RAILWAY NOISE & VIBRATION AND THE ENVIRONMENT

PRESENTATION BY
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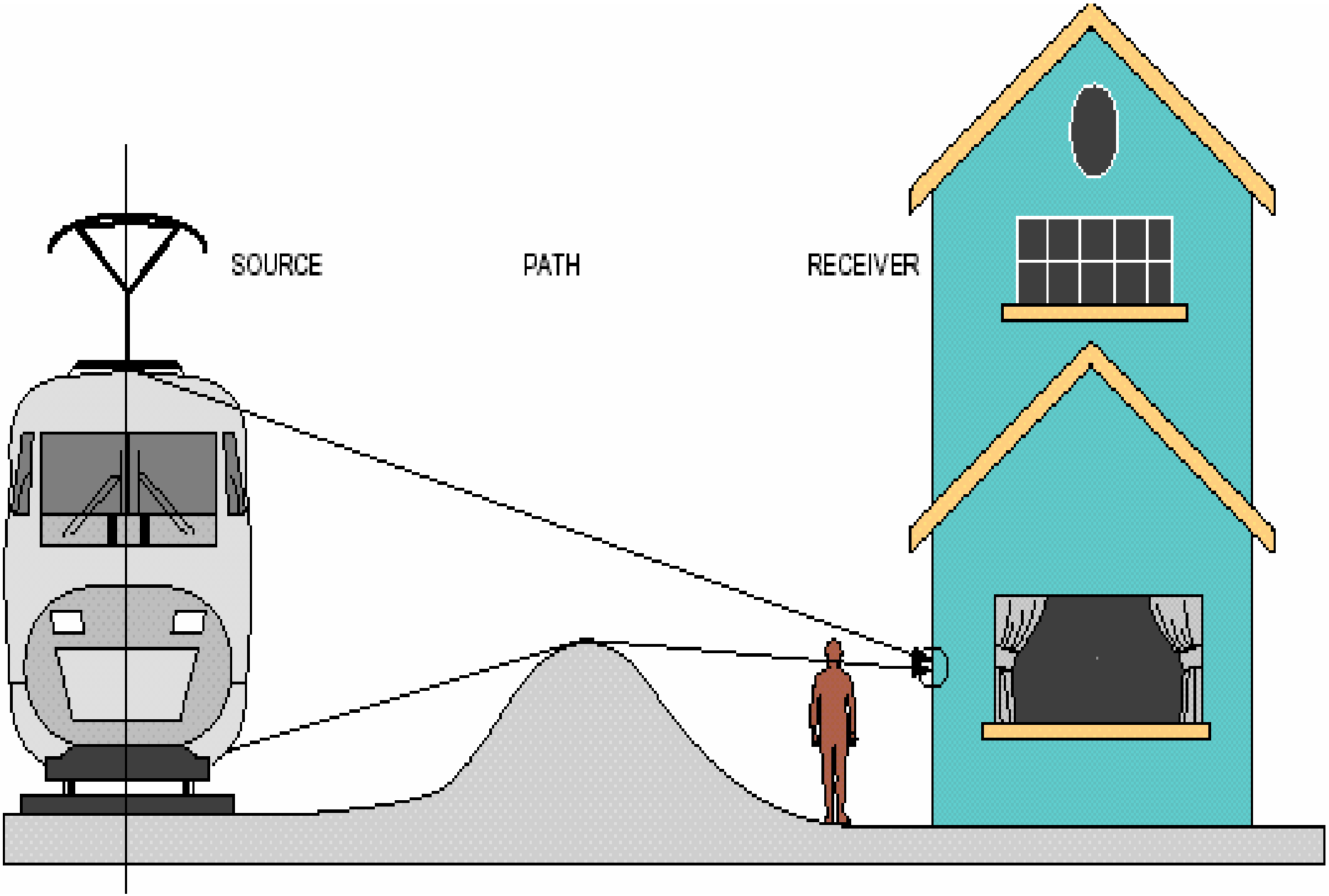
BACKGROUND

- No regulations exist at present in South Africa for railway generated noise or vibration emissions.

The Source-Path-Receiver Framework



- Province of Gauteng has noise control regulations limiting noise emissions to 60 dBA ($L_{Aeq, 24\ Hr}$)
- $L_{Aeq, 24\ Hr}$ represents the cumulative 24-hour exposure and combines all noise sources during that period.
- No limitation at present on $L_{A\ max}$ i.e. the maximum noise level of a single noise event.

The letter “A” in the symbol “dBA” indicates that the sound has been filtered to reduce the strength of the very low and the very high-frequency sounds, much as the human ear does.

Note:

When used to describe sound level, the number of decibels (dB) is 10 times the logarithm (to the base 10) of the ratio (p^2/p_{ref}^2), where p is the sound pressure (in micropascals) and p_{ref} is a reference pressure (20 micropascals).

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- 1995 Summary of Legislation governing rail traffic noise in Europe reveals night-time noise limits $L_{Aeq,t}$ of 50 dBA to 60 dBA and day-time limits of roughly 60 dBA.
- Rail generated noise is sometimes given a “bonus” of 5 dBA i.e. rail noise can be up to 5 dBA **higher** for the same perceived nuisance.
- $L_{A\ max}$ 85 dBA (where specified)

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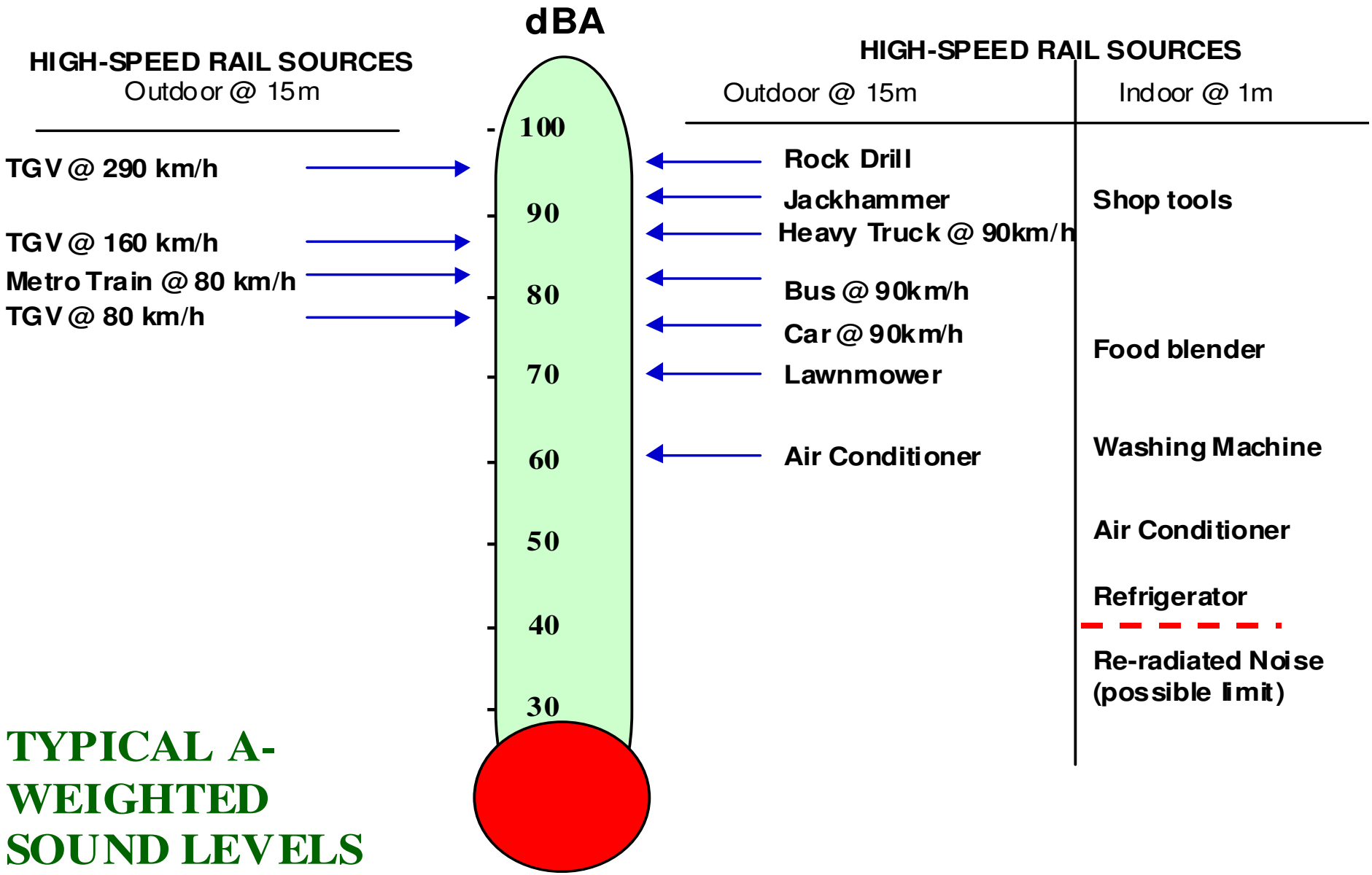
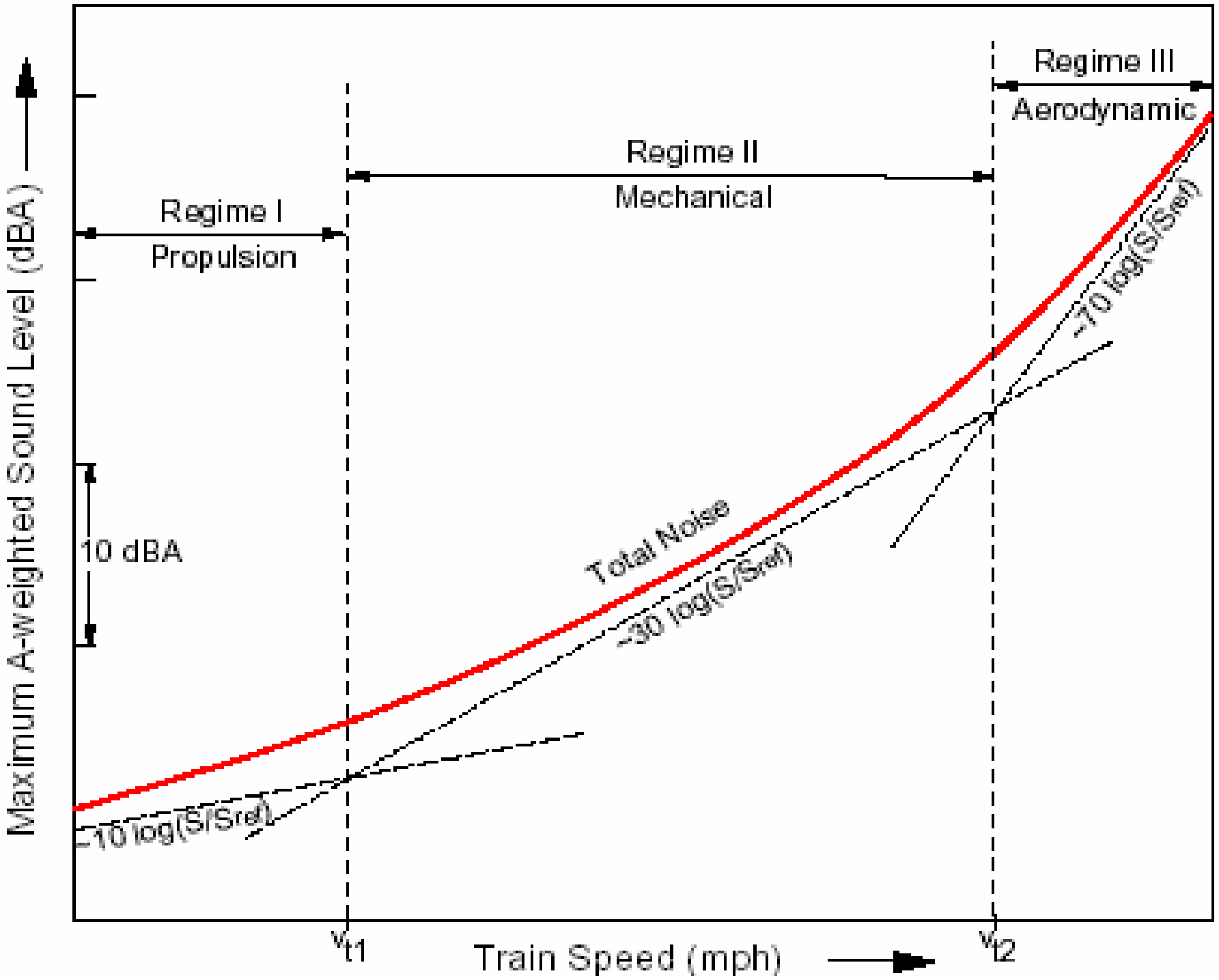
NOISE DESCRIPTORS



TYPICAL A-WEIGHTED SOUND LEVELS

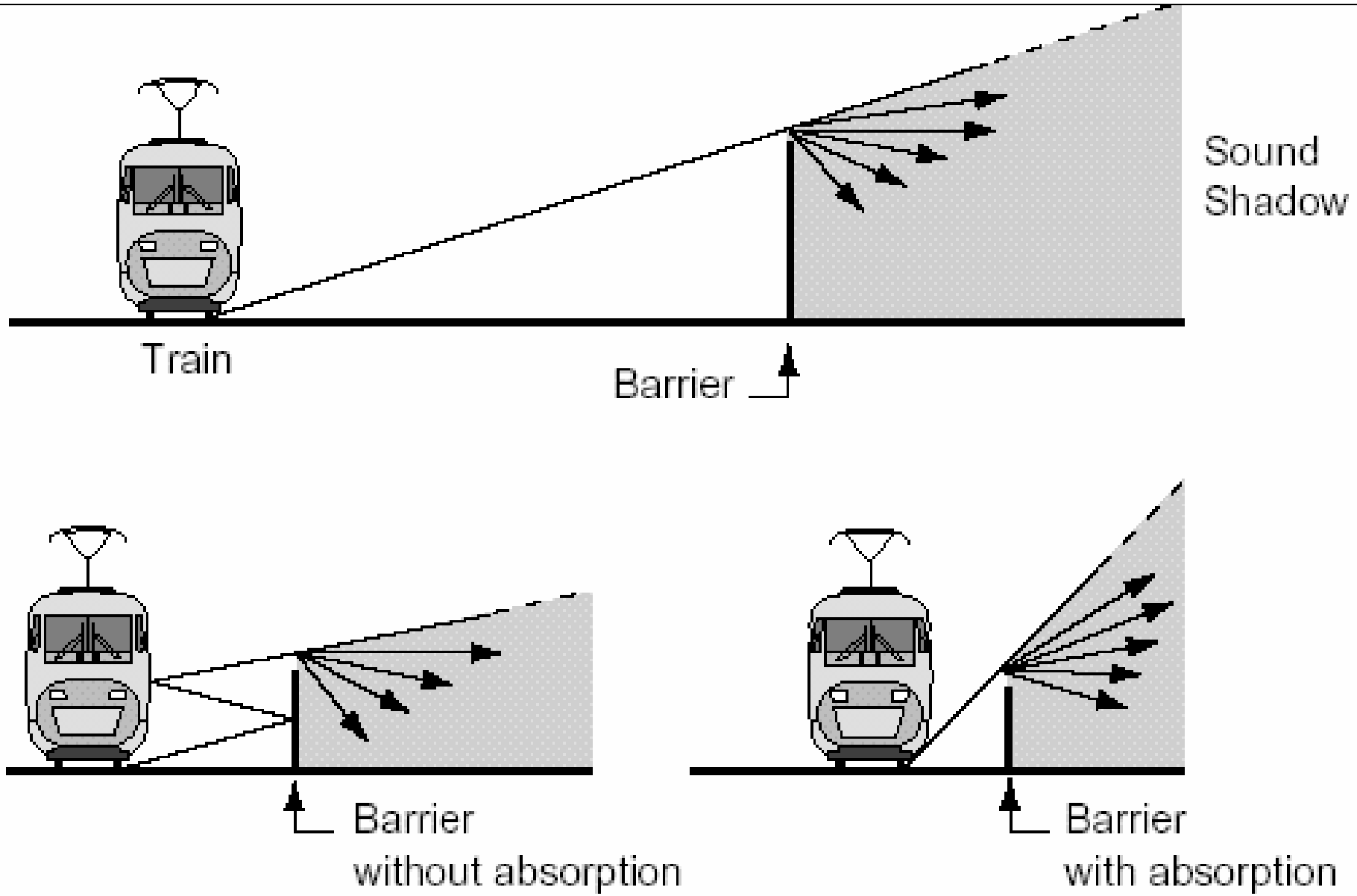
- 40 dBA is considered “very quiet” and 90 dBA is considered very loud
- On average, each A-weighted sound level increase of 10 decibels (10 dBA) corresponds to an approximate doubling of subjective loudness.
- Speed Regime II is mainly responsible for noise generation from train between stations.
- This is due to the wheel-rail interaction.


Regime III
Aerodynamic
Regime II
Mechanical
Regime I
Propulsion
Maximum A-weighted Sound Level (dBA)
10 dBA
Total Noise
-30 log(S/Sref)
-70 log(S/Sref)
-10 log(S/Sref)
Vt1
Vt2
Train Speed (mph)

- Depending on the rail cars chosen, the lower limit of Regime II, V_{t1} will probably be in the range 20 – 60 km/h, and
- The upper limit of Regime II, V_{t2} will probably be in the range 230 – 280 km/h.

- Shielding can attenuate noise at the receiver by 5 to 15 dBA
- Shielding can be provided by noise barriers and/or track geometry:

NOISE ATTENUATION MEASURES - SHIELDING

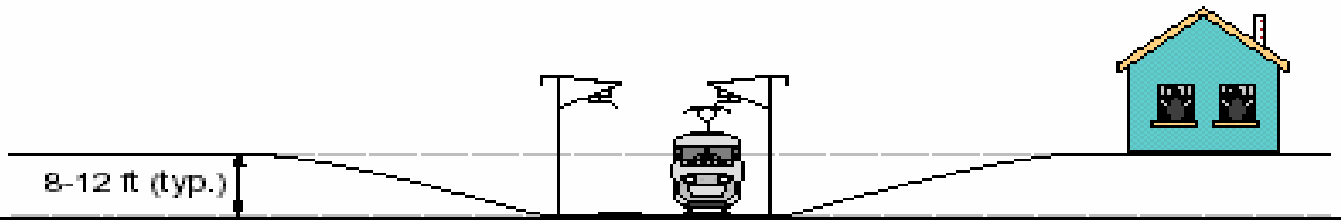
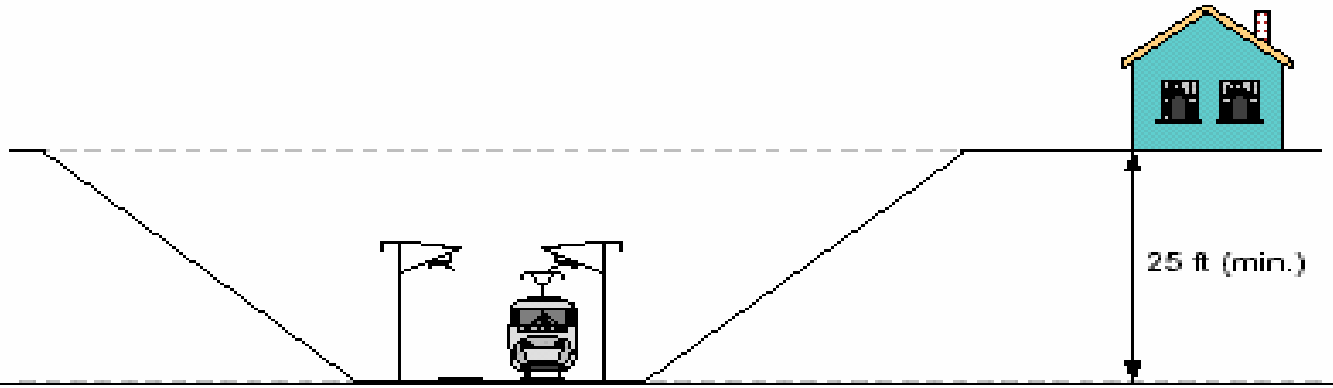
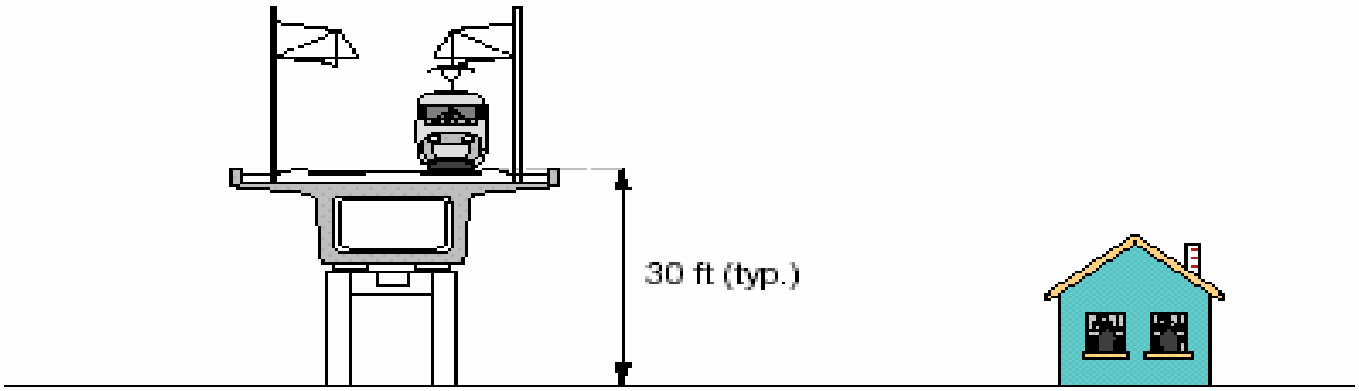


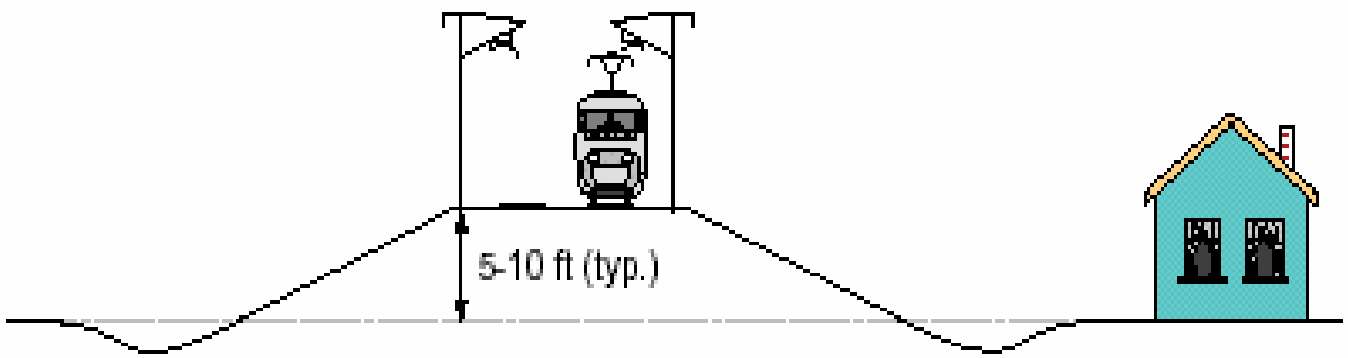
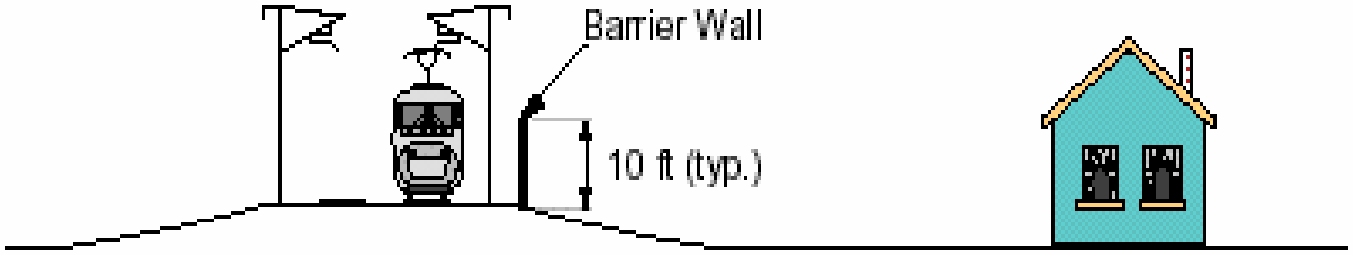
GAUTRAIN NOISE IMPACT STANDARDS

- Maximum sound pressure levels at the railway boundary

Period of Day (T)	$L_{Aeq,T}$ (dBA)	L_{Amax} (dBA)
06h00 – 22h00 (daytime):	60	85
22h00 – 06h00 (night-time):	50	85

- Measurement methods in accordance with international standards for measuring railway noise, such as draft European Standard prEN ISO 3095: Railway applications - Acoustics - Measurement of noise emitted by railbound vehicles (ISO/DIS 3095:2001)

Table 4-3 Shielding Corrections for Track Geometry		
CASE	**Speed Regime**	**Shielding Correction (C_s)**
1) Tracks in Shallow Cut 	I	0 dBA
	II	–10 dBA
	III	–3 dBA
2) Tracks in Deep Trench or Cut 	I	–10 dBA
	II	–15 dBA
	III	–10 dBA
3) Tracks on Aerial Structure 	I	+4 dBA
	II	+4 dBA
	III	+2 dBA

4) Tracks on Embankment 	I	0 dBA
	II	-5 dBA
	III	0 dBA
5) Noise Barrier 	I	0 dBA
	II	-10 dBA
	III	-5 dBA

RAIL GENERATED VIBRATIONS

- Very little legislation or literature on rail generated vibrations.
- The USA Federal Railroad Administration (FRA) and Federal Transit Administration (FTA) have published two manuals for evaluation procedures of noise and vibration impacts.

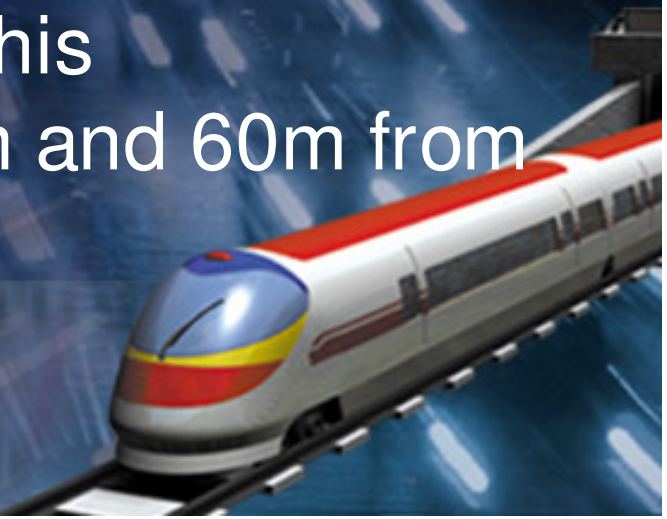
- US DOT FTA Transit Noise and Vibration Impact Assessment: Final Report DOT-T-95-16, April 1965, and,
- US DOT FRA: High-Speed Ground Transportation Noise and Vibration Impact Assessment, Final Draft, December 1998.
- This last manual is being used by the team carrying out the EIA for the Gautrain Project as well as by the Gautrain technical team.

PROCESS - VIBRATION ASSESSMENT

- Preliminary vibration assessment has three levels of detail for predicting ground-borne vibration and re-radiated noise:

Screening: Uses a table of distances to determine likely areas of impact.

For speeds up to 160 km/h this extends to between 40m and 60m from the track centre-line.



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General Assessment: Uses generalised data to develop a curve of vibration level as a function of distance from track.

- These data are based on the high range for "normal" geology. Actual can be 5 dBV or more lower, in general.
- Not an exact science - can find a variation of 5 to 10 dBV under apparently similar conditions.

Detailed Analysis: Usually performed during final design phase where there is sufficient reason to suspect adverse vibration impact.

Note:

When used to describe vibration, a decibel scale is often used. The vibration level, the number of decibels (dBV in metric terms) is 20 times the logarithm (to the base 10) of the ratio (v/v_{ref}), where v is the root mean square (RMS) of the velocity amplitude and v_{ref} is a reference RMS velocity amplitude.

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Note continued:

Because the net average of a vibration signal is zero, the root mean square (RMS) amplitude of the velocity is used to describe the "smoothed" vibration amplitude. It is the average of the squared amplitude of the vibration velocity.

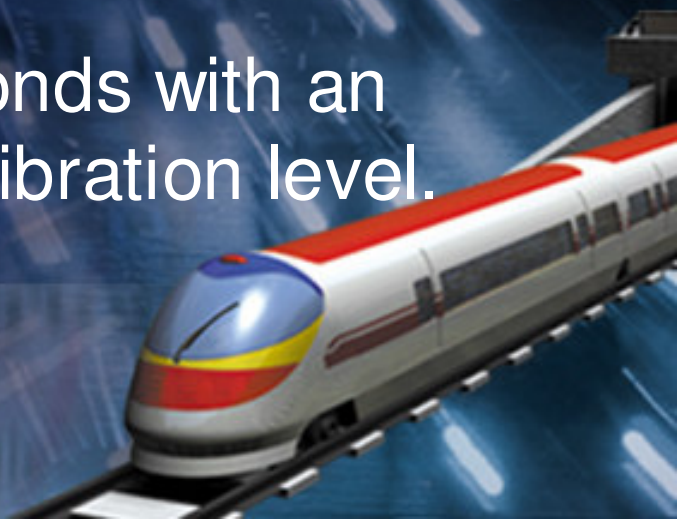
In metric terms, the ISO reference velocity amplitude is 1×10^{-9} m/sec and the abbreviation dBV is used.

Note Continued:

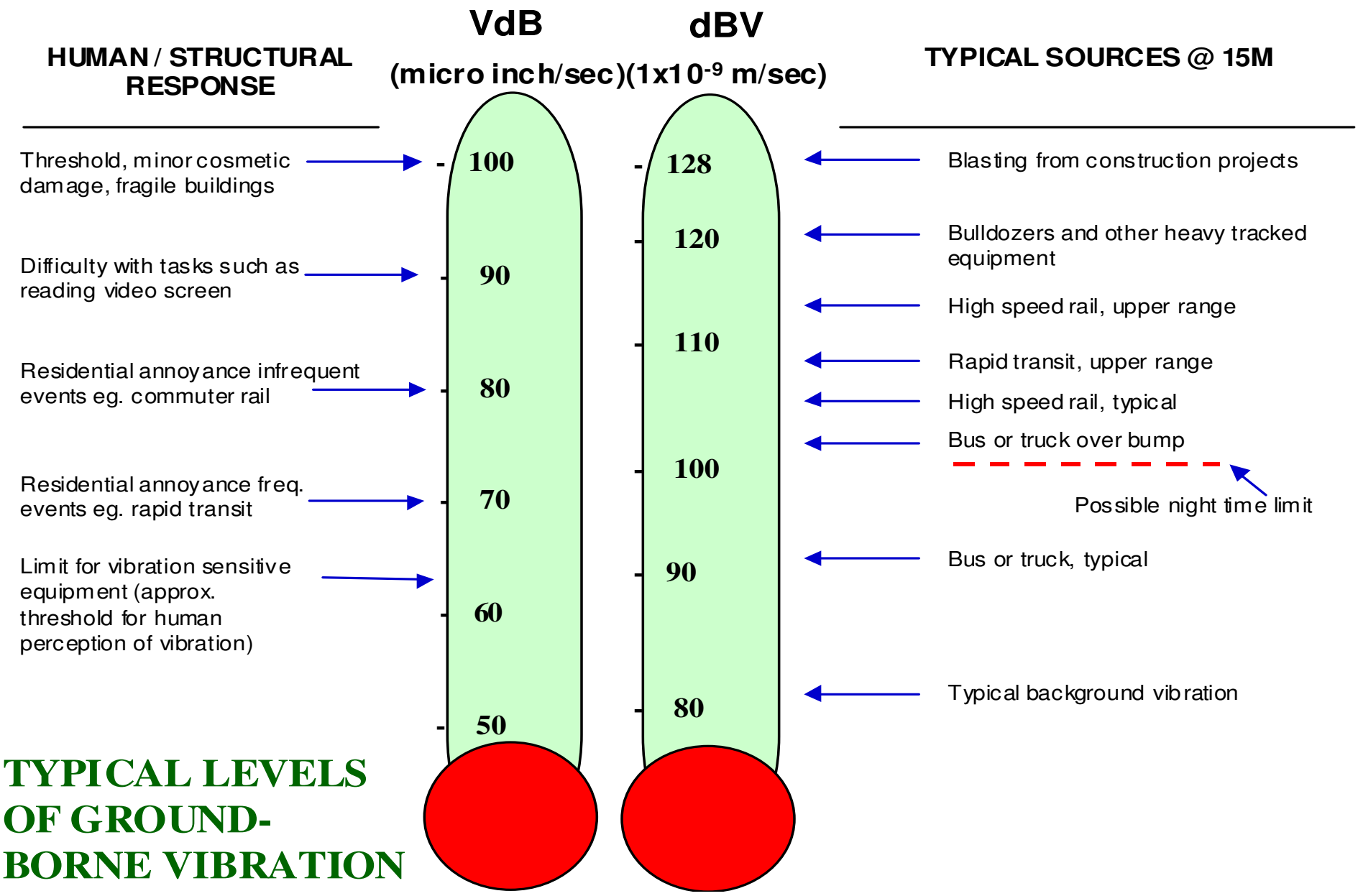
In USA the accepted reference amplitude is 1 x 10^{-6} in./sec and the abbreviation VdB is used to differentiate the different reference velocity amplitudes.

To convert VdB to dBV, add approximately 28. i.e. 72VbB = 100 dBV.

An increase of 6dBV corresponds with an approximate doubling of the vibration level.



VIBRATION DESCRIPTORS



TYPICAL LEVELS OF GROUND-BORNE VIBRATION

SOME VIBRATION CRITERIA

Application	Vibration	Velocity	Multiple
Vibration limit for “fragile” buildings	130 dBV	3,2mm/s	32X
Vibration limit for “historic fragile” buildings	118 dBV	0,8mm/s	8X
Daytime limit proposed for Gautrain	112 dBV	0,4mm/s	4X
Nighttime limit proposed for Gautrain	103 dBV	0,14mm/s	1,4X
Limit proposed for high-sensitivity buildings (e.g. vibration sensitive equipment etc)	100 dBV	0,10mm/s	Ref
Other Aspects			
Threshold of human perception (approx)	93 dBV	0,045mm/s	0,45X
Natural background vibration (approx)	75 dBV	0,006mm/s	0,06X

Note: A difference of 6dBV results in a doubling or a halving of the velocity level.

GROUND-BORNE VIBRATION

- Ground-borne vibration travels through a succession of media – various kinds of soil, rock, building foundations and building structures. This makes vibration more complicated to measure and predict than noise.

- These vibrations are almost never annoying to persons outdoors.

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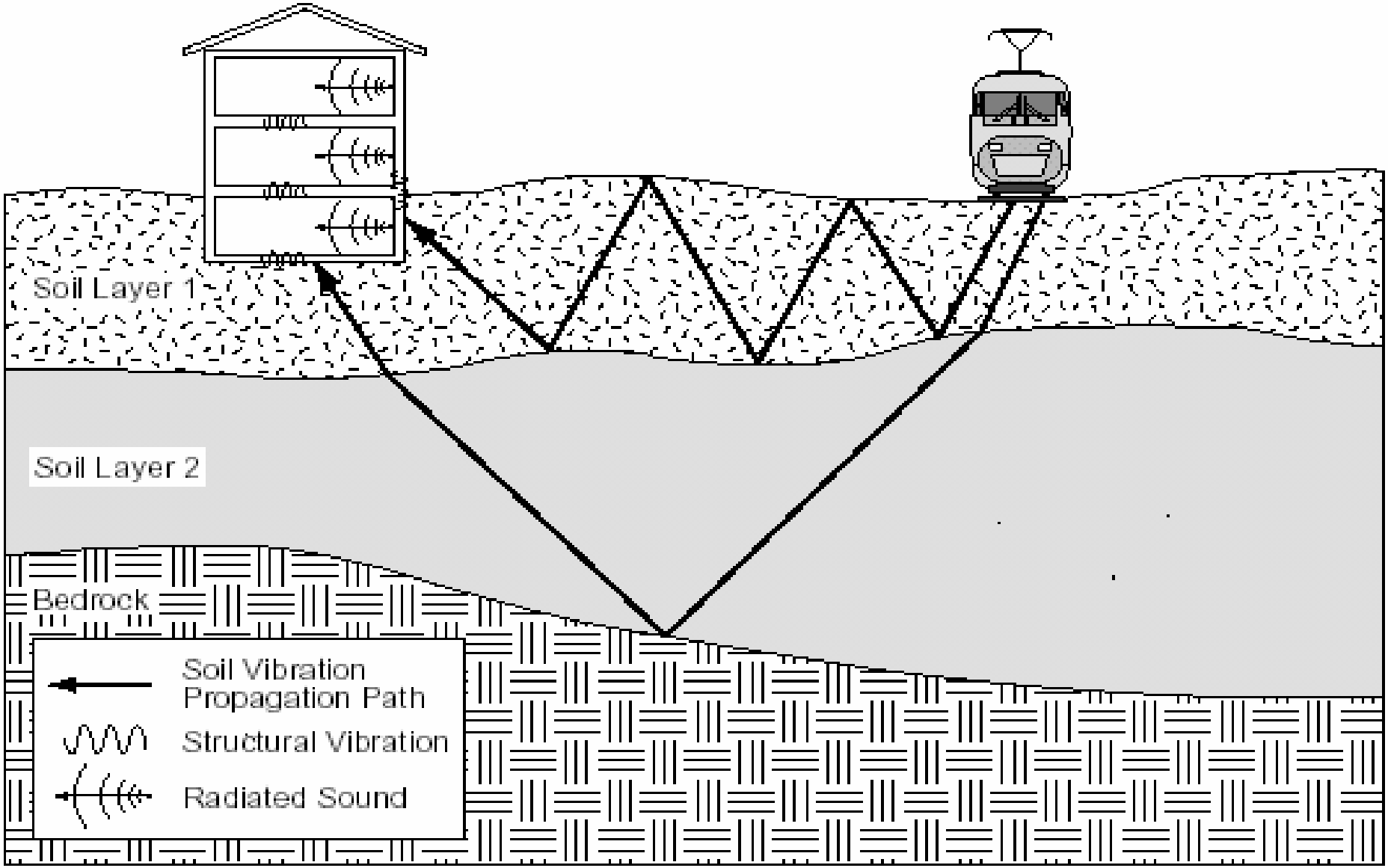
Propagation of Ground-Borne Vibrations into Buildings



- Vibrations of walls and floors may cause perceptible vibration, rattling or a rumble noise.
- Rumble is generated by motion of the surfaces of the room. In essence these surfaces act as sound sources.
- Called ***ground-borne noise***.

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ASPECTS OF VIBRATION

- The use of high resilience rail fastenings will attenuate vibration at source by about -5 dBV.
- Where needed to meet design requirements, the use of a floating track slab will attenuate the vibration by about -15 dBV.
- As vibration travels through the ground it steadily reduces as the distance increases. For normal geological conditions, at 10m from the track it reduces by about -6 dBV, at 25 m by about -13 dBV and at 100 m by about -28 dBV

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- The vibration in the ground must then penetrate the building, with appropriate coupling losses. These vary from –7 dBV for a 1-2-storey brick building to –13 dBV for a large masonry building on spread footings.

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RE-RADIATED NOISE

- In practice, the ground vibration itself is unlikely to cause annoyance. The vibration of, say, a wall which will then act as a “sound source” is the most likely cause of annoyance.

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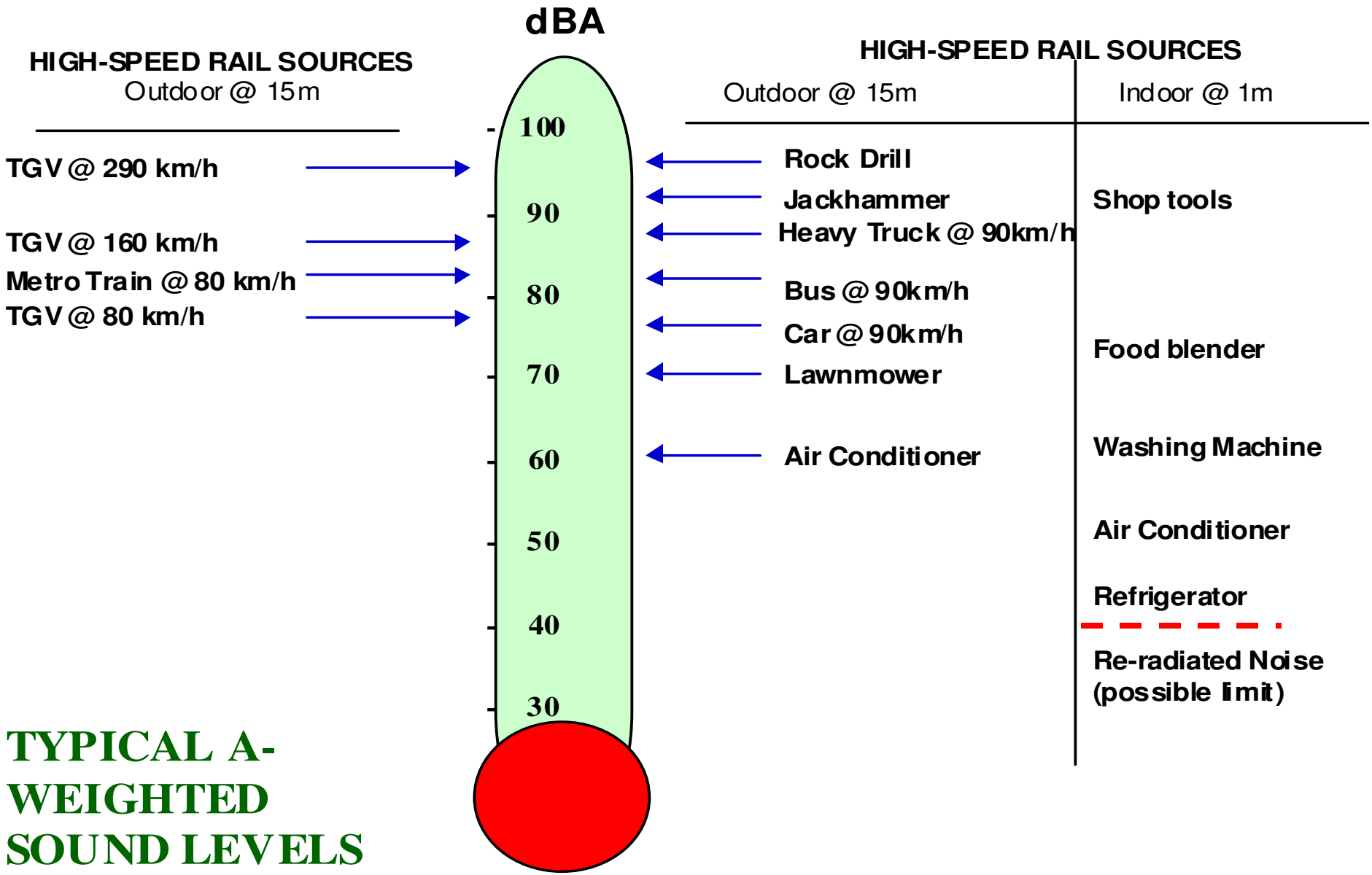
- Due to the relatively low frequency and the fact that this noise cannot be reduced by “closing a window”, the permissible re-radiated noise level is set much lower than that for normal noise.

- Some idea (again) of relative A-Weighted sound levels:

NOISE DESCRIPTORS



TYPICAL A-WEIGHTED SOUND LEVELS

GAUTRAIN VIBRATION IMPACT STANDARDS

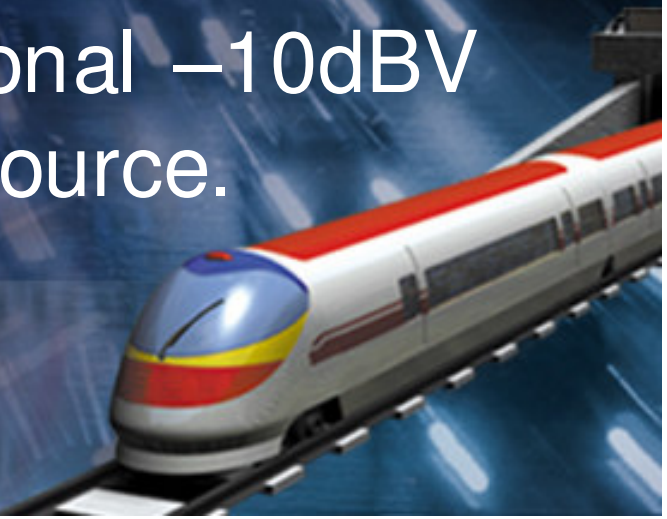
The proposed limits for vibration have been set as follows:

Period of Day	Vibration Level (Ref $1X10^{-9}$ m/sec)	Noise Level (Re-radiated)
• 06h00-22h00 (daytime/evening)	112 dBV	40dBA
• 22h00-06h00 (night-time)	103 dBV	35 dBA
• Critical working areas	100 dBV	30 dBA

- **Critical areas include:**
  - Hospital operating theatres, precision laboratories (vibration)
  - Concert halls, theatres, recording studios (vibration & noise)

BUT HOW WILL IT AFFECT ME?

- The following are some typical evaluations for slab track in tunnel, fitted with normal rail fixings and a normal building with a –7dBV coupling factor. NB – in problem areas, use of a floating slab track will provide up to an additional –10dBV to -15dBV reduction at source.



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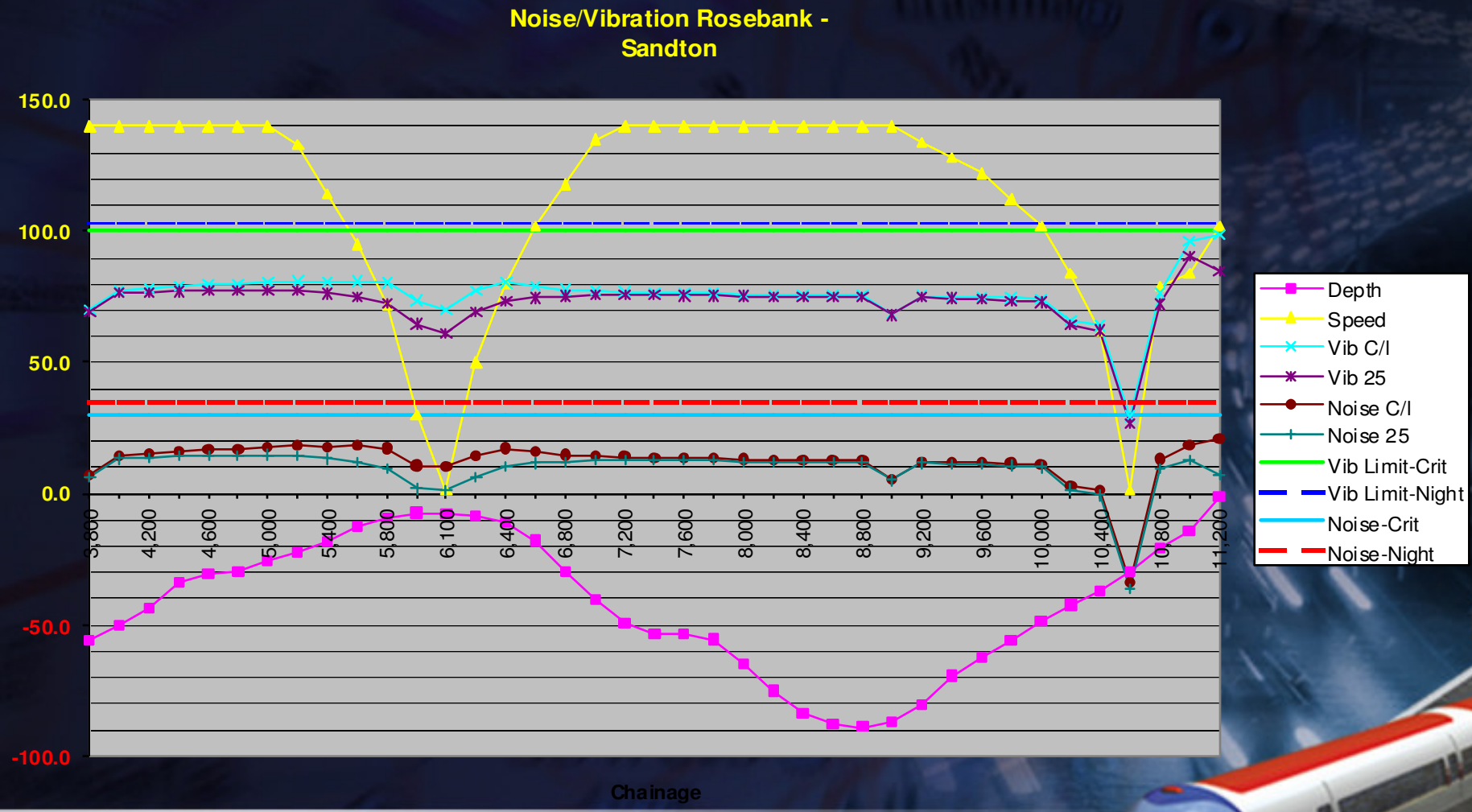
- The lower speeds at the shallower depths reflect the fact that the stations are usually closer to the surface – hence the slower speed used in the calculation.

- It can be seen that, the deeper the tunnel, the slower the vibration and re-radiated noise levels reduce as you move away from the tunnel.

Noise & Vibration Dunkeld



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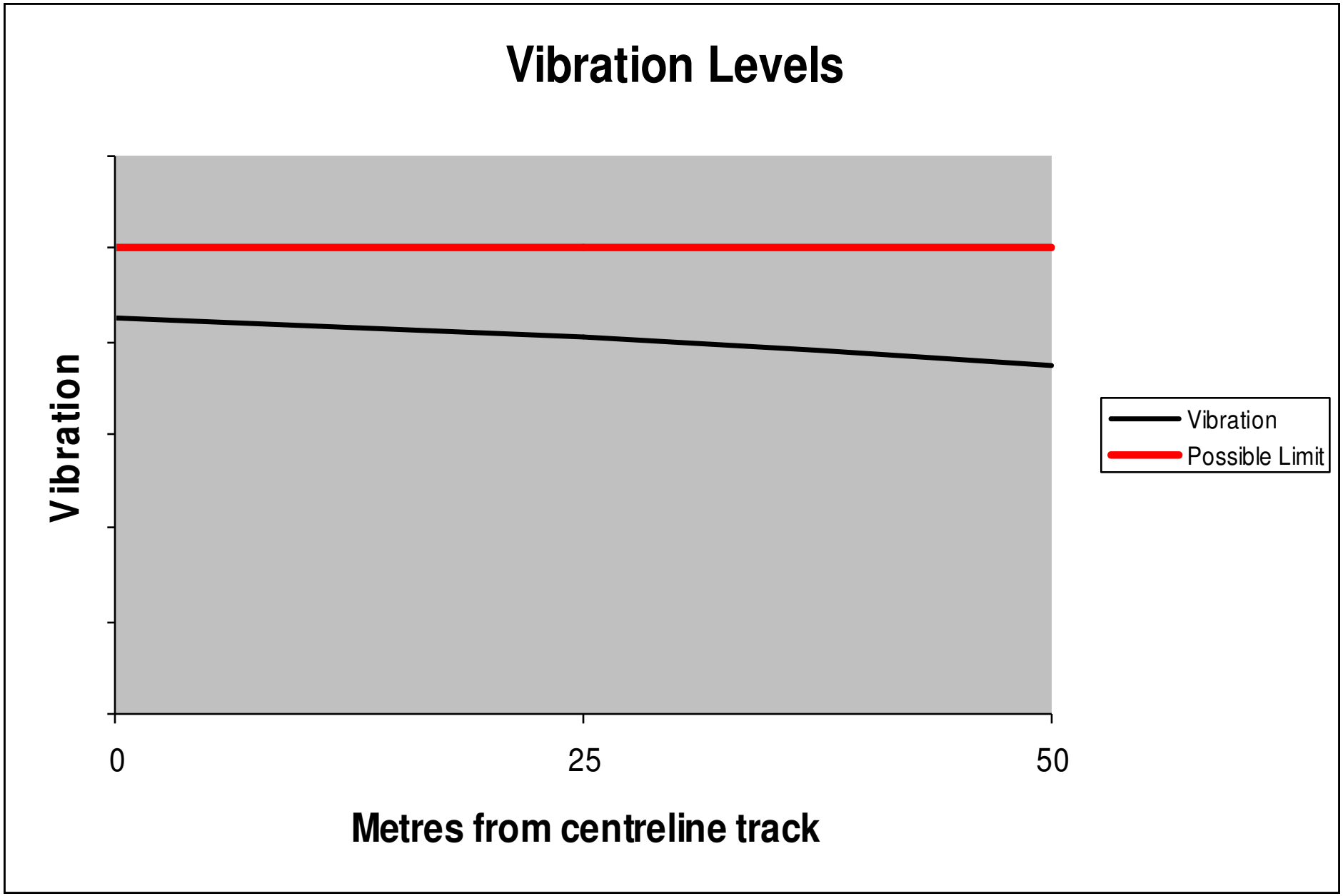
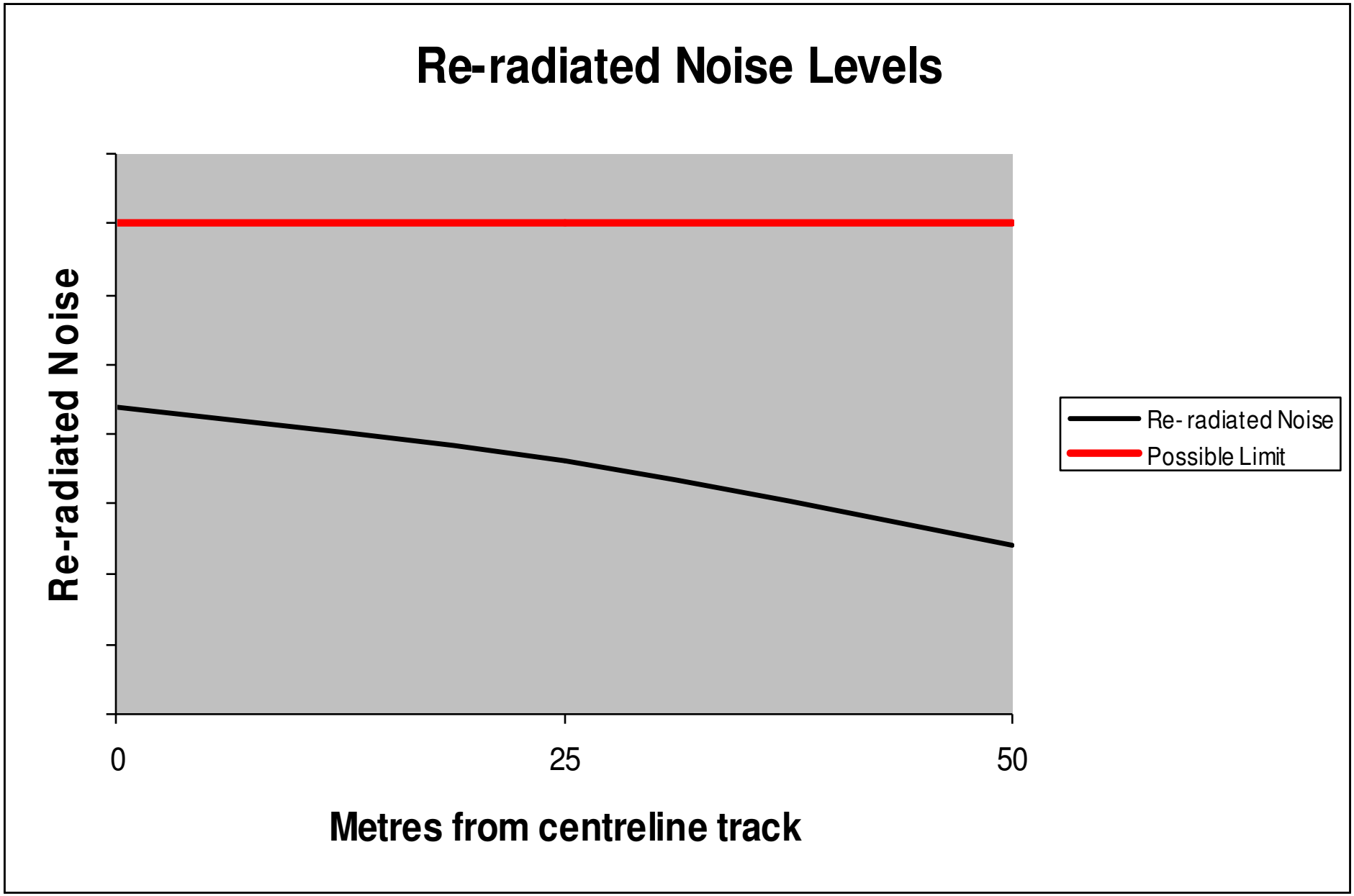
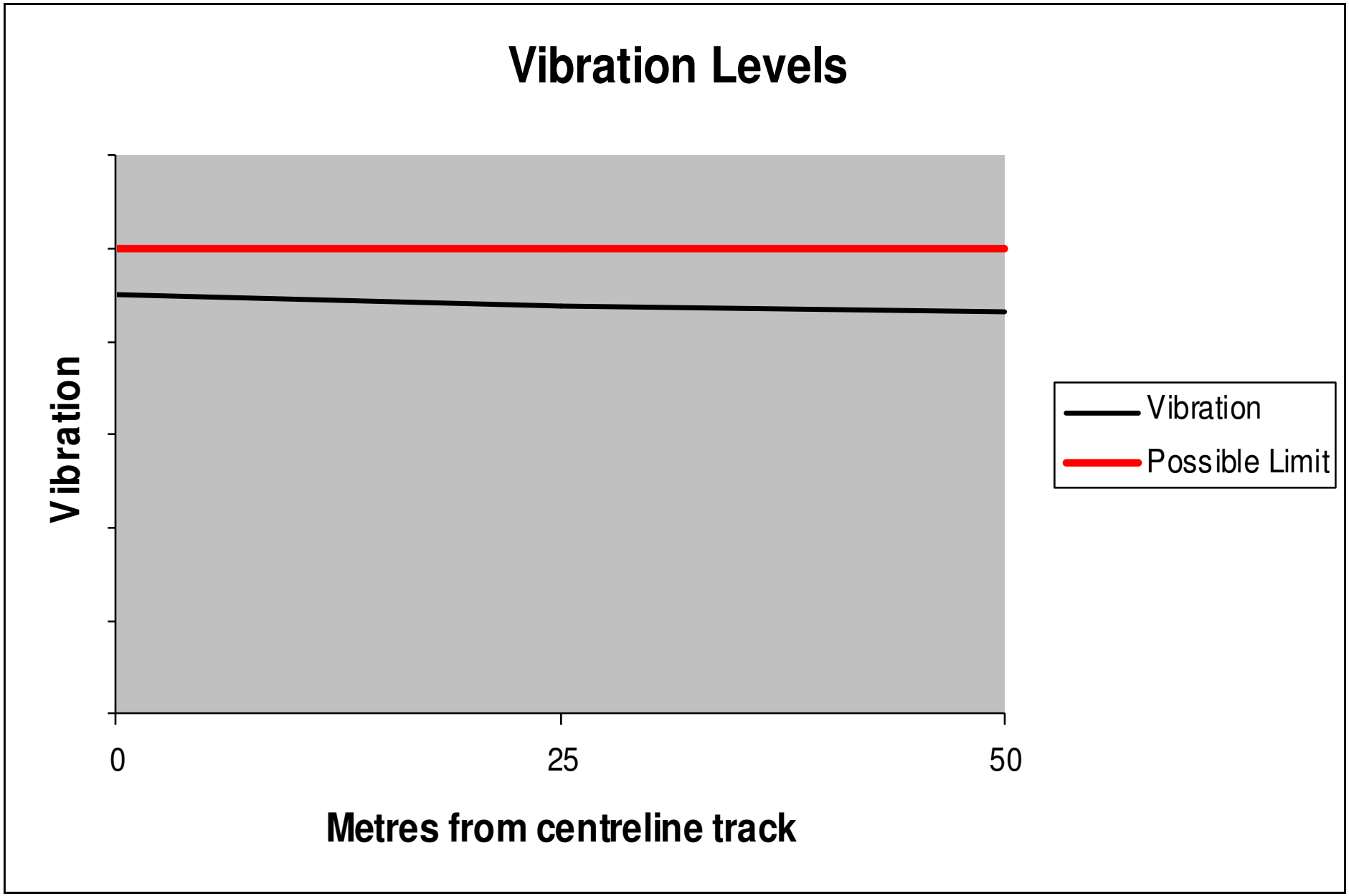
VIBRATION AND RERADIATED NOISE ABOVE TUNNELS
Tunnel 20m Deep, Speed 60km/h



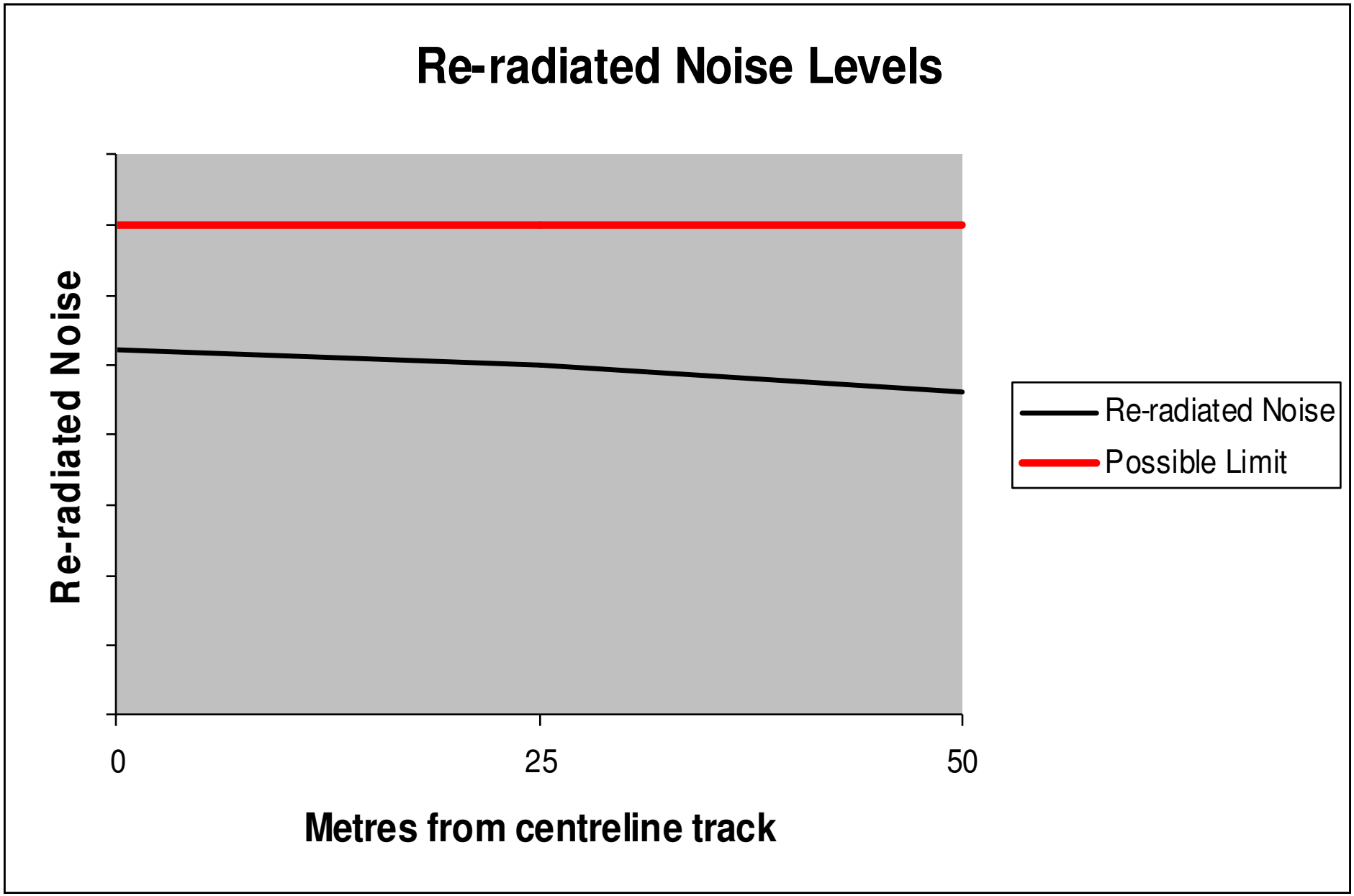
VIBRATION AND RERADIATED NOISE ABOVE TUNNELS
Tunnel 20m Deep, Speed 60km/h



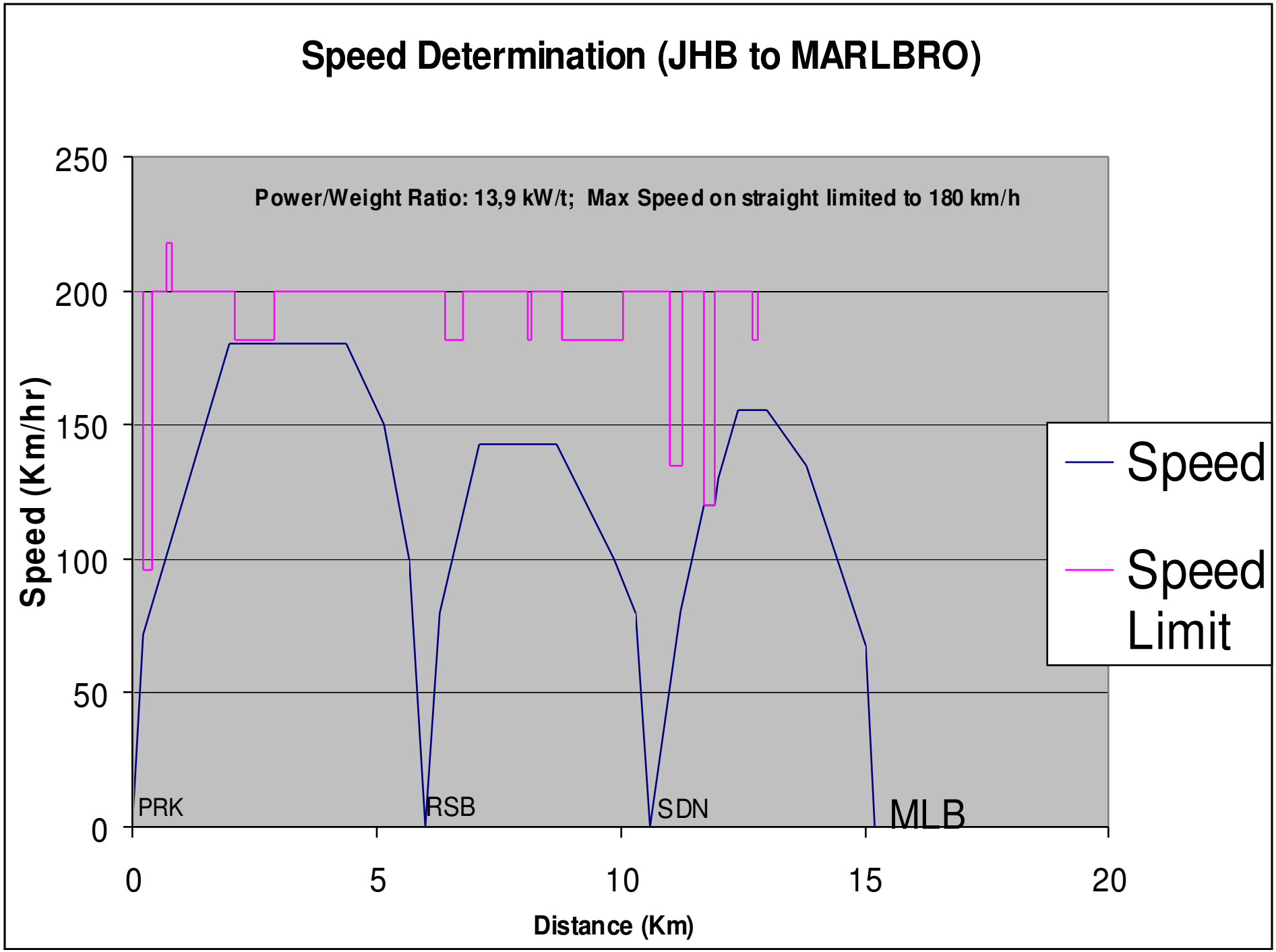
VIBRATION AND RERADIATED NOISE ABOVE TUNNELS
Tunnel 60m Deep, Speed 160km/h

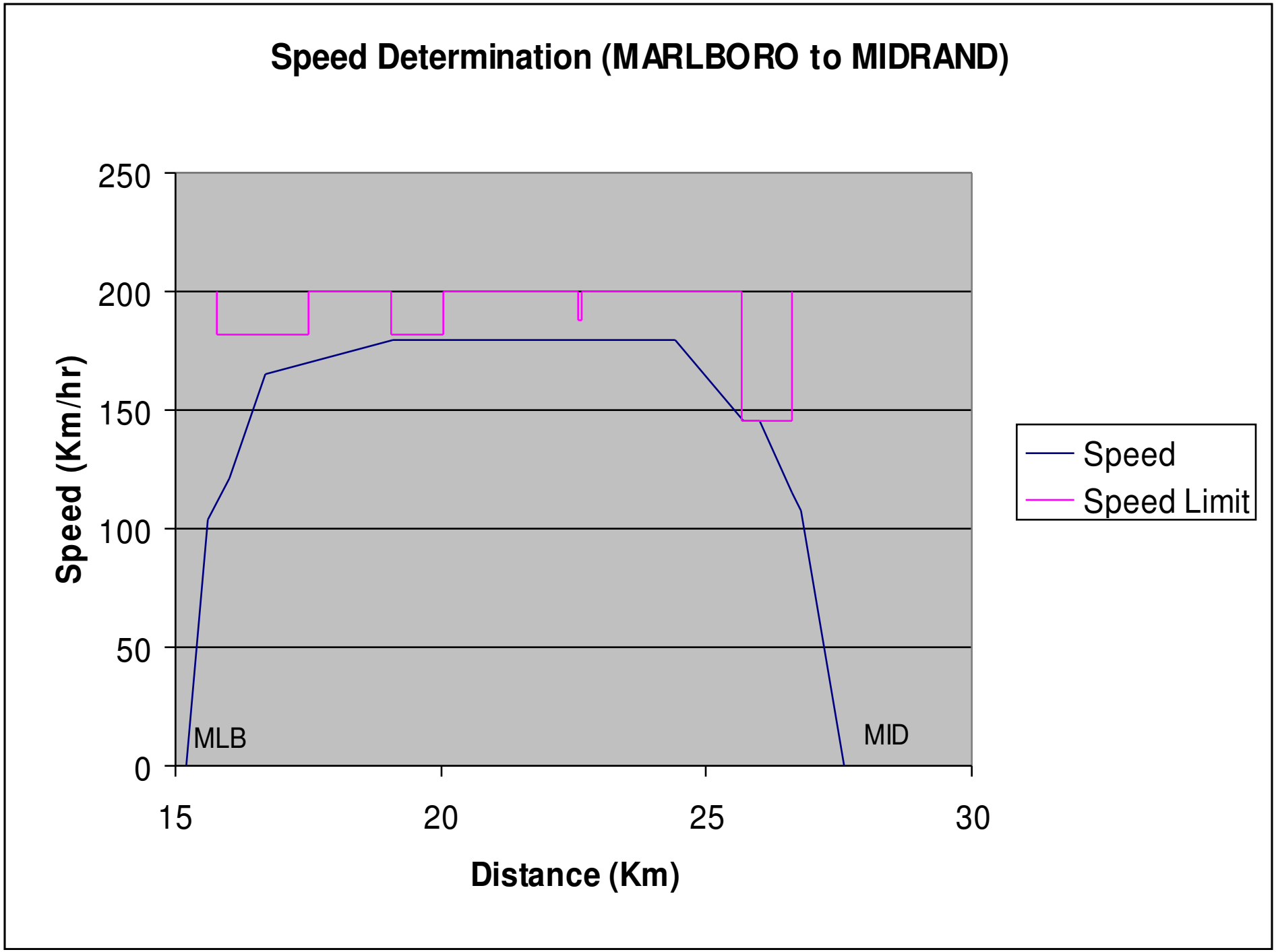


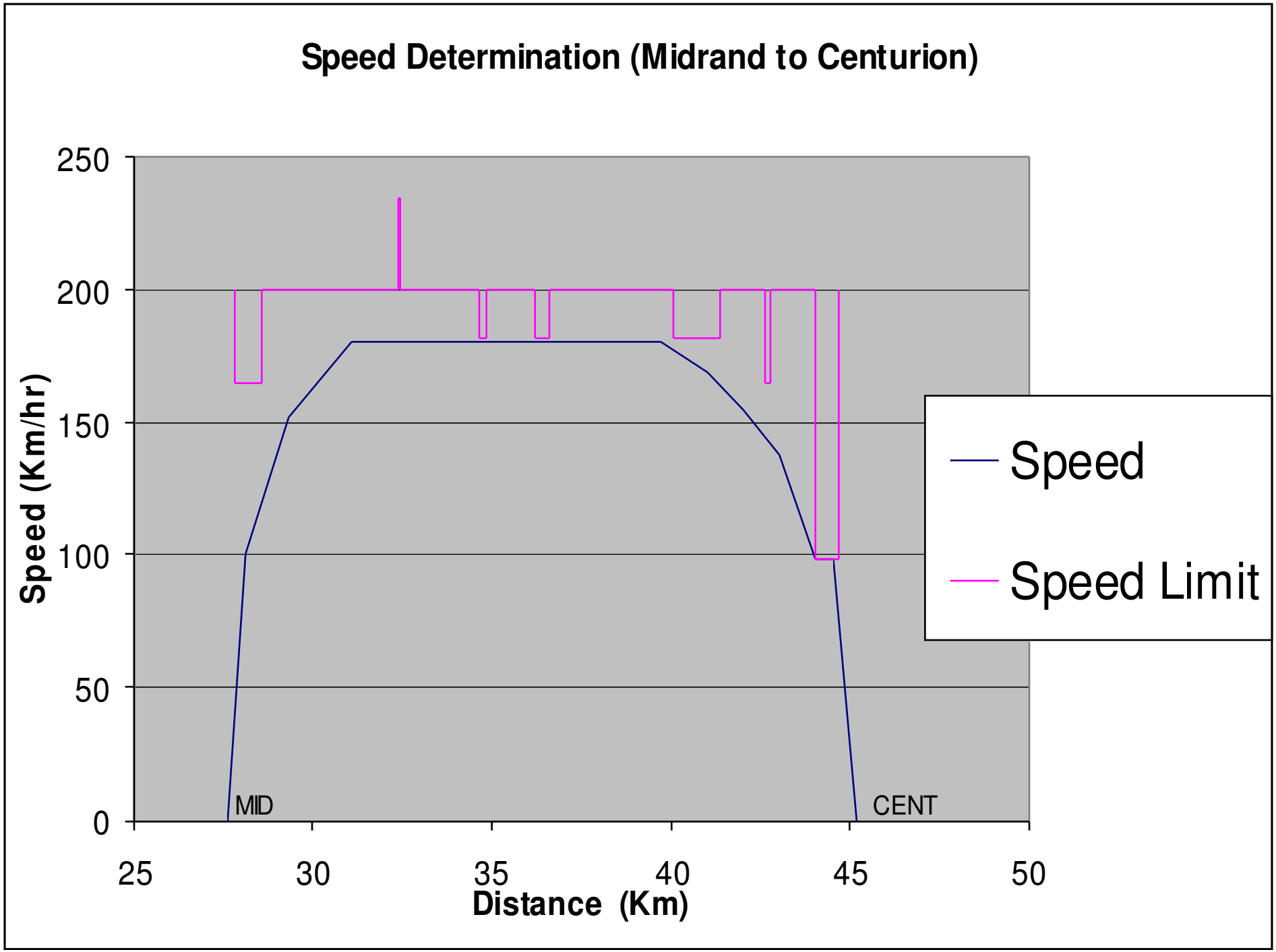
VIBRATION AND RERADIATED NOISE ABOVE TUNNELS
Tunnel 60m Deep, Speed 160km/h

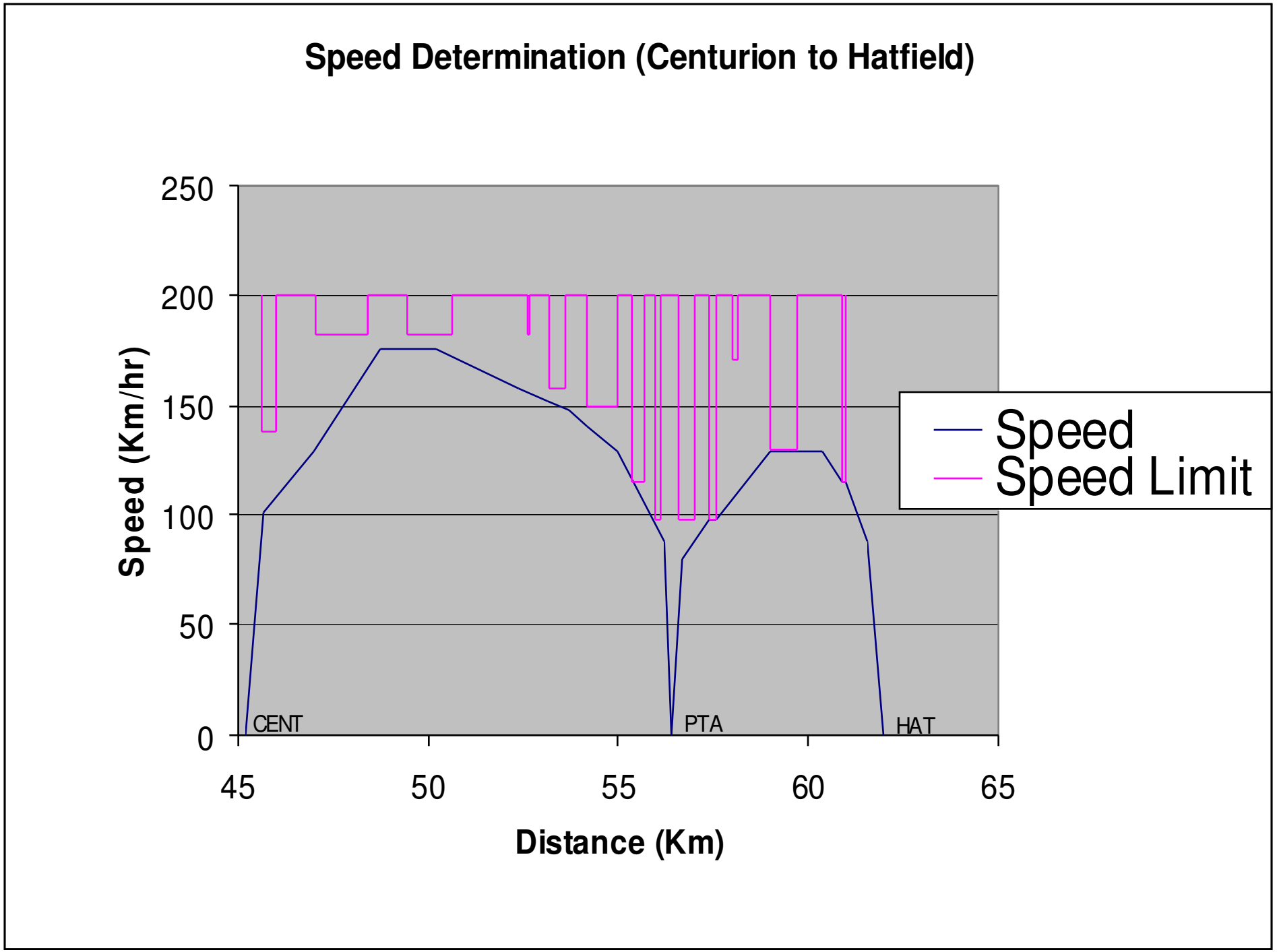


- Some idea of the speed profile according to distance is shown on the graphs that follow. These were based on theoretical considerations and use a maximum speed on the straight of 180km/h and a power/weight ratio of 13,9 kW/t.


Speed Determination (JHB to MARLBRO)
Power/Weight Ratio: 13,9 kW/t; Max Speed on straight limited to 180 km/h
Speed (Km/hr)
250
200
150
100
50
0
0
5
10
15
20
Distance (Km)
PRK
RSB
SDN
MLB
Speed
Speed Limit


Speed Determination (MARLBORO to MIDRAND)
250
200
150
100
50
0
Speed (Km/hr)
MLB
MID
15
20
25
30
Distance (Km)
Speed
Speed Limit


Speed Determination (Midrand to Centurion)
250
200
150
100
50
0
Speed (Km/hr)
MID
CENT
25
30
35
40
45
50
Distance (Km)
Speed
Speed Limit


Speed Determination (Centurion to Hatfield)
250
200
150
100
50
0
Speed (Km/hr)
CENT
PTA
HAT
45
50
55
60
65
Distance (Km)
Speed
Speed Limit

THANK YOU

THE END

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