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Transportation-Related Noise & Vibration
TRB Summer 2009 Tech Program

Tire/Pavement Interaction Noise (T/PIN)
Highway Vehicles
Prepared by
The Rubber Manufacturers Association
Washington, DC

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TRB Meeting
Tire/Pavement Interaction Noise (T/PIN)

- Agenda
  - » **Mechanisms of T/PIN –**
  - » T/PIN – Characteristics of Existing T/P
  - » Mitigating T/PIN: Tire Response
  - » T/PIN – Forward Direction

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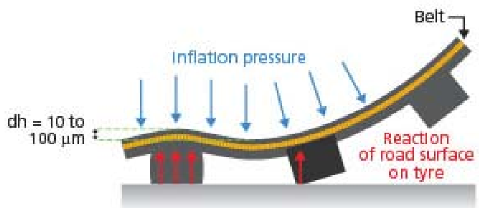
Mechanisms of T/PIN

Tire Parameters



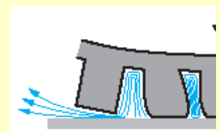
⇨ Tread pattern

Excitation

⇨ Pavement surface

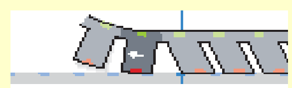
Road Parameters

Air Pumping



Structure vibration

Friction



Amplification «Horn effect» Acoustic Transfer

Acoustic Pressure (Noise)

Amplification «Horn effect» Acoustic Transfer

Impacts: Excitation/Structure Vibration

Impacts - At the leading edge of the tire contact patch, pavement texture and tire tread pattern induces a drumming action on the tire, and the tire responds by vibrating .

Pavement - macro texture is important to the impact phenomena.

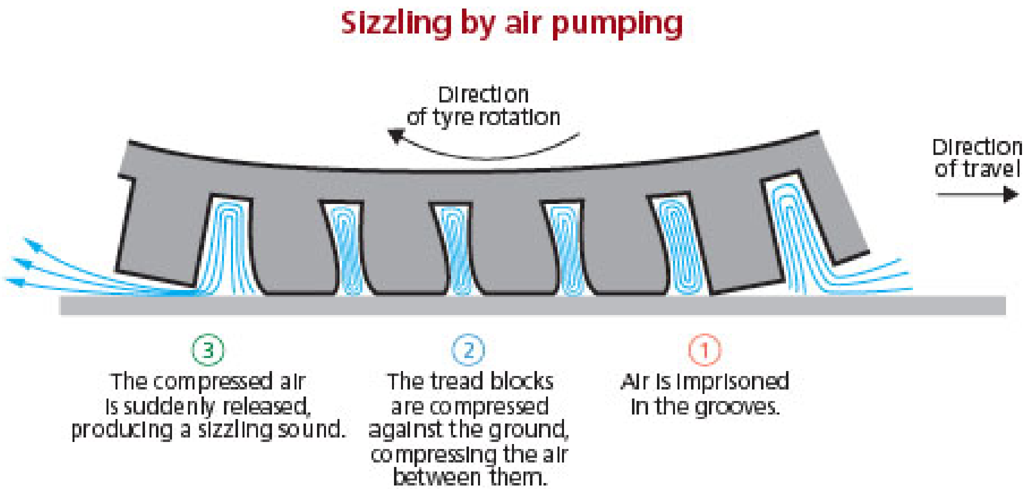
Tire tread – through the tread blocks, the belt structure is accelerated upward and downward, causing the tire to vibrate.

The vibrations create noise in two ways:

1. by exciting the surrounding air, making air-borne noise;
2. by making the vehicle vibrate, then the air inside the vehicle vibrates, creating structure-borne noise.

Air Pumping: Capture / Rapid Release

Air pumping – At the entrance of the contact patch, the air is imprisoned in the grooves, the compressed air is suddenly released at the exit generating noise.



Pavement – the porosity of the pavement influences the level of the pumping action.

Tire tread – the shape and size of the openings in the tread pattern, and the movement of the blocks in the tread pattern, influence the level of the pumping action.

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Friction: Stick-Slip / Vibration

Friction – In the tire's contact patch, the tread blocks slip and stick on the road surface when rolling, generating vibrations in the tire.

Pavement – influences the level of the adhesive forces between the tread and the pavement.

Tire tread – the stick – slip action between the tread and the pavement also causes the tire structure to vibrate.

Horn Effect: Amplification

Horn effect – amplifies the airborne noise produced by air pumping and vibration.

Tire – forms one half of the tire/pavement wedge in front of and behind the contact patch. The width of the tire influences the amount of magnification.

Pavement – forms the other half of the tire/road surface wedge in front of and behind the contact patch. The acoustical characteristics of the pavement influence the amount of magnification (absorption).

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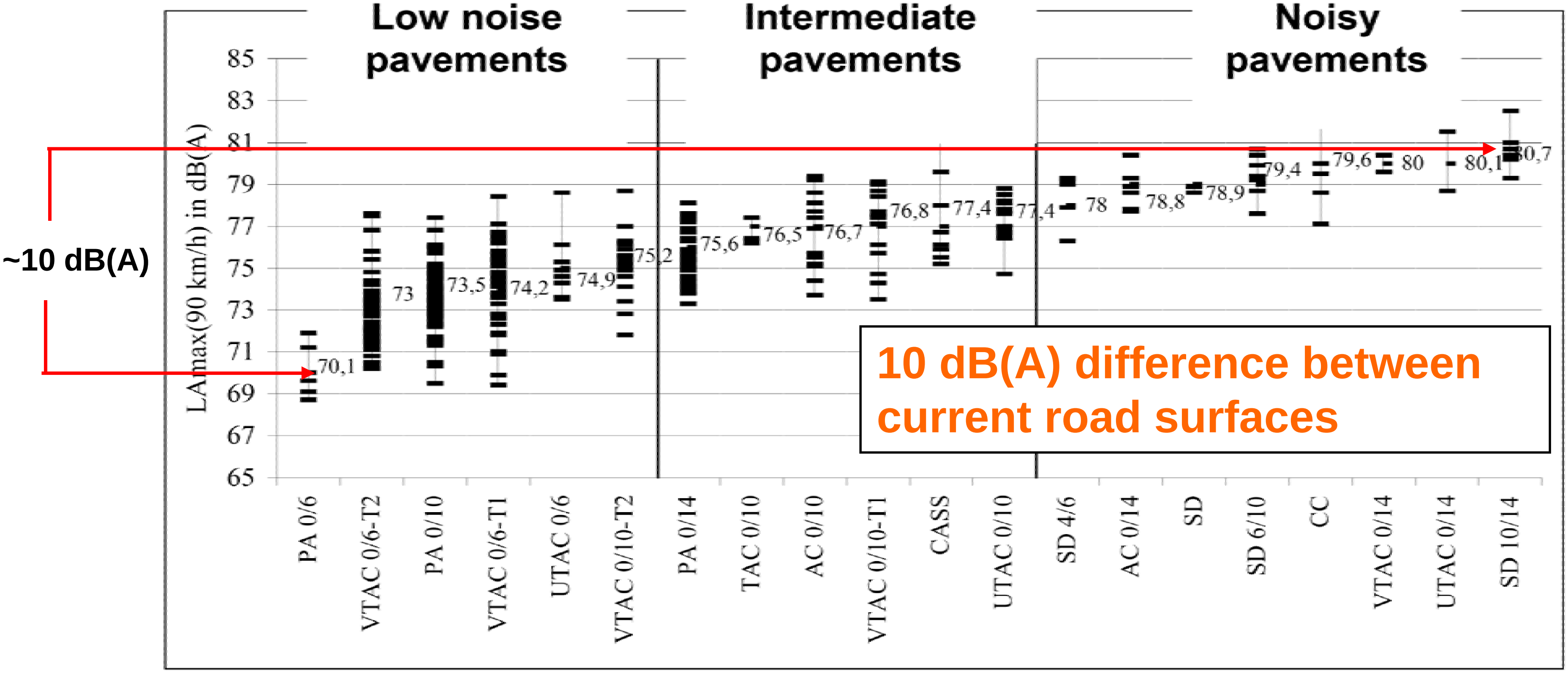
T/PIN-Pavement: Response Variation



low-noise pavements: 0/6 and 0/10 porous asphalt (PA), 0/6 and 0/10 type 2 very thin asphalt concrete (VTAC), 0/6 ultra-thin asphalt concrete (UTAC);
intermediate pavements: 0/14 porous asphalt (PA), 0/10 asphalt concrete (AC), 0/10 thin asphalt concrete, 0/10 very thin asphalt concrete (VTAC), cold-applied slurry surfaces (CASS);
noisy pavements: 0/14 asphalt concrete (AC), surface dressings (SD), cement concrete (CC), 0/14 thin asphalt concrete and 0/14 ultra-thin asphalt concrete (UTAC).

Source: Yves MEUNIER - USIRF/ROUTIÈRE MORIN : LOW-NOISE PAVEMENTS : THE SOLUTIONS OFFERED BY THE FRENCH ROAD BUILDING INDUSTRY, Internoise 2001, The Hague, The Netherlands

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T/PIN-Pavement: Response Variation

Physical Phenomena

- Indentation / drumming at the tread
- Acoustical pressure attenuation

Pavement Component or Characteristic involved

- surface roughness (texture)
- aggregate size
- porosity near the pavement surface

Response Variation Among Existing Pavements

- Excitation related to 'texture' : ▲10 dB(A)
- Absorption from porosity : ▲3 dB(A)

T/PIN - Tire: Response Variation
(existing passenger car products)

Physical Phenomena	Tire Component or Characteristic Involved
➢ Vibration of the tire ➢ Air Pumping action	Vibration ➢ tread & architecture rigidity ➢ tread pattern design Air pumping ➢ tread pattern design

Response Variation Among Existing Tires
Rigidity*: ▲2 - 3 dB(A) Tread Pattern**: ▲4 dB(A)

*Rigidity Source - Michelin
**Tread Pattern Source – Acoustic Research Laboratory

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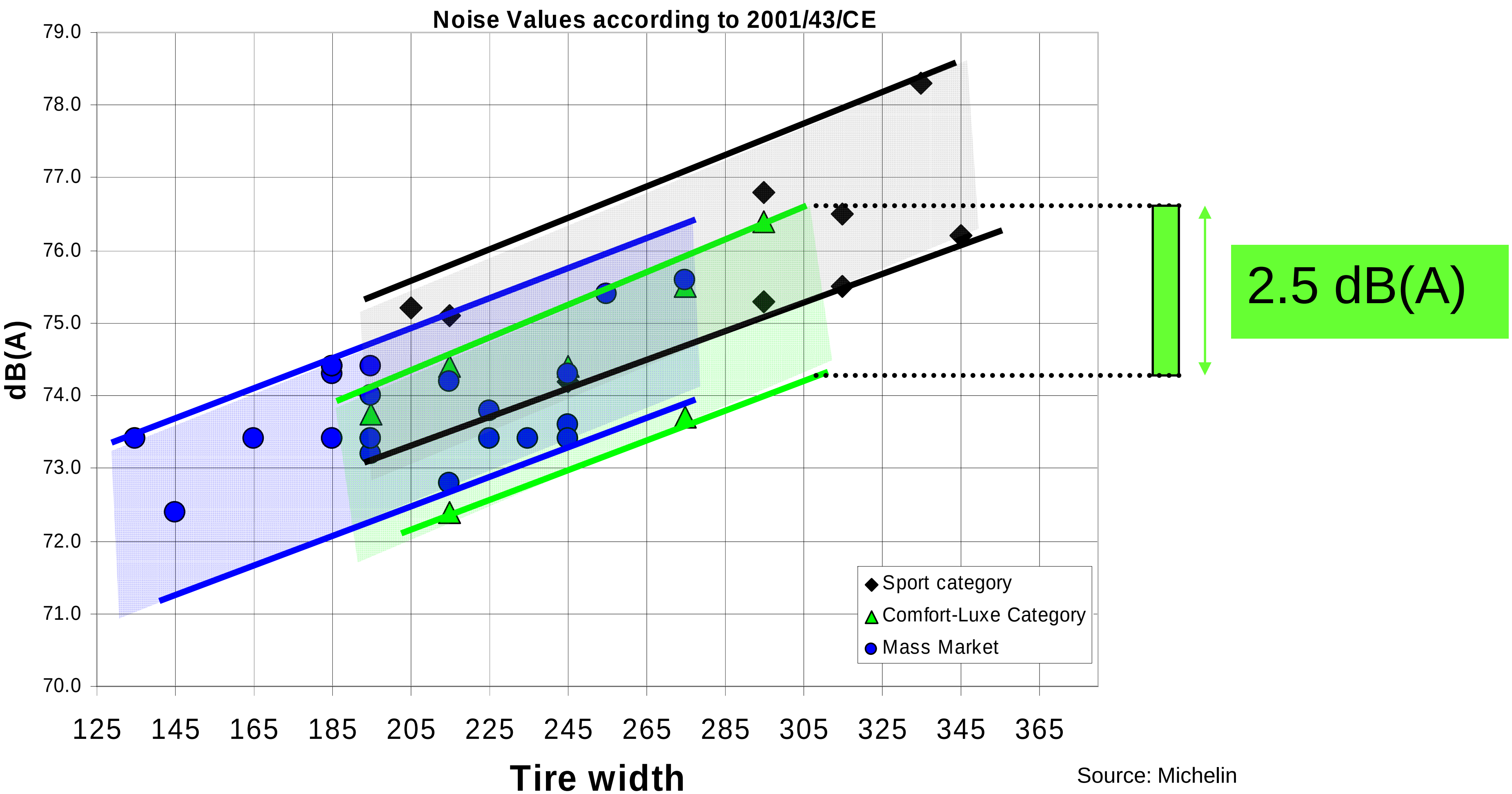
T/PIN – Tire : Response Variation
(existing passenger car products)

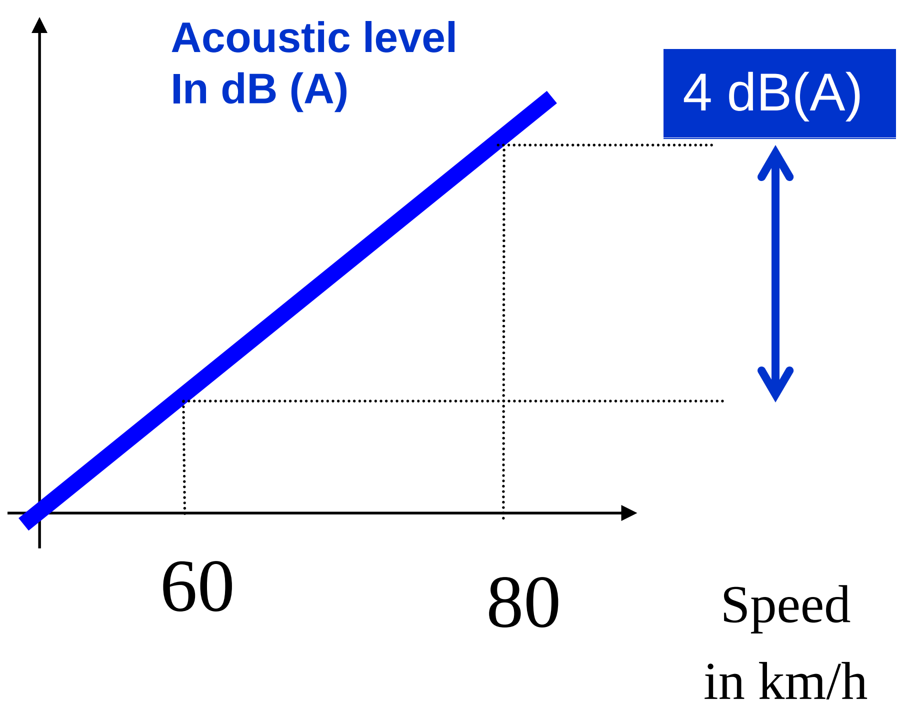
➔ **For a <u>given dimension</u> in a <u>given segment</u>, tire/pavement acoustic level variation does not exceed 2.5 dB (A)**



Source: Michelin

T/PIN - Speed : Response to

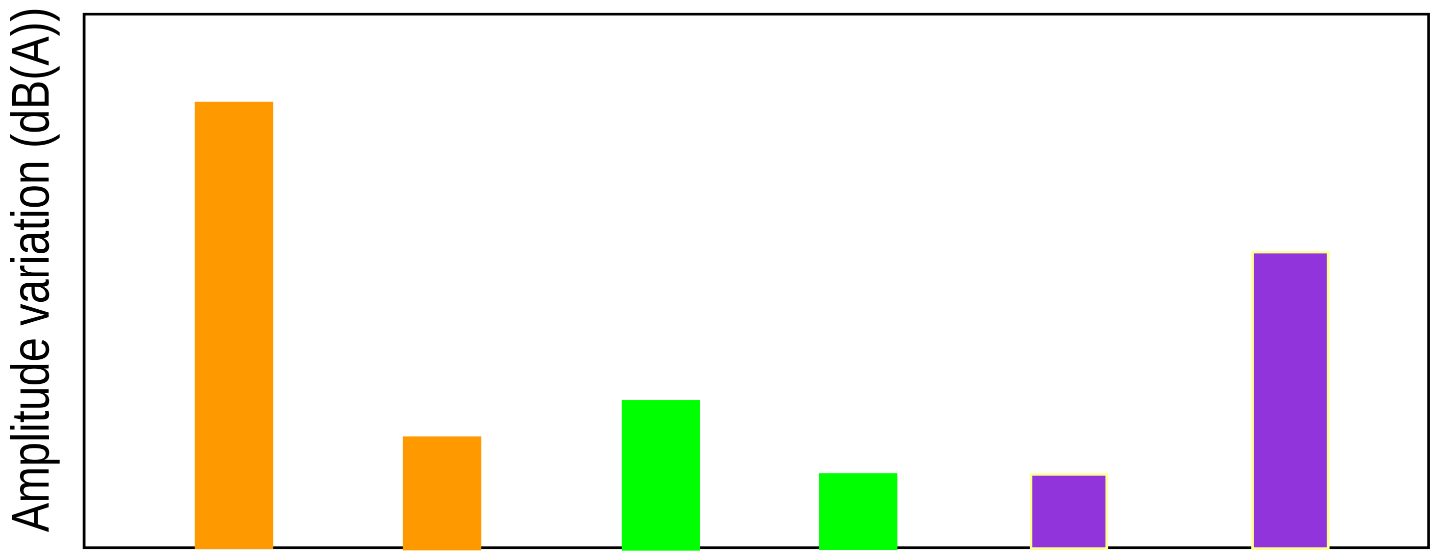
Vehicle Speed Impact



* Source : Bulletin des Laboratoires des Ponts et Chaussées n°224, janvier février 2000

Main Factors
In Tire/Pavement Interaction Noise

- The main parameter influencing noise is the road roughness.
- Tire solutions for noise, when balanced among traction, wear, rolling resistance, handling performance requirements, have a relatively minor impact.



Contributor	Road		Tire		Speed (Kph)	
Parameters	Roughness	Absorption	Tread pattern	Rigidity	50	90
Possibilities	Large		Very limited			

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Mitigating T/PIN:
How to reduce the tire contribution?

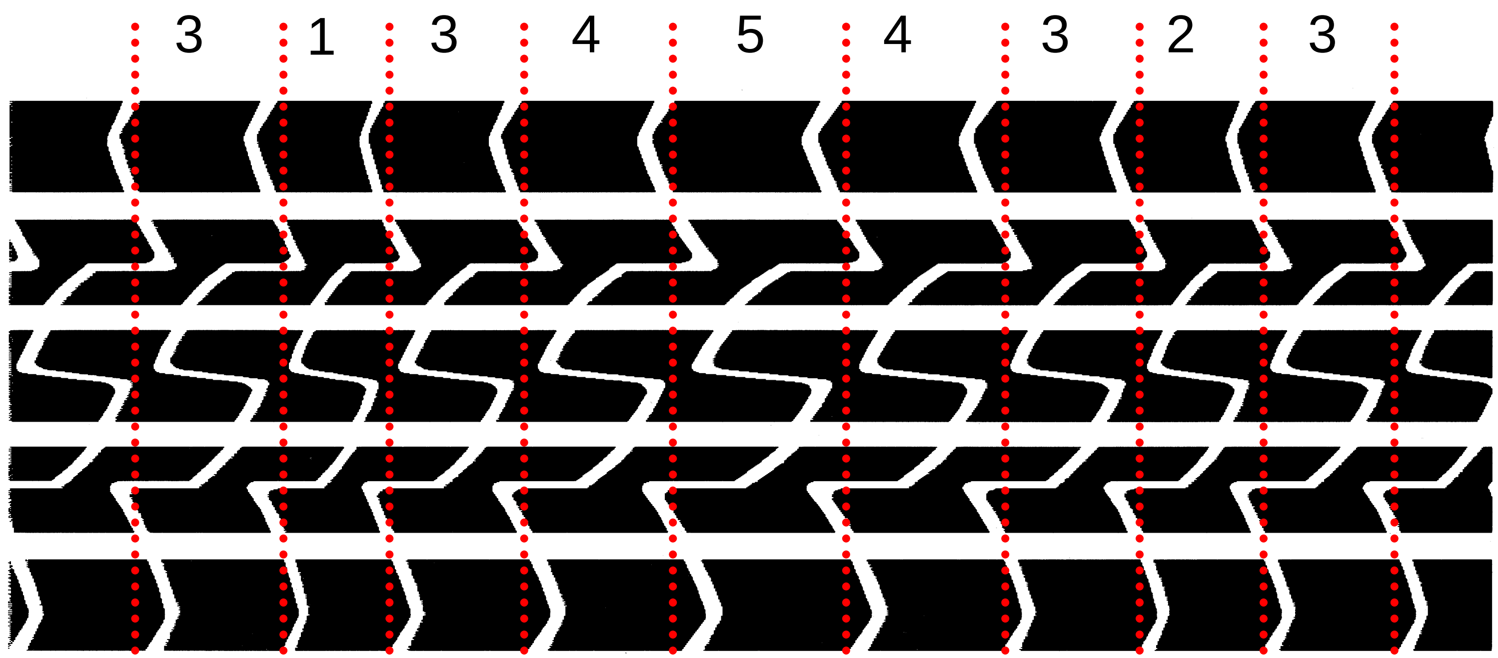
- Reduction of tire/pavement interaction noise through tire design involves:

» **Tread pattern design**

» Internal structure

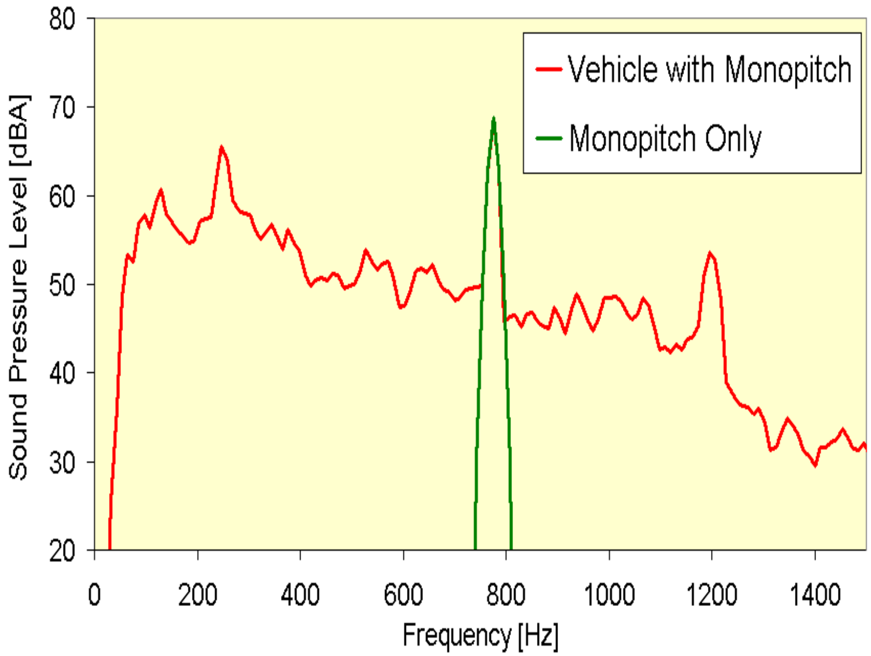
» Tread rubber compound

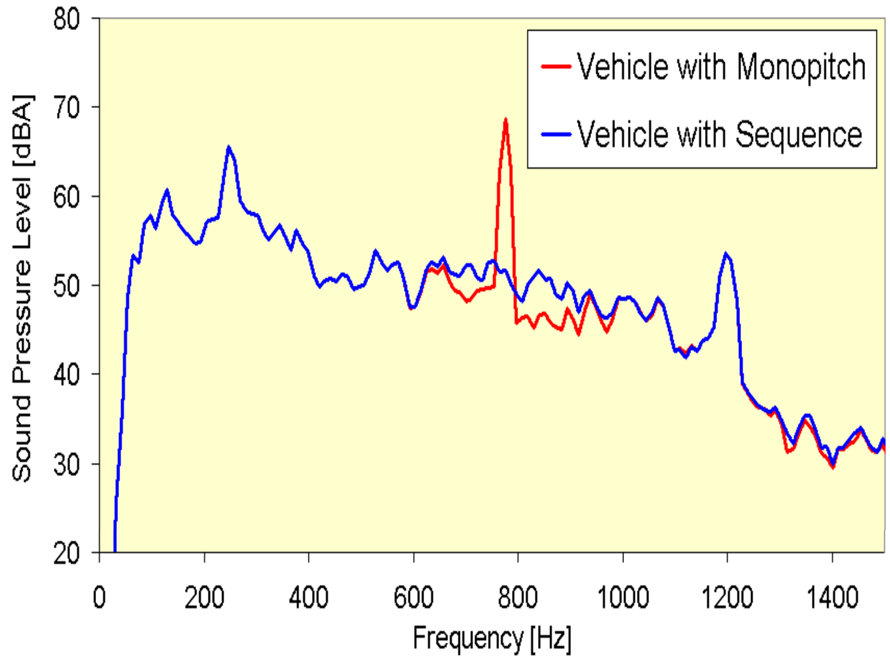
T/PIN – Tire Tread Pattern Sequence Randomization



- Passenger tires have a multi-pitch noise sequence.
- The lengths are randomly or specifically placed about the tire circumference.
- A tire with only one pitch length is referred to as a mono-pitch.
  - » Mono-pitch tires can be found in Agriculture and Truck & Bus applications.

T/PIN – Tire Tread Pattern Randomized Noise Sequence: Audio Example





Simulation of Vehicle Interior with Monopitch Noise Sequence

Only Monopitch Noise Sequence

Simulation of Vehicle Interior with a Randomized Noise Sequence

- **The frequency of pattern noise will reduce as the vehicle slows.**
  - **This is because the lugs are hitting the road slower as the vehicle slows.**

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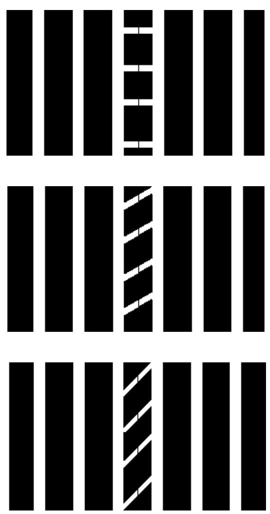
T/PIN – Tire Tread Pattern Optimization for Noise

Example : *Lateral groove angle effect (tire only)*

Example : *Pattern Phase effect (tire only)*



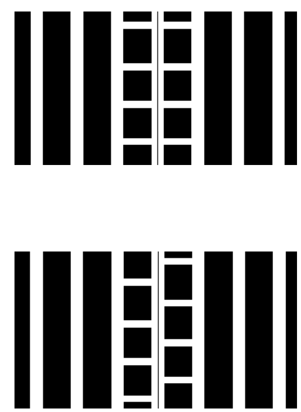
Angle = 0

Angle = 30

Angle = 45

Less Quiet

More Quiet

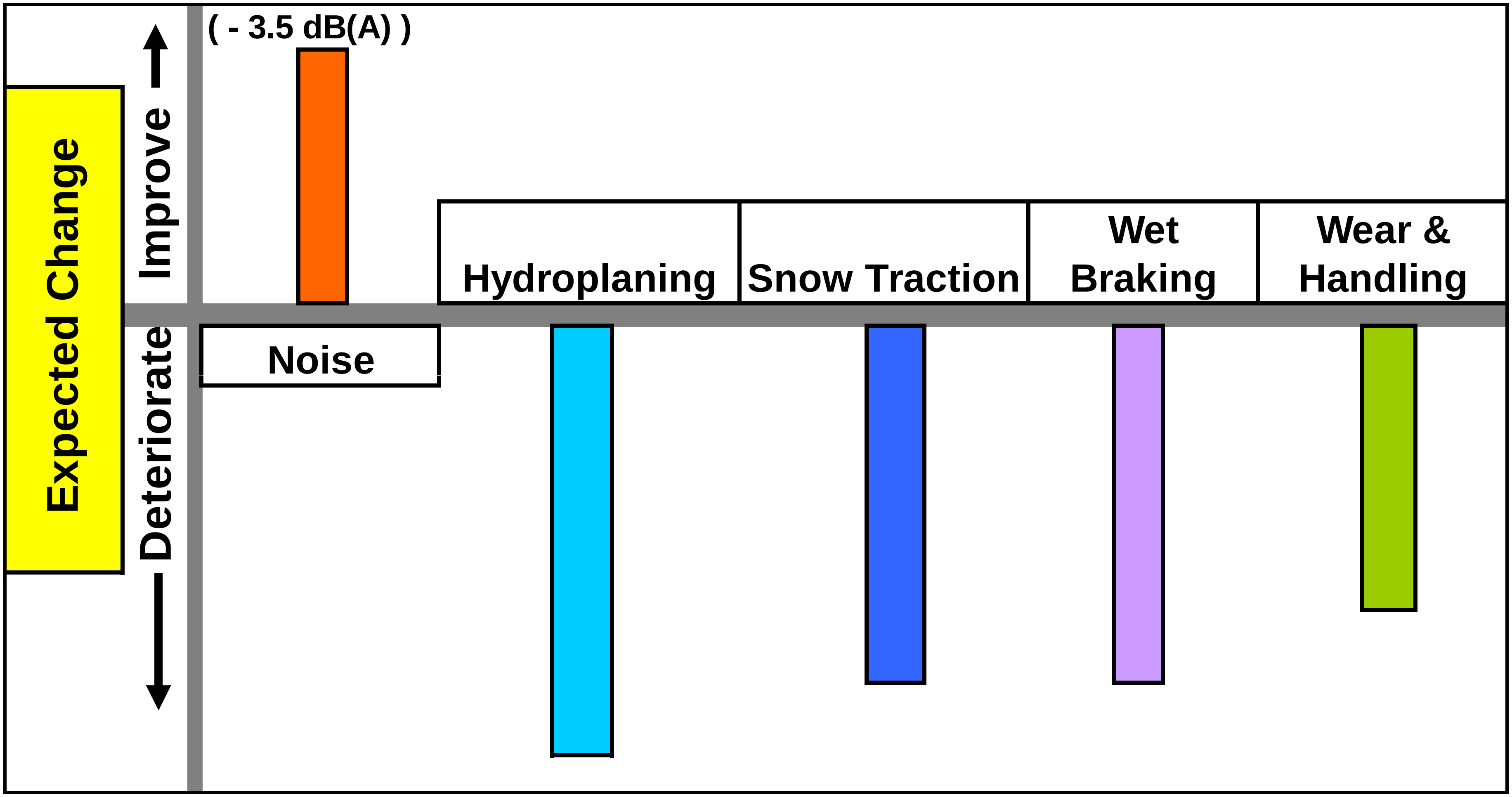


Phase = 0

Phase = Pas/2

Standard practice in the industry today

Mitigating T/PIN:
Trade-offs when addressing T/PIN



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Tire/Pavement Noise Progress:
Requires a Total System Approach

Input by Road and Driver	→	Interaction between Pavement and Tire	→	Interaction between Tire and Vehicle	→	Perception Objective: Exterior Subjective: Interior

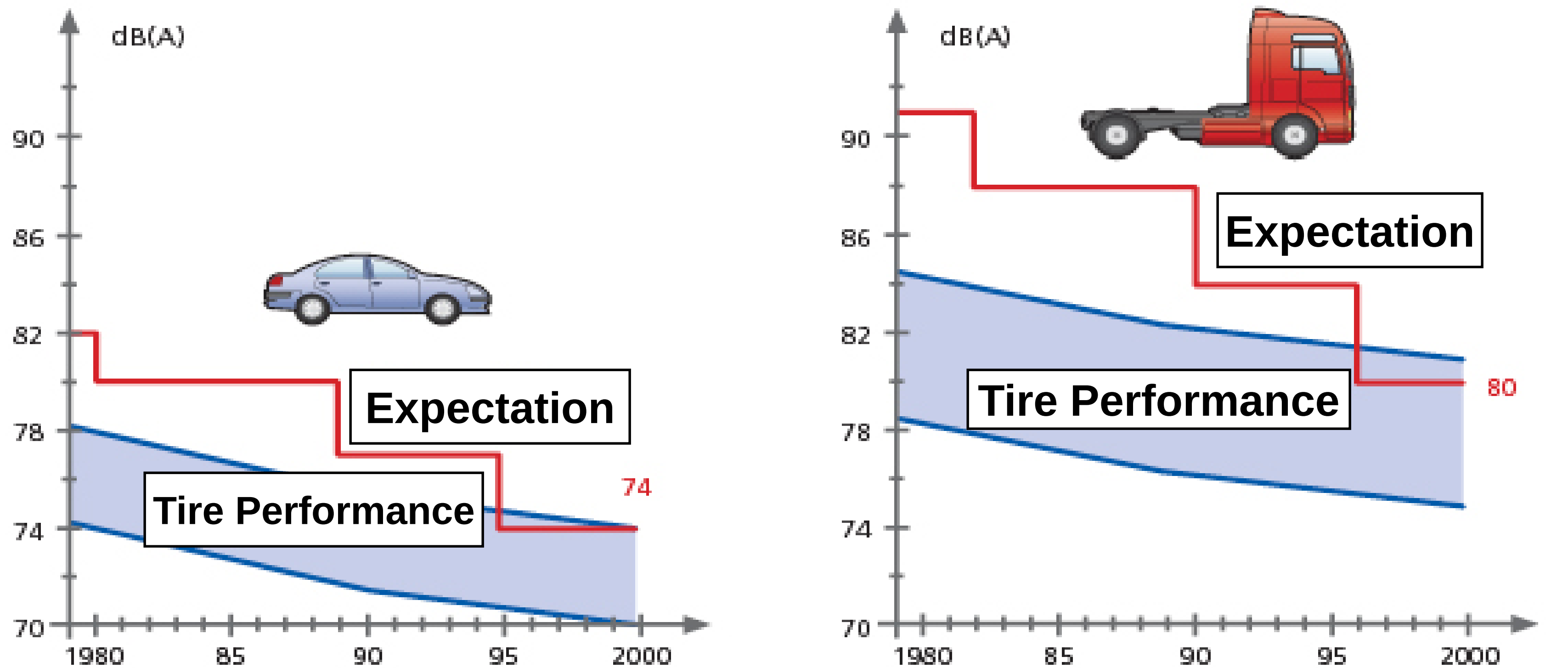
There is no: ***TIRE NOISE***

But there is: **PAVEMENT <>TIRE NOISE and**

PAVEMENT<>TIRE<>VEHICLE NOISE

T/PIN Noise : 1980 → 2000

Evolution of Tires & Expectations



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T/PIN Noise – Current Expectations

Coast-by Values (80 kph)

Tire Class		Current Expectations (dB(A))	Typical Tire (dB(A))
Passenger	By Nominal Width	72 - 76	70 – 74
Truck (Light)	By Type	75 - 77	75 - 81
Truck (Commercial)	By Type	76 - 78	

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T/PIN Noise – Future Expectations

Coast-by Values (80 kph)

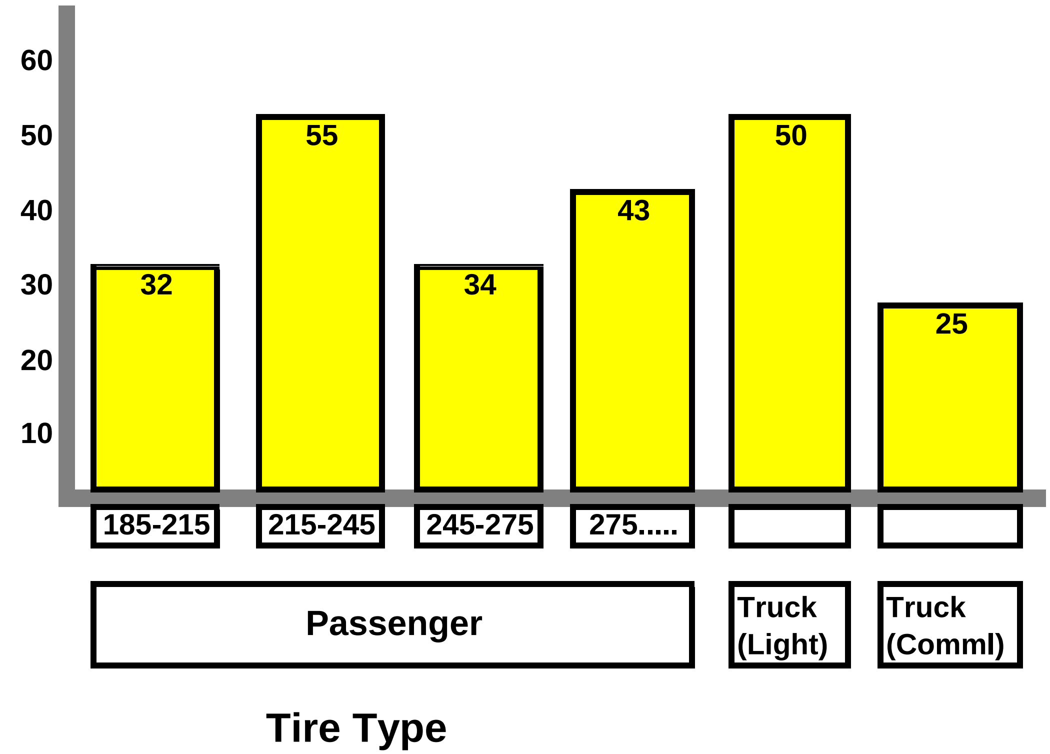
Tire Class		Current Expectations (dB(A))	Typical Tire	Future Expectations (dB(A))
Passenger	By Nominal Width	72 - 76	70 – 74	70 - 74
Truck (Light)	By Type	75 - 77	75 - 81	72 - 75
Truck (Commercial)	By Type	76 - 78		

Existing Tires on the market :

% of Tested Tires (by Category) potentially impacted by future expectations in Tire noise.

Data Source - FEHRL Study – (Forum of European Highway Research Laboratories)

Percentage exceeding
Current Expectation less 3 dB(A)



Conclusions

- Tire/ Pavement Noise reduction, without compromising safety, is an industry goal.
- ‘Pavement’ must be an active participant in the noise reduction effort.
- ‘Pavement’ contributions are immediate and can be significant.
- ‘Tire’ contributions take time, and have a relatively minor impact.

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