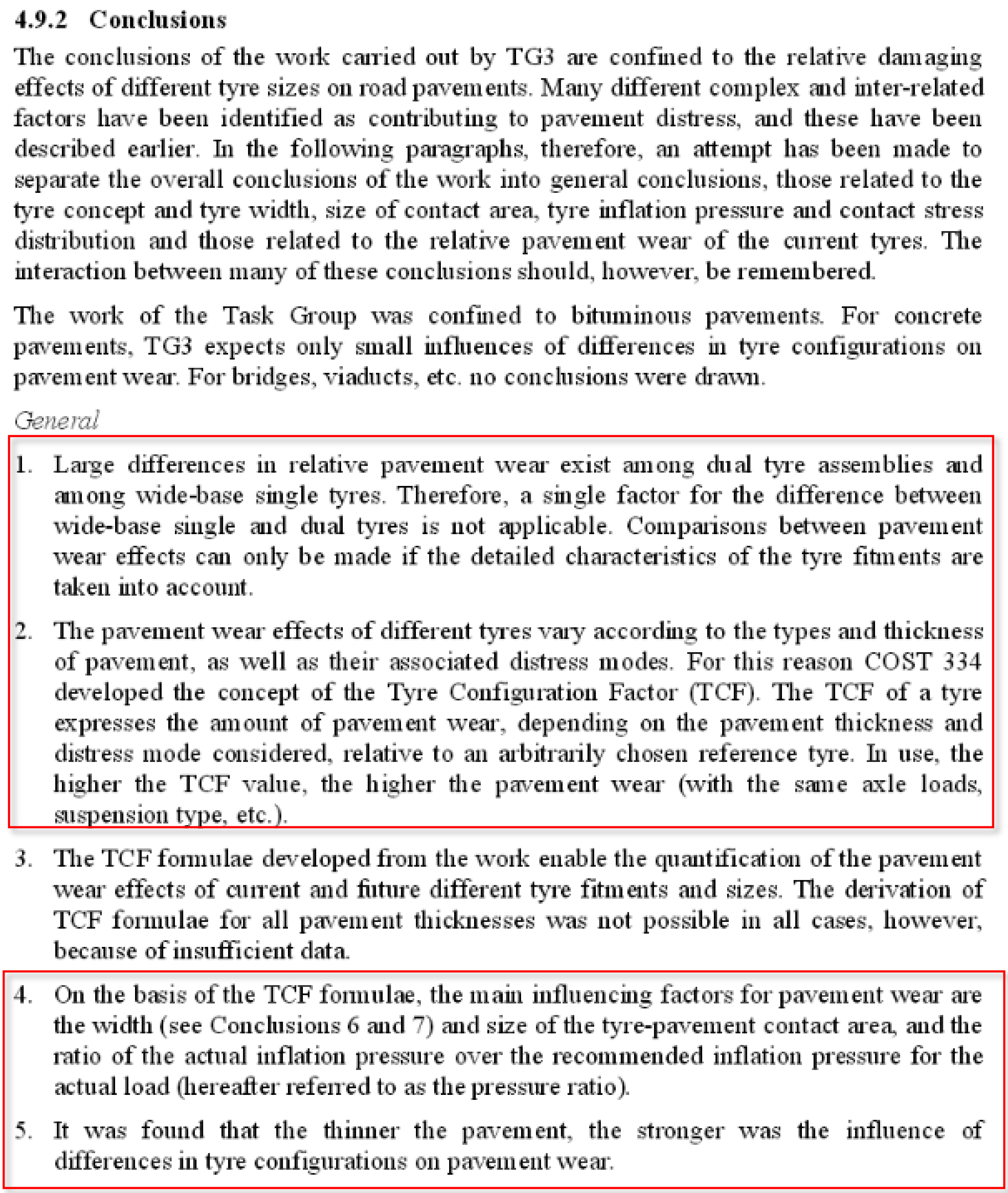
Attachment 2. COST 334 Conclusions and Recommendations



4.9.2 Conclusions

The conclusions of the work carried out by TG3 are confined to the relative damaging effects of different tyre sizes on road pavements. Many different complex and inter-related factors have been identified as contributing to pavement distress, and these have been described earlier. In the following paragraphs, therefore, an attempt has been made to separate the overall conclusions of the work into general conclusions, those related to the tyre concept and tyre width, size of contact area, tyre inflation pressure and contact stress distribution and those related to the relative pavement wear of the current tyres. The interaction between many of these conclusions should, however, be remembered.

The work of the Task Group was confined to bituminous pavements. For concrete pavements, TG3 expects only small influences of differences in tyre configurations on pavement wear. For bridges, viaducts, etc. no 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 6 and 7) 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

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

    Experimental work reported by COST 334 shows that, for the tyre fitments tested, the dynamic loading applied by the truck is not changed significantly by the choice of tyre fitment. Dynamic loading can significantly increase pavement damage, and it had been thought that the contribution of tyre stiffness to the suspension characteristics controlling the phenomenon may be a significant factor. On the basis of the work carried out, this appears not to be the case.

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.

    Load imbalance between tyres on a dual tyre assembly is brought about primarily by different inflation pressures in each of the tyres, and by truck axle geometry and pavement profile. Surveys have shown that this difference (in relation to the recommended inflation pressure) can be large, but is confined to a small proportion of the truck fleet. The work of COST 334 has shown that load imbalance effects on pavement wear and other aspects is negligible in comparison with other effects.

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.

4.9.3 Recommendations

On the basis of the conclusions noted above, a number of recommendations can be made. These apply to the use of the experimental and analytical results obtained on the relative pavement wear effects of different tyres in the wider work of COST 334, and to the specific case of those effects as they arise in practice.

1. *On the use of results in the further work of COST 334*

   TG3 recommends the use of the TCF formulae it has developed, to quantify the relative effects of different tyre load configurations on the wear of pavement structures. These factors may be used to calculate the contribution of pavement wear of different tyre types in the overall assessment of the use of wide single and dual tyres.

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.

Implementation of this recommendation will require that the design authority undertakes appropriate surveys of the national fleet of road transport vehicles, to establish the numbers and types of vehicle, their tyre equipment, and other factors. Approximations can of course be made by the judicious use of sample surveys, the results of which are extended to the national situation. Alternatively, specific surveys may be carried out for the design of a given road.

3. *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.

4. *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.

Much progress has been made in recent years on the development of on-board systems for the measurement and control of tyre inflation pressures. It is further recommended, therefore, that consideration is given to introducing legislation requiring the use of such systems on the largest (5 and 6-axle) vehicles, in order to ensure compliance with tyre manufacturer's recommended inflation pressures for given loads and duty cycles. This will produce benefits to operators in terms of improved tyre performance (tyre wear and rolling resistance), and to society in terms of minimised pavement wear and reduced safety risks.