 9 to 10 tons (10.17 tonnes). In 1968 the length limit was raised to 15 metres. The latter figure accommodated 40 ft containers, and was adopted throughout Western Europe, but most countries went to a gross weight of 38 tonnes.

In the late '60s and early '70s the 4 axle articulated vehicle rapidly became the predominant vehicle for freight movement in this country (see Fig.2). Our mileage of motorways was growing, but towns and villages not yet bypassed found these large vehicles most objectionable. Their use for distribution in larger urban areas also gave rise to much ill feeling. People were reacting to the

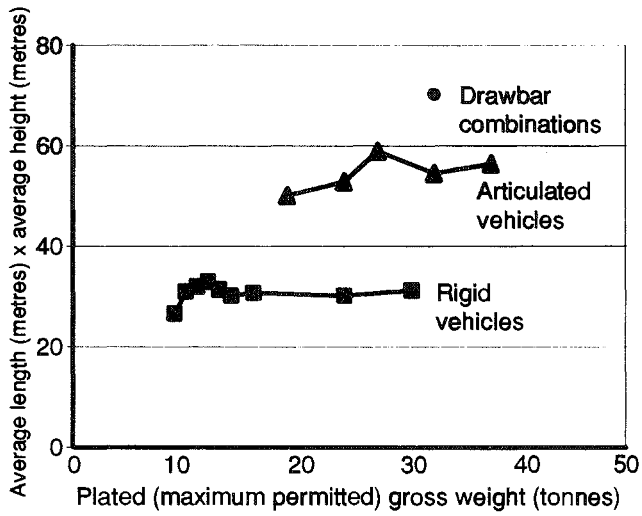
Figure 2 Proportion of all HGV traffic that is articulated (all roads Great Britain)



Source; Transport Statistics Great Britain

characteristics obvious to them, principally the size, but also noise. However, the gross weight became the symbol of everything objectionable. Actually, there is very little correlation between size and weight of heavy vehicles in present use (see Figure 3). But this is a difficult point to explain, and it was commonly thought that "heavier" meant the same as "bigger".

Figure 3 Vehicle dimensions : size in relation to weight



Source; TRL surveys at Doxey (1983 and 1985), Boughton (1984), Towcester (1986), Wylye (1988) and Carlisle (1988).

	Rigid	Artic	Drawbar
9-10	26.67		
10-11	30.99		
11-12	31.93		
12-13	32.94		
13-14	31.41		
14-15	30.20		
16-17	30.75		
19-20		50.12	
24-25	30.15	52.91	
27-28		58.90	
30-31	31.17		
32-33		54.50	70.29
37-38		56.39	

Against this background the Government commissioned an inquiry led by a distinguished lawyer, Sir Arthur Armitage (previously a Fellow of Queen's College Cambridge). He produced his report on "Lorries, People and the Environment" in 1980. The report had a wide range of recommendations to lessen the impact of the lorry, by traffic management and new roads as well as by improved vehicle technical standards. But the most controversial recommendations related to the maximum gross weight. From 32 tons (32.5 tonnes) on 4 axles, Armitage recommended increases to 38/40 tonnes on 5 axles (depending on configuration) and 44 tonnes on 6 axles. A small increase on the drive axle limit was recommended (from 10.17 to 10.5 tonnes). For tri-axle bogies a total weight of 22.5 tonnes was recommended.

The Armitage Report stressed the differences between the effect of lorry weights and the effects of lorry dimensions. It took a very firm stance against increases in the dimensions of articulated vehicles. It pointed out that the great majority of semi-trailers had been built as box vans or platforms 40 ft (12.2 metres) long, suitable for carrying freight of all kinds. In most cases the load was limited by the gross weight permitted on the articulated vehicle, not by the space available in the trailer. Thus increases in weight could be accommodated without any increase in size. To reinforce the point Armitage recommended a statutory limit on semi-trailer length of 40 ft (12.2 metres) and a statutory height limit of 4.2 metres.

After a great deal of political debate, the Government decided to raise the maximum weight of articulated vehicles to 38 tonnes on 5 axles. Their semi-trailers were required to have sideguards and conform with the length and height limits recommended by Armitage. The limit on drive axle weight was raised to 10.5 tonnes, and the limit on the tri-axle bogie set at 22.5 tonnes (7.5 tonnes on each axle with minimum spacing of 1.3m). Figure 4 depicts a typical vehicle.

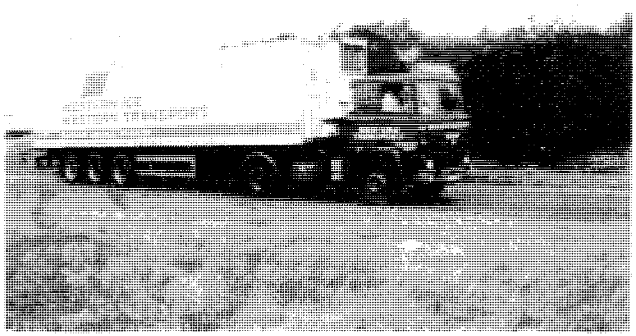
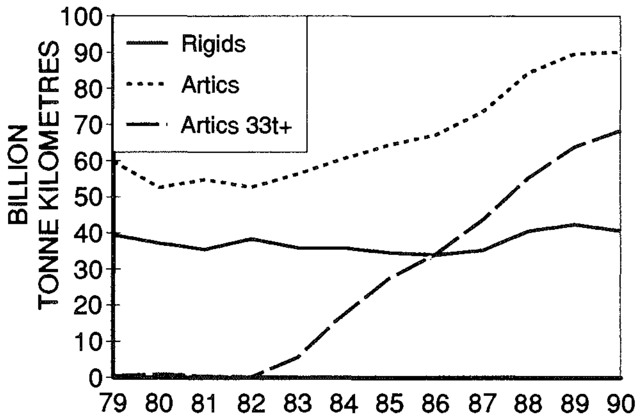


Figure 4 5 axle articulated vehicle

From 1983 when the new limits applied, the number of 5 axle articulated vehicles grew rapidly to overtake 4 axle articulated vehicles as the principal means of heavy road transport. Figure 5 shows tonne kilometres by vehicle type.

Figure 5 HGV freight moved by type and weight of vehicle (tonne kilometres)



Source; Continuing Survey of Road Goods Transport (CSRGT)

4 LOAD COMPENSATION AND AIR SUSPENSION

Before 1983 there had not been much use of triaxle semi-trailers in this country. We did not have evidence about the performance and effects of super single tyres, nor about the more complex compensating mechanisms needed for these bogies. The legal limits on weight and spacing were set to give equivalent bridge loadings to those imposed by existing 2 axle bogies. The low individual axle weight of 7.5 tonnes produces favourable road damage factors using the normal fourth power method of calculation.

It soon became apparent from our enforcement weight checks and other evidence that load compensation on the new triaxle bogies was poor. We therefore introduced in 1988 an incentive to the industry to adopt suspension arrangements that gave very good compensation. The incentive took the form of an increased weight allowance on each axle - 8 tonnes instead of 7.5 tonnes, providing the difference between axle weights (when measured statically) did not exceed 500 kg. Air suspension systems commonly available can achieve this, and operators have been quick to change to air suspension. This enables vehicles to be loaded up to 38 tonnes with far more confidence that individual axle weight limits will not be exceeded.

Research also showed that the performance of the suspension has a significant effect on the dynamic loads applied to the road by vehicles. Air suspension was shown to have beneficial characteristics but for cost and operational reasons was not considered suitable for all vehicle types. However, in 1989 a major step forward was taken when the European Community acknowledged the benefits of better suspensions and introduced a Directive (89/338/EEC) which increased the maximum permissible weight of certain vehicles used on international transport provided they were fitted with so called road friendly suspension. As the benefits of air suspension have been proved, road friendly suspension was defined as air or "equivalent" suspension. A subsequent Directive (92/7) has defined equivalence with a simple frequency and damping test. This is regarded as a first step with research continuing to find a more precise method. This is something on which the Symposium will be looking at the latest research evidence.

5 SAFETY

Figure 6 shows the overall accident involvement rate for heavy goods vehicles over the last 30 years. Involvement rate in fatal accidents has gone down by 70% and in accidents of all severities has gone down by 74%. The reasons for this include better primary safety - antilock brakes, tyres, lights, mirrors etc - better secondary safety - rear end protective devices and sideguards - and more professional driving and maintenance standards. Above all, the safety record has been helped by the growing mileage of motorways and high class road. In 1990 a third of all lorry mileage, and 45% of articulated lorry mileage, was on motorways.

Figure 6 Lorry accident involvement rates on roads in Great Britain

Heavy goods vehicles (over 3.5 tonnes gross weight) involved per 100 million kilometres

Accident type	1960	1965	1970	1975	1980	1985	1990
Fatal	10.0	9.7	8.5	5.1	3.7	3.6	3.0
All severities	212	174	149	90	68	63	56

For many years the lorry speed limit on motorways has been 60 mph (96 kph), but compliance with speed limits has been poor in recent years. In fact the most recently observed **average** speed of lorries on British motorways was 60 mph compared with 40 mph observed 30 years ago. We now have a programme for fitting speed limiters set at the 60 mph limit on all new HGVs over 7.5 tonnes, with a retrospective requirement for articulated vehicles less than four years old (first used after 1 January 1988). A recent European Community directive will require speed limiters to be set at 85 kph so as to provide a maximum speed under power of 90 kph (56 mph). This reduction in maximum speed will bring lorry speeds on motorways into a much narrower range. The effect on safety remains to be seen.

6 NOISE AND EMISSIONS

Noise limits on new vehicles in the UK became subject to Community Directives when we joined the Community in 1973. Initially, this was a setback; we were unable to implement improvements that TRRL research had shown to be technically feasible and cost effective. However, during the 1980s Community directives improved the standard so that a new lorry meeting the latest limit of 84 dB(A) (applicable in 1991) emits only 10% of the acoustic energy and sounds subjectively about half as loud as the equivalent new lorry 10 years ago. This improvement, combined with the numbers of bypasses taking lorries out of urban areas, has very much reduced nuisance from lorry noise. For the future we see three main areas of further improvement:

- a further improvement of at least 4 dB(A) for all new lorries
- increasing attention to noise prevention in the design of new roads; in particular earth mounds (bunds) and noise barriers
- on some sections of the road system, the use of porous asphalt road surfacing. Although tests show this material to be not as long lasting, and therefore more expensive than conventional rolled asphalt, a noise reduction effect of up to 4 to 5 dB(A) is obtainable initially; but reduces to 3 dB(A).

Better engines, better maintenance and better fuels combined to reduce the problem of smoke from lorries. For many years the Department's Vehicle Examiners have observed HGVs at similar sites throughout the country and have noted the percentage observed to be emitting excessive smoke. The trend has been downward as shown in Figure 7.

Figure 7 Lorry emissions
Percentage of HGVs observed emitting excessive smoke

1975	15.0
1980	12.2
1985	8.4
1989	2.8

Note: Average of roadside observations of approx.70,000 vehicles in each year

Other pollutants are now the subject of an EC type approval directive. Directive 91/542/EEC introduces improvements on Directive 88/77 EEC in two stages; the first takes effect (for new registrations) in October 1993 and the second in October 1996. The first stage makes substantial reductions in CO, HC and NO_x emissions and introduces a particulate limit for the first time. The second stage will require more effective pollution control systems on engines to achieve the limits set out in Figure 8.

There is considerable debate about the relative pollution of petrol and diesel engined vehicles, and the following comparison is of interest. If the concern is acid rain, then petrol engines are much to be preferred.

Figure 9 Comparison of petrol and diesel emissions from vehicles meeting EC standards

		Catalyst Equipped car (1992 onwards)	HGV (October1996 onwards)
grams per litre of fuel	CO	24.9	4.1
	NO_x	3.3	23.9
	HC	2.7	2.9

7 LORRY TAXATION

The taxation of lorries can be related to axle weights, and thus is of particular interest to this Symposium. In Britain it has been a longstanding principle of vehicle taxation that the total of fuel tax and vehicle excise duty paid by each category of vehicle should cover at least the proportion attributed to them of the public expenditure incurred in providing, maintaining and policing the road system. (These public expenditure costs are referred to as track costs.) One object of this is to ensure that road transport is not subsidised in comparison with transport by other modes, particularly the railways. Another objective is to discriminate between different types of heavy vehicle so as to charge more to those types that cause more wear and tear to roads.

Figure 8 Emission standards for heavy duty diesels

	Ec Directive 88/77/EEC	EC Directive 91/542/EEC Stage I 1993		EC Directive 91/542/EEC Stage II 1996		
Pollutant	Type approval limit	Type approval limit	% reduction over 88/77/EEC	Type approval limit	% reduction over 88/77/EEC	% reduction over 91/542/EEC Stage I
CO (g/kW.hr)	11.2	4.5	60%	4.0	64%	11%
HC (g/kW.hr)	2.4	1.1	54%	1.1	54%	0%
NOx (g/kW.hr)	14.4	8.0	44%	7.0	51%	12.5%
Particulates (g/kW.hr)	N/A	0.61/0.36	N/A	0.15	N/A	75% (max)

This second objective was not achieved in Britain until, in 1982 legislation was brought in to relate vehicle excise duty on different types of vehicle to the gross weight and number of axles. We are fortunate in having an excellent data base for road transport operation derived from our continuing survey of roads goods transport. This gives us up to date information on loads, lengths of haul and fuel consumption. This is combined with traffic census data for vehicle classes on different road types, and highway expenditure returns. All expenditure on reconstruction and resurfacing, and 80% of expenditure on patching and minor repairs, is allocated on the basis of standard axle kilometres. The table at Figure 9 reproduces the main figures for the 1992/93 track costs account for the four main classes of articulated vehicle.

Figure 9 shows how unit track costs for six axle articulated vehicles at 38 tonnes are around 20% less than for five axle articulated vehicles of the same maximum weight. This reflects not only the standard axle calculation, but also the fact that at present road reconstruction and the other items sensitive to standard axles make up a substantial proportion of total road costs - about £1 billion out of £6 billion in 1992/93. Although six axle vehicles have a favourable rate of VED as compared with five axle vehicles, they make a bigger surplus of tax income over costs.

We intend to apply the same taxation principles to weight increases which must be implemented by the beginning of 1993 to meet EC directive requirements. The weight limit on 4 axle articulated vehicles will be raised from 32.5 tonnes to 35 tonnes if either:

- the vehicle is on an international journey, or
- the driving axle is fitted with twin tyres and road friendly suspension.

Despite the road friendly suspension on the drive axle, this vehicle will be very damaging to roads compared with those we allow at present in the UK. The VED rate at 35 tonnes will therefore be set initially at £5,000, compared with £2,450 at 32.5 tonnes.

8 DEVELOPMENTS ON THE ROAD NETWORK

Lorry transport in Britain today is highly dependent on a high quality and reliable road network. Modern roads must be designed not only for heavy goods vehicle in normal service, but also for abnormal indivisible loads. Decisions made in the early days of the post-war Road Programme allowed quite a margin for accommodating large vehicles. The standard bridge clearance height of 16ft 6ins (5 metres) is more generous than in most other European countries. The standard has allowed the continued exploitation of vehicles that are high by European standards - double deck buses which are allowed up to 15 ft (4.57 metres) and high sided semi-trailers used generally for carrying bulky goods of low density. Such semi-trailers are used only in domestic transport; they can be regarded as an alternative to drawbar trailers for providing maximum cargo space.

Pavement designs have historically been based on the cumulative number of standard axles predicted to pass over the pavement during its prescribed life. With the growth of goods traffic and the increase in vehicle weights, existing empirical design methods had to be supplemented by analytical techniques. Research by TRL in the 1980s enabled design standards to be revised to reflect these changes. As a result pavements are

Figure 10 Road track costs and vehicle taxation 1992/93 Maximum weight articulated vehicles

					Annual Costs (£)		Annual Revenue (£)			
Max gross weight (tonnes)	axle con-figuration	number of vehicles (thousands)	Average km travelled (thousands)	Fuel consumption litres/1000km	per 1000km	Total	Fuel Tax (net of VAT)	VED	Total	Taxes minus costs
32.5	2+2	17.4	78	448	123.2	9,611	7,968	2,450	10,418	807
38	2+3	34.5	94	507	139.4	13,107	10,874	3,100	13,974	867
38	3+2	16.5	94	517	134.3	12,628	11,084	2,730	13,814	1,186
38	3+3	11.0	94	517	109.5	10,290	11,084	1,240	12,324	2,034

Note: diesel duty is 22.85p per litre (net of VAT) regularly required to accommodate up to 200 million standard axles (msa) compared with less than 20 msa only 30 years ago.

Updated design standards were published in 1987 in HD 14/87 (Structural Design of New Road Pavements) which made allowance for future HGV growth trends and changes in vehicle wear factors as a result of changes in vehicle weights and fleet composition.

Bridge Design: All **new** highway bridges on the UK road network are designed for loading effects which are equivalent in intensity to the load effects of normal traffic (maximum gross vehicle weight 38 tonnes), and to the effects of 40 tonne vehicles with 11.5 tonne drive axles. They are also checked for the effects of abnormal vehicles.

All **existing** highway bridges in the UK are currently being assessed to confirm whether they can carry the same normal loadings, including the 40 tonne vehicle. Those bridges which are found to be not capable of carrying these loadings will be temporarily weight-restricted pending strengthening.

We expect to complete our bridge assessment exercise by the end of 1998. Bridges in a dangerous condition may need to be removed. Figure 11 depicts the removal of such a bridge earlier this year at Ingst near Bristol. The bridge carried a minor road over the M4 motorway. It weighed 2,045 tonnes and was transported on a vehicle with 328 wheels, to a place where it could be safely broken up.

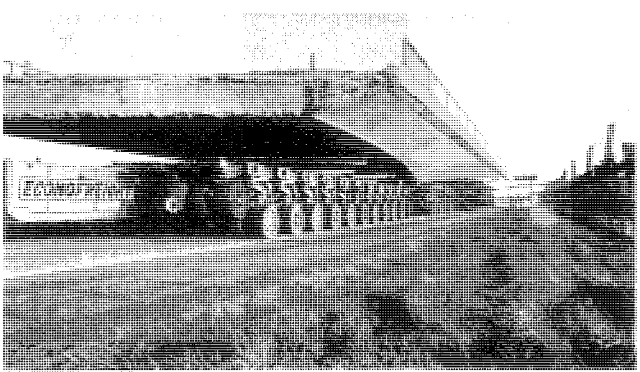


Figure 11 Bridge being carried on trailer

In the longer term any new vehicle types proposed for use on our roads must have axle weights and axle spacings such that the load effects on bridges are no greater than from vehicles in the current EC directive. The costs of another bridge assessment and strengthening exercise to deal with higher axle weights would be absolutely prohibitive.

Trunk roads are the direct responsibility of the Government - the Department of Transport in England, and the Scottish and Welsh Departments in those countries. The trunk roads amount to 4% of total road mileage, but they carry one third of all traffic and over half of heavy goods vehicle traffic. The trunk roads include 3,100 km of motorway, most of which was originally built or has been widened to dual three-lane standard, and a further 3,800 km of dual carriageway of varying standard. The current programme for trunk road improvements in Britain envisages a further 500 km of new motorway, (including 300 km of converted trunk road), 1,000 km of motorway widening, mostly to dual four-lane standard, and 2,300 km of trunk road improvement - providing dual carriageways

9 NATIONAL TRAFFIC FORECASTS

The programme is based on our national road traffic forecasts for Great Britain, last revised in 1989. Total traffic, and especially peak hour traffic, is of course, dominated by the private car, but forecasts of road freight and lorry traffic are nonetheless very important.

Demand for road freight depends on the rest of the economy - trading patterns, distribution methods, the organisation of other industries, and the price and quality of service offered by road hauliers in comparison with other modes. We do not have, and it is believed that nobody else has, information on stable relationships between all these factors which could be modelled and used as a basis for forecasts. But it is a fact that over the last 25 years in Britain the volume of road freight has risen remarkably closely in line with gross domestic product. If that relationship continues to hold, we can expect the volume of freight carried by road to more or less double over the next 25 years. (See Figure 12.) Nobody knows what will be the pattern of commodities carried in 25 years time. But it is reasonable to assume that bigger incomes will be spent on more goods which require movement and on more services which also require the movement of goods.

Figure 12 Road freight and lorry traffic 1965-2015

Road freight		billion tonne kilometres
1965	1990	2015
69	136	220-300

Lorry traffic		billion vehicle kilometres
18.2	29.6	40-53

On the assumption that the trend to using lorries with higher capacity continues, but with no change to maximum weight limits, lorry kilometres would rise by around 50% over the same period. As the figure shows, this is what has happened over the last 25 years.

These forecasts seem sufficiently robust to remove any doubts about the growing economic importance of the lorry, and therefore of the importance of research aimed to help optimise the design of the vehicle and of the road which it uses. The use of rail freight for distribution within Britain continues to decline, and there is no realistic prospect of any revival on a scale that could dent the forecasts. If coal and petroleum products are excluded, road transport in 1990 had 94% and rail transport 6% of the traffic carried by those two modes. The Channel Tunnel will produce opportunities for international rail freight, but the volumes which the operators expect to carry, though important in their particular markets, are very small in comparison with total freight movement in Britain.

10 COMPARISON OF SOME CONFIGURATIONS OF HEAVY ARTICULATED LORRY

Current UK weight limits at least for international vehicles must, by 1999, be raised to those prescribed in the European directive. The Commission know that we are extremely concerned about this because it will lead to a very substantial increase in standard axles from heavy lorry traffic. The potential scale of increase is illustrated in Fig 11 which gives calculations of damage numbers for fully loaded vehicles by applying the fourth power rule to typical axle weight distributions. The damage number for the 38 tonne vehicle on 4 axles is particularly alarming. For 5 axle vehicles, the increase from 38 to 40 tonnes increases the damage number by 15%. The EC directive gives no encouragement to operators to equip with 6 axle vehicles. The table shows the favourable effects of a 6 axle vehicle at 44 tonnes with equal loading on the second and third tractor axles, as recommended by the Armitage Inquiry 12 years ago. Besides helping reduce highway maintenance expenditure, that vehicle offers

Figure 13 Comparison of UK maximum articulated lorries with those to be permitted under EC Directives in 1993 and 1999

	Maximum weights (tonnes)		Typical axle weights of fully loaded vehicle								For each 1,000 tonnes freight	
	Gross weight	Drive axle	Tractor unit 1st	2nd	3rd	Trailer 1st	2nd	3rd	Standard axles	Pay load (tonnes)	Number of vehicles	Damage number (total wear & tear to roads)
4 Axles:												
existing UK	32.5	10.5	5.9	9.6	-	8.3	8.7	-	2.0	20.1	50	101
to be permitted On 1/1/93	35	10.5	6.0	10.4	-	9.1	9.5	-	2.8	22.3	45	125
to be permitted on 1/1/99	38	11.5	6.5	11.5	-	10.0	10.0	-	3.9	25.1	40	156
5 axles:												
existing UK	38	10.5	6.2	9.8	-	7.2	7.4	7.3	1.9	24.2	41	80
to be permitted on 1/1/99:												
(1) generally	40	11.5	6.3	10.3	-	7.8	7.8	7.8	2.4	26.1	38	92
(2) in "combined transport"	44	11.5	6.2	6.8	11.0	10.0	10.0	-	3.8	29.6	34	129
6 axles:												
existing UK	38	10.5	5.6	4.9	7.6	6.6	6.6	6.6	1.1	23.2	43	47
as recommended by Armitage Inquiry	44	9.0	6.0	7.3	7.3	7.8	7.8	7.8	1.8	28.5	35	63

considerable economic advantages to operators.

All European manufacturers produce models of 3 axle tractor units satisfactory for 44 tonne operation, and with equal loading of the two rear axles already a feature, or one that could be provided very easily. There are two main alternatives; the 3 axle tractor unit can be fitted with double drive, or the single drive axle can be arranged to operate at no more than 9 tonnes in normal conditions but with a load transfer device to increase temporarily the weight on the drive axle when extra adhesion is necessary.

There seems to be an opportunity here that should be assessed by all those concerned to get the best out of lorries in future years. It is to be hoped that the work of this Symposium helps governments and industry to quantify the advantages of a 6 axle heavy freight vehicle, and identify the technical features to produce the best result on balance for operators, for those responsible for designing and maintaining roads and, ultimately, the general public.