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# Research:

"What length of time was required to run a tyre underinflated and show visible signs of running underinflated?"

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Executive Summary:

Many crash cases will result in some query relating to tyres; it may be that the major investigation of the case will centre around a tyre issue where an allegation or suspicion of some tyre related problem is raised.

Statistics internationally and locally have shown that the greatest percentage of tyre related issues raised are usually traced back to abuse of tyres such as overloading, previous repairs such as plugs, incorrect tyre pressures, improper vehicle maintenance and therefore inappropriate tyre wear and even other factors such as pothole damage or kerb strikes.

It is somewhat alarming that all too often, it appears that a driver will allege a “blow-out” or tyre failure of some sort being the cause, and thereby assuming that they will have an “escape route”.

In countless cases investigated by the writer, tyre related issues have been raised or were evident, some of which gave rise to many questions that needed answering. One such question is that of “What length of time is required to run a tyre underinflated and show visible signs of running underinflated?”, it is this aspect that is considered herein.

The modern tyre is inherently well designed and reliable, able to absorb massive punishment and still remain reliable. This in itself could also be cause for concern, particularly where underinflated tyres may well be in very poor condition internally, but display very little external evidence thereof.

The parameters tested, suggest that very little evidence would be created and shown on a tyre, particularly on the external surface, even under extreme low pressures and over reasonably high driving distances.

The testing re-affirms that the investigation of a crash case where tyre related problems are raised requires particular attention to be paid to all aspects of the tyre and possible effects thereon, especially to the internal examination of the tyre.
Glossary:

Bead - A ring of steel wire that anchors the tire casing/carcass plies to the rim.

Belt - An assembly of plies extending from shoulder to shoulder of a tire and providing a reinforcing foundation for the tread. In radial-ply tires, the belts are typically reinforced with fine steel wire having high tensile strength.

Blowout - The rapid air loss or sudden deflation of a tire through an opening (i.e., hole) in the tire.

Casing - The tire structure, except tread and sidewall rubber, that bears the load when the tire is inflated.

Detachment - One or more of the tire’s laminar components having become physically detached from adjacent components (e.g., the tread, or the tread and one or more steel belts, completely detaching from the casing).

Failure – The generic indication of the failure of a tyre in this context, this could due to any number of causes, however is generally indicated as generic indication of the failure of a tyre for whatever reason.

Fatality - Any death resulting from a fatal injury at the time of the crash or within 30 days of the crash.

Fragment - Any portion of detached tread, or tread and belt(s), or belt(s) that is less than the total circumference.

Intact - Tyres that have come out of service for some reason (road hazard, etc.), but have not sustained a detachment of any of the tire’s laminar components.

Over-inflation - A state when the cold inflation pressure in the tyre exceeds what is needed for the tire to maintain an optimal footprint for the load it is carrying.

Ply - A sheet of rubber-coated parallel tyre cords. Tyre body plies are layered.

Retread Manufacturer - The business entity that provides the retread materials, equipment, and other items required in the retreading process. The retread manufacturer is most often NOT the entity that actually retreaded the tyre.

Retreader - The business entity that actually retreads tyres. Retreaders are very often independently-owned businesses that have made arrangements (franchise, dealer agreement, etc.) with a particular retread manufacturer to utilize its materials, equipment, and process. Some retread plant operations are owned and operated by the retread manufacturer.

Retreading - The process by which an additional tread is attached to a casing that has been appropriately prepared.

Rolling Resistance - The force at the axle in the direction of travel required to make a loaded tyre roll.

Separation - One or more of a tire’s laminar components having become separated from an adjacent component (or components) in the structure. The components, though separated, remain attached to the tyre. The condition may be evidenced by polishing or other indications of movement of the separated layers.

Sidewall - The portion of the tyre between the bead and the tread. The tyre’s name, codes and size designation date of manufacture and other factors are moulded on the sidewall.

Tyre – British English / South African spelling (Tire -USA)

Tyre Scrub - A result of wheels that are rigidly secured together for rotation at the same speed but which must travel different distances at the inside and outside of the turning radii.
**Tread** - The peripheral portion of the tyre designed to contact the road surface. The tread band consists of a pattern of protruding ribs and grooved channels on top of a base. Tread depth is measured on the basis of groove depth. Traction is provided by the tread.

**Truck (Medium or Heavy)** - A motor vehicle designed primarily for carrying property/cargo that has a gross vehicle weight rating of more than 3500 kilograms). In South Africa, also referred to as a Commercial vehicle.

**Vehicle Kilometres Travelled** - The number of kilometres travelled by a vehicle for a period of one year. Vehicle kilometres travelled is either calculated by using two odometer readings or, for vehicles with less than two odometer readings, imputed using a regression estimate.
Acronyms:

ABS
Anti-lock Brake System

AWD
All Wheel Drive

COE
Cab Over Engine

EBA
Electronic brake assist

EBD
Electronic Brake force Distribution

EDVSM
Engineering Dynamics Vehicle Simulation Model

EPA
Environmental Protection Agency

ESP

FWD
Front Wheel Drive

GPS
Global Positioning Satellite system

ISO
International Organization for Standardization

LDV
Light Delivery Vehicle

LSD
Limited Slip Differential

MAG
Magnesium wheel or rim (Either as OEM or aftermarket fitment)

NDOT
National Department Of Transport

OE
Original Equipment

OEM
Original Equipment Manufacturer

OHS
Occupational Health & Safety

OTD
Original Tread Depth

PDOT
Provincial Department Of Transport

RIM
Generic reference to metal structure of the wheel (Steel or Aluminium or other)

RMA
Rubber Manufacturers Association

RSA
Republic Of South Africa

RTD
Remaining Tread Depth

R&D
Research and Development

SABS
South African Bureau of Standards

SAE
Society of Automotive Engineers

SAGMJ
South African Guild of Motoring Journalists

SANS
South African National Standards

SAPS
South African Police Service

SIC
Standard Industrial Code Classification
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUV</td>
<td>Suburban (Sport) Utility Vehicle</td>
</tr>
<tr>
<td>TBR</td>
<td>Truck or Bus Radial [Tyre]</td>
</tr>
<tr>
<td>TIA</td>
<td>Tyre Industry Association</td>
</tr>
<tr>
<td>TIN</td>
<td>Tyre Identification Number</td>
</tr>
<tr>
<td>TPMS</td>
<td>Tyre Pressure Monitoring System</td>
</tr>
<tr>
<td>TRIB</td>
<td>Tyre Retread and Repair Information Bureau</td>
</tr>
<tr>
<td>USDOT</td>
<td>U.S. Department of Transportation</td>
</tr>
<tr>
<td>UTD</td>
<td>Useful Tread Depth</td>
</tr>
</tbody>
</table>
In dealing with Traffic Accident Investigation, it is inevitable that some issue of tyres will be raised, it is therefore important that the investigator has at least a thorough understanding of tyres. As in other countries, high speeds, overloading, improperly maintained vehicles and improperly maintained road surface conditions among many other factors, lead to many tyre related issues. This is arguably no more prevalent than in RSA and to some extent is verified by the extremely high number of accidents on our roads.

As an example of such a situation, the following case study\(^1\) highlights the issue of an underinflated tyre and its contribution to the cause of a major fatal accident.

**The scenario:**

A Mahindra Scorpio (2007 model) travelling in a generally northern direction on the R33 in the Pietermaritzburg area, carrying four occupants, i.e. the driver and three passengers; the BMW (1998 3 Series) travelling in a generally southern direction on the R33 carrying five occupants, i.e. the driver and four passengers.

Whilst negotiating a right hand bend, the BMW lost control, subsequently rotated (Yaw) clockwise across the centre barrier line and into the path of travel of the Mahindra. The Mahindra and BMW collided in what is generally described as a right angle type accident in the north bound lane (lane of travel of the Mahindra).

At impact, the BMW split in half with the rear half of the BMW coming to rest a distance away in the north bound lane facing in a generally northern direction. The Mahindra came to rest partially on the roadside verge of the north bound lane and partially in the yellow line of the north bound lane facing in a generally eastern direction, with the front half of the BMW still “attached” to the Mahindra, the following images attest:

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\(^1\) A major crash that resulted in 6 fatalities and two serious injuries, a crash investigated by the author
Scene location:

The scene is located at the outskirt of Pietermaritzburg, KwaZulu-Natal, South Africa on the R33, a busy sub-road serving a combination of residential, farming and industrial areas with GPS co-ordinates 29°30'54.90"S / 30°25'33.77"E.
Scene evidence:

The scene was attended to by the SAPS and likewise the author, where extensive scene evidence was pointed out and likewise was patent. The following images attest to the evidence of particular interest, namely that of the typical tyre mark and associated intermittent rim marks alongside the tyre mark.

---

2 The following morning
3 Ref. material 43 – (Discussion)
Roadway Physical Evidence - Following each run, the physical evidence deposited on the roadway was documented. During each test, a single tire mark was deposited by the separating tire. The marks were irregular and non-continuous, consistent with the tread flap striking the ground. When the tread released from the tire, the tire mark ceased. If the tread flap remained attached, the tire mark continued until the vehicle speed reduced considerably. When air loss occurred, the tire mark was noticeably different. Specifically, the mark was still irregular, but more continuous than when the tire retained air pressure. When air loss occurred, the edges of the tire mark were darker, as a result of point loading from the rim.
Underinflated Tyres – Case Study: Continued:

- BMW Tyre mark
- SAPS scene image, Captain D Otto
- Rim contact
- Tyre mark

Author’s image

- BMW mark
- Tyre mark
- Rim

Accident Specialist – Underinflated Tyre – Case study and research – 2014 - 2015
As a quick highlighting, the loading (side force) applied to the tyre has been so severe in the particular case that the deformation of the tyre has caused the tyre to be displaced from the rim, bringing the rim into contact with the road surface\(^4\). The following descriptive shows this effect:

Documenting of scene evidence:

The scene was attended to, where the road layout and associated items were recorded likewise the physical evidence from the accident, where this was undertaken in detail with the use of a Nikon NPR 352 Total Station.

Calculations there from:

Although there is far more to the consideration and application of the various formulae and the specific input values related to the formulas used in determining speed indications for the accident, where these will not be referenced in detail herein, it is simply highlighted that:

The initial speed indicator determined was that of the “critical curve speed” – see formula confirmation below, for the right hand bend on which the accident occurred. The speed was determined as at approximately 225km/h. This indicated an extremely high speed for the bend, however was not considered an unusual indicator for this bend when the large radius (approximately 454.3m) and good condition of the tar surface and related parameters were considered.

\[
\nu = \sqrt{\frac{R_g (\mu + \epsilon)}{1 - \mu\epsilon}}
\]

\(^4\) Reference material 3 & 5
Although the particular vehicle is quite capable of reaching extremely high speeds, it was highly unlikely that the BMW had lost control simply due to exceeding the critical curve speed and this improbability was a “red flag” contributory factor.

It was not possible to obtain information from any of the onboard systems (CDR), as these were utterly decimated during the accident.

The vehicle:

Although an older model vehicle, with evidence of general maintenance, the general condition of vehicle appeared good.

Examination of the vehicle for evidence quickly identified various damaged and deflated tyres, although not uncommon in this type and of such a violent accident. Further examination of the tyres revealed clear evidence of plugs and that the left rear tyre had been running underinflated for some period of time. The wheels and tyres fitted were documented as follows:

<table>
<thead>
<tr>
<th>Position</th>
<th>Type</th>
<th>Size</th>
<th>Condition</th>
<th>Date of manuf.</th>
<th>Inflated / Deflated</th>
<th>Inner</th>
<th>Middle</th>
<th>Outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Right</td>
<td>Talon Triangle</td>
<td>205/40/17 84V</td>
<td>Well worn</td>
<td>17 / 10</td>
<td>Inflated</td>
<td>1.22</td>
<td>2.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Front Left</td>
<td>Talon Triangle</td>
<td>205/40/17 84V</td>
<td>Well worn</td>
<td></td>
<td>Deflated</td>
<td>1.8</td>
<td>2.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Rear Right</td>
<td>Talon Triangle</td>
<td>205/40/17 80V</td>
<td>Well worn</td>
<td></td>
<td>Inflated</td>
<td>1.1</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Rear Left</td>
<td>Talon Triangle</td>
<td>205/40/17 84V</td>
<td>Well worn / plug evident</td>
<td>37 / 09 (September 2009)</td>
<td>Deflated</td>
<td>1.4</td>
<td>1.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Spare</td>
<td>Pirelli P6000</td>
<td>225/45 R17</td>
<td>Could not be checked as could not be removed from vehicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The particular tyre of interest at the left rear and identified as being deflated, with outer flange circumferential rim damage and as having been plugged, is highlighted in the following images:

---

5 Typical visual examination while wheels and tyres were intact and on the vehicle.
Underinflated Tyres – Case Study - Continued:

Date of Manuf.  
Specification

Circumferential outer rim flange

Circumferential outer rim flange
Subsequent removal and inspection of the tyre revealed not only the internal section of the plug already identified, however also identified a steel object, that could not be seen externally, protruding internally (Nail?).
Underinflated Tyres – Case Study - Continued:

Plug

Metal

Severe liner abrasion of the inner sidewall

Severe line abrasion deposits

Severe liner abrasion deposits

Metal

Metal
It was obvious that the particular tyre was well worn and beyond the legal limit of use with regards the tread depth and notable that the tyre was nearly three years old. Inspection of both the tyre and rim revealed no obvious indicators of tyre slippage on the rim, nor any issues with the rim itself.

Comments:

The basic details supplied of the case study are intended to simply highlight the issue of underinflated tyres being a factor in accidents, sometimes the direct cause. Likewise, intended to quickly yet briefly identify that there can be very clear physical evidence of an underinflated tyre. The case study is not intended to teach one the finer nuances of investigating such a case, that would be the culmination of training and experience; however it is assumed that the case study would also highlight an interesting and perhaps difficult question posed as a result of this particular case:

What length of time is required to run a tyre underinflated and show visible signs of running underinflated?

It is notable that, although there is relatively minor evidence on the outside of the tyre of under inflation, the extent of the tyre damage is predominant and substantially evident on the inside of the tyre. The severity thereof immediately suggested that the degradation of the tyre to this extent had occurred over a considerable period of time. However, what is a considerable period of time? Fifteen minutes?, a 30km shopping trip to town from home; or a two hour trip to visit family 150kms away?

Opportunistic related incident considered:

During October 2014, as a member of the South African Guild of Motoring Journalists, driving a test vehicle being a 2014 Mercedes, Four Door sedan CLA180, fitted as standard with Good Year Eagle F1 225/40/R18 92W – Asymmetric 2, Run Flat tyres, with approximately 4600kms use (Date of Manufacture 25th Week 2013), a pot hole was struck. The following images highlight the actual tyre and specifications:

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6 Also raised on other cases
7 With no imperial data to verify this, perhaps this train of thought is rooted in the many research papers indicating that tyres are inherently underinflated
8 Membership number 946
The following image highlights the particular vehicle:

The incident occurred on the R603 in the Pietermaritzburg area, KZN, just south of and after the farmers market, on a gentle uphill, travelling at approximately 90km/h (100km/h speed limit), two adult male occupants, sunny and clear weather. The pothole was struck with the front right hand wheel, totally unexpected and unseen, the following images highlight the pothole:
Underinflated Tyres – Case Study - Continued:
Underinflated Tyres – Case Study: Continued:

Height Reference - Blackberry Z10 – approximately 65mm width (Depth of Pothole)
Almost immediately the damage to the tyre was felt as a “rolling thud”, the vehicle internal tyre pressure warning system almost immediately displayed on the onboard display. The vehicle was stopped within a kilometre and inspected, the damaged tyre immediately evident. The following images reflect (actual images taken):
Footage of damage whilst moving evident at:  https://www.youtube.com/watch?v=JYyH51uSLXE

Having no spare wheel\(^9\), the vehicle was driven at approximately 50\(\text{km/h}\) (approximately 1\(\text{hour 40min drive}\)) from the incident to Durban, directly to a tyre fitment centre:

\(^9\) Questionably for South African Conditions, Standard practice by Mercedes, hence the “Runflat” tyres fitted, likewise the tyre pressure monitoring system
Removal and inspection of the tyre revealed the following damage:

Note the damages directly opposite one another, both lacerations penetrated through both sidewalls.
Interestingly, no evident damage, or marks were notable on the tread surface section between the side wall lacerations, the following image highlights:
Of particular interest was the identifying of any visible damage (besides that of the obvious impact lacerations) to the tyre, created where the tyre was driven for some 72kms in a wholly deflated condition (although notably at a slow and steady speed). Externally, there were no obvious damages or evidential factors that would allude to having been driven underinflated or wholly flat as was the case. The only slight indicator was what appeared to be a very slightly scuffed (darkening) of the rim cushion area (highlighted below). This was only notable where the tyre was removed.

Internally, there was substantial indication of being driven underinflated (wholly flat in this case), where severe abrasion of the inner liner was obvious, where the standard “pattern” was visibly eroded. Likewise, visible creasing and fold lines were evident circumferentially near the shoulder. Most notably, actual minor lacerations and abraded / scuffed (Granules) sections of the inner liner were notable circumferentially in the vicinity of the shoulders. These pieces (Granules) are evident in the image below.
Comments:

Fortunately, and unlike the first case study, this event did not lead to death, injury nor damage, as so often and very easily can be the case. It did present a fortuitous scenario to consider certain parameters being asked in the study that follows. Without the specific knowledge of all the parameters surrounding the above incident, had the damage to the tyre not initially been so severe and obviously disabling and at some later stage led to a failure resulting in a far worse result, it may have been at that stage that the question may have been raised at to “when did the original damage to the tyre occur?” and therefore the related question of “What length of time is required to run a tyre underinflated and show visible signs of running underinflated?”

Some local statistics:

The eThekwini Municipality (Durban, KwaZulu-Natal) is one of the major cities (Coastal) in South Africa, Durban being the largest city in the province of KwaZulu-Natal. The specific area of the eThekwini Municipality some 2297 km/sq (885mi/sq), a population of some 3.442 million (2011\textsuperscript{10}) and a registered vehicle population of some 829552\textsuperscript{11}.

The eThekwini Municipality maintains a Municipal database for accident statistics at a world class level; nonetheless as is identified internationally, there are inherent shortcomings with recording standard accident data from basic accident reports. For example, a driver may report an accident themselves and indicate “blowout” or “tyre failure”, but this remains unconfirmed and likewise the resulting extent of damages and involved parties indicated in the report may be wholly or somewhat incorrect.

Nonetheless, it remains interesting to simply consider these stats over a three year period (2012 through 2014), where a total of 537 reported incidents of “Tyre Blowout” are indicated, a substantial number by any consideration.

\textsuperscript{10} Census 2011
\textsuperscript{11} eNatis 2014
Somewhat expected, and without delving into the plethora of possibilities that arise, the majority of these accidents (130 + 240 = 350) are single vehicle accidents and accidents where a loss of control has occurred resulting in impacts with fixed objects.
Research:

As a result of the question raised, “What length of time was required to run a tyre underinflated and show visible signs of running underinflated?”, extensive literature research was undertaken to determine an answer. It was quickly evident that there was very little or no indicators in the many direct and indirect tyre related research papers that gave a clear or even alluding indication to this. In order to better understand this scenario, it was proposed that some basic research testing to this effect be undertaken, resulting in the proactive collaboration of Bridgestone with the researchers (www.accidentspecialist.co.za).

The research undertaken has no implication for brand used in the testing; the use of the brand has come about due to the author’s initial approach to Bridgestone from a previous co-operation. Their extensive proactive research and involvement in all tyre related safety issues and their willingness to assists in such a proactive manner is commendable.

The reader is referred to the listing of reading material (Reference material – Page 93) attention is drawn at this early stage to the following specific comments:

Judgement: Case Number: 280 / 93 - In the Supreme Court Of South Africa (Appellate Division)

“For negligence to be established on the part of the driver before the tyre burst the appellants have to prove two things. The first is that the bus was driven for a considerable distance with an under inflated tyre, which led to the building up of heat and the eventual destruction of the tyre. The second is that the driver should have been aware of the under inflation and ignored it.”

“I return to the first point, has it been proved that the tyre was under inflated? There is no direct evidence of any kind on this point.”

Executive summary

“Established methods in accident investigation and reconstruction rely on the identification and interpretation of physical evidence from the scene and from the vehicles,...”

“In the course of investigations work, many examples arise where the conclusions of expert reports are limited by the absence of supporting test data. In particular, incorrect tyre pressure is often cited as a contributory or even main cause of an accident in the absence of independent knowledge of the effects of such incorrect tyre pressures.”

It is noted, somewhat ironically, that in almost all the reference material reviewed very little emphasis appears to be placed on the supply or specific reference to actual photographic evidence, even where the crux of the research lends to detailed photographic images being supplied, either for a first line descriptive indication or as a cross reference to a written description. Nonetheless, it is with the nature of the visual and tactile non-destructive tyre examination that the evidence being considered herein is assessed and documented.

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12 Online and in various publications, as well as telephonic queries with specialist tyre practitioners at manufacturers & non manufacturers
13 Ref 22 – Pg 93
14 Writer – What is a considerable distance?
15 Writer – The exact physical evidence being considered herein
16 Ref 21 – Pg 93
17 See black and white images in Ref paper 25 – Pg 93, et al.
Methodology:

Vehicle:

A largely new 2013 Opel Astra sedan (Odometer 17810), front wheel drive vehicle was used as the test vehicle, see images below, representative of a large percentage of vehicles on the road in RSA. Likewise for the reasons that slightly lower profile tyres are in use on the vehicle and that at this stage the particular interest was that of the slightly lower profile typical sedan tyres.

Driver:

The driver (85kg) is highly experienced and was familiar with the vehicle and the route (see the route below) and generally maintained a speed not in excess of the posted speed limit. He was accompanied by one front seated passenger (78kg), and a further left rear seated passenger (65kg).

Test time and conditions:

Testing was undertaken during January 2014, between 09:00 and 14:00 on the respective mornings, with general weather parameters of the day recorded as sunny, hot and dry, with an average temperature around 30 degrees Celsius.

Tyres used, their fitment and positioning:

A brand new set of Bridgestone Sporty Style MY-02 205/50/17 89V, as evident below, were fitted as per manufacturers’ specification, particular attention being paid to ensure that the tyres were correctly inflated, wheels correctly balanced and that wheel alignment was correct. Only one tyre was monitored during the testing, at the left rear position.

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18 The reader may note that two identical vehicles were used, differing only in colour
19 Perhaps further research undertaken at a later stage
20 Air only
Bridgestone had also supplied a set of brand new Bridgestone Sport Tourer MY-01 205/50/17 93V Extra Load (XL) tyres, as evident below. These were subsequently fitted in identical procedure and identical testing undertaken. Once again, only the left rear tyre analyzed.
Research: - Continued:

The essential difference between the tyres being the extra belt, note the following indications on the respective tyres:

<table>
<thead>
<tr>
<th>Sizes</th>
<th>Ply</th>
<th>Load Index</th>
<th>Speed Rating</th>
<th>Overall Width (mm)</th>
<th>Overall Diameter (mm)</th>
<th>Loaded Radius (mm)</th>
<th>Rolling Circ.±2% (mm)</th>
<th>Recom. Rim (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>195/50R15</td>
<td>15</td>
<td>82</td>
<td>V</td>
<td>199</td>
<td>576</td>
<td>273</td>
<td>1760</td>
<td>15</td>
</tr>
<tr>
<td>195/55R15</td>
<td>15</td>
<td>85</td>
<td>V</td>
<td>201</td>
<td>595.5</td>
<td>280</td>
<td>1815</td>
<td>15</td>
</tr>
<tr>
<td>205/40R17</td>
<td>17</td>
<td>84</td>
<td>V</td>
<td>212</td>
<td>595.8</td>
<td>281</td>
<td>1824</td>
<td>17</td>
</tr>
<tr>
<td>205/45R16</td>
<td>16</td>
<td>83</td>
<td>V</td>
<td>206</td>
<td>590.9</td>
<td>278</td>
<td>1800</td>
<td>16</td>
</tr>
<tr>
<td><strong>205/50R17</strong></td>
<td>17</td>
<td><strong>83</strong></td>
<td><strong>V</strong></td>
<td><strong>636.8</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>17</strong></td>
</tr>
<tr>
<td>205/55R16</td>
<td>16</td>
<td>91</td>
<td>V</td>
<td>210</td>
<td>631.9</td>
<td>294</td>
<td>1928</td>
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<td>215/45R17</td>
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<td>91</td>
<td>V</td>
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<td>292</td>
<td>1909</td>
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<td>225/45R17</td>
<td>17</td>
<td>91</td>
<td>V</td>
<td>220</td>
<td>634.3</td>
<td>295</td>
<td>1934</td>
<td></td>
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</table>

Testing and setting of tyres:

The four Bridgestone 205/50/17 tyres utilized on the vehicle were fitted as brand new tyres with wheel alignment and balancing undertaken at fitment, likewise tyre pressure (air) was checked to manufacturer specification at 2.2Bar.
Research: - Continued:

All testing was undertaken making use of all four brand new tyres fitted as a set; however only the left rear tyre evaluation, with a total of 4 & 5 consecutive\textsuperscript{21} test runs undertaken.

The first test run (A) undertaken on Route 1, as a standard, correct setting base line run with the tyres all correctly inflated to 2.2 Bar, subsequently the three temperatures and pressure readings taken.

The second test run (B) undertaken at 1.65Bar (25\% down), the vehicle driven on Route 1, subsequently the three temperature and pressure readings taken. The tyre visually inspected externally on all sides; the tyre is not removed from the rim. The tyre not subjected to any X-Ray on this test run.

The third test run (C) undertaken at 1.1Bar (50\% down), the vehicle driven on Route 1, subsequently the three temperature and pressure readings taken. The tyre visually inspected externally, likewise the tyre removed from the rim and inspected so as to determine if any physical damage could be identified by the eye. The tyre not subjected to any X-Ray on this test run.

The fourth test run (D) undertaken at 0.55Bar (75\% down), the vehicle driven on Route 2, subsequently the three temperature and pressure readings taken. The tyre visually inspected externally, likewise the tyre removed from the rim and inspected so as to determine if any physical damage could be identified by the eye. The tyre on test 1 (MY-02) subjected to any X-Ray on this test run, not on test 2 (MY-01).

This pressure drop being substantial, the “movement” effect of the tyre as the vehicle was driven throughout the route was also recorded on video camera footage\textsuperscript{22}.

The fifth test run (E) undertaken at 0.55Bar (75\% down), the vehicle driven on Route 3, subsequently the three temperature and pressure readings taken. The tyre visually inspected externally, likewise the tyre removed from the rim and inspected so as to determine if any physical damage could be identified by the eye. The tyre subjected to any X-Ray on this test run (Test 2 – MY0-1).

This pressure drop being substantial, the “movement” effect of the tyre as the vehicle was driven throughout the route was also recorded on video camera footage\textsuperscript{23}.

Equipment used:

Measurement of pressures and temperatures was undertaken with the use of a combination of an Alfano gauge and a MajorTech touch heat sensor probe, these evident below:

Readings taken:

The readings taken on the tyre were taken at the positions graphically indicated below, immediately as the vehicle stops:

\textsuperscript{21} Therefore total Kilometres travelled for the tyre from fitment is as per the accumulative routes (Route 1 / 2 / 3) distances travelled.
\textsuperscript{22} See ref material 40
\textsuperscript{23} See ref material 40
The aim of the research is not primarily an issue of temperature nor pressure. Nonetheless, the basic monitoring thereof serving as a monitoring of the product of the induced under inflation. The increased heat generation has a well researched effect on the components which make up the structure of the tyre. Likewise, the general indication of the variation in the temperature and pressure should generally fall in line with that of long standing empirical data.

Routes:

Although no specific route was considered, it was practical to undertake a typical “to work / to home” type round route\textsuperscript{24}. All three routes utilized are of typically average to good condition bitumous (Tar) surface, the routes covered a variation of 60kph, 80kph 100kph and 120kph zones. All three routes were recorded on GPS plotting and are indicated below:

Route 1 (Westville)

\textsuperscript{24} Returning to the point of origin simply for convenience of the testing
Visual inspection:

Visual inspection was undertaken on the outer sidewall, the inner sidewall, the tread surface and once the tyre was removed, on the bead seat and the complete internal sections of the tyre for such factors as\textsuperscript{25}.

\textsuperscript{25} The list is not exhaustive as to evidential factors that may be evident, the reader is directed to the extensive reference material listed
Tears, belt separation, cuts, gouges, liner abrasions, torque cracks, inner liner cracks, combination of chaffing, scrubbing, rubbing, folding and creasing at any position on the tyre, broken ply cords or beads, “powdering” or discoloration.

Similarly, as far as could reasonably be done, the “texture” or “feel” of the tyre was also an issue considered, likewise the smell (“burnt”) was considered.

X-Ray

Inspection of the tyre by colour X-Ray on a Bosello machine was only undertaken after test run 5 & 6, a full circumferential inspection of the sidewall and the tread surface area undertaken. A general image supplied thereof for confirmation of process.

Video recording:

On certain test runs, a video recording was undertaken with the use of a GoPro mounted on the side of the vehicle, facing the tyre / road interface, in an attempt to show or highlight tyre movement. Where such recordings were undertaken, they will be indicated at the relevant test results.
Test 1 results: Bridgestone Sporty Style MY-02 205/50/17 89V

Test A - (2.2Bar - Correctly inflated) - Route 1 (Westville):
The following readings were obtained after the test run:

![Tyre pressure gauge](image)

Outer sidewall
Research: Continued:

Test B - (1.65Bar - 25%) - Route 1 (Westville):

Set at 1.65 Bar - 25%

No noticeable difference from standard stance
The following readings were obtained after the test run:

No noticeable difference from standard stance
Research: - Continued:

Note increase in pressure to at 1.75
Comments on Test Run B:

Tyre was removed and inspected, externally and internally, no evidence whatsoever was noted.

The notable effect with the 25% reduction in tyre pressure, is that of an increase in tread surface (48 inner / 48 outer) and sidewall (48) temperature and likewise an increase in the tyre pressure (1.75) reading.
Research: - Continued:

Test C - (1.1 Bar - 50%) - Route 1 (Westville):

Set at 1.10 Bar - 50%

Note the expected visible bulge or deformation in the tyre
The following readings were obtained after the test run:

Note the expected bulge or deformation in the tyre.
Research: - Continued:

Note the increase in pressure up to 1.25 Bar.
Tyre was removed and inspected, externally and internally, at quick glance, it appears that there is no evident damage; however on close inspection a feint circumferential dark line is evident on the sidewall.
Inner sidewall – no indicators whatsoever
Tyre was also removed from the rim and inspected; although no clear evidence was immediately obvious, it appeared on careful inspection that some “darkening” or “polishing” of the inner shoulder areas from the flexing was evident:
Research: Continued:

Comments on Test Run C:

The tyre was not subjected to X-Ray examination on this test run as although there were visible factors, these were negligible.

Generally keeping to the posted speed limits, no noticeable difference in feel was evident in the vehicle handling and ride.

The notable effect with the 50% reduction in tyre pressure, is that of an increase in tread surface (56 inner / 53 outer) and sidewall (50) temperature and likewise an increase in the tyre pressure (1.25) reading.
Test D - (0.55Bar - 75%) - Route 2 (Waterfall):

The following readings were obtained after the test run:

Note the increase in pressure up to 0.75 Bar

The following readings were obtained after the test run:
The same external sidewall circumferential darkened line noted in the previous test was still notable; however did not appear to have become any more prominent.

It appears that some crease lines began to show just below the circumferential darkened line:
Research: Continued:

As with the results from the previous test, the same darkening and polished effect of the inner shoulder sections of the tyre was evident and had become somewhat pronounced. Nonetheless, no separations, delamination or liner abrasion and particles were found.
Research: Continued:
Research: - Continued:
Research: Continued:

Some scuffing of the bead area appeared evident.

The tyre was subjected to X-Ray examination after this test run where no evidence was noted of any damage.
Comments on Test Run D:

Generally keeping to the posted speed limits, a gentle “pull” to the left was felt (as expected), at the slightly higher speeds a very slight unsettling of the vehicles normal travelling was evident.

This test run was recorded on video camera and part thereof is evident at:

https://www.youtube.com/watch?v=zENWtkmOLyc
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Route 1</td>
<td>47.2kms</td>
<td>Driver; front pass, rear left pass, full tank</td>
<td>2.20 Bar - Standard</td>
<td>2.4 Bar</td>
<td>46</td>
<td>44</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B</td>
<td>Route 1</td>
<td>47.2kms (84.4)</td>
<td>Driver; front pass, rear left pass, full tank</td>
<td>1.65 Bar - 25% reduc.</td>
<td>1.75 Bar</td>
<td>49</td>
<td>48</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>C</td>
<td>Route 1</td>
<td>47.2kms (141.6)</td>
<td>Driver; front pass, rear left pass, full tank</td>
<td>1.10 Bar - 50% reduc.</td>
<td>1.25 Bar</td>
<td>56</td>
<td>53</td>
<td>Yes, external &amp; internal</td>
<td>Yes, very slight to left</td>
</tr>
<tr>
<td>D</td>
<td>Route 2</td>
<td>85.5kms (227.1)</td>
<td>Driver; front pass, rear left pass, full tank</td>
<td>0.55 Bar - 75% reduc.</td>
<td>0.75 Bar</td>
<td>51</td>
<td>45</td>
<td>Yes, external &amp; internal</td>
<td>Yes, notable to left</td>
</tr>
</tbody>
</table>
Test 2 results: **Bridgestone Sport Tourer MY-01 205/50/17 93V XL**

**Test A** - (2.2 Bar - Correctly inflated) - Route 1: (Westville)

The following readings were obtained post run:

The following images taken post test highlight the “brand new and correct” condition of the tyre:
Research: Continued:

Test B - (1.65Bar / 25%) - Route 1: (Westville)

Initial setting:

The following readings were obtained:
Research - Continued:

It is already noticeable that with the 25% reduction in tyre pressure that an increase in tread surface and sidewall temperature has been attained, likewise that this has also resulted in an increase in the tyre pressure reading.

The following images taken post test highlight the slight “bulging” and evidently underinflated condition of the tyre:
Comments on Test Run B

Tyre was removed and inspected, externally and internally, no evidence whatsoever was noted.

The notable effect with the 25% reduction in tyre pressure, is that of an increase in tread surface (44 inner / 44 outer) and sidewall (42) temperature and likewise an increase in the tyre pressure (1.80) reading.
Test C - (1.1Bar - 50%) - Route 1: (Westville)

The following readings were obtained:

It is noticeable that with the 50% reduction in tyre pressure that an increase in tread surface and sidewall temperature has been attained, likewise that this has also resulted in an increase in the tyre pressure reading.

The following images taken post test highlight the slight “bulging” and evidently underinflated condition of the tyre:
Research: - Continued:
Comments on Test Run C:

Tyre was removed and inspected, externally and internally, no evidence whatsoever was noted.

The notable effect with the 25% reduction in tyre pressure, is that of an increase in tread surface (50 inner / 48 outer) and sidewall (45) temperature and likewise an increase in the tyre pressure (1.20) reading.

No noticeable effect in driving feel was noted.
Research - Continued:

Test D - (0.55Bar - 75%) - Route 2: (Waterfall)

Initial setting:
The following readings were obtained:

It is noticeable that with the 75% reduction in tyre pressure that an increase in tread surface and sidewall temperature has been attained, likewise that this has also resulted in an increase in the tyre pressure reading.
Most importantly, it is at this point that the first externally visible signs of under-inflation are noted, with a light smudging or darkening of the upper edge of the sidewall, nearest the shoulder of the tyre on both sides, circumferentially.

Post test run outside sidewall photographs – slight evidence visible.
Post test run inner sidewall photographs – slight evidence visible, however appear less evident than the outer side wall:
Research - Continued:

**Flash used**
Likewise, and somewhat pronounced to that of the external evidence, evidence internally at this same general location was notable on removal and inspection, the following images highlight these factors:
Flash used

Outer side
Comments on Test Run D:

Tyre was removed and inspected, externally and internally, as highlighted, evidence was located somewhat more prevalent internally.

The notable effect with the 75% reduction in tyre pressure, is that of an increase in tread surface (55 inner / 55 outer) and sidewall (54) temperature and likewise an increase in the tyre pressure (0.80) reading.

A very slight effect in the vehicle stability when cornering was noticed.

No X-Ray was taken at this stage.

This test run was recorded on video camera and part thereof is evident at:

https://www.youtube.com/watch?v=zENWtkmOLyc
This test run was undertaken at the same pressure as the previous test (D), in an attempt to evaluate the extent of “further” damage that may be caused and be evident, beyond that already identified in the previous test (D):

The following readings were obtained:

It appeared that no further damage was evident on the respective outer sidewalls than that already presented in Test Run D above.
On removal and inspection of the tyre, it was immediately notable that far more severe damage was evident internally, the following images highlight:
Research - Continued:

Severe circumferential creasing highlights the deflation damage

The granular rubber particles highlights the deflation damage
X-Rays were taken post this run, notably no obvious damage was located.

Inner side wall:
Research: - Continued:

Outer side wall:

![Image of outer side wall with 59k and 61k readings]
Research: - Continued:

XL tyre testing (A-E) overview:

<table>
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<tr>
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<tbody>
<tr>
<td>Test run A</td>
<td>Route 1: 45-24km (80-44)</td>
</tr>
<tr>
<td>Test run B</td>
<td>Route 1: 45-24km (80-44)</td>
</tr>
<tr>
<td>Test run C</td>
<td>Route 1: 45-24km (80-44)</td>
</tr>
<tr>
<td>Test run D</td>
<td>Route 2: 45-24km (80-44)</td>
</tr>
<tr>
<td>Test run E</td>
<td>Route 3: 13-24km (80-44)</td>
</tr>
</tbody>
</table>

2014 Opel Astra sedan 1.4 Turbo Front Wheel Drive

<table>
<thead>
<tr>
<th>Good</th>
<th>Good</th>
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<th>Good</th>
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<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Can feel slight movement

Yes, able to left

Yes, as normal & more internal

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |

No |
Review & Discussion:

It is not the intention of this basic research to delve into the finer details of why or how such issues as the specific type of tyre, products used in the construction of the tyre, process of manufacture, thermal energies and the many varying forces acting on a tyre during its use, among countless other factors, cause or contribute to the visibly evident damages to the tyre. Nonetheless, it is immediately acknowledged that it is crucially important to understand that there are many factors that will have an effect on the creation of visibly evident factors on the tyre.

It is simply the resulting evidential damages to the tyre that can be visually identified on the external surface of the tyre (both externally and internally within the tyre to rim cavity once the tyre is removed) and to a minor extent the further damages that would possibly be determinable by X-Ray, that is of interest here.

Although efforts were made to maintain an accurate and detailed level of parameters, by the inherent nature of extensive variables that can affect readings, such as the weather, likewise that although all equipment used was checked for general accuracy, the level of absolute calibrated accuracy was not checked; as such a level of disparity is accepted, any such margins would likely be relatively minor. Nonetheless, this does not deter from the general findings of the analysis.

It is well known that manufacturers undertake exhaustive R&D testing on products, none more critical than the type of testing generally indicated herein\(^{26}\). It is this type of testing that is required to ensure that the product meets or exceeds the minimum requirement standards of the relevant guiding bodies such as that of the International Organization for Standardization (ISO), applicable in 164 countries, among other requirements. Although the precise results of these OEM tests are largely not accessible to the public\(^{27}\), any recognized brand is required to at least meet these standards. It is therefore key that the brand and specific specification of tyre under investigation is determined and the specific standards to which the tyre conforms is researched and referenced to as a starting point.

It is important that it is understood that both the practical case study examples shown and likewise the field testing set out highlight the importance of any practitioner considering any issues of tyres, must make every effort to ensure that as detailed as possible examination of the tyre is undertaken. This must include as high resolution as possible images of the tyre in question. Although not exhaustive, this should include at least the 18 basic images of the tyre, described in prose as follows:

1. Overall outside facing wall;
2. At least four (12 / 3 / 6 / 9) different positions at right angles (as close to as possible) to the inner (inside) if the outside facing sidewall;
3. Overall inside facing wall;
4. At least four (12 / 3 / 6 / 9) different positions at right angles (as close to as possible) to the inner (inside) if the inside facing sidewall;
5. At least four (12 / 3 / 6 / 9) different positions at right angles to the tyre tread surface;
6. At least four (12 / 3 / 6 / 9) different positions at right angles to the inner (inside) if the tread surface.

As evident herein, it is not always easy to place in prose an appropriate descriptive indication, only a quality image can relay the factors. Even with an image, it is sometimes still difficult to clearly see what is being highlighted. As many specific images and this may include video footage, in as high resolution as possible should be taken of specific details in consideration on the tyre.

Perhaps most important is that the tyre and rim combination in question be secured and held safely as unfortunately and all too often, very few and poor quality images are taken.

\(^{26}\) Effectively destructive testing
\(^{27}\) Typically privileged information
Having undertaken the basic test on the question posed, “What length of time was required to run a tyre underinflated and show visible signs of running under inflated”, allows some interesting discussion.

By the very nature of the original question it is understood that the most obvious issue to be dealt with first would be the issue of “How underinflated was the tyre?”\(^{28}\). This poses somewhat of a dilemma as this is almost always unknown pre-accident. Likewise, that very often severe impact damage to the wheel and tyre during an accident causes total pressure loss. Even where the driver or someone that knew the vehicle intimately pre-accident attests to the tyre being correctly inflated, this is very often not so\(^{29}\) and does not preclude the possibility that there was some air loss pre-accident for some reason, such as puncture. This situation is notably highlighted in the paper “Practical evaluation of the effect of a sudden deflation of a tyre on the dynamics of passenger cars, light delivery vehicles & heavy vehicles”, B Grobbelaar (RSA):

A slow deflation is considered to be a deflation where the exit of air from the tyre occurs gradually. Examples of a slow deflation are a valve leak, intrusion of an alien object remaining in the tyre, sand or dirt between the tyre beading and the rim, cracked rim, etc. The effect of such a slow deflation on the change of the dynamics of the vehicle would therefore also be gradual due to the gradual introduction of a change in forces and moments acting on the vehicle. Such a gradual deflation generally goes unnoticed to a driver until such a time as the tyre has deflated completely and the rim and/or squashed tyre is running directly on the road surface or when, and if, the forces on the vehicle and/or steering wheel become significant.

In general, the deflation (slow or sudden) of a wheel of a modern vehicle (passenger car, bus, truck or truck-tractor of a truck combination) has a small effect on the deviation of the vehicle from a straight path where the wheel is not a steered wheel and the vehicle is travelling on a straight, flat, road in an un-braked condition at the time of the deflation.

A further aspect to be taken into account especially currently is the use of higher profile tyres on modern SUV’s and off-road vehicles to enhance their off-road mobility. This higher profile implies the corner of the vehicle where the sudden deflation occurs dropping further creating a larger rolling moment to the vehicle which, accompanied by a higher centre of gravity, would lead to greater instability of the vehicle when the rim and deflated tyre are forcibly checked against the road surface.

It is to this question that it is crucial that any tyre incident dealt with should ensure that careful and quick analysis of the post accident tyre pressures is checked and recorded. Likewise, that if any incorrect tyre pressure is noted, that the root cause of this be determined as a starting point.

Notably, and although a topic for discussion on its own, the current system of driver training and proper driving procedure in that of the K53 system employed here in RSA, would have drivers checking their tyres at least on a daily basis as they use the vehicle for the first time and perhaps unrealistically so, at every use.

In the same vein that reference has been made to the question “How underinflated was the tyre?”, we turn attention to the question of What is a considerable distance\(^{30}\)? It may be that a tyre was not correctly inflated and may perhaps be very slightly underinflated, this could be driven on indefinitely and not cause, nor show any visible signs. This situation may fortuitously also never lead to the cause or even be contributory to a crash. Nonetheless, where an underinflated tyre has been identified (to whatever extent) on a crash vehicle, the starting point would be as already discussed, determining the tyre specifications (?), standards of conformity (?) and why it was underinflated (?). Following this would be trying to determine how long the tyre may have been driven in such a state.

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\(^{28}\) Note once again the comments of the “Judgement” at page 28.

\(^{29}\) NASS-CDS February 2001 survey - crash investigators found that about 36 percent of passenger cars and about 40 percent of light trucks had at least one tire that was at least 20 percent below the placard pressure. About 26 percent of passenger cars and 29 percent of light trucks had at least one tire that was at least 25 percent below the placard pressure / Bridgestone SA four year tyre survey - “ten percent in the "dangerous" border fell from 1.5 to 1.7 bar. This was significantly higher than the seven percent from last year” - et al.

\(^{30}\) Note once again the comments of the “Judgement” at page 28.
It may on occasion be possible to determine this by determining what had caused the under-inflation, where by example, on the rare occasion it may be confirmed by physical damage to the tyre and/or rim and perhaps by an occupants’ testimony, that the vehicle struck an object or pothole at some position. This is rare and therefore determining what a considerable distance or time is, is almost always very difficult.

Nonetheless, by consideration of the individual and accumulative distances traversed in these test, under the respective states of under-inflation, some basic indications as to this question; are that a considerable distance would likely be any distance in excess of the distance travelled to the point where evidential factors became evident to the tyre, notably:

- For the standard tyre (MY-02), as distance of some 141.6kms (Consecutive total of the three tests A, B & C resulting in the first evidential factors);
- For the XL tyre (MY-01), as distance of some 227.1kms (Consecutive total of the four tests A, B, C & D resulting in the first evidential factors).

The results are tabulated as follows:

These tests and results could be populated into graphs and perhaps considered from different perspectives and detail statistically, this is not the intention at this stage. This may be done on possible future detailed testing.

It is assumed that the nature of the tyre itself given their different design parameters, and here we refer to the specific type of tyre such as a commercial vehicle tyre (305/70R22.5), a typical light truck (225/75/15), a general purpose sedan tyre (195/65/15) or a high performance low profile tyre (225/40/R18), would have a significant effect on how quickly under-inflation evidence is evident.

This basic research supports the indications of the manufacturers in their usual indications of the importance of maintaining the appropriate operating parameters of the tyre. Without a pressure loss, theoretically there would be no problem.

Ref. Material 47: “An alternative view defining tire failure is put forward by Rohlwing (2004) where he states that ‘tires, by themselves, don’t fail. Maintenance, road survey conditions, and driving skills determine what happens to tires.’”
The greater the under-inflation, the quicker the resulting visual damage to the tyre would appear. Likewise, it would follow suit that the greater the load, the farther the distance and the more aggressive the driving style and terrain covered, would accelerate the onset of and intensity of underinflated tyre evidence.

Although it is common that vehicles run with tyres underinflated, vehicle are also commonly overloaded in South Africa. This may not necessary be as a result of the number of occupants but often as a result of substantial “groceries” included with passengers. Although a subject matter on its own, the accepted mass for an occupant is highly questionable given the generally large stature of South Africans. This mass indicator being long standing and quite likely outdated.

An investigator may also be faced with the problem of not being able to determine the actual mass of occupants, particularly where multiple fatalities have occurred. Although the post mortem document and process should see the mass recorded, for many reasons, is almost always not indicated.

For these reasons and where applicable, careful attention should be given to the loads being carried.

The difference between the “Standard” tyre and the “Extra Load” tyre, being essentially that of an extra ply and therefore the extra strength, the increased mass of the tyre is immediately noticeable on the scales (evident below). Although it may seem questionable that a single extra ply would make a notable difference to the overall rigidity (where this could immediately be felt by simply pressing on the tyre structure) and strength of the tyre, likewise as is found from the testing, this appears to be exactly the result. It is reasonably assumed that this is exactly what the manufacturers were attempting to, and have achieve.

Bridgestone Sporty Style MY-02 205/50/17 89V  
Bridgestone Sport Tourer MY-01 205/50/17 93VXL

It is interesting to note that there are specific tests and procedures specified and undertaken as to the issue of tyre strength, with the paper entitled Evaluation of Laboratory Tire Tread and Sidewall Strength (Plunger Energy) Test Methods highlighting these. Some notable comments as follows:

... with increasingly lower-aspect-ratio tires coming to market, there may be a limit to the rim well depths available to accommodate the additional plunger travel."

The final goal of the agency research was to evaluate tire sidewall bruise resistance / strength, a region prone to separations / bubbles from impacts with potholes, curbs, or other road hazards. Literature states that tires with larger rim diameters and lower-aspect-ratio, an increasing popular trend, are more susceptible to being damaged in the sidewall area due to such impacts.
This damage, generally a rubber-to-fabric delamination and/or broken body cords, appears as a bulge (blister) in the sidewall that can appear immediately, or some period of time after the impact has occurred. This bulge can create a weak area in the tire, which poses a possible safety concern because the tire may eventually blowout at the point of separation or broken cords."

There was a statistically significant difference between the force for the 2-ply polyester and the 2-ply rayon, with the polyester fabric generating higher force. The inflation pressure interacted with number of plies to influence force.

**Plunger penetration**

The penetration distance is primarily related to the number of plies, which is covariant with plunger position and inflation pressure.

Unsurprisingly, the answer to the question posed, “What length of time was required to run a tyre underinflated and show visible signs of running underinflated?” appears to become exponentially difficult to answer where such “stronger” 39 tyres are involved. The XL tyre in the tests only showed evidence of damage after a longer distance.

Perhaps the most telling result of the analysis of this particular category of tyre (XL), is that even in the relatively low speed, controlled conditions and not heavily loaded vehicle of the test situation undertaken here, that evidence of under-inflation was visible even on the stronger tyre. This serves as a further reminder and highlight of the importance of the investigator establishing the exact specifications of the tyre in question and to keep this in mind when starting off any investigation.

Of particular note and perhaps a key issue; even though evidential factors were located and that the tyre (MY-01 & MY-02) would be considered by the manufacturer as damaged and therefore to be replaced. The general integrity of the tyre appeared visually to remain, even under X-Ray examination 40 no obvious major damage was detected. In detailed examination of the tyre a cutting and/or “peel back” may be required, however the key issue here was that of externally evident evidence.

Perhaps the issue of the tyre appearing visually to be “undamaged”, none more so to the general untrained member of the public, is cause for concern. This is highlighted to some extent in the research of Jennifer A. Cowley et.al – 2006 41 - People do not identify tire aging as a safety hazard, where the following key comment is noted:

“An unsafe tire due to tire aging might not visibly show (to the naked eye) any obvious degradation.”

Perhaps a consideration would be to have some “material” 42 based indicator built into or onto the tyre that would allow visual indication of the tyre being damaged due to under inflation

The case study example of the BMW highlighted at the outset sees that the internal of the tyre was decimated, with the external largely appearing immaculate. This essentially confirming the comments above, likewise the general indications of the testing showing somewhat obvious evidence internally against very little external evidence.

Although tyres have seen massive development over the years, this is particularly in the specific makeup of the materials used and the manner in which the tyre is constructed, resulting in what is typically a tough and therefore extremely reliable piece of equipment. There can be no doubt that the general public expects extremely high levels of reliability, but at the same time it is rare that a driver will realistically realize the level of punishment that a tyre takes and perhaps most importantly a driver will rarely admit to having abused the tyres.

39 This would included Run Flat style tyres.
40 Although the author is not trained nor highly experienced on X-Ray examinations, reasonable consideration along with a colleague and the owner and operator of the machine noted no obvious problems.
41 Ref. material 26 – pg. 863 – Discussion.
42 Possibly built into the compound itself on the sidewalls that would indicate excessive flex
Perhaps, testament to the largely high standards attained by current tyre manufacturers, the strong indications are that where clear evidence to the effect of and underinflated tyre is found post accident, such as in the case study example; that this has resulted from severe under-inflation and prolonged time and/or distance in this state and that it is highly unlikely that this has occurred immediately prior to the accident, or even as a result of the accident and post impact movement of the vehicle.

The tests have shown that even on the standard tyre and under as much as a 50% reduction in tyre pressure (1.1 Bar) and on a reasonable length trip of 141.6kms (consecutive tests A, B and C), with three occupants in the vehicle, at varying speeds however largely maintaining the general speed limit, that very little evidence was located.

Although we cannot delve into the specifics of improvements of vehicles in general, perhaps most notably to that of suspension and general handling geometry, it has to be accepted that as a whole, the modern vehicle has come a long way and are extremely forgiving to the average driver43. The vehicle itself, combined with well developed, well manufactured and generally reliable tyres is also a cause for concern in the general requirement of a driver to be aware of and maintain their tyres appropriately, as both local and international research has shown time and again. It is for these reasons, with accidents now at epidemic proportions worldwide44, that this basic testing and understanding will assist not only the writer, but the reader to answer, or perhaps give clearer indication as to why a tyre may have been the direct cause, or perhaps a contributing factor to an accident.

The Prima Facie evidence presented here in allows the strong indication that it is highly unlikely that any severe damage to a tyre, from being underinflated, would be evident in any short period of distance or time.

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43 This has been well researched, with direct and indirect comments to this effect in many research papers
44 United Nations research
Reference and reading material:

1. The traffic accident investigation manual – At scene investigation and technical follow up
   By: J Stannard Baker & Lynn B Fricke
   Published by: North Western University Traffic Institute – USA

2. Traffic accident reconstruction
   By: Lynn B Fricke
   Published by: North Western University Traffic Institute – USA

3. The investigators guide to tyre failure
   By: R J Grogan
   Published by: Institute of Police Technology & Management - University of North Florida – USA

4. Car tyres, service and maintenance. 1996
   By: W E Walker
   Published by: Immins Naude’ - RSA

5. Tire Forensic Investigation - Analyzing tire failure
   By: Thomas R. Giapponi
   Published by: SAE International

6. The role of tyre pressure in vehicle safety, injury and environment
   By: Road safety solutions, New South Wales, Australia, prepared for the “heads of compulsory third party insurance in Australia and New Zealand” – 2007

7. The importance of tyres / tread patterns - Book of the car
   By: Various Authors
   Published by: Readers Digest

   By: M J Nunney
   Published by: BUTTERWORTH-HEinemANN

9. Inappropriate tyre characteristics and high ambient temperature: a recipe for traffic accidents
   By: S Bendak, advances in transportation studies an international journal section b 16 (2008) - 61 – Department of industrial engineering, King Saud University, P O Box 800, Riyadh, 11421, Saudi Arabia

10. Reducing potential for aquaplaning
    By: Roy Spillance, senior advisor (design consulting) planning and environment division road system and engineering group, Queensland department of main roads (planning and design symposium 2003)

    By: Dr Sanjay Govindjee (Ass. Prof. of Civil Engineering, Univ. of California at Berkeley)
    Published by: Bridgestone / Firestone

12. Influence of water depths on friction properties of various pavement types
    By: Bob M Gallaway, et. al.
    Published by: Technical Reports Center Texas Transportation Institute

13. How to make your car handle: Pro methods for improved handling, safety and performance
    By: Fred Puhn
    Published by HP books

14. SABS 1207 - 1985: Motor vehicle safety standard specification for braking
    Published by: Council of the SA Bureau of Standards (Gr. 14)

15. Understanding car crashes: Basic physics
    By & published by: Insurance institute for highway safety

16. Antilock brakes don't reduce crashes; people in cars with antilocks at greater risk - but unclear why
    By & published by: Insurance institute for highway safety

17. Reducing potential for aquaplaning
    By: Roy Spillane
    Published by: Planning and design symposium 2003

18. Tyres, road surfaces and reducing accidents: A review
    By John C Ballas – May 2004
    Report on research carried out for the AA foundation for road safety research and the country surveyors society
19. **The role of tyre pressure in vehicle safety, injury and the environment**
Prepared by Michael Paine, Michael Griffiths and Nimmi Magedara


21. **Investigating the effect of inflation pressure on our ability to conceptually reconstruct accidents**
By C Grover, L Walter, T L Smith and R F Lambourn
PPR 209 / July 2007

22. **Judgement (RSA): CASE NO: 280/93**
In the Supreme court of South Africa (Appellate Division) in the matter between: Emmah Mbokan 1st Appellant David Mnguni 2nd Appellant Versus National employers general insurance company limited 1st Respondent Putco Limited 2nd Respondent Coram: Smalberger, Vivier, FH Grosskopf, Howie et Schultz JJA – Date heard: 25 May 1995 Date delivered: 12 September 1995

23. **Firestone Tire Failure Analysis**
Dr. Sanjay Govindjee
January 30, 2001

24. **Skidmark patterns and identification of ABS equipped passenger car**
Ying-wei Wang - Associate Professor / Jian-da Wu - Associate Professor / Chao-nan Lin – Master
Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 3401 - 3412, 2005

25. **Tire-Related Factors in the Pre-Crash Phase**
DOT HS 811 617 (NHTSA Technical Report) - April 2012
Author - Eun-Ha Choi, Ph.D. - Bowhead Systems Management, Inc.

26. **People do not identify tire aging as a safety hazard**
Jennifer A. Cowley, Soyun Kim & Michael S. Wogalter - Department of Psychology North Carolina State University Raleigh, North Carolina 27695-7650 USA

27. **12 & 15 Passenger Vans Tire Pressure Study: Preliminary Results - May 2005**
National Highway Traffic Safety Administration – National center for statistics and analysis
DOT HS 809 846
By: Kristin K. Thiriez, Eric Ferguson, Rajesh Subramanian

28. **Tire Tread Damages – Michelin North America**
Passenger and light truck

29. **Retreaded Tire Use and Safety: Synthesis**
Prepared for Paula J. Hammond Secretary of Transportation Washington State Department of Transportation
Prepared by Kathy Lindquist, WSDOT Research Office Michel Wendt, WSDOT Library September 3, 2009

30. **Roadside alligators & the UMTRI tire debris survey**
By: John Woodroofe, Ms Oliver Page, Ph.D.
University of Michigan Transportation Research Institute

31. **Heavy vehicle tire blowout and explosions – March 2009**
By: René Benoît - Research Department, Institut de recherche Robert-Sauvé en santé et

32. **Tire modelling & contact problems – heat generation in aircraft tires**
By: Samuel K. Clackr and Richard N. Dodge - University of Michigan. Ann Arbor, MI 48109, U.S.A.

33. **Study on some safety-related aspects of tyre Use – December 2014 – final report - TNO 2014 R11423**
By: TNO: Sven Jansen, Antoine Schmeitz, Sander Maas, Carmen Rodarius / TML: Lars Akkermans

34. **Tyres, road surfaces and reducing accidents: a review** - A report on research carried out for the AA Foundation for Road Safety Research and the County Surveyors’ Society
By: John C Bullas – May 2004 - AA Foundation for road safety research

35. **Driving through tyre blowouts** (Online)

36. **The invisible danger of aging tyres** (Online)

37. **Tire Inspection Chart** – Maxxis – Maxxis.com

38. **Analysis of the scientific aspects related to minibus taxi collisions**
By: R Govender and D Allopi

39. **Determining Vehicle Steering & Braking from Yaw Mark Striations** (SAE 2009-07-0092)
40. Mechanical Failures as a Contributing Cause to Motor Vehicle Accidents  
   By: Ockert van Schoor / University of Pretoria Mechanical Engineering Thesis

41. Commercial Medium Tire Debris Study – Final Report  
   By: Woodrooffe JF, Page O, Blower D, Green PE - NHTSA – USA

42. Practical evaluation of the effect of a sudden deflation of a tyre on the dynamics of passenger cars, light delivery vehicles & heavy vehicles  
   By: Mr Barry Grobbelaar M. Eng. (Mechanical) MSAIMeGI MSAE MSAGMJ - Engineering Dynamics and Design Consultants - South Africa

43. A Comparison of 25 High Speed Tire Disablments Involving Full and Partial Tread Separations  
   Gray Beauchamp, Daniel Koch and Dana E. Thornton / Kineticorp LLC (2013)

44. The role of tyre pressure in vehicle safety, injury and environment  
   Michael PAINE, Michael GRIFFITHS and Nimmi MAGEDARA

45. Evaluation of Laboratory Tire Tread and Sidewall Strength (Plunger Energy) Test Methods  
   John R. Harris, Larry R. Evans, James D. Maclsaac Jr.


47. Tire force test - http://www.youtube.com/watch?v=nmo_dkNZIHM


50. Underinflated video footage (writer) - http://www.youtube.com/watch?v=zENWtkmOLyc

### 2014 Opel Astra sedan 1.4 Turbo Front Wheel Drive

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Bridgestone Sporty Style MY-02 205/50/17 89V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test run A</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run B</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run C</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run D</td>
<td>Route 2</td>
</tr>
</tbody>
</table>

### 2014 Opel Astra sedan 1.4 Turbo Front Wheel Drive

<table>
<thead>
<tr>
<th>Test 2</th>
<th>Bridgestone Sporty Style MY-01 205/50/17 83V XL [Extra Load]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test run A</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run B</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run C</td>
<td>Route 1</td>
</tr>
<tr>
<td>Test run D</td>
<td>Route 2</td>
</tr>
<tr>
<td>Test run E</td>
<td>Route 3</td>
</tr>
</tbody>
</table>
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Without the backing and very kind assistance from the following companies, the undertakings would not have been possible, your assistance is not only appreciated, but is commendable.

1. **Bridgestone Tyres South Africa**
   
The supply of the various test tyres

2. **Hi-Q Fitment Centre, 441 Umgeni Road, Durban, Mr D Gounden**
   
   Use of their facilities and staff during the removal, changing, fitting and balancing of wheels and tyres

3. **Eagle Wheels, 60 Sydney Road, Durban, Mr Rashid Elsaadi**
   
   Use of X-Ray machine & guidance

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   For the research, review, supply and guidance on the local statistics

To the colleagues and associates that offered insight, guidance, peer review and general input, you guidance is appreciated:

- Mrs. Angelique Olivier (My secretary/PA for the endless work on the document)
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- Mrs. Wilna Badenhorst (Forensic Road Crash Investigation Services)
- Mr Redvers Marlow (Retired tyre specialist – Continental South Africa)
- Mr. Rob Fletcher (Engineer extraordinaire – Accident Specialist)
- Mr. Stephen Norris (Field Engineer Bridgestone)
- Mr. Charles Levy (Independent tyre specialist - Durban)

*There is no doubt that the case study has been carried out in a highly professionally manner and is factually correct. The findings reinforce my experiences in the tyre manufacturing and service operations of the industry spread over 38 years with Dunlop Tyres South Africa. I have no hesitation endorsing the study.*

*The study quite rightly states in his review and discussion that “there are many factors that will have an effect on the creation of visibly evident factors on the tyre”. This case study is the tip of the iceberg, however its findings will allow the experienced assessor the ability to refer to factual material.*

*The most critical factor to come out of the study is the fact that in all instances where degradation was evident, it was more evident on the tubeless inner lining than the outer sidewall surfaces. It is for this very reason that all tyre manufacturers recommend that internal inspection should be done when a puncture is noted. They also recommend mushroom type repairs as being more effective than externally inserted plug repairs.*

*It is also quite correct that tyres of different aspect ratios will behave differently due to the variability of the sidewall flex point. This case study deals specifically with a passenger tyre with a 50% aspect ratio, which in my opinion could be applied with reasonable accuracy to 45% and 55% ratio passenger tyres.*
The further one moves away from the test aspect ratio in the study and the construction of radial ply light commercial and commercial tyres, the more likelihood for different findings. However the surface of the inner liner would predominantly reveal greater degradation.

The study deals specifically with externally visual evidences, however intense internal inter-component inspection and destructive peel back of components is needed to accurately determine incipient separations.

A case in point being that, whilst x-ray inspection revealed no evidence of obvious damage during the evaluation, belt edge looseness could have been initiated. Component separation at the belt edge in a steel belted radial ply tyre, irrespective of application, is an indication of abuse of a correctly constructed tyre, which if left to develop will ultimately cause catastrophic failure.

Mr. Luchas Steenkamp (TMS Mobility)

This is a long overdue study. As far as I know there is no local research paper on the subject. I want to congratulate you on the effort, my brief comment as follows:

The paper highlights under inflated tyres, this is also as relevant to overloaded tyres. This fact should be highlighted as the flexing effect would generally be the same in both the instances. This is very relevant to South Africa as many of our vehicles are overloaded.

Disclaimer:
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