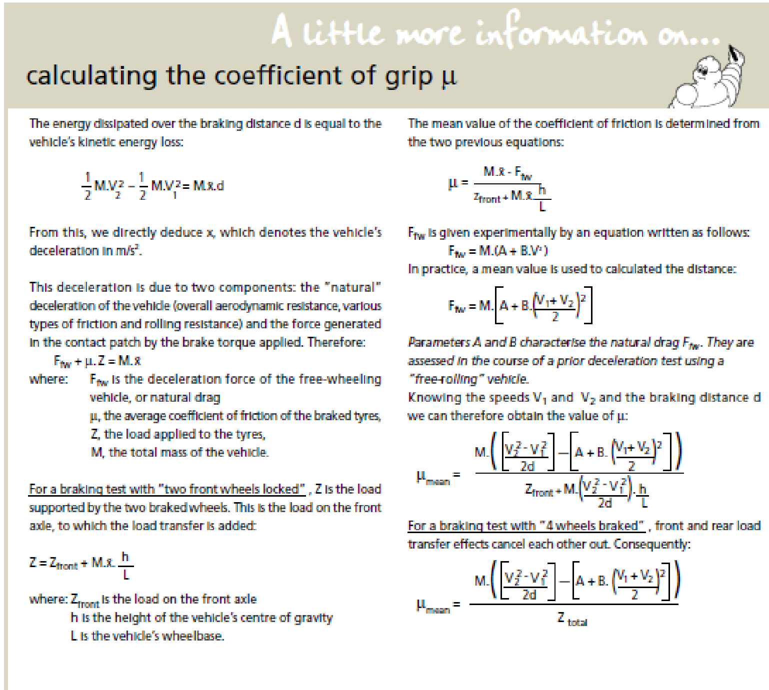
Tyre Development and its Relationship with the Road Surface

Road simulator in operation. Here, the tyre is running on the inside of the drum.

Road simulator in operation. Here, the tyre is running on the outside of the drum.

Flat road-surface simulator.



A little more information on...

calculating the coefficient of grip μ

The energy dissipated over the braking distance d is equal to the vehicle's kinetic energy loss:

$$\frac{1}{2}M.V_2^2 - \frac{1}{2}M.V_1^2 = M.\ddot{x}.d$$

From this, we directly deduce x, which denotes the vehicle's deceleration in m/s².

This deceleration is due to two components: the "natural" deceleration of the vehicle (overall aerodynamic resistance, various types of friction and rolling resistance) and the force generated in the contact patch by the brake torque applied. Therefore:

$$F_{fw} + \mu.Z = M.\ddot{x}$$

where: F_{fw} is the deceleration force of the free-wheeling vehicle, or natural drag
μ, the average coefficient of friction of the braked tyres,
Z, the load applied to the tyres,
M, the total mass of the vehicle.

For a braking test with "two front wheels locked", Z is the load supported by the two braked wheels. This is the load on the front axle, to which the load transfer is added:

$$Z = Z_{front} + M.\ddot{x}.\frac{h}{L}$$

where: Z_{front} is the load on the front axle
h is the height of the vehicle's centre of gravity
L is the vehicle's wheelbase.

The mean value of the coefficient of friction is determined from the two previous equations:

$$\mu = \frac{M.\ddot{x} - F_{fw}}{Z_{front} + M.\ddot{x}.\frac{h}{L}}$$

F_{fw} is given experimentally by an equation written as follows:

$$F_{fw} = M.(A + B.V^2)$$

In practice, a mean value is used to calculated the distance:

$$F_{fw} = M.\left[A + B.\left(\frac{V_1 + V_2}{2}\right)^2\right]$$

Parameters A and B characterise the natural drag F_{fw}. They are assessed in the course of a prior deceleration test using a "free-rolling" vehicle.

Knowing the speeds V_1 and V_2 and the braking distance d we can therefore obtain the value of μ:

$$\mu_{mean} = \frac{M.\left(\left[\frac{V_2^2 - V_1^2}{2d}\right] - \left[A + B.\left(\frac{V_1 + V_2}{2}\right)^2\right]\right)}{Z_{front} + M.\left(\frac{V_2^2 - V_1^2}{2d}\right).\frac{h}{L}}$$

For a braking test with "4 wheels braked", front and rear load transfer effects cancel each other out. Consequently:

$$\mu_{mean} = \frac{M.\left(\left[\frac{V_2^2 - V_1^2}{2d}\right] - \left[A + B.\left(\frac{V_1 + V_2}{2}\right)^2\right]\right)}{Z_{total}}$$

Darren Lindsey

MICHELIN
A better way forward

Content

- Understanding the role of the tyre (video)
- The tyre as a critical safety component (Grip)
- Relationship between the tyre and the road surface
- Elements that impact the safety performance of the tyre
- Evolution through advanced technology - smart tyres

General Perceptions!

- 70% of crashes happen in the wet? False
- 75% of crashes occur on straight roads True
- 60% of crashes occur at a relatively low speed in an urban environment True

In 2012, 205 people were killed or seriously injured in an accident where illegal, defective or under-inflated tyres were a contributory factor*

The VUFO institute based at Dresden University runs what is probably the most comprehensive analysis of vehicle crashes in the world.

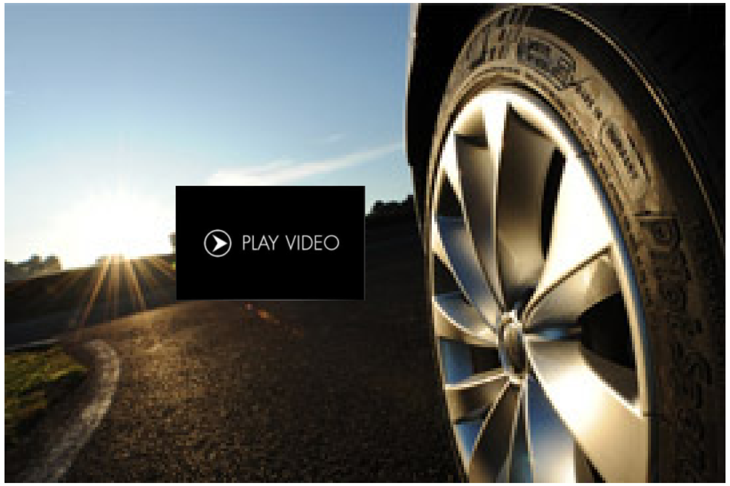
It's called the German In Depth Accident Database (GIDAS), so far based on 68,000,000 pieces of information gleaned from the study of 20,000 crashes over 3 years within a 50-kilometre radius of Dresden.

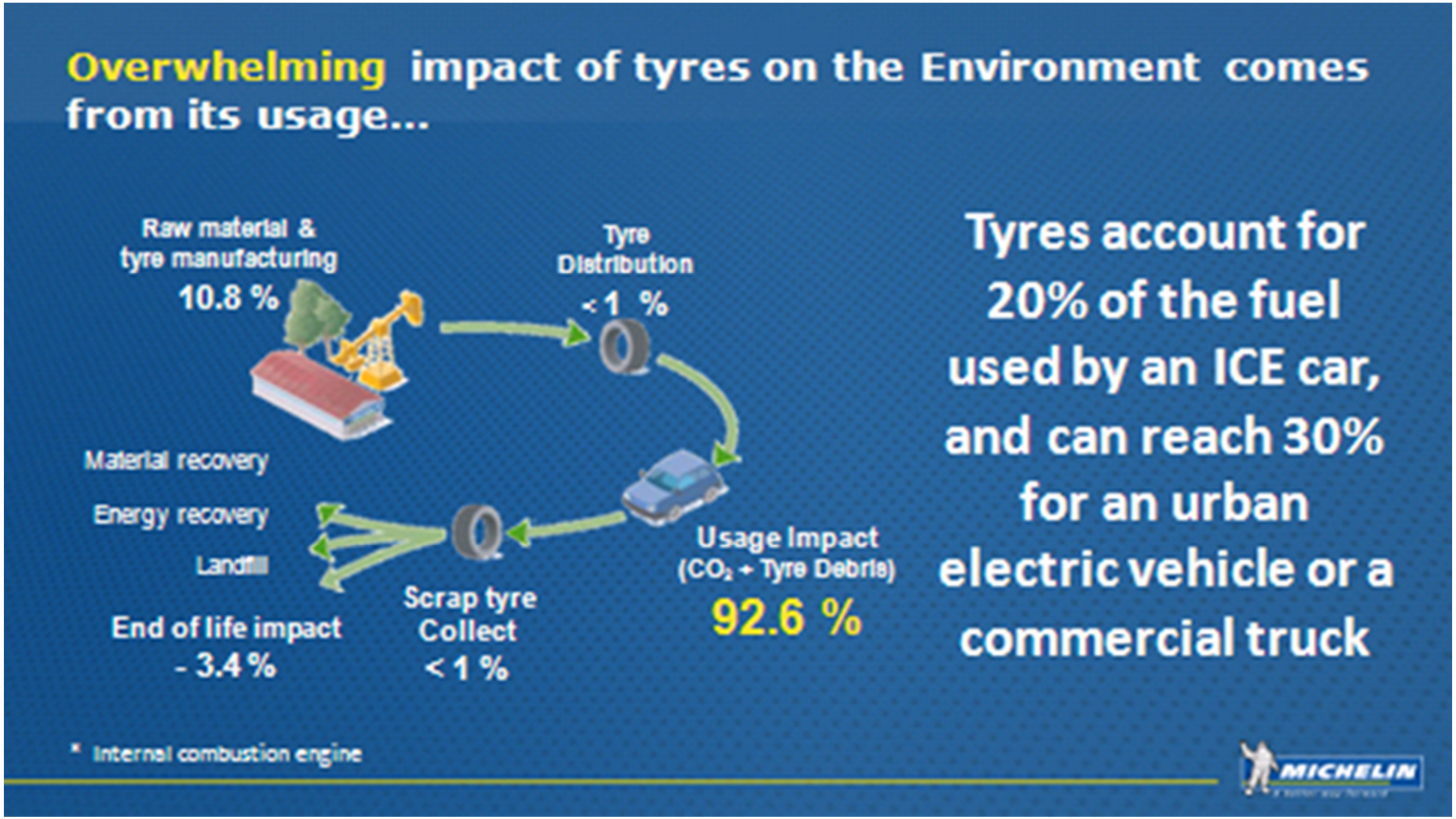
*DfT statistics 2012

MICHELIN
A better way forward

The role of the Tyre

- Provides traction (grip)
- Carries load
- Braking
- Acceleration
- Cornering
- Comfort (suspension)
- Mobility
- Safety

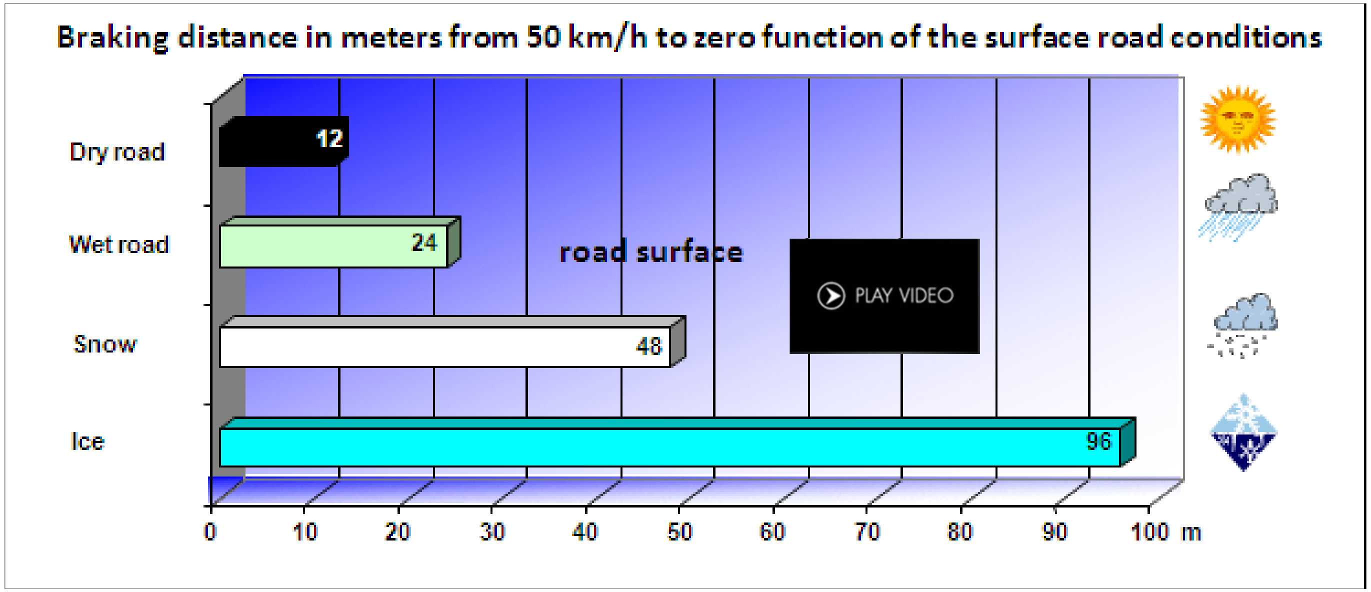




- **More stakeholders are becoming interested in the role of the tyre…**

Safety critical component - Grip

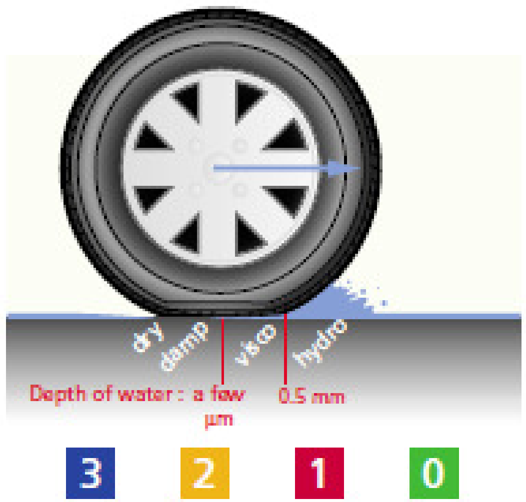
Grip implies **contact between two surfaces**. In road grip, one is the tyre surface and the other is the road surface. Grip depends on the type of road surface and its state of repair, not to mention its roughness and whether it is wet or not.



It's the only component of a vehicle that is in contact with the road…

Tyre Grip on wet surfaces

0	• Depth of water on the road MINIMISED by	• water DRAINED AWAY down the road slope and through the road's draining mixes. • water STORED in the MACROROUGHNESS of the road surface.
1	• Water THRUST BACK by	• adequate PRESSURE AT THE LEADING EDGE of the contact patch provided by the INFLATION PRESSURE and the so-called "BOW" EFFECT.
	• Water DRAINED AWAY to the side by	• angled TREAD GROOVES.
2	• Water CHANNELLED into the tread grooves by	• adequate PRESSURE IN THE CONTACT PATCH (rubber/void ratio + roughness of the road surface) and a SYSTEM OF SIPES opening out into the tread grooves.
	• Water STORED in	• the TREAD GROOVES.
3	• Residual film BROKEN THROUGH by	• very high PRESSURE SURGES created by the edges of tread blocks and sipes, and the microroughness of the road surface.



Fact: Designed to evacuate 30 litres of water per second

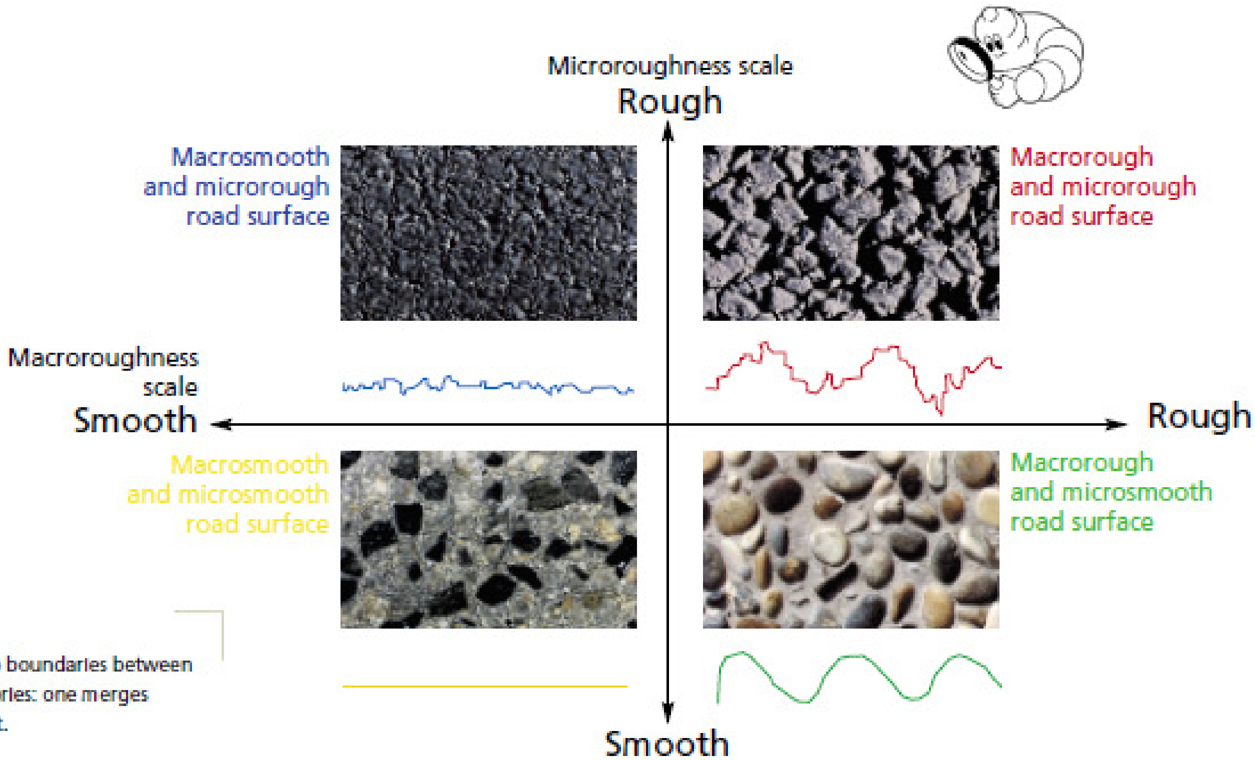
MICHELIN
A better way forward

Different Road Surfaces…

As an initial approximation, road surfaces can be classified into four categories.

It has been observed that the value of the coefficient of friction - or coefficient of grip - μ on a dry road surface is always between 1 and 1.3*.
However, on a wet surface, the coefficient of grip is always worse and varies enormously with the nature of the surface.

* *Values for* μ_{max}

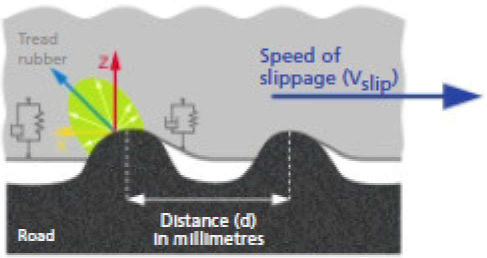


N.B.

There are no boundaries between these categories: one merges into the next.

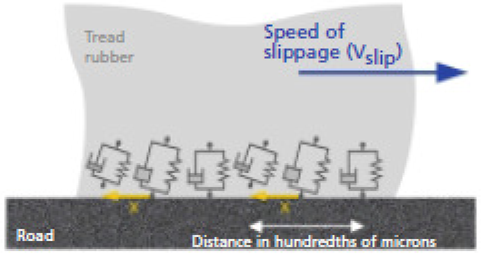
Tyre & Road Interaction

ROAD ROUGHNESS EFFECTS (INDENTATION)



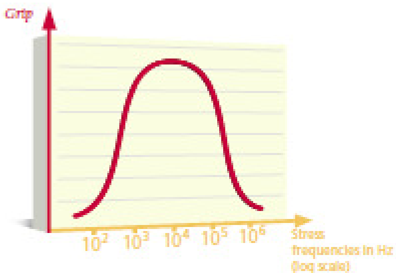
The tread block strikes against the rough spot and deforms, but, by a hysteresis effect, it does not immediately revert to its initial shape on the other side of the rough spot. This asymmetrical deformation generates a force field, the tangential resultant force of which (X) opposes skidding.

MOLECULAR ADHESION



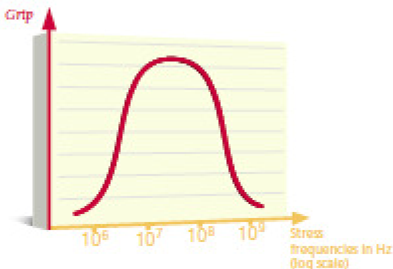
The molecular chain is stretched: its viscous properties, represented by the piston, resist deformation, generating a friction force X which opposes skidding.

FREQUENCY RANGE OF ROAD ROUGHNESS EFFECTS



Road roughness continues to generate grip even when the road surface is wet.

MOLECULAR ADHESION FREQUENCY RANGE



Surface wetness inhibits adhesion.

- **Molecular adhesion - contact patch**
- **Road surface deformations**
- **Indentations**

MICHELIN
A better way forward

Sipes - Grip on Wet Surfaces

The art of sipe design is based on the combination of different sipe shapes, to provide optimum traction in wet conditions whilst still offering driver feedback

MICHELIN
A better way forward

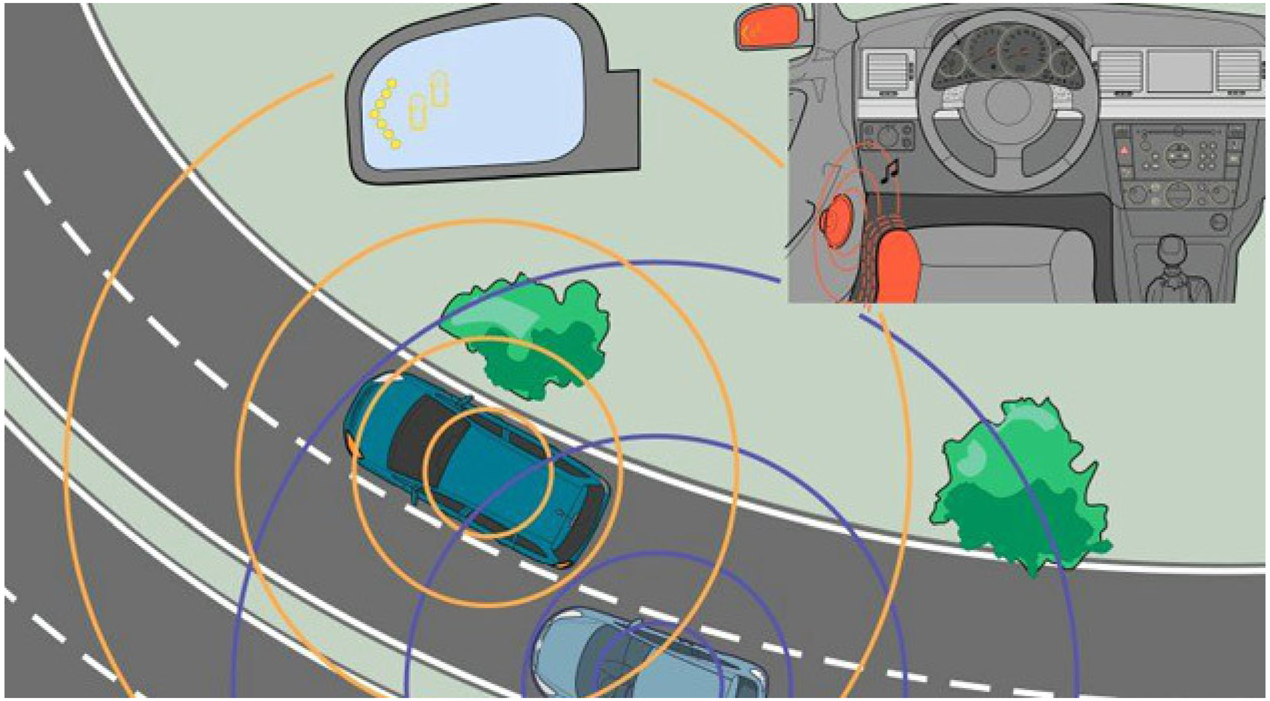
Smart Tyres - RFID combined with a TPMS*

- **reliable and high-quality readings of information**
- **significant operational improvements: 5 minutes instead of 15 minutes for checking vehicles (identification, pressure, temperature and RTD)**
- **Paves the way for more complete and frequent checks**

MICHELIN
A better way forward

***tire Pressure Monitoring System**

So what's around the corner….?



Smart Vehicles - Vehicle to Vehicle Communication

Even tyre technology!

Thank You

darren.lindsey@uk.michelin.com