Bridgestone Tyre Debris Study Report 2015-17

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Author	P. Moulding
Contributors	G. Powell K. Hales S. Finn C. Scott

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Executive Summary

This report provides an analysis of the tyre debris study carried out between 2015 and 2017 using sample inspection sites across England.

Results of the data analysed show that penetration by road hazards was consistently the primary reason for tyre failure. These also show that almost a quarter of tyre failures were due to easily avoidable issues, i.e. tyre or vehicle maintenance issues. Of the vehicle maintenance issues around a quarter of these were due to severe axle misalignment, an easily detectable maintenance issue, which results in wear through the shoulder if unchecked.

Although an already established damage classification system was used to categorise the samples, ascribing the primary cause of the tyre failure into these categories was subjective, especially in the cases where more than one factor may have contributed. In case of any doubt around cause of tyre failure, samples were classed as indeterminate rather than risking contaminating the data.

The report concludes that retreaded tyres show no greater likelihood of failure in service than a first life tyre when considering these results against the market usage of new tyres vs retreaded tyres. It is noted that with proper vehicle inspection and maintenance programs, many of the failures recorded in these results can be detected and prevented.

Inspection Sites

We have been allowed access to four locations:

EM Highways (Kier Group)

Coleshill
Coleshill Heath Road
Coleshill
B46 3HL

Strensham Motorway Compound
Hill View Road
Strensham
Worcester
WR8 9LJ

Highways Agency

Leicester Forest East
M1 J21 Service Area N/B Baines Lane,
Leicester Forest East
LE3 3GB

Sandiacre
M1 J25, Bostocks Lane
Sandiacre
Nottingham
NG10 5ND

Inspection Criteria

Classification of Sample

Tyre and wheel	• Whole tyre still mounted to wheel.
Whole tyre	• Tread, sidewall, beads and belt package. • Not all of the above part stated needs to be 100% complete, but all components must be present to some extent.
Tread strip	• Complete tread with or without belt package but no sidewalls. • Sample can be a ring, or broken.
Casing	• Tyre carcass without tread rubber. • Belts present.
Sidewalls only	• Sidewalls present but no belts or tread.
Sidewall and tread	• One but not both sidewalls with belts and or tread attached.
Fragment	• Incomplete tread strip with or without belts attached, no sidewalls.
Product Segment	• MC, Off-Road, Passenger, Truck and Bus, Van.
Tyre Life	• New* / Retread / Not identifiable. • If tyre life cannot be identified, do not guess.
Tyre Brand	• If identifiable: Manufacturer’s name only.

* ‘New’ refers to a first life tyre i.e. one which has not undergone the retreading process, and is used irrespective of the age or wear stage of the tyre

Damage Classification

We utilised the damage classification system as set out in the 2007 University of Michigan Transport Research Institute (UMTRI) study:

1) Over-deflection

2) Excessive heat

3) Road hazard

4) Maintenance

5) Manufacturing

6) Indeterminate

7) Excessive intra-carcass pressure

However, we decided to clarify these with our own comments in order to further examine the reason for the failures.

Table 9.2 – Tire Casings and Debris Damage/Failure Categories

Damage/Failure Category	Damage/Failure Sub-Category

Overdeflected Operation	• Run Flat
	• Sidewall Flex Fatigue Rupture
	• Detachment
	  ○ Tread only
	  ○ Tread and outer belt(s)
	  ○ Tread & belts from casing
	• Other
	• Three-Piece Flex Break

Excessive Heat	• Excessive Heat Damage
Road Hazard	• Cut/Snag • Impact Break/Rupture • Radial Split • Pinch Shock • Crown penetration • Sidewall Penetration • Other
Maintenance/Operational	• Excessive Wear • Skid-Through • Petroleum Damage • Improper/Failed Repair • Mounting Damage • Vehicle Damage • Unrepaired Puncture • Incorrect Application • Other
Maintenance/Process Issues	• Bond Failure/Separation (retread) • Improper Repair • Missed Repair • Questionable Remaining Casing Life • Tire manufacturer issue • Other

Indeterminate Cause	• Detachment
	  ○ Tread Rubber Only
	  ○ Tread & Outer Belt(s)
	  ○ Tread and all belts from casing
	• Runflat
	• Other

Excessive Intra-carcass Pressurization	• Compromise of Inner Liner • Bead Damage • Other

Data Analysis

Sample Damage Classification

Sample Condition	Total	%
Tread strip	687	66.38%
Fragment	165	15.94%
Whole tyre	89	8.60%
Wheel and tyre	67	6.47%
Sidewall only	12	1.16%
Casing	9	0.87%
Sidewall and tread	5	0.48%
Beads	1	0.10%
Grand Total	**1035**	

The majority of the samples in the skips were complete tread strips. Incomplete tread strips (fragments) were the second most frequent found.

It is probable that tyres which are not destroyed (whole tyres, wheel and tyre, casing) are taken away on the recovery vehicle when the tyre is changed. As Truck & Bus Radial casings potentially have a retread value, there is a likelihood some of these may have been removed for casing sale. Also, tyres which have been destroyed during a traffic incident may have been removed by the emergency services.

Some of the whole tyre or wheel and tyre samples found were suspected to be worn out removals from Highways agency vehicles. These have been removed from the results.

Failure Reason

Problem	Total	%
Road Hazard	577	55.75%
Over-deflection	185	17.87%
Indeterminate	167	16.14%
Maintenance	84	8.12%
Heat	11	1.06%
Manufacturing defect	11	1.06%
Grand Total	**1035**	

Tyres damaged by road hazards accounted for over 50% of the tyres inspected.

Where a cause could not be definitively ascertained, we erred on the side of 'indeterminate' rather than risk contaminating the data. For example, a tyre showing runflat damage but where we could not categorically state whether the damage was caused before or after the tyre failure was classed as 'Indeterminate'.

'Over-deflection' accounted for all tyres which had failed through runflat damage from poor pressure maintenance, but not those where a tread penetration or other damage has been detected. In our consideration, such cases could have also been classified as poor maintenance.

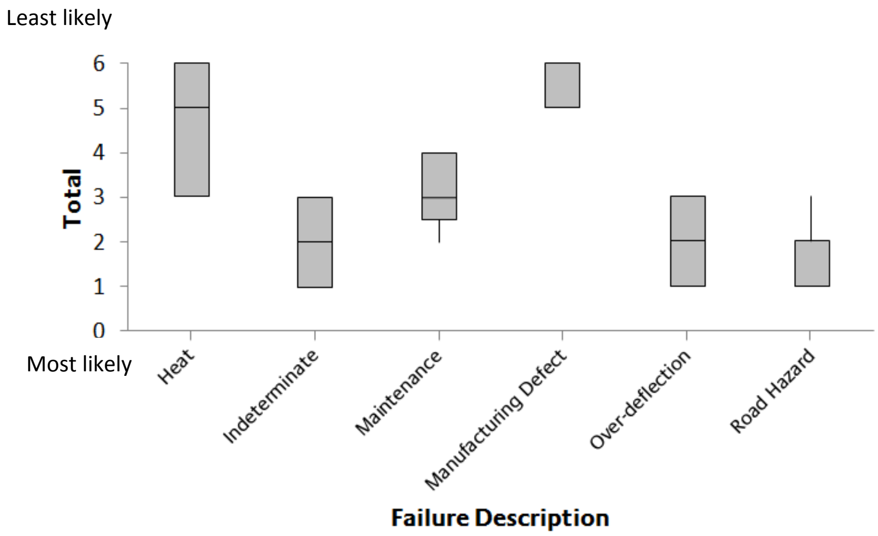
Few incidents of manufacturing problems were noted.

Sample Condition and Failure mode

Sample Condition	Failure Description	Total	%
Tread strip	Road Hazard	409	59.53%
	Over-deflection	166	24.16%
	Indeterminate	49	7.13%
	Maintenance	48	6.99%
	Heat	9	1.31%
	Manufacturing defect	6	0.87%
Tread strip Total		**687**	
Fragment	Road Hazard	76	46.06%
	Indeterminate	72	43.64%
	Maintenance	7	4.24%
	Over-deflection	5	3.03%
	Manufacturing defect	4	2.42%
	Heat	1	0.61%
Fragment Total		**165**	
Whole tyre	Road Hazard	56	62.92%
	Indeterminate	20	22.47%
	Maintenance	9	10.11%
	Over-deflection	3	3.37%
	Manufacturing defect	1	1.12%
Whole tyre Total		**89**	
Wheel and tyre	Road Hazard	28	41.79%
	Maintenance	21	31.34%
	Indeterminate	14	20.90%
	Over-deflection	4	5.97%
Wheel and tyre Total		**67**	
Sidewall only	Indeterminate	7	58.33%
	Road Hazard	3	25.00%
	Heat	1	8.33%
	Maintenance	1	8.33%
Sidewall only Total		**12**	
Casing	Indeterminate	4	44.44%
	Over-deflection	3	33.33%
	Road Hazard	2	22.22%
Casing Total		**9**	
Sidewall and tread	Road Hazard	3	60.00%
	Over-deflection	2	40.00%
Sidewall and tread Total		**5**	
Beads	Indeterminate	1	100.00%
Beads Total		**1**	
Grand Total		**1035**	

Road hazard is consistent across sample conditions as being the primary reason for tyre failure.

Ranking of failure description:



This box plot visually shows the data from the 'Sample Condition and Failure mode' table on the previous page. It shows that Road Hazard has the greatest likelihood of being the reason for failure, followed by indeterminate, over-deflection, maintenance, excessive heat and then manufacturing defect.

Easily Avoidable Problems

Failure Description	Description	Total	%
Over-deflected	Runflat	148	80.00%
	Poor pressure	33	17.84%
	Underinflated + overage	1	0.54%
	Overladen	1	0.54%
	Extreme runflat	1	0.54%
	Ply end sep	1	0.54%
Grand Total		**185**	

Failure Description	Description	Total	%
Maintenance	Worn through shoulder	21	25.00%
	Poor repair	19	22.62%
	Overage	14	16.67%
	Brakeflat	5	5.95%
	String repair	5	5.95%
	Broken wheel	3	3.57%
	Worn through centre	2	2.38%
	Hub fault	2	2.38%
	Age cracking	2	2.38%
	Rim damaged	2	2.38%
	Worn to destruction	1	1.19%
	Poor regroove	1	1.19%
	Wheel loss	1	1.19%
	Casing failure	1	1.19%
	Seized wheel bearing	1	1.19%
	Temp spare - over used	1	1.19%
	Sidewall cords exposed	1	1.19%
	Broken wheel bearing	1	1.19%
	Rim fault	1	1.19%
Maintenance Total		**84**	

‘Over-deflection’ accounted for the instances where the tyres have been run at insufficient pressure over time resulting in various methods of casing failure.

25% of maintenance issues were from severe misalignment resulting in wear through the shoulder. This method of failure is easily detectable and would most likely have occurred over some time.

Poor or failed repairs accounted for 22% of maintenance issues, with string (improper) repairs accounting for 6%. String repairs are not considered safe for permanent use (BSAU 159g).

Maintenance issues and over-deflection issues (Over 25% of total samples) could have been easily avoided with proper tyre husbandry.

Product Group

BSNOR Survey Results

Product Group	Total	% total
Truck & Bus Radial	472	45.60%
Passenger Car	452	43.66%
Van	104	10.05%
Motorcycle	6	0.58%
Off Road	1	0.09%
Total	**1035**	

Vehicle Usage Data from 'Provisional Road Traffic Estimates 2016'

Vehicle	Billion Miles/Year	% total
Car/Taxi	249.5	77.85%
Large Goods Vehicle	48.5	15.13%
Heavy Goods Vehicle	17.1	5.34%
Others	5.4	1.68%
Total	**320.5**	

Even taking into account that Heavy Goods Vehicles represent more tyres per vehicle than passenger cars, we are seeing far more truck and bus tyre debris than we would expect to see based on the Road Traffic Estimates 2016 data. (see also appendix – Road Traffic Trend 2016)

Potential reasons could be :

- A tyre can fail on a Heavy Goods Vehicle with potentially less impact to the vehicle mobility than on a Passenger Car vehicle.
- A stripped tread on a trailer may be noticed on stopping at a service station.
- A failed tyre on a car would likely be attended roadside or the vehicle would be recovered, so the tyre debris may be recovered along with the vehicle.
- Passenger Car tyres are much easier to transport away than a Truck & Bus Radial tyre.

New/Retread	Total	% total
New	270	57.20%
Retread	165	34.96%
NK	37	7.84%
Total	**472**	

New vs retread market split is currently around 65:35 (2016 Europool data). So the failure rate of new vs retread is in line with usage.

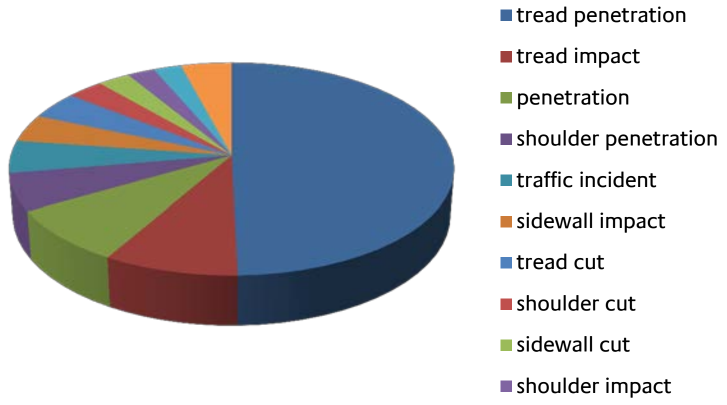
So retreads are not more likely to fail than new tyres.

The % failure reasons for a first life ('new') truck/bus tyre and retreaded truck/bus tyre are similar – if a first life tyre fails it is likely to be for exactly the same reasons as a retread tyre.

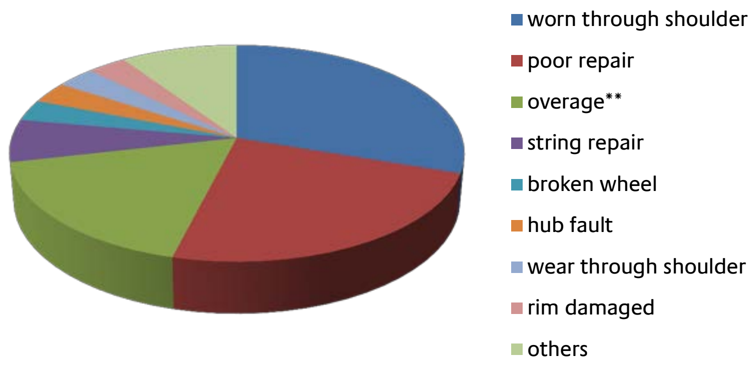
For the passenger car tyre samples, road hazards account for 47% of problems.

Incorrect vehicle alignment and poor repairs on passenger car tyres are surprisingly common. i.e : Four tyres being found with string repairs, and a temporary spare run to destruction indicates vehicles are being run in an unroadworthy condition, or without consideration of the limits of such temporary remedies.

Road Hazard Categorisation (passenger car):



Maintenance Issues Categorisation (passenger car) :



**'Overage' refers to tyres which have suffered from age-related perishing (cracking).

Road Hazard Damage

Category	Description	Total	%
Tread	Tread penetration	283	69.53%
	Tread impact	80	19.66%
	Tread cut	41	10.07%
	Tread edge cut	2	0.49%
	Brakeflat	1	0.25%
Tread Total		**407**	**70.54%**
Not Noted	Penetration	55	68.75%
	Impact	25	31.25%
Not Noted Total		**80**	**13.86%**
Shoulder	Shoulder penetration	22	51.35%
	Shoulder cut	12	26.67%
	Shoulder impact	11	24.44%
Shoulder Total		**45**	**7.80%**
Sidewall	Sidewall impact	**11**	40.74%
	Sidewall cut	**9**	33.33%
	Sidewall damage	**3**	11.11%
	Kerbing	**2**	7.41%
	Sidewall penetration	**1**	3.70%
	Sidewall abrasion	**1**	3.70%
Sidewall Total		**27**	**4.68%**
Traffic	Traffic incident	**17**	100.00%
Traffic Total		**17**	**2.95%**
Vehicle	Vehicle damage	**1**	100.00%
Vehicle Total		**1**	**0.17%**
Grand Total		**577**	

Over 50% of the tyres found to have suffered from a Road Hazard were found to have at least one penetration.

Due to the preponderance of tread strip samples, most damages noticed were to the tread or shoulder area. However, according to BSEMA data, 81% of punctures occur in the tread area,12% in shoulder area and 6% in sidewall.

Taking the data for penetration and cuts from our survey we find …

Category	Total	%
Tread	326	88.11%
Shoulder	34	9.19%
Sidewall	10	2.70%
Grand Total	**370**	

Which would indicate our data is quite representative of the whole market.

Many tread penetrations were noted as the result of bolts, resulting in large holes to the tread area; however the actual proportions were not noted.

Tread Penetration Severity

The stress to a tyre is a combination of the speed, load carried, and the degree of underinflation. The excessive deflection of the tyre produces heat, and fatigues the tyre, resulting in degradation of the rubber – typically at the shoulder, and eventual failure of the tyre. If a tyre is able to lose some of the heat generated, then the tyre's destruction will be slower, which is why it is impossible to gauge how long the tyre has been run underinflated before failure.

However it would be reasonable to assume many of the tyres which had suffered from penetrations had been operating penetrated for some time. The penetrating object can often partially plug the hole and be carried for some time if not detected, resulting in a slow deflation.

Reg 661 (2009) requires all new passenger vehicles be fitted with a tyre pressure monitoring system from Nov 2014, so we should see a reduction in the number of tyres failing on our motorways; however this does not prevent the penetrations from occurring, or being able to rectify the issue before failure.

Marks such as these indicate the object has been in the tyre for some time prior to failure =>

RAC Annual Breakdown Calls (Breakdown Britain 2006)

Fault	Number of Breakdowns
Punctured tyre	194549
Jumpstart (flat battery)	177916
Dead battery (replacement required)	130575
Road Traffic Accident	90263
Engine fault	67881
No fault found (driver error)	64773
Alternator fault	58887
Starter Motor fault	57380
Clutch - Assembly	51969
Interior lights left on (flat battery)	48681

Data from RAC shows tyre punctures represent the majority of breakdown call-outs.

Conclusion

1) Our study finds that retreaded tyres show no greater likelihood of failure in service than a first life (new) tyre. **57% new Vs 35% retread**, against market usage of **65% new Vs 35% retread** (2016 Europool data).
2) Failure due to manufacturing defect is extremely unlikely. **1%** of whole population.
3) The greatest contributors to tyre failure while in service are road hazards (impacts, penetrations and cuts). **56%** of whole population.
4) With proper vehicle inspection and maintenance programs, many of the failure methods noted should be detectable and preventable. **26%** of whole population.
   - *Education on the limitations of temporary mobility solutions may prevent some vehicles being operated in an unsafe condition.*
5) Our study generally confirms the findings of the UMTRI study both in terms of retreaded tyres vs new, and road hazards as the no1 reason for tyre failure, within HGV products.

General comment:
Tyre Pressure Monitoring System being fitted to vehicles should assist with the detection of penetrations and deflations. Also, fitment of self-supporting tyres (PSR) would limit the impact of such air-loss events.

2% of Motorway road traffic accidents in 2015 were attributed to illegal, defective or underinflated tyres.
14 of the accidents attributed to tyres were fatal.

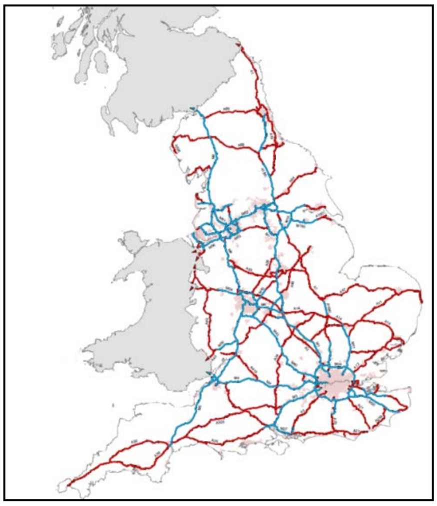
(Reported Road Casualties 2015)

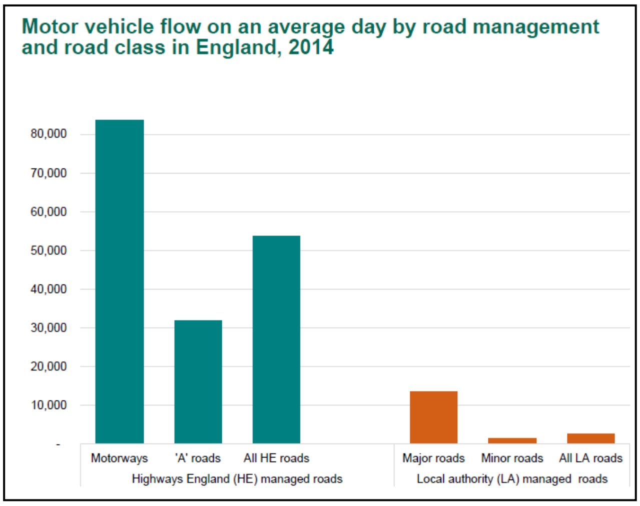
Data Accuracy

If we can mainly sample only the failure modes which create tread strips/fragments then it could be said that we are not capturing a representative sample of the tyre failures. However, as these tread strip failures are likely to be the most ‘theatrical’ or dangerous due to the complete destruction of the tyre, then these are likely to be the ones of which customers are most wary.

There may be tyre debris being accumulated which we do not have access to – on country roads where it is not collected or disposed, or on roads not patrolled by the contracted highways agency. However, Annual Road Traffic Estimates 2014 shows that the contracted highways agencies account for 80% of the road traffic miles in the UK.

East Midlands and West Midlands managed highways represents 18.5% of total managed highway roads in UK *(2015 Road Usage datafile TRA0103),* so we can be reasonably sure we are capturing a good proportion of the available data.

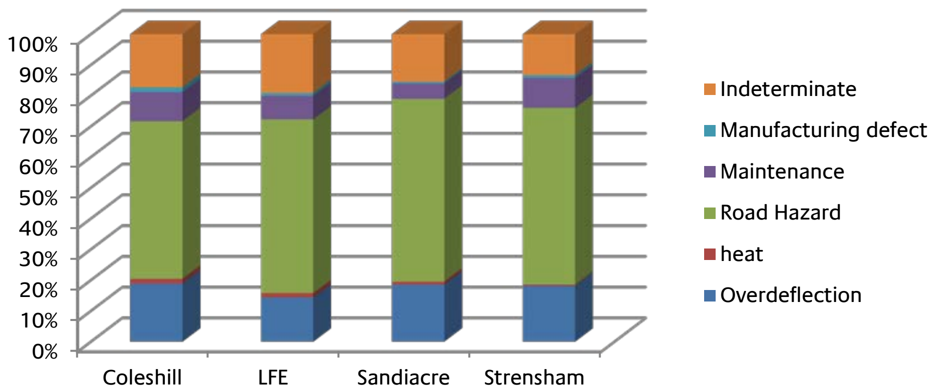




Most samples come from Coleshill and Strensham due to period of changeover between contractors, during which we could not visit the LFE and Sandiacre sites. Comparison of the data from the four depots shows the same distribution of failure reasons (P-correlations 0.988-0.993), so it is reasonable to believe the data from the four sites can be treated as equal.

While we visited regularly, we could not capture 100% of the tyre debris collected. However I would expect in excess of 50% of the debris collected by the agencies was inspected by our engineers.

Depot	Total
Coleshill	318
LFE	209
Sandiacre	200
Strensham	308
Grand Total	**1035**



There is a risk of misclassification of data samples between engineers. Due to potentially multiple failure types contributing to the eventual failure of the tyre, samples could be placed into different damage categories based on the opinion of different engineers. The regular certification process for a Field engineer involves blind inspection of many tyres, which are then scored against a master file of agreed correct inspection result. The engineers assisting with this debris project were all certified in Jul'13 and each scored 100% vs correct inspection and 100% correlation with each other. Therefore we can assume a high level of inspection correlation for the debris project.

UMTRI Survey Comparison

> The analysis of tire fragments and casings collected in this study has found that the proportion of tire debris from retread tires and OE tires is similar to the estimated proportion of retread and OE tires in service. Indeed, the OE versus retread proportions of the collected tire debris broadly correlated with accepted industry expectations.
>
> Additionally, there was no evidence to suggest that the proportion of tire fragments/shreds from retread tires was overrepresented in the debris items collected. Examination of tire fragments and tire casings (where the OE or retread status was known) found that road hazard was the most common cause of tire failure, at 38 percent and 36 percent respectively. The analysis of tire casings found maintenance and operational issues accounted for 32 percent of the failures while over-defection accounted for 16 percent. Analysis of tire fragments found that excessive heat was evident in 30 percent of the samples examined. These results suggest that the majority of tire debris found on the Nation’s highways is not a result of manufacturing/process deficiencies. Similar findings are corroborated in earlier studies of tire debris.
>
> ***(Commercial Medium Tyre Debris Study - UMTRI 2007)***

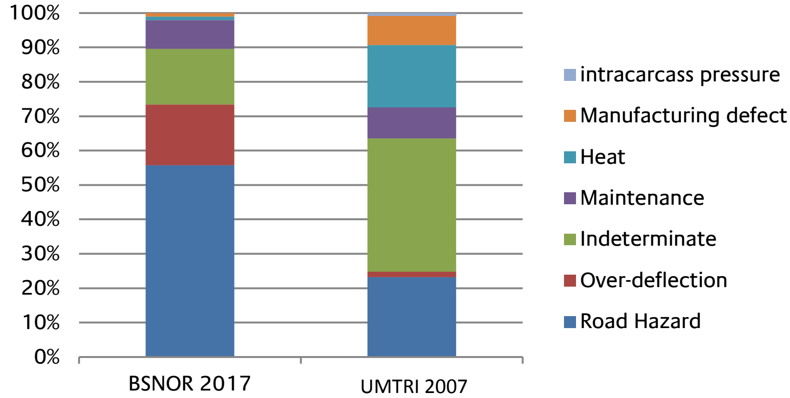
Our study supports the findings of the 2007 UMTRI study that the incidence of retreaded tyre debris vs new tyre debris matches the market usage of these products. This indicates there is no greater risk of sudden tyre failure when using a retreaded tyre vs using a new tyre.

Each study inspected a similar number of roadside debris (BSNOR=1035, UMTRI=1196). The UMTRI study also inspected 300 casings collected at truck stops but as these have not failed on the road network, I have not included these in the comparison.

UMTRI study classified many more tyres as indeterminate (BSNOR=16%, UMTRI=39%). The reason for this may be that the samples collected in USA may have been less complete than those collected in UK, or the US inspector may have been more cautious in adjudicating. The US inspector(s) is stated as a tire forensic consultant, so there should be no doubt of competency.

The UMTRI study is of Truck tyres only, but even restricting our data to truck tyres does not significantly change the % of indeterminate.

Comparison of all results:



If we remove the indeterminate adjudications from the results, we can see both studies agree that most tyre debris originates from a road hazard (BSNOR=66%, UMTRI=39%)

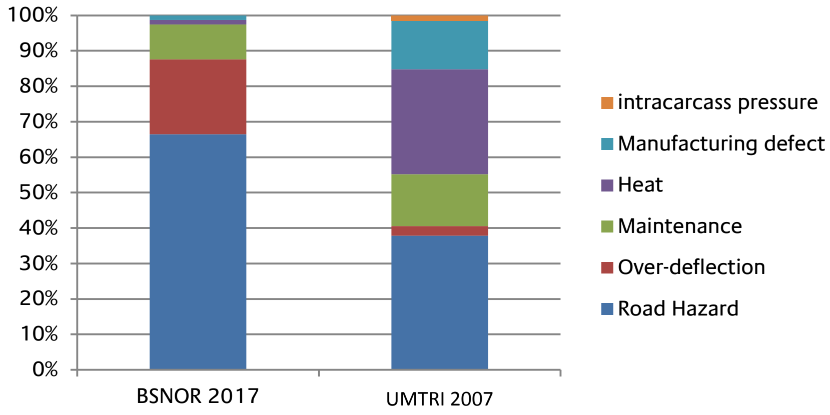
It may be that roads in USA are cleared of road hazards more frequently than in UK, which is why they have experienced less instances of this failure type. With regard to damage from road features (i.e. potholes, raised ironworkings etc.): for 2015-2016 period, World Economic Forum rated United Kingdom 29th in world for road quality (scoring 5.2/7) and United States 14th in world (scoring 5.7/7). So this may partly explain the greater incidents of road damage noted in UK (*The Global Competitiveness Report 2015–2016 – World Economic Forum*). We believe the USA has straighter roads and lower traffic density than the UK, which would also help prevent road hazard damage, but no data could be found to confirm this.

The UMTRI study has a much lower incidence of over-deflection (BSNOR=21%, UMTRI=3%), but attribute much more to excessive heat (BSNOR=1%, UMTRI=31%). These two failure types are very similar in appearance as already described. I suspect that tyres BSNOR have attributed to over deflection would have been classed as excessive heat if part of the UMTRI study. Therefore we should consider these two failure types as a whole when comparing the two studies. If we do so, then our results are much more in line with the UMTRI study (BSNOR=22%, UMTRI=34%)*

The UMTRI study found a greater contribution from maintenance issues than in UK (BSNOR=10%, UMTRI=15%). We note there are fewer checks on roadworthiness in USA, which could go some way to explain this.*

* NB – figures in these paragraphs are the result of removing the 'indeterminate' values

Comparison of results w/o indeterminate:



The UMTRI study found a much higher incidence of manufacturing defects than BSNOR (BSNOR=1%, UMTRI=14%). All of the manufacturing defects found in UMTRI relate to retreaded tyres, and are stated as being mostly 'casing selection and repair, or tread rubber application issues'. It is a trend in US that smaller retreading shops are closing while total output remains the same *(TRIB 2012).* We would expect that the smaller retreading shops would have less quality control processes than a larger retreader, so that should correspond to a reduction in manufacturing defects over time.

There have been improvements in non-destructive testing since 2007, particularly with the implementation of shearography machines. So if the study was repeated, we would expect a reduction in manufacturing defects in the USA.

Project Expansion

The data obtained within this project relates to UK operation, and there may be significant variation with data obtained in a more or less demanding environment. E.g. countries with higher ambient temperatures may see increased heat failure. Thus to compare our data with that obtained in a different market will give a wider perspective on the generation of roadside tyre debris.

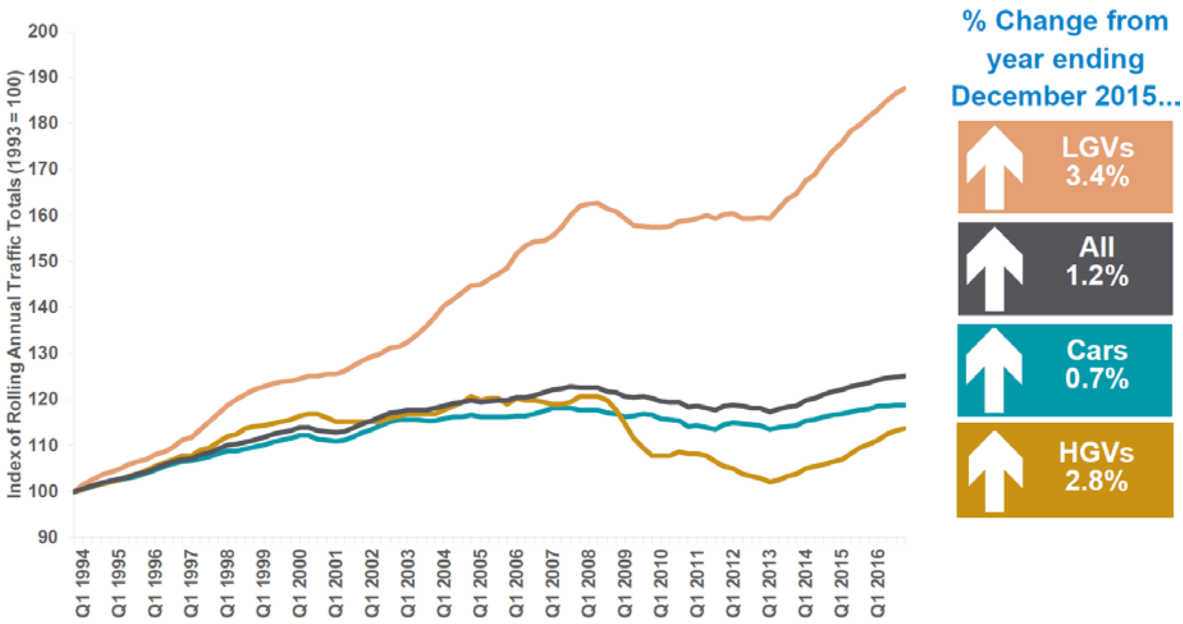
While obtaining original tread depth values for each sample would not have been possible, measuring the remaining tread depth (where tread was remaining) may have given an indication to the wear stage of the tyre.

For TBR tyres, it may have been interesting to note the probable axle position of each sample, to indicate whether steer/drive/trailer tyres are more likely to sustain damage or suffer maintenance issues.

For data accuracy reasons, it may be useful to note which engineer inspected each sample to compare judgement statistics. We could also collect samples and conduct a measurement system analysis for further confidence in the data.

Appendix

Road Traffic Trend 2016



Additional resources utilised

2007 UMTRI Tyre Debris Study – U.S. DoT
Tyresafe news bulletin 2014
Preliminary Road Traffic Estimate 2016
Reported Road Casualties Great Britain: 2015 Annual Report
The Global Competitiveness Report 2015–2016 – WEF
TRIB 2012 (US retreaders)
Road Traffic Estimate 2014 – UK DoT
2015 Road Usage datafile TRA0103
RAC Annual Breakdown Calls – Breakdown Britain 2006