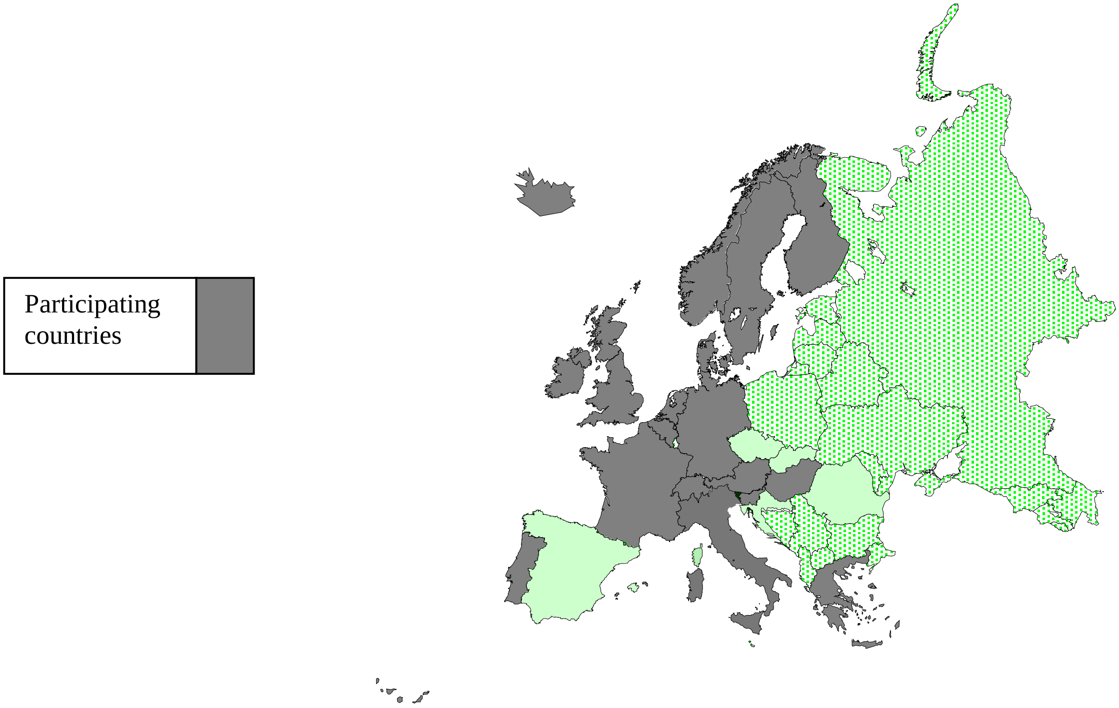
COST 334

Effects of Wide Single tyres and dual Tyres

EXECUTIVE SUMMARY

Chairman of COST Action 334:	R. R. Addis
Project duration:	From September 1996 to March 2000
Further information:	http://www.minvenw.nl/rws/dww/home/cost334tyres/

Participation in the Action

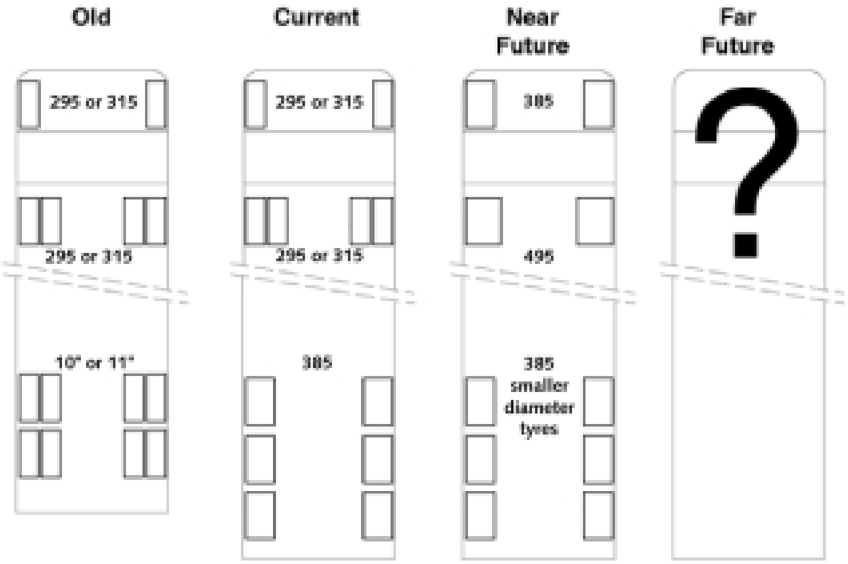


ISO Code	Country	Institute / Organisation	Acronym
AT	Austria	Institut für Strassenbau und Strassenerhaltung Technische Universität Wien	ISTU Wien
BE	Belgium	Belgian Road Research Centre European Tyre and Rim Technical Organisation	BRRC ETRTO
CH	Switzerland	Laboratoire des Voies de Circulation Ecole Polytechnique Fédérale de Lausanne	LAVOC-EPFL
DE	Germany	Bundesanstalt für Strassenwesen Institut für Kraftfahrwesen	BASt IKH
DK	Denmark	Danish Road Institute	DRI
FR	France	Michelin	
FI	Finland	Technical Research Centre of Finland	VTT
GB	United Kingdom	Department of Environment, Transport and the Regions	DETR
		Transport Research Laboratory	TRL
GR	Greece	Greek Road Federation	
HU	Hungary	Institute for Transport Sciences	KTI
IS	Iceland	Public Roads Administration	PRA
NL	Netherlands	Dienst Weg- en Waterbouwkunde European Asphalt Pavement Assocaition	DWW EAPA
NO	Norway	Norwegian Roads Administration	
PT	Portugal	Laboratório Neçional de Enghenaria Civil	LNEC
SE	Sweden	Swedish Road and Transport Research Institute Association of European Automobile Constructors	VTI ACEA
SI	Slovenia	Zavod za Gradbenistvo Slovenije	ZAG

Executive summary

The trend for some years on heavy goods vehicle weights and dimensions regulation has been to increase allowable weights. Generally, such increases have been to maximum gross vehicle weights. In order to take advantage of increased gross vehicle weights, the total number of axles on the vehicle has increased. Other developments have taken place, however, in both the tyre and vehicle industries and these have enabled heavy goods vehicle operators to become efficient contributors to the European economy, and that will no doubt continue to do so.

These developments may be summarised in the following figure.



From the "Old" to the "Current" situation, for example, the number of trailer axles increased from 2 to 3. As a result of economic pressures, vehicle operators later took advantage of developments to then existing tyre fitments that improved performance and reliability. Such tyres produced significant advantages to the operator: these included reduced tare weights (and therefore increased payloads), reduced fuel consumption due to lower rolling resistance, and reduced tyre maintenance costs.

In the "Near Future" scenario, further tyre developments will be used to again reduce tare weights and rolling resistance, probably on the drive axle, and to decrease tyre maintenance costs by rationalising the number of different tyre fitments used on a vehicle. An example of the latter is the trend to use of wide single tyres on steering axles, which the use of power steering on most vehicles makes possible. This reduces the need to stock or carry on the vehicle combination more than two tyre sizes, brings about savings in tyre wear, and allows re-use of front tyres on the trailer after re-capping. The use of technologically advanced materials in tyre construction, generally to reduce rolling resistance, has enhanced these savings.

In the "Far Future" scenario, it is anticipated that the tyre industry in particular, and to a lesser extent the vehicle manufacturing industry, will make additional advances that will enable further economies to be made in the road transport sector. However, these economies could occur at the expense of additional road maintenance costs or other disadvantages.

During the period of these technological advances, there have also been other developments that significantly affect the interaction of vehicle and road, often to the detriment of the road and its function. For example, the increase in road traffic over the past 30 years, for both passengers and goods, has been dramatic, often exceeding predictions. Despite considerable capital investment in road infrastructure over the same period, road capacity is frequently severely tested, particularly on major routes. Road strengthening to meet the increased numbers and weights of heavy vehicles has taken place, more recently using advanced materials for surfacing and underlying layers.

Simultaneously, the trend towards increased use of wide single tyres instead of dual tyres, coupled with more "canalising" of goods vehicles due to increased traffic, have raised the stresses to which pavement surfacings have been subjected. A degree of overloading of a small proportion of heavy goods vehicles in most European countries adds to these stresses, with the result that pavement deterioration takes place more rapidly than expected.

Against this background, of unquantified but perceived reduced costs to vehicle operators, increased costs to road owners, benefits in safety, and reduced costs in environmental aspects, COST 334 has carried out a programme of work to quantify these costs and benefits, and propose ways in which they may be balanced.

The conclusions of the work relate to:

- Tyre fitment and pavement wear
- Tyre fitment and vehicle handling
- Tyre fitment and environmental effects
- Tyre fitment and vehicle operating costs
- Overall economic effects of the use of different tyre fitments.

On the basis of the conclusions drawn from the work, it was also possible to make recommendations on the development of future tyre fitments, including current sizes, and on the use of the results obtained in pavement design.

CONCLUSIONS

Tyre fitment and pavement wear

In examining the conclusions of the work in this area, it is useful to define some of the terms used.

Footprint	The area of the contact patch between the tyre and the road surface.
Tyre fitment	Refers to the tyre as a wide single fitment, or as a dual tyre assembly.
Primary Road Network	Defined, for the purposes of COST 334, as the network of principal roads in a country or state, generally comprising motorways (autoroutes, autostrade, etc) and other principal roads, state owned or otherwise. This network provides the major links between large urban areas and key national long-distance routes.
Secondary road network	Defined, for the purposes of COST 334, as the network of secondary roads in a country or state, generally comprising those roads owned by state, regional or local authorities, and acting as links between primary routes, but excluding some rural roads.
Primary rutting	The mode of pavement deterioration by which rutting occurs principally in the bituminous layers, mainly occurring in the pavement surfacing of the primary network.
Secondary rutting:	One of the modes of pavement deterioration of the secondary network occuring in the subgrade or granular layers of the pavement.
Fatigue cracking	Cracking in the bituminous or cement bound material originating at the bottom of the respective layers, due to fatigue of the material by a great number of repetitions of bending due to wheel loads. (Such cracking does not include surface cracking and cracking due to thermal cycling.) Fatigue cracking is one of the modes of deterioration of the secondary network.

Thin pavement	A pavement with a thickness of bituminous layers of 100 mm or less,
Medium pavement	A pavement with a bituminous thickness of around 200 mm,
Thick pavement	A pavement with bituminous thickness of around 300 mm or more.

Terms used in modelling of pavement wear in relation to tyre parameters:

"Width" (for width-based model)	In the context of tyre parameters, this term is used to describe the footprint width for wide base singles. For dual tyres the width is taken as twice the footprint width of the individual tyres. (All width values consider footprint (tyre contact area envelope) width, not tyre section width.)
"Total Width" (for total width-based model)	In the context of tyre parameters, this term is used to describe the footprint width for wide base singles. For dual tyres the Total Width is taken as twice the footprint width of the individual tyres plus the spacing between the footprints of the dual. This spacing is of the order of 100 mm for all dual tyre fitments.

Axle Wear Factor	The Axle Wear Factor (AWF) is a dimensionless factor that relates the damage contribution of a single passage of an axle fitted with tyres of a specific tyre width and inflated to a given cold inflation pressure, carrying a given axle load , to the damage contribution of a single passage of an axle with the reference tyre (295/80R22.5 dual fitment with a cold inflation pressure of 650kPa) carrying the reference load of 10 tonnes.
Tyre Configuration Factor (TCF)	A factor describing the pavement wear attributable to different tyre fitments and sizes, when compared with an arbitrarily selected reference tyre, at equal load. The TCF includes factors for specific tyre characteristics, in relation to their performance regarding dynamic force transmissibilty, and potential load imbalance.The chosen reference tyre, with a TCF of 1.0, is the most commonly used drive axle dual tyre, namely a 295/80R22.5, under maximum recommended loading conditions.
Load imbalance	Differences in tyre load between the tyres of a dual wheel assembly.
Dynamic Loading	The effect by which vehicle loads applied to the road surface increase and decrease in response to pavement unevenness and other factors. Dynamic loading is strongly influenced by vehicle suspension type.

The work of COST 334 was confined to bituminous pavements; for concrete pavements, it is expected that there will be only small influences on pavement wear due to differences in tyre configuration. For bridges, viaducts, etc. no specific conclusions were drawn.

General

1. Large differences in relative pavement wear exist among dual tyre assemblies and among wide-base single tyres. Therefore, a single factor for the difference between wide-base single and dual tyres is not applicable. Comparisons between pavement wear effects can only be made if the detailed characteristics of the tyre fitments are taken into account.
2. The pavement wear effects of different tyres vary according to the types and thickness of pavement, as well as their associated distress modes. For this reason COST 334 developed the concept of the Tyre Configuration Factor (TCF). The TCF of a tyre expresses the amount of pavement wear, depending on the pavement thickness and distress mode considered, relative to an arbitrarily chosen reference tyre. In use, the higher the TCF value, the higher the pavement wear (with the same axle loads, suspension type, etc.).
3. The TCF formulae developed from the work enable the quantification of the pavement wear effects of current and future different tyre fitments and sizes. The derivation of TCF formulae for all pavement thicknesses was not possible in all cases, however, because of insufficient data.
4. On the basis of the TCF formulae, the main influencing factors for pavement wear are the width (see Conclusions 5 and 6) and size of the tyre-pavement contact area, and the

ratio of the actual inflation pressure over the recommended inflation pressure for the actual load (hereafter referred to as the pressure ratio).

5. It was found that the thinner the pavement, the stronger was the influence of differences in tyre configurations on pavement wear.

On the tyre concept (one or two contact areas) and the tyre width parameter:

6. For primary rutting (mainly on thick and medium pavements) the main width parameter is Width, being the footprint width for wide base singles, and for dual tyres twice the footprint width of the individual tyres. (All width values consider footprint (tyre contact area envelope) width, not tyre section width.) As a consequence, for this distress mode, pavement wear due to wide base single tyres or dual tyre assemblies does not differ significantly, when the axle load, tread pattern width, contact area, tyre diameter and pressure ratio are equal.
7. For secondary rutting and fatigue cracking on thin and medium pavements the main width parameter is the Total Width of the footprint of the tyre assembly. [For dual tyre assemblies this includes the distance (100mm) between the footprints of the individual tyres.]. As a consequence, single and dual tyre assemblies will produce equal TCF values indicating equal pavement wear, when the Total Width is equal (all other factors being equal). Usually, however, for the same axle load, current dual tyres will have a greater Total Width than a current wide single tyre.
8. For secondary rutting and fatigue cracking on thick pavements there is little difference between different fitments and sizes of tyres, as the pavement wear is dominated by the overall magnitude of the load carried in these cases.

On size of contact area:

9. In addition to its width, the length of the tyre-pavement contact area was shown to be influential in the cases of primary rutting on thick (and probably thin and medium) pavements and fatigue on thin and medium pavements. Combined, this signifies the influence of the size of the tyre-pavement contact area, and hence the average contact stress. Sensitivity analysis showed that a decrease of 10% in contact area results in a 9-39% increase in pavement wear for these cases. No similar conclusion could be drawn for secondary rutting because of a lack of data.
10. The tyre diameter can also be taken as an indicator for the contact area length and the related pavement wear. A reduced tyre diameter will lead to increased pavement wear (when all other tyre parameters remain constant). This is important in the context of a trend towards the use of smaller-diameter tyres in Europe, to allow the lower platform heights that will accommodate volume-limited loads to be carried, rather than mass-limited loads

On tyre inflation pressure and contact stress distribution:

11. The tyre inflation pressure is not a direct parameter in the TCF formulae. For the same load and tyre, higher inflation pressures generally result in a smaller tyre-pavement contact area, and thereby increased surface stress in the pavement As a consequence, higher inflation pressures generally result in higher pavement wear, especially on thin pavements.

12. The ratio of actual to recommended inflation pressure was shown to be influential for the cases of primary rutting on thick (and probably medium) pavements and secondary rutting on thin and medium pavements. An inflation pressure 10% higher than that recommended for the actual tyre load results in about 15% increase in pavement wear. In such a case of over-inflation, the contact stress distribution is non-uniform and the load is concentrated on a smaller area.
13. The detailed contact stress distribution within the contact area is probably relevant for distress modes whose origin is at or close to the pavement surface, such as ravelling (loss of aggregate in the pavement surfacing) and surface cracking. Although COST 334 established good techniques for the measurement of these distributions, insufficient data was obtained to draw robust conclusions.

On the effect of dynamic loading and load imbalance

Dynamic loading occurs as a vehicle passes over a road surface. A road with poor longitudinal profile will produced increased dynamic loading, compared with the same vehicle passing over a smooth road.

Load imbalance occurs when each tyre of a dual tyre assembly is inflated to a different pressure (where the tyres are of the same type), or when each tyre has a different diameter (as is the case when the tyres used are worn to different degrees)

14. By comparison with other effects, tyre fitment does not significantly affect the dynamic loading of the road pavement.

15. By comparison with other effects, the effect of load imbalance between tyres on a dual assembly was found not to significantly affect pavement wear or other aspects.

On TCF values for current common tyre fitments and possible future tyre fitments

As stated earlier, TCF values vary according to the pavement thickness and distress mode under consideration. For practical use, values for the current common and possible future tyres (rim sizes 19.5 and 22.5 inches) were determined for the European primary road network (based on primary rutting in the bituminous layers of thick pavements) and the European secondary road network (based on a weighted average of the three distress modes on medium pavements, namely primary rutting, secondary rutting and fatigue cracking). Most road freight in Europe is carried on the primary networks, however, and greater importance is attached to these.

16. Common current and possible future dual tyre assemblies for towed axles have TCF values for primary roads ranging from 1.5 to 1.7 and for secondary roads TCF values of 1.3 to 1.5. Current common and possible future wide base single tyres for towed axles have TCF values for primary roads ranging from 1.5 to 2.2 and for secondary roads TCF values ranging from 2.2 to 3.6. On average the use of current common or possible future wide base singles on towed axles, instead of dual tyre assemblies, increases the contribution of these axles to pavement wear on primary roads and secondary roads by 17% and 97%, respectively.

17. Common current and possible future dual tyre assemblies for driven axles have TCF values for primary roads ranging from 0.9 to 1.3 and for secondary roads TCF values ranging from 0.9 to 1.2. The prototype extra-wide base single tyre 495/45R22.5 for use on drive axles has a TCF value of 1.2 on primary roads and 1.6 on secondary roads. On average, the use of wide base singles on driven axles, instead of common current dual tyre assemblies, increases the contribution of these axles to pavement wear on primary roads and secondary roads by 17% and 64%, respectively.
18. Conventional single tyres for steering axles have TCF values for primary roads ranging from 2.8 to 4.0 and for secondary roads TCF values ranging from 5.0 to 8.0. Current common and possible future wide base single tyres (from the 385 - fitment and wider) for steering axles have TCF values for primary roads of 1.9 to 2.2 and for secondary roads TCF values of 2.8 to 3.6. On average the use of current common and possible future wide base singles on steering axles reduces the contribution of this axle to pavement wear on primary and secondary roads by 36% and 45% respectively.
19. Conventional single tyres for steering axles are relatively more damaging than the common dual tyre assemblies for driven and towed axles, and wide single tyres for towed axles. This is partly alleviated by lower loads on the steering axles, but in practice the steering axle still may cause more pavement wear than a driven or towed axle.

On Axle Wear Factors for the different axle types fitted with current common and possible future tyres.

Based on the TCF value of tyres, the damage contribution of a single passage of an axle can be calculated using the appropriate formula, taking into account the actual axle load. This damage contribution is expressed as the number of passages of the reference tyre with the reference load of 10 tonnes, that gives the same amount of damage. This number is called the Axle Wear Factor (AWF).

For the current common and possible future tyre sizes (for rim sizes 19.5 and 22.5 inches), AWF values were determined for different axle loads for the European primary road networks.

20. Current common and possible future tyre assemblies for the driven axle, either with duals or wide base singles, have, at a load level of 11.5 tonne, AWF values ranging from 1.2 to 1.7. Current common and possible future tyre sizes for the towed axle, either with duals or wide base singles, have, for their respective maximum allowable load levels (between 8 and 10 tonne), AWF values ranging from 1.1 to 1.9. This range of values is very similar to that for the driven axle. Finally, current common and possible future tyres for the steering axle, fitted with either conventional singles or wide base singles, have, at their respective maximum allowable axle load (between 6.5 and 9 tonne), AWF values ranging from 1,4 to 1,9. This range is marginally higher than that for the driven axle. That the lower level of the axle loads on the towed axles is not reflected in lower AWF values, is explained by the fact that generally, relative to the axle load, wider tyres are used on the driven axle. The marginally higher AWF values of the steering axle, though having a much lower load in comparison with the driven axle, is explained by the fact that on the steering axle, all load must be transferred by two tyres, whereas for the driven axle, four tyres are usually used.

Tyre fitment and vehicle handling

In the area of the effects of tyre fitment on vehicle handling, some definitions of effects are useful.

Vehicle handling	Those characteristics of the vehicle that control the ability of the driver and vehicle to carry out driving manoeuvres safely and efficiently.
Lateral stability	For a single unit vehicle the stability is related to the under-steering/over-steering characteristics. The under-steering or stability gradient, expresses how the steer angle is related to the lateral acceleration in a steady-state turn. If the stability gradient is negative there is a critical speed when the vehicle is unstable.
Longitudinal stability	The factor governing the ability of the vehicle to stop, and therefore controlling the stopping distance of the vehicle.
Off-Tracking	Off tracking is the lateral deviation between the path of the centre-line point of the front axle of he vehicle and the path of a centre-line point of some other part of the vehicle. If a single number is given, it refers to the maximum off-tracking
Rearward Amplification	The Rearward Amplification is the ratio of the maximum value of the quantity of interest of a following vehicle unit to that of the first vehicle unit during some kind of manoeuvre. The quantity of interest may be, for instance, lateral acceleration or yaw velocity

The results of COST 334 work in the area of vehicle handling are based on the experimental testing of selected vehicle types in a range of test conditions. These are supported by theoretical work using widely accepted simulation models of vehicle behaviour, which were validated by full-scale tests. The vehicles considered were:

A rigid truck, conforming to ISO 3833
A rigid truck and trailer conforming to ISO 3833
An articulated vehicle (tractor and semi-trailer) conforming to ISO 3833

On the basis of the work carried out, it was concluded that:

21. In general, the use of wide single tyres on drive axles, when compared with dual tyres, improves vehicle under-steering in the direction of increased lateral stability, for the vehicles and tyres tested.

22. In the case of the 2-axle rigid truck, the handling behaviour brought about by the use of the wide base single tyre on the drive axle also reduced the lateral acceleration lag of the vehicle during a given driving manoeuvre.

One of the benefits previously claimed for the use of wide single tyres is that the wider spring base they provide leads to increased vehicle stability, i.e. reduced risk of “roll-over”. This conclusion supports this view, but suggests that the improvement is mainly due to the increased lateral stiffness of the tyre.

23. In relation to sudden tyre defects (punctures) in the drive axle tyres, no increased risk due to the use of wide single tyres was established by the simulated tests carried out.

Tyre fitment and environmental effects

COST 334 addressed the matter of the environmental effects of the use of wide single and dual tyres in two ways. First, their effects on tyre-road noise emissions was assessed, and second, their effects on gaseous emissions were assessed by consideration of changes in the rolling resistance (and thereby fuel consumption) of each tyre fitment.

24. In relation to tyre-road noise emissions, the work found no significant overall difference between the noise generated by each tyre fitment, when used on drive axles or trailer axles.

25. The use of the wide single tyres generally reduced fuel consumption, and thereby reduced total CO_2 emissions.

Tyre fitment and vehicle operating costs

Vehicle Operating Costs (VOC) are significantly affected by the choice of tyre fitment. Thus, tyres with reduced rolling resistance lead to reduced fuel costs, and tyre fitments lighter than those used previously bring about potential increases in payload, with associated economic benefits. The work of COST 334 in the area of VOC made use of the "Past", "Current", and "possible Future" scenarios identified by the Group as being appropriate in Europe. The work also examined more particular situations, such as the possible use of prototype wide single tyres on the drive axles of heavy goods vehicles. As a result of this work, it was concluded that:

26. The choice of tyre fitment on the driven axle of a 40 tonne gross vehicle weight truck-semi-trailer vehicle can affect the VOC by up to 1%, as a result of 2% changes in fuel consumption.

27. A further saving of 1% is available to truck operators from the use of lighter tyres and wheels, when these weight savings are translated into increased payload.

28. VOCs are strongly influenced by taxes, particularly fuel taxes.

29. When VOC is considered without taxes, differences between the past and current tyre configurations selected by COST 334, and described in the Figure at the beginning of this Chapter, may be up to 3% in VOCs. A further 0.5% saving is available between the current and possible future tyre configurations.

Overall economic effects of the use of different tyre fitments.

The work of COST 334 in the various areas noted above was consolidated into an overall view of the effects of the use of wide single tyres and dual tyres by aggregating their effects in financial terms, for those European countries for which data was available. In order to achieve this, costs and values needed to be attributed to each separate effect, and this was done using, wherever possible, widely accepted figures. The estimation of overall costs and benefits was applied to the three situations considered by COST 334, namely:

a) the past situation, before the introduction of wide base single tyres.
b) the present situation in which wide base single tyres are widely used on the towed axles (trailer and semi-trailers), of vehicles, but not on the driven axles of motor vehicles.
c) a possible future evolution in which motor vehicle steering axles would be fitted with wide base single tyres of the size currently used on towed axles, and driven axles would also be equipped with wide base single tyres - the all-wide-base tyre vehicle. (The necessary tyre sizes for fitting drive axles are not yet commercially available, but sufficient data were generously provided by the tyre manufacturing industry.

Other possible future configurations were evaluated, to enable comparisons to be drawn.

The overall results of the estimation of total costs and benefits were as shown in the following Table.

Impact of the tyre and vehicle fitments on the economic stakeholders, haulage operators, governments and society (All figures in Million €).

	Period (vehicle and tyre fitments)	Pavement Maintenance Costs	Tax Income	Vehicle Operating CostsB	Non Pavement Costs - Gov	Non Pavement Costs - Ope	Costs Diff. Related to Present
Operator	Past			2648		785	2686
	Present			Ref		747	Ref
	Future			-881		699	- 929
Government	Past	6084	+572		4474		- 384
	Present	6095	Ref		4275		Ref
	Future	6026	- 483		4107		246
Evolution of	Past	6084	572	2648	4474	785	2302
Society	Present	6095	Ref	Ref	4275	747	Ref
Costs	Future	6026	- 483	- 881	4107	699	- 682

NB :

- The non pavement costs attributed to the governments are the consequences of the compensation of the HGV polluting emissions. The ones attributed to the hauliers are the consequences of the tyres and wheels recycling.
- The difference between past and present situation is due to both the tyre characteristics improvement and the evolution in maximum authorised vehicle weight (38 to 40 tonnes).

- With the "diameter model" for the TCF computations, the final differences for the Society would be very comparable : 2360 and –779 M€ instead of, respectively, 2302 and –682 M€ in the before mentioned table .

Comparing the past (a) to the present (b) situation:

30. The benefits of the use of wide single tyres on heavy goods vehicles, in terms of reduced vehicle operating costs and reduced gaseous emissions, are significantly greater than the additional pavement maintenance costs they cause.

Comparing the present (b) situation to the possible future (c) situation:

31. On the same basis, it was found that the use of a possible future all-wide-base-single tyre configuration on the same 5-axle vehicle would lead to a new societal cost reduction, when compared with the present tyre configuration on that vehicle.

Comparing the present (b) situation with other possible future situations:

Other Possible Future situations were also investigated by COST 334, namely:

- Using 425/65R22.5 tyres on the towed axles, instead of the present 385/65R22.5. The reference 80 series tyres would be kept on the motor vehicles. This would increase the tread width and reduce the tyre inflation pressure on the towed axles and lead to a reduction of pavement wear and pavement maintenance costs. However, it would increase the rolling resistance and the tyre and wheel weight, with a negative impact on the vehicle operating costs and the environmental costs.

- Retaining standard 70 or 80 series tyres on the front axles, while using wide-base single tyres on the driven and standard wide base single tyres on towed axles. This would allow conclusions to be drawn on the effect of the introduction of prototype wide base single tyres on driven axles.

32. These results showed that:

    32.1 Replacing current 385/65R22.5 by 425/65R22.5 on the towed axles of the HGV would be less damaging to the pavements, but globally more expensive at the EU level.

    32.2 Retaining the 70-series tyres on steering axles, with 495/45R22.5 wide base single tyres on the driven axles, and standard wide base single tyres on towed axles of the vehicles is more damaging to the pavement by about 70 million €, but globally less expensive at the EU level, by about 500 million €.

33. Building on the Tyre Configuration Factor, further work was carried out to include other economic aspects of tyre performance, namely rolling resistance and mass of the tyre-wheel assembly.

On the current Legal and Regulatory setting

A comprehensive review of the technical standards, Directives and Regulations that might be suitable for the implementation of the results of COST 334 showed that:

34. There is no current technical standard or piece of legislation that accurately reflects the findings of this COST action.

35. Introducing or amending a technical standard to incorporate the findings of this COST action, without the force of legislation, is only likely to have a limited impact in preventing or reducing road pavement damage.

Introducing legislation at the European level that is binding on all Member States both nationally and internationally would be the most effective way of preventing or reducing road pavement damage throughout the EU.

Recommendations

In the opinion of COST 334, some of the recommendations made will need to be implemented into current or future legislation, while others may be voluntary. In either case, it is useful at this point to highlight some of the main points of the current regulatory framework affecting the use of different tyre fitments.

Current Legal and Regulatory setting

On the basis of the review carried out, and the conclusions it reached, the following recommendations are made for implementation of the results of COST 334.

At the European Level:
- The UNECE tyre construction Regulation 54 and the EU tyre construction Directive 92/23/EEC should be amended to include the findings of COST 334.
- Directive 96/53/EC on the maximum authorised dimensions and weight of vehicles on an international journey should be amended to include a link between the findings of this COST action and the maximum gross and axle weights of lorries and buses.
- Directive 97/27/EC should be amended to recognise the findings of this COST action in the same way that it already recognises a specification for road friendly suspension.
- Any future European Vignette system should include the findings of this COST action.

.

At the National level.
- To encourage road friendlier vehicle designs Member States should consider linking the findings of this COST action to national maximum vehicle weight limits.
- To encourage improved vehicle designs Member States should consider ways of introducing or linking fiscal measures to the findings of this COST action.

Specific Recommendations

1. *On the use of tyre parameters in road pavement design.*

   The development of the Tyre Configuration Factor allows discrimination between different tyre fitments based on the corresponding damage they cause to road pavements. It is recommended, therefore, that the TCF should be used by national road authorities in the design process to better estimate the damaging effect of the traffic that roads are designed to carry.

2. *On the application of the Tyre Configuration Factor to tyre design and use*

   The results of the COST 334 work show that the use of a limit on TCF can be used to guide the design of new tyre sizes, and the further development of existing tyre sizes. It is recommended, therefore, that limiting values of TCF be placed on new and developing tyre fitments.

   The limits to be used should be as follows:

Proposed TCF limits for axle types in relation to applied axle load (rounded to nearest 0,05)

		Axle load in tonne						
		6,5	7,0	7,5	8,0	9,0	10,0	11,5
TCF limits								
*Proposed limit**								
all axle types: ie. Steering, driven and towed	AWF=1,65	**3,90**	**3,35**	**2,95**	**2,60**	**2,05**	**1,65**	**1,25**

* with possible exceptions for tyre sizes having a low market share and for special purpose vehicles.

3. *On Maximum Designed Operating Tyre Inflation Pressure*

   In addition to the proposed limits on TCF value of the tyre, it is also recommended that a maximum limit be placed on the manufacturer-recommended inflation pressure of the tyre (measured cold) according to the allowable load level of the specific axle on which the tyre is mounted. This will ensure that the TCF limits cannot be inadvertently exceeded by the use of increased inflation pressure.

The proposed maximum designed operating tyre inflation pressure (measured cold) is 9 bars.

4. *On further work to improve the Tyre Configuration Factor*

   With further work on a number of tyre parameters, to establish reference values, etc., as discussed in Chapter 7.10, a more comprehensive index could be established in addition to the Tyre Configuration Factor. It is therefore recommended that such work is encouraged and supported. The aspects to be included could cover, but need not necessarily be limited to, rolling resistance, noise, and mass of the tyre-wheel assembly.

5. *On the specific issue of the proposed amendment to European Directive 96/53/EC*

This Directive deals (in Annex 1, parts 2.2.4.2, 2.3.2, 2.3.3 and 3.5.3 of the Directive) with the maximum authorised dimensions in national and international traffic, and the maximum authorised weights in international traffic, for certain road vehicles used within the Communty. Among other things, it limits the use of wide single tyres on axles other than towed axles stating that for tandem axles of motor vehicles, "the allowable load is 19 tonnes if the driving axle is fitted with twin tyres and air suspension." A member state proposal to modify the Directive to allow the use of wide single tyres on such axles was deferred until COST 334 had reported.

The COST 334 view on this specific issue is as follows. On the grounds of pavement wear alone, for which this part of the Directive is intended, the modification should not be permitted. However, on other grounds, namely the benefits to vehicle operators, and the potential reduction in gaseous emissions, the modification should be permitted.

The recommendation, therefore, is that the use of wide single tyres should be allowed for 19 tonnes on a tandem axle of a motor vehicle, provided that the proposed Axle Wear Factor is complied with for each axle of the motor vehicle.

List of Contents of the Final Report

Address of the Project Coordinator

Mr. R.R. Addis
FEHRL Office
Boulevard de la Woluwe, 42, Bte 3

B-1200 Brussels

Telephone: + 32 2 7758238
Fax: + 32 2 7758254
E-mail: fehrloffice@compuserve.com