Heavy Vehicles — Some European Observations

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INTRODUCTION

This paper has been prepared to give some facts regarding weight, dimensions, and influence on pavements of heavy vehicles in Europe, particularly in the EEC countries.

Studies related to axle loads, road wear, and pavement maintenance are briefly described through examples mainly from Denmark. Finally, a few shortcomings and problems are discussed.

Europe, including the European part of the Soviet Union, covers an area of 10,400,000 km^2, which is only a little more than Canada (9,221,000 km^2) or the USA (9,347,000 km^2).

Europe consists of 35 states that each has its national legislation and regulations on heavy vehicle weight and dimensions.

In Western Europe road transport is the most important transport mode. This is so both for passenger and for goods transport. As for the latter, heavy vehicles play the major role, except on short distances in urban areas.

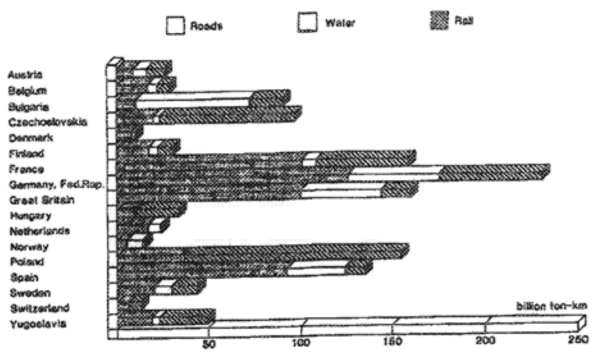
Figure 1 illustrates the volume of domestic goods transported in some European countries expressed in ton x km and distributed on 3 transport modes: truck, ship and railway.

The figure shows that the transport volume in Eastern European countries is larger on railways than on roads. In some countries the volume of domestic transport by ship is high.

Twelve of the countries are members of the European Economic Community (EEC).

Within the EEC, studies and negotiations regarding weight and dimension of vehicles have taken place almost since the initial formation of the Community. The aim has been to harmonize the regulations on weight and dimensions of heavy vehicles to ensure equal opportunities for goods transport and thus also the trade relations between the EEC countries. These efforts have now resulted in an issuing of a directive on these questions from the EEC council, cp chapter 2 and 3. This directive will apply only for international transports and will come into force in the summer of 1986.

National regulations for weight and dimensions of heavy vehicles in Western Europe are not very identical. The regulations for vehicle trains may be especially complex.



Inland surface goods transport – 1983

FIGURE 1

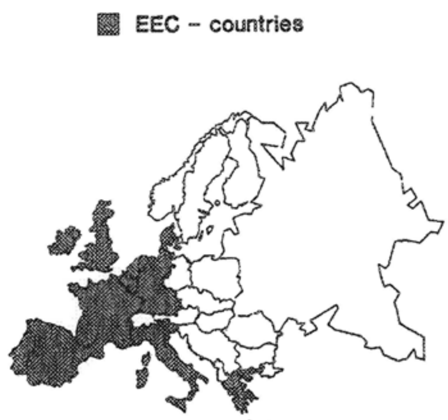


FIGURE 2

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AXLE LOAD LIMITS IN WESTERN EUROPE

In the following, weight regulations are elucidated through description of the regulations for axle loads on single axles, double axles, and triple axles, and the maximum total weight of vehicle trains.

SINGLE AXLES

Figure 3 shows the maximum axle load of a simple single axle with twin wheels. All countries now allow at least 10 tons axle load on the primary road network. Local roads may be subject to restrictions. The maximum load is 12 tons in Italy, and 13 tons in France, Belgium, Spain and Greece.

The new EEC directive for international transports between the EEC countries establishes the maximum axle load on a single axle that is not a driving shaft at 10 tons. The directive establishes no regulations on axle loads for driving shafts because agreement on this point has not yet been reached. Presumably, all countries have accepted 11 tons axle load as the limit for driving shafts, but some countries propose 11.5 tons as the maximum. Until agreement is reached, the national regulations apply in this matter.

DOUBLE AXLES

Figure 4 shows the conditions prevailing for double axles, i.e. total axle load for 2 axles placed closely together. All the countries mentioned below allow -- on certain conditions -- a double axle weight load of 16 tons. Some countries, e.g. France and Spain, allow as much as 20-21 tons. In many countries the maximum double axle weight depends on the distance between these two axles and possibly the distance to other axles.

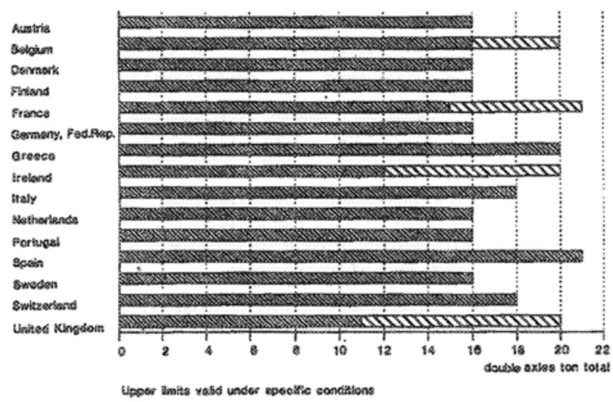
When the distance between the two axles exceeds a given distance, the axles are, in some countries, considered as two single axles. In Denmark, to take an example, this limit is 2.00 m.

The EEC directive for international transport establishes the maximum total axle load for double axles on trailers and semi-trailers at 11 to 20 tons depending on the distance between the axles as shown in Figure 5. The normal axle distance corresponds to 16 to 18 tons.

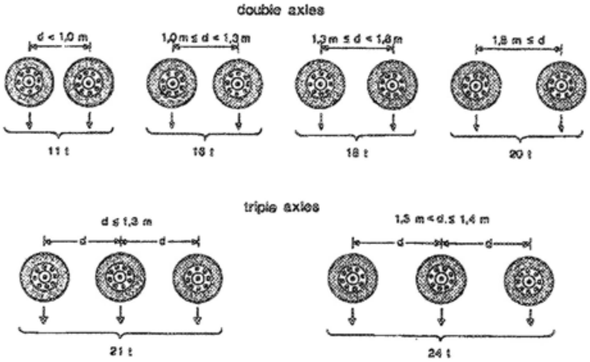
TRIPLE AXLES

For triple axles (3 axles mounted close to each other), the national regulations on the maximum

Maximum axle load
(double axles with twin wheels)
FIGURE 3



Maximum axle load
(double axles with twin wheels)
FIGURE 4



EEC – directive
FIGURE 5

axle load vary between 18 and 31.5 tons. The EEC directive establishes the total axle load at 21 tons and 24 tons, respectively, depending on whether the axle distance is below or exceeding 1.3 m (Figure 5).

MAXIMUM TOTAL WEIGHT

Figure 6 shows the maximum total weight for vehicle trains (truck and trailer). In this category the limits vary from 28 to 51.4 tons. Many countries have so far allowed a maximum of 38 tons total load.

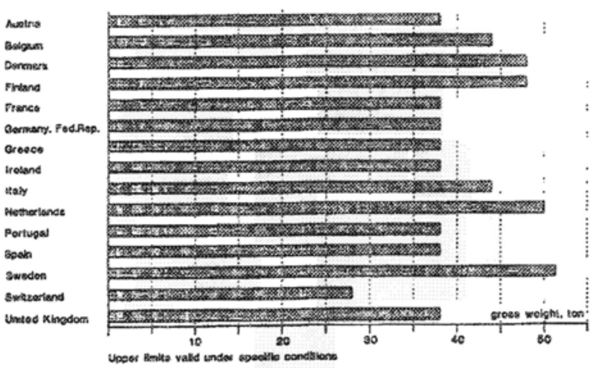
The EEC directive lays down the maximum total load for vehicle trains with 5 and 6 axles (including trailers or semitrailers) at 40 tons but allows up to 44 tons if a three-axle motor vehicle with a two- or three-axle semitrailer carries a 40 feet ISO container.

HEAVY VEHICLE DIMENSIONS IN WESTERN EUROPE

The EEC directive establishes the maximum height and width of vehicles at 4.0 metres and 2.5 metres respectively which corresponds to prevailing national regulations.

One European country outside EEC: Sweden - allows a width of 2.6 metres. As to the length of vehicles the following regulations prevail:

Truck: National regulations in European countries are found in the interval of 10 - 12 metres. The EEC directive provides for 12.0 metres.



Maximum gross weight of road trains (truck and trailer)

FIGURE 6

Tractor and Semitrailer: National regulations in the EEC countries: 15 - 16.5 metres. The EEC directive states 15.5 metres (Sweden allows 24.0 metres)

Truck and Trailer: National regulations in the EEC countries: 16.5 - 18.0 metres. The EEC directive: 18.0 m which already prevails in many countries. Sweden allows 24 m total length. Finland and several Eastern European countries allow 22.0 metres.

INFLUENCE OF HEAVY VEHICLES ON PAVEMENTS

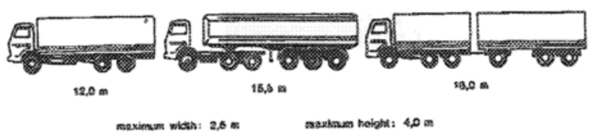
It is a well known fact that heavy vehicles have a decisive impact on deterioration of pavements and thus on the need to maintain pavements. The Danish Government, for example, spends almost 50 percent of its total road and bridge maintenance budget on pavement maintenance and rehabilitation. Therefore, it seems natural to look briefly into the phenomenon of road wear and to seek data for the single parameter carrying greatest importance: heavy vehicle loads.

ROAD WEAR

Road wear involves any form of deterioration of pavements that results in a constant lowering of the functions of the pavement.

The causes of the deterioration are partly mechanic influence from traffic, partly physical-chemical changes of the components of road materials through the influence of climate, i.e. humidity, temperature fluctuations, oxygen, and partly from salting in areas with snow.

The relative influence on road wear from the 3 (or 2) major parameters is now well-known. At this time this very subject is being studied by an expert group under OECD's Road Transport Research programme. In countries like Denmark which has long periods of frost and thaw and medium heavy traffic, we are of the opinion that about 80 percent



EEC – directive

FIGURE 7

of the road wear stems from traffic, i.e. heavy axle loads. However, this is a subject area in need of much further research.

The traffic load is transmitted to the road pavement through the contact surface of tyres. Basically the size of the footprint and the tire pressure determine how far down into the pavement and subgrade the influence of the wheel pressure will be felt. The total wheel load (1 or 2 tyres) is decisive for the influence i.e. strain and stress on the lower layers and the subgrade.

On the basis of road tests - most notably the AASHO tests - the conclusion has been the well-known 4th power rule. This means that a doubling of the axle load will increase the road wear by 16 times.

Since the AASHO tests, a number of supplementing tests have been executed in several countries. These tests have indicated power exponents in the interval of 2 - 6. On the other hand, laboratory tests of cohesive subgrade soils from the Nordic countries seem to show that higher axle load exponent (possibly 12 - 20) based on permanent deformations, may prevail under certain circumstances.

REGISTRATION OF AXLE LOADS

A road pavement is designed to carry a certain number of specified heavy axle loads. At the end of a design period, a redesign (pavement strengthening or rehabilitation) must take place. Therefore, information on present and expected future axle loads is essential as a tool for highway engineers.

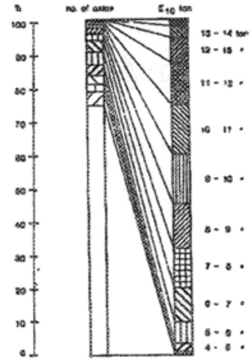
In Denmark we have for 20 years registered axle loads by weighing traffic in motion on scales built into the pavement.

An example of the influence of axle loads is shown in Figure 8. The left column shows the percentage distribution of the number of axle loads on main road E4. It appears from the figure that axle loads below 1 ton, i.e. passenger cars and small commercial vehicles constitute approximately 74 percent of all axles passing, while 14 percent of the axles passing weigh over 5 tons, and approximately 1.7 percent over 10 tons which is the legal upper limit.

In the right column the registered axle loads have been converted to equivalent 10 tons axles by using the 4th power rule mentioned above. Thus this column provides an impression of the deteriorating influence of the individual vehicle classes. It appears, that the light vehicles (passenger cars, etc.) in this column have decreased to nil. They hardly have any influence on the deterioration of the pavement. Trucks and buses with axle loads exceeding 5 tons are responsible for 97 percent of the wear even though they only constitute 14 percent of the axles passing. It also appears that the axles exceeding 10 tons contribute with almost 45 percent.

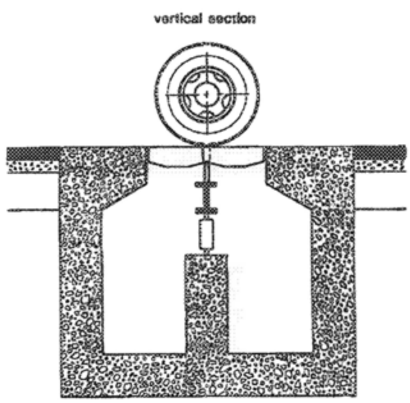
Figure 9 shows our first scale built into the pavement. This scale has now been used continuously for 24 hours daily since 1967 - and it still works.

Traffic development as registered on this scale in the period 1967 - 85 is illustrated in Figure 10 that among various comparable data shows the number of equivalent 10 tons axle loads passing in one direction. It is interesting to note that the oil crisis and economic trends are clearly reflected in the



Axle load on Route E4

FIGURE 8



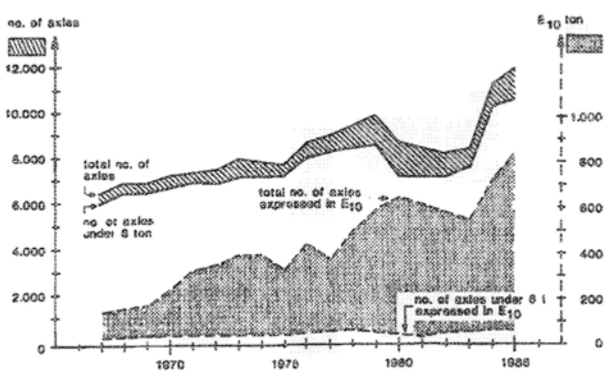
Scale platform from 1967

FIGURE 9

traffic. From 1977 the permitted axle load for single axles was increased from 8 to 10 tons. In a number of European countries a good relation can be shown between E10 loads and GNP.

Weighing-in-motion is a most topical subject today and many countries are involved in developing better and more reliable equipment and a systematic approach to registration strategies for a road network. In Europe the equipment development has passed several stages and especially in France and Denmark reached a state where inexpensive, simple, and movable weighing cables can be used to determine axle loads and classify vehicles. Thus the size of WIM equipment has developed like computers i.e. instead of meters as shown in Figure 9, todays cables are measured in millimeters. Likewise from previously only being able to register axle loads we now add speed, axle distances, wheel base, number of vehicles and classification of vehicles e.g. according to EEC-standard classification.

Within a very short span of years most major highway authorities will undoubtedly make use of WIM equipment. This development, however, gives rise to at least two major problems: 1) where should WIM equipment be placed to obtain sufficiently accurate data and 2) how can E10 or EAL's be predicted for rehabilitation design purpose. As for the latter, we have in Denmark looked into E10 forecast and actual development over a 10 year period at random selected roads. The result showed differences of up to ± 70 percent. Depending on the basic design of the pavement this might have a very unfortunate economic influence on future pavement maintenance. We have in our country undertaken some studies to that effect. It is our opinion that both 1) and 2) are general problems in Europe in need of further studies.



Development of axle load on Route E4

FIGURE 10

COST OF ROAD WEAR — A CASE STUDY

It is not the intention of this paper to go into any details of costs of (goods) transport or of pavement rehabilitation or their relations, however interesting and important that wide subject is. But it is very encouraging to note the increasing emphasis and efforts that are devoted around the world to this problem and its solutions.

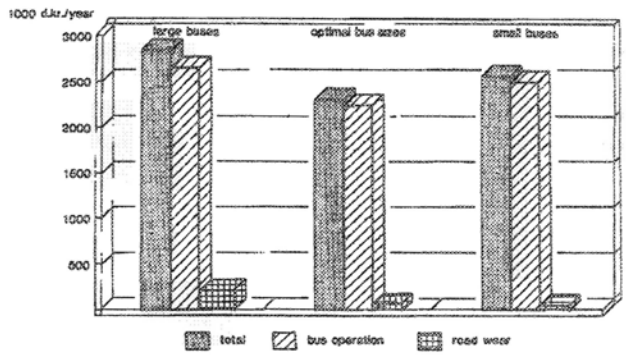
As a small example of some of the very practical and yet strategic problems of the interrelation between costs of transport and road wear we have in Denmark looked into whether it would be advantageous to replace large heavy buses with smaller ones. This problem of course can related to big vs small trucks.

The study concerned 4 bus routes (length of routes 18 - 30 km) in the surrounding area of a Danish provincial town, i.e. on minor roads with very little heavy traffic.

The calculations have been carried out on the basis of the existing bus schedule and the actual passenger utilization, but with three different bus sizes:

1) large buses (max 71 passengers including standing places)

2) optimal bus sizes, i.e. the bus sizes that are large enough to handle peak volumes



Total traffic costs

(4 bus routes in Vamdrup)

FIGURE 11

3) small buses (with room for 20 - 38 passengers).

The road wear costs were calculated theoretically in accordance with the 4th power rule as the cost of the marginal extra pavement strengthening that will be necessary because of the bus traffic share of total equivalent 10 tons axle loads.

Traffic costs were calculated in accordance with the standard contracts between the transport companies and the bus contractors. (In Denmark there is a public transport company in each county that has the sole right to operate bus routes. These companies do not own any buses but enter into contracts with bus contractors that carry out the actual operation.)

From the figure it appears:

- that road wear costs constitute approximately 1 - 10 percent of the traffic costs,
- that it is less expensive to drive with optimal bus sizes when all factors are taken into account, that running unnecessarily large buses result in road wear 3 to 4 times as high as the optimal alternative,
- that only to run small buses - that necessitates relief buses - results in road wear that is only 40 percent of the optimal buses, but that the total costs will be higher (especially because of extra staff costs for drivers).

SOME SHORTCOMINGS AND PROBLEMS

There are of course numerous problems related to weight and dimensions of heavy vehicles.

In the following just two matters are mentioned which have direct relations between Europe and North America.

CONTAINER TRANSPORT

As previously mentioned it is very important for international traffic that the regulations on weight and dimensions of heavy vehicles are uniform - at least on the same continent.

Trucks normally stay on one continent but containers do not. The use of containers is increasing in international shipping. Thus it is important that containers comply with certain measures that ensure that they may be transported by vehicles in other parts of the world. The new EEC regulations facilitates transport of 20 to 40 feet ISO containers (that are 8 feet wide). Thus it is of some concern in Europe that Canada and the USA may want to introduce higher, wider (8 1/2 feet), and heavier containers. Such containers cannot be transported by vehicles in Europe (perhaps except in Sweden).

TRUCK DESIGN

Vehicles and pavements influence each other mutually, i.e. through damaging dynamic shocks. Road unevenness should of course by kept at a fair level, but suspension of the truck and especially shock absorbing should be constructed to compensate for unevenness so that shock strains should be minimal. Furthermore, an efficient neutralizing should be ensured of the axle load between the rear axles of a heavy vehicle so that load concentration is avoided on uneven roads (e.g. on one axle) causing extremely heavy damage to the road.

In Europe a technical development in the design of vehicle construction has taken place is this area in recent years.

It is encouraging that this symposium also deals with the subject. Hopefully this will mean a further development that will ensure better load transmission between vehicle and road to the mutual benefit of truck owners and road authorities.