Ride & Building Comfort in Vertical Transportation

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smooth Dedicated to People Flow™

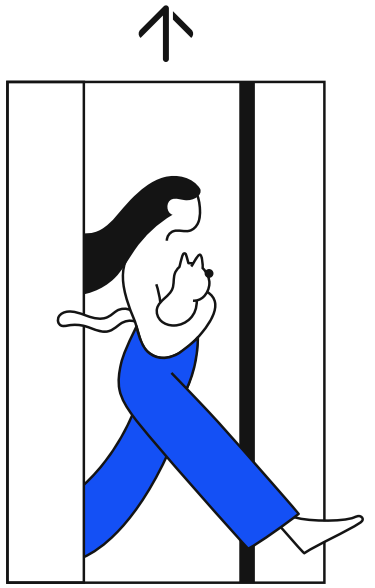
Agenda

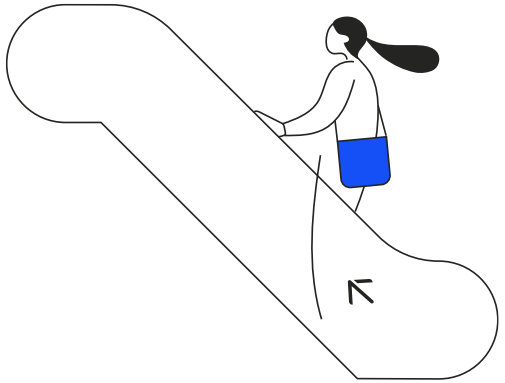
1. Why is ride and building comfort important ?
2. What is elevator ride and building comfort?
3. Measurement parameters and tools
4. What is escalator ride and building comfort?

kone.co.uk

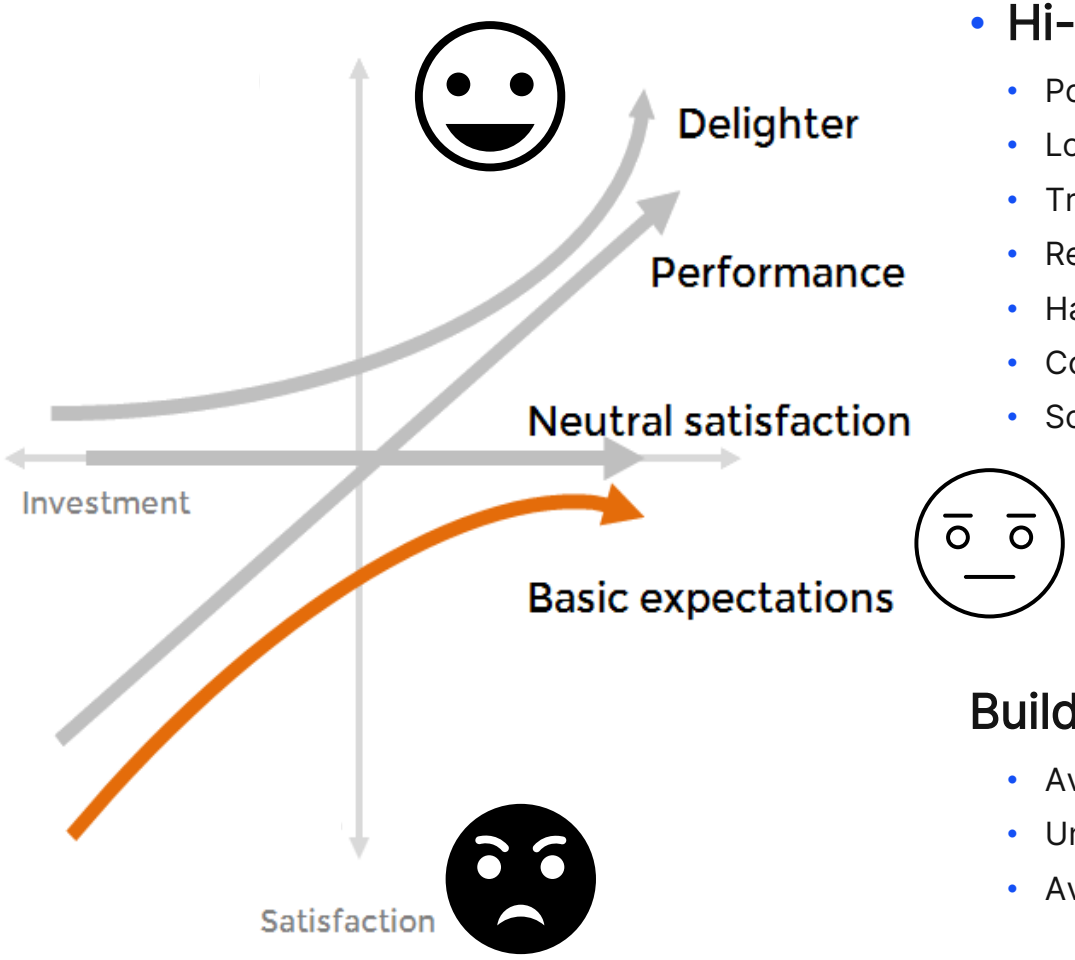
Why is ride and building comfort important for Vertical Transportation?

- **Reputation**
  - Any customer's feedback are the supplier's fault , whether they are right or not
  - Affects future relations with customers
  - Statistical studies have shown correlation between ride comfort and customer satisfaction
- **Performance**
  - Competitiveness & Differentiation
- **Cost**
  - Call-outs; cost of poor quality; feedbacks ; unnecessary material and installation cost
- **Building Regulations**
  - Global/local legal and code compliance
    - Cost of non-compliance
    - User will feedback a Ride Comfort non-compliance faster than a safety or energy non-compliance, because it is more noticeable



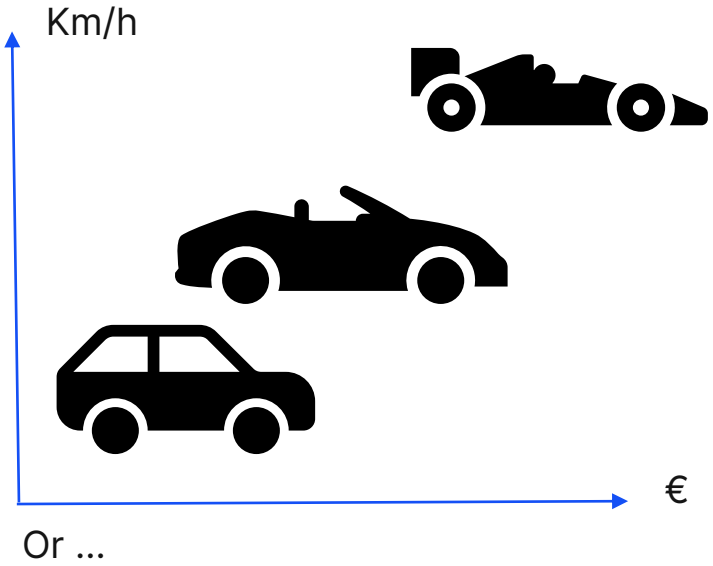


Are we selling products or experiences?



Kano model

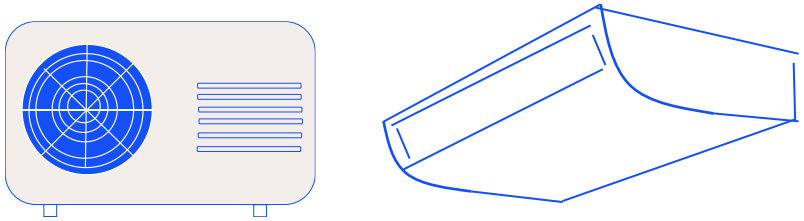
- **Hi-Tech Innovative consumer product?** (As Advertised by suppliers.....)
  - Power
  - Looks
  - Traffic Capacity (speed, size, logic)
  - Reliability
  - Handling (vertical dynamics)
  - Comfort
  - Sound Quality



Or ...

Building equipment that nobody notices unless they irritate?

- Availability – traffic handling; reliability
- Unobtrusive
- Availability



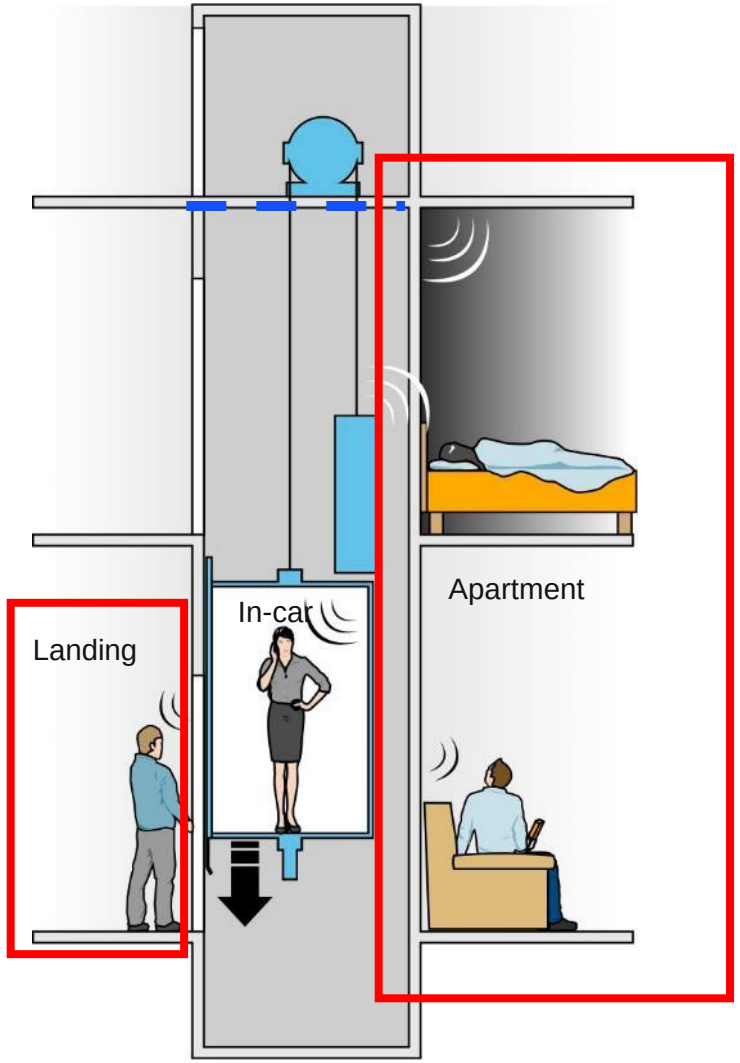
What is Elevator Ride Comfort & **Building** Comfort?

Background

- What is end-user and resident comfort?
  - Affects 2/5 senses; sound, feel (touch)

- Important Customer locations:
  - In-car
  - Landing
  - Apartment

- Building Interfaces
  - Elevator car landing doors
  - Elevator shaft

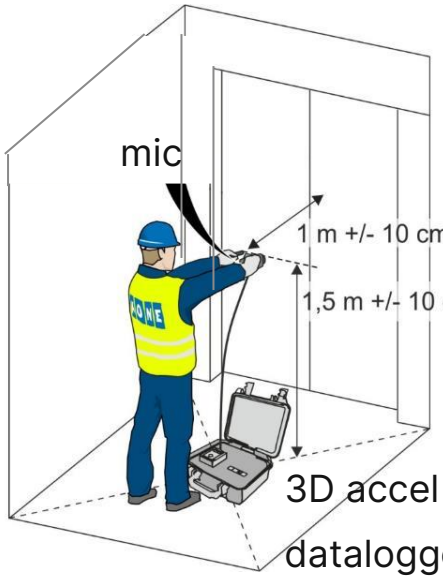


How is Ride Comfort Measured?

- Why measure RC?
  - 90% of RC feeling can be measured
  - We want to verify our own quality
  - Our customer and competitors sometimes measure
- We can consider a lot of metrics to communicate RC….
  - Noise
  - Lateral quaking
  - Vertical dynamics
  - Levelling
  - Door RC
  - Noise in apartment

https://www.henning-gmbh.de/

www.pmtvib.com



3D accel sensor

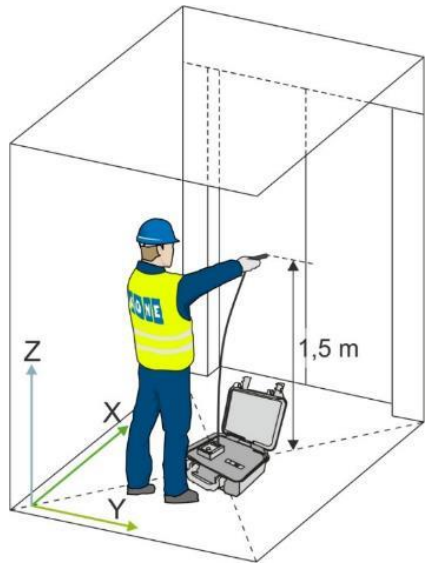
datalogger

Example Vertical Transportation

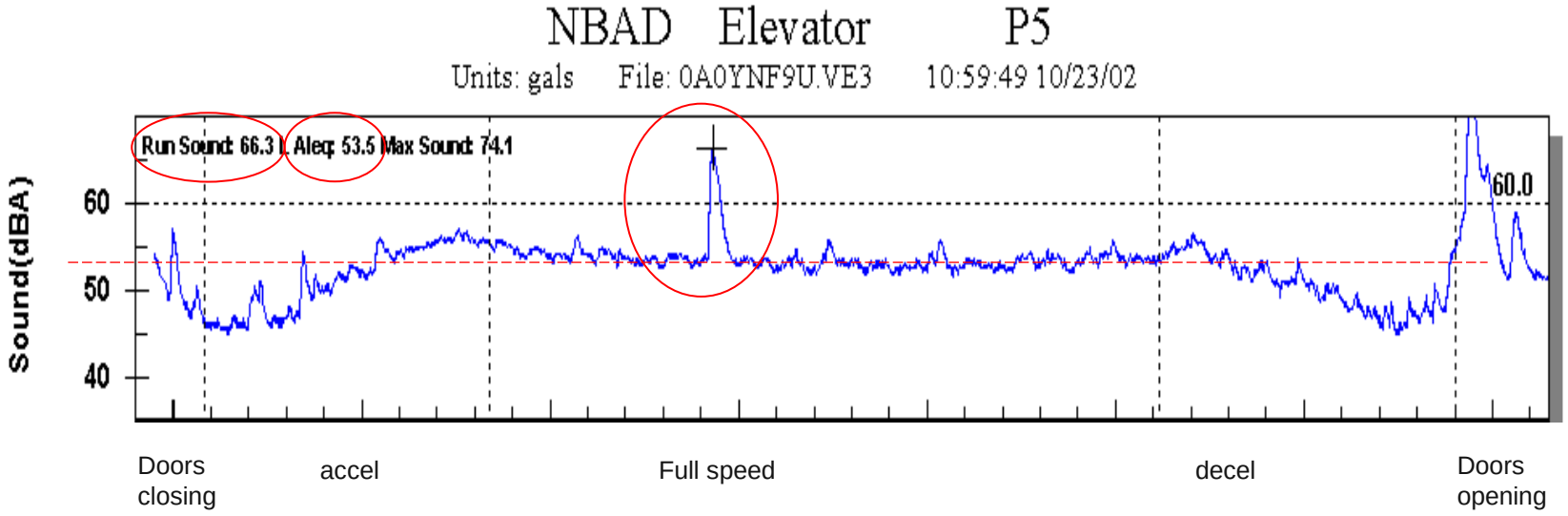
Commercial RC tools

Elevator System Level RC
in-car RC

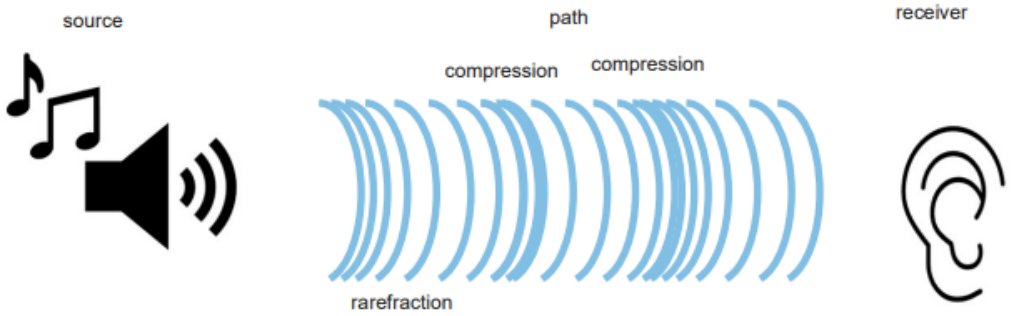
- Sound
  - max sound (RMS, A-weighted Fast)
  - power average sound (Laeq)
  - Door operation sound (not in ISO)
  - Neglectable sound (construction time)

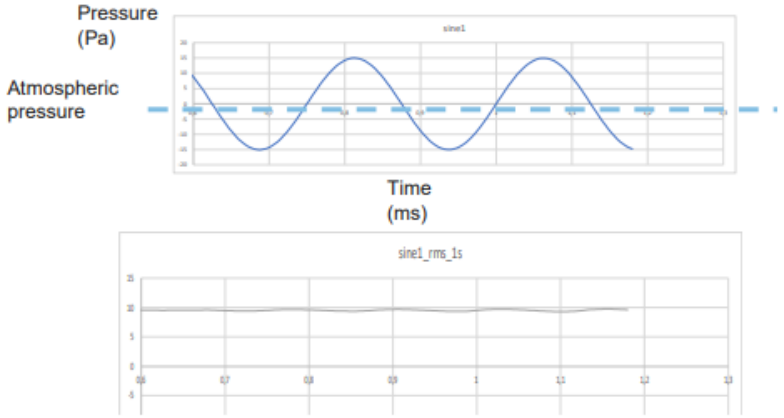


mic towards door

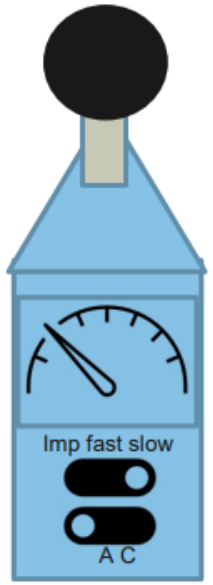


Sound - introduction





The pressure variations are
- Frequency Weighted (A,C, Z flat)
- Time averaged (Fast, Slow; imp)
- Root Mean Squared
- Converted to log scale (Lp=20logP/P0)
- Where P0=20e-6Pa

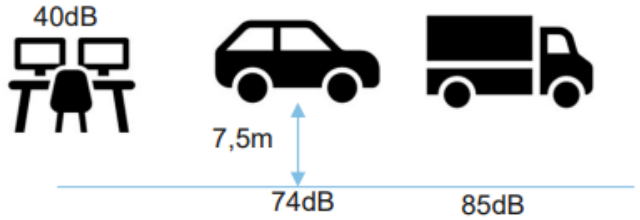


https://www.nats.aero/environment/noise-and-emissions/measuring-noise/

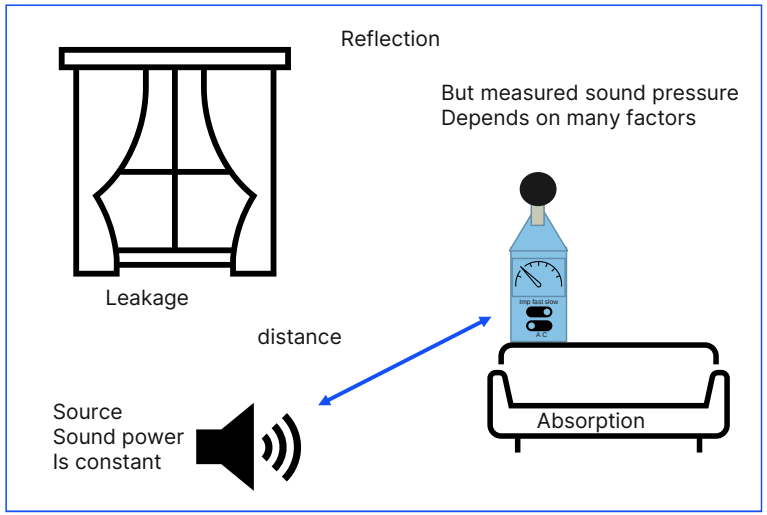
incredibly complex
Elecromechanical
process between
Ear and brain

Sound pressure variation
Is measured using a sound
Level meter

The range of the human ear Is so huge that noise levels
Are better represented using LOG scales
A Bel and decibel are variations Of a LOG scale
(Lp=20logP/P0



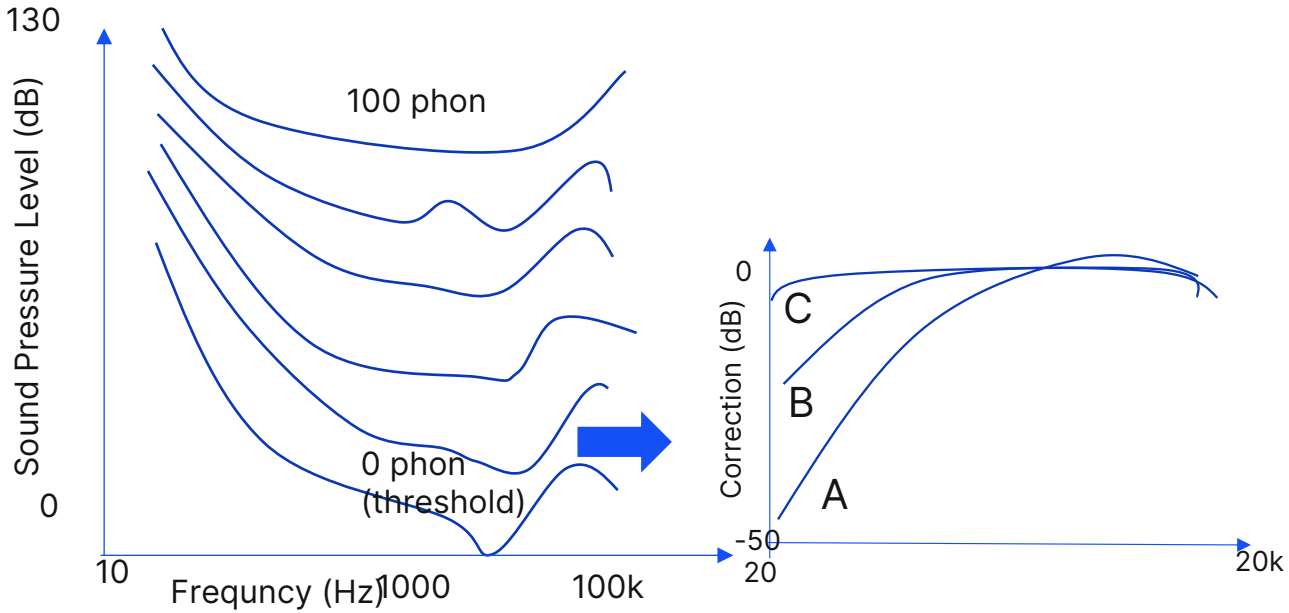
Automotive regulations (bypass test)
Ref: REGULATION (EU) No 540/2014 OF
THE EUROPEAN PARLIAMENT AND OF THE COUNCIL



Environment can
affect
Levels by 10dBA

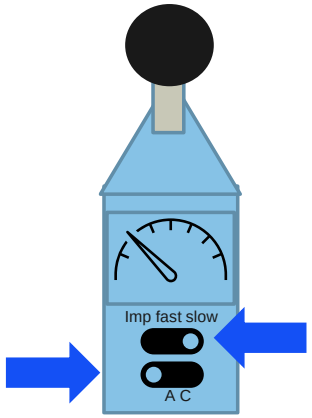
Common Sound Level Meter settings

A-weighting



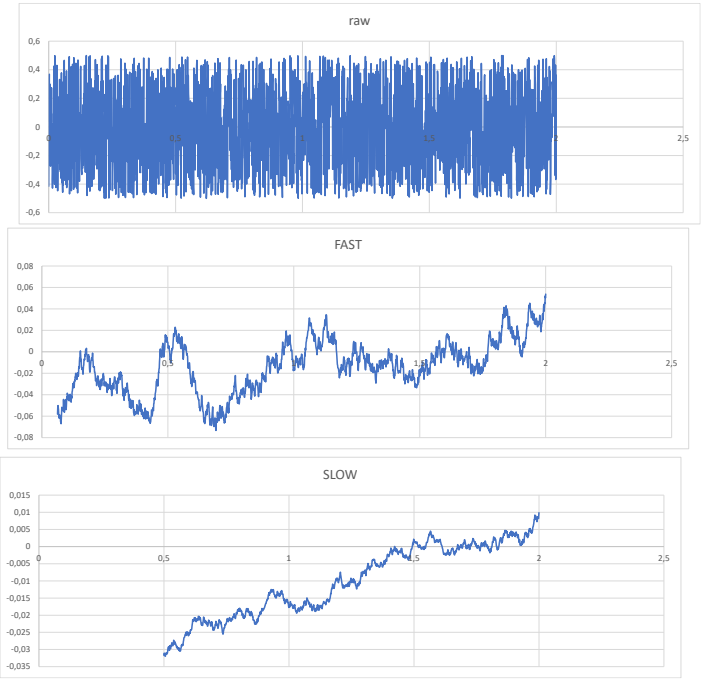
Our sensitivity to sounds depends on both the amplitude and *frequency* of a sound. Here is a graph of the range of human hearing.

A-weighting is designed
To compensate raw
Sound pressures according
To human sensitivity



Slow (1s)weighting originally designed to
slow the needle in analogue
Sound level meters

"Fast" v "Slow"

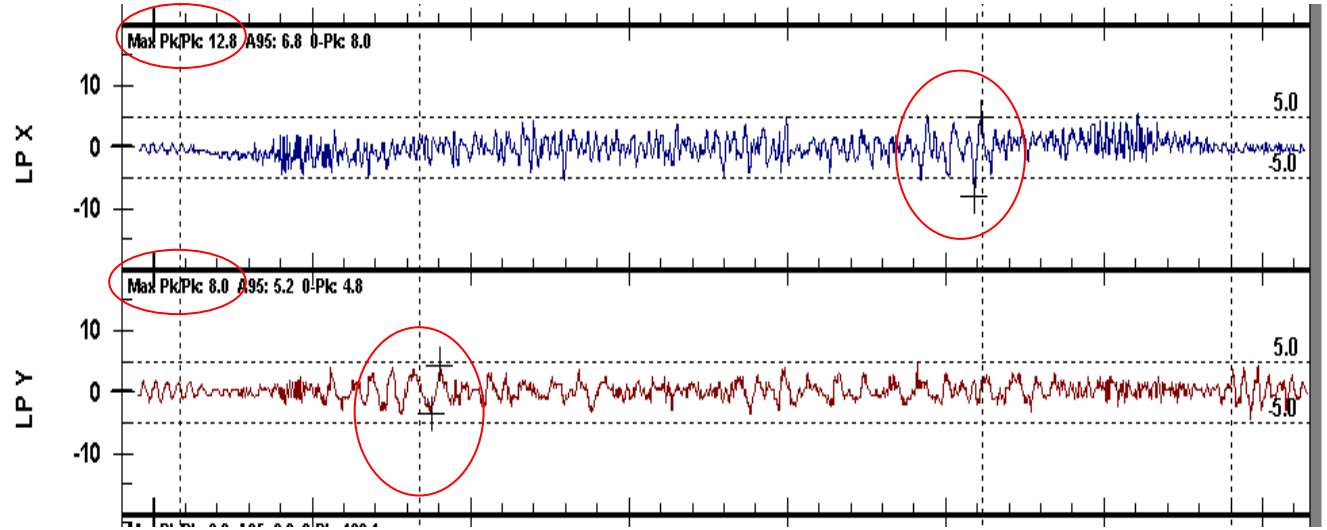


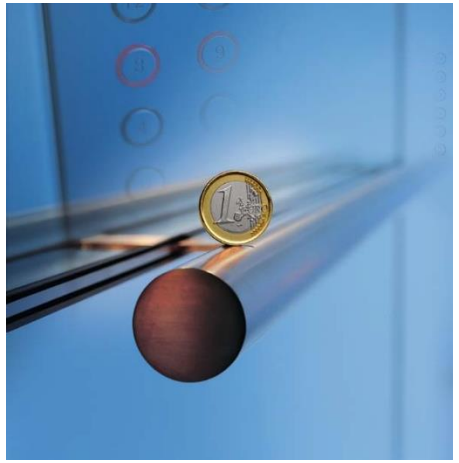
Vertical transportation
Industry usually
Specifies "fast" (0,125s)
Weighting

Usually slow makes the dBA look about 3dBA lower

Elevator System Level RC in-car

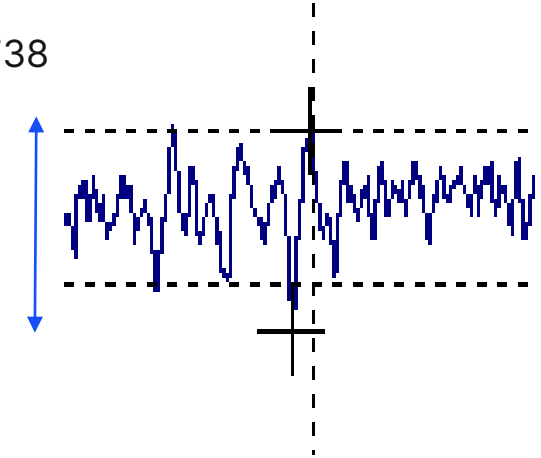
- Lateral (Horizontal) Quaking
  - Generally human body is much less sensitive to low freq (>12Hz)



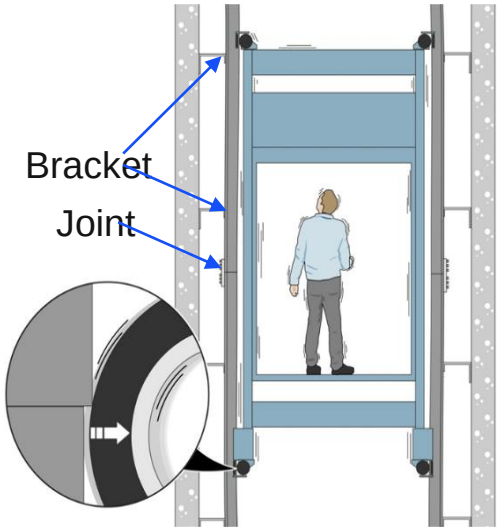


Yes, it is possible to balance a coin
On the handrail if lateral quaking is very low

Elevator industry and ISO18738 usually uses Peak-to-Peak

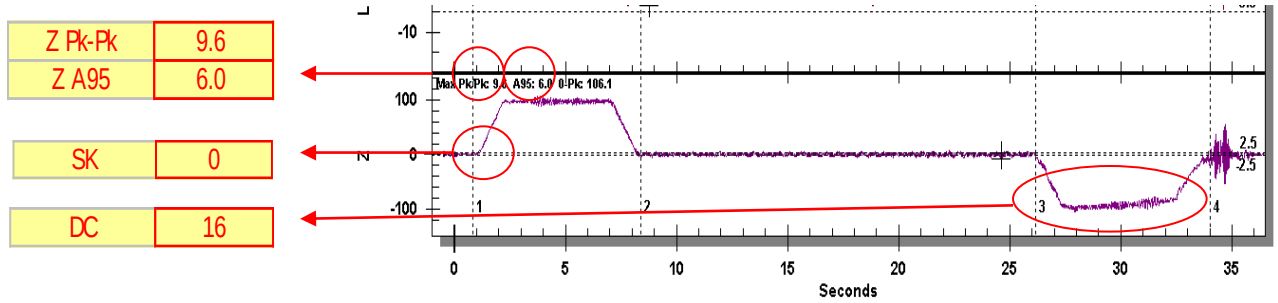


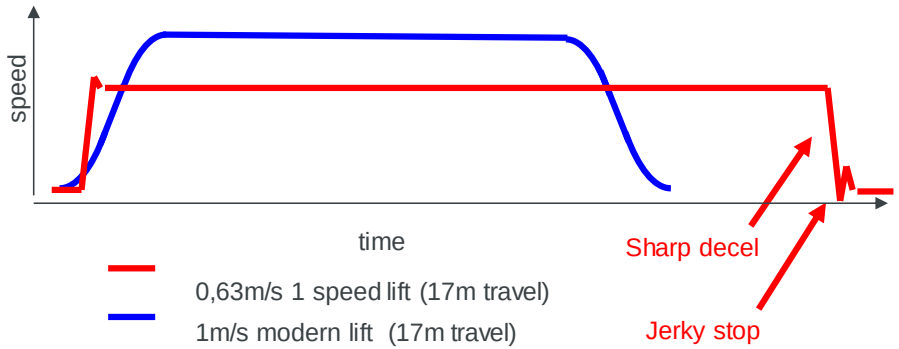
Escalator and Building Acoustics Industry use something else (see later)



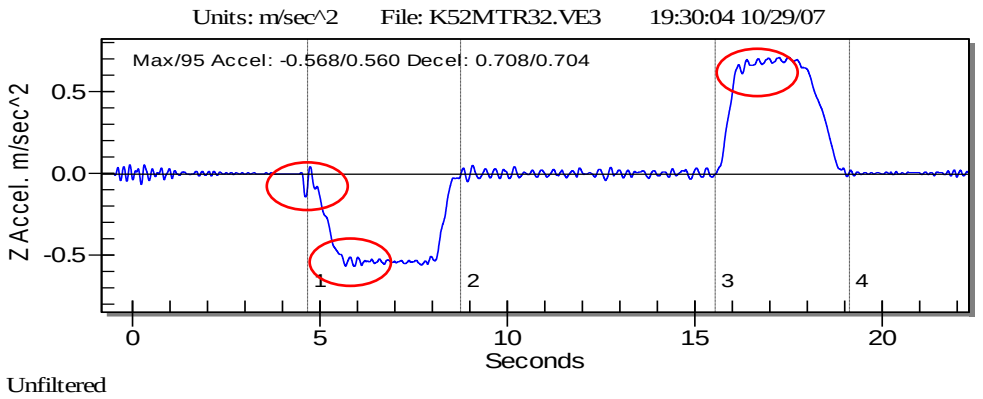
Elevator System Level RC
in-car RC

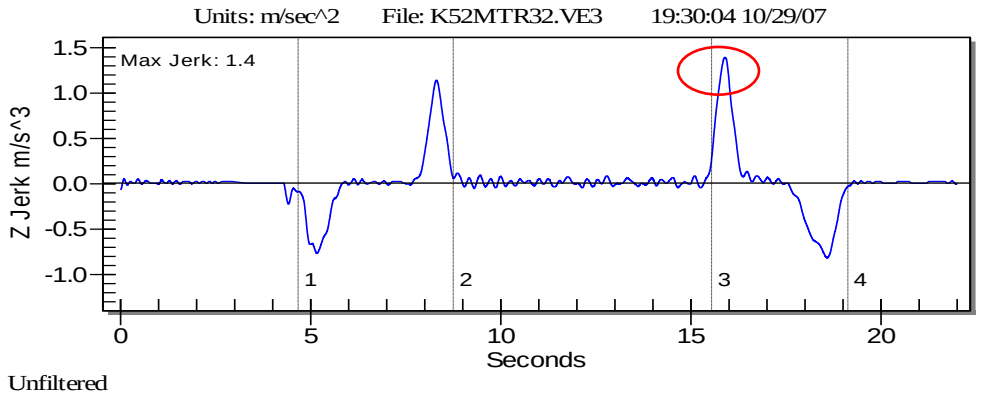
- Vertical Dynamics
  - max levels
  - full speed average
  - drive curve
  - start kick
  - accel
  - jerk





Smoother travel = better feeling of safety for sensitive & aged users





Body most sensitive up to 80Hz in vertical direction
< 10Hz … sensation of comfort
10- 80Hz … sensation of quality

ISO 18738 Measurement of Ride Quality: Part 1 Lifts (elevators).

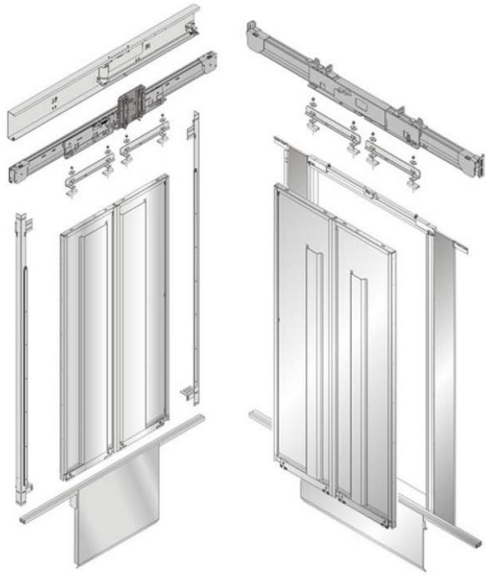
- Managed By ISO TC/178 / WG9

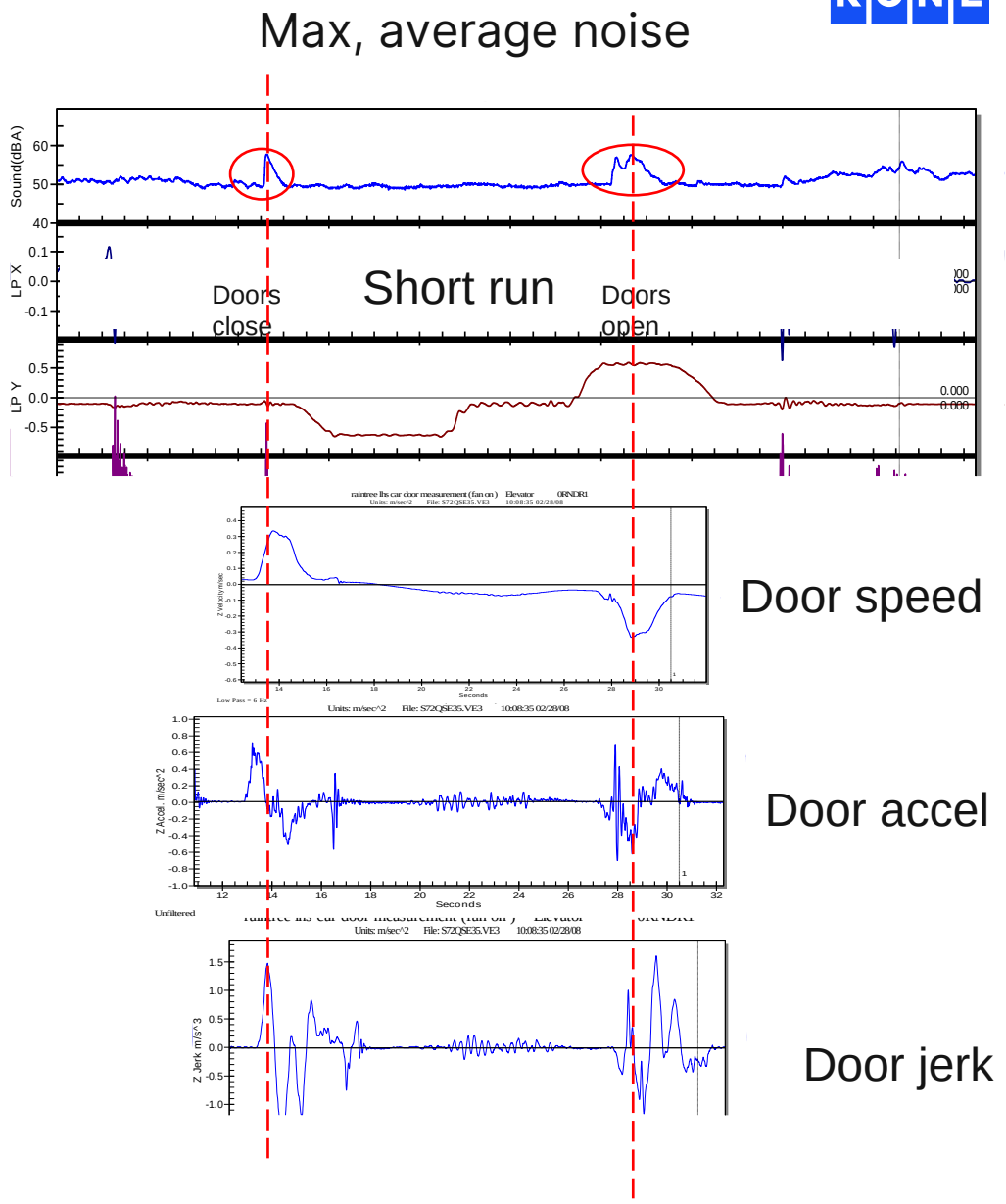
- Now replaced by ISO8100 - 34
- Standardized measuring of ride comfort in elevators.
- Refers to ISO8041/ISO 2631 Whole Body Vibration filters to weight according to human feeling
- No reference to allowable limits, or levels describing good, medium or poor ride comfort
- Ride Comfort Levels are separately agreed between customer and supplier

Doors are like mini-elevators

- On of the most important elevator components
- (the ”business card of the elevator”)

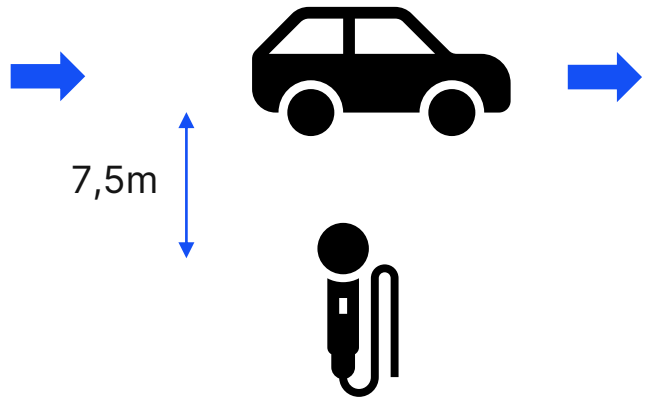
- Door movements must be safe, smooth, and well timed
- Doors have own drives and motors, and dynamics
- Door RC v. door-to-door performance time





Why building noise is becoming more important

Megatrends (focus on EU, but applies globally)



- Reduction in **external** environmental noise
  - Automotive by-pass noise reduction, quieter (electric) drivetrain, quieter tyres
  - Quieter aero-engines
  - Road surfaces and noise blocks

"The **A350** is on average up to 6 dB quieter on departure than the A330 and 777"
https://publicapps.caa.co.uk/docs/33/CAP%201733%20Final.pdf

Automotive pass-by noise targets:

1978 – 82dBA
2016 - 74dBA
2026 – 68dBA

Automotive regulations (bypass test)
Ref: REGULATION (EU) No 540/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Why building noise is becoming more important

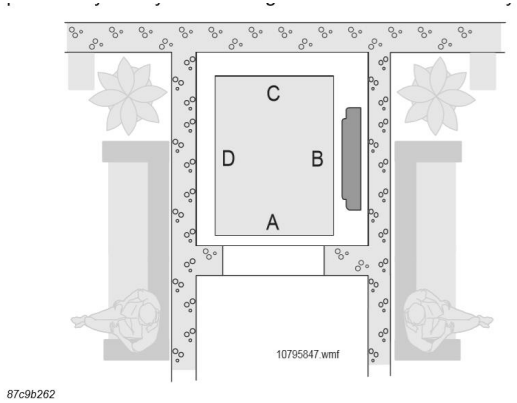
Megatrends

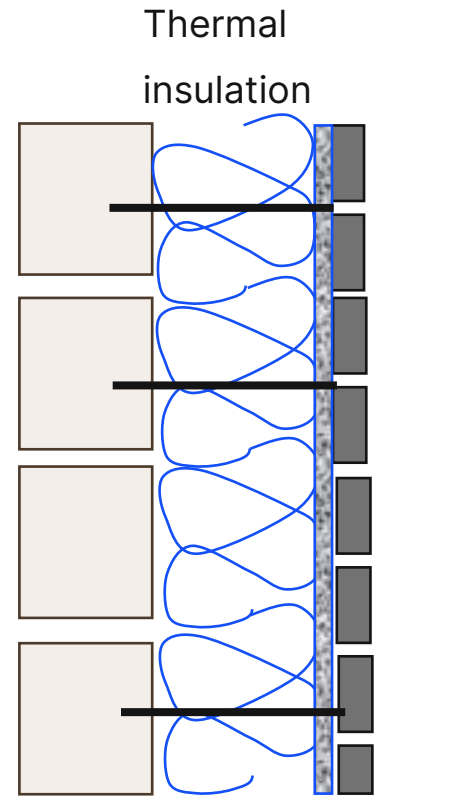
- Efficient Building Material and Layouts

- Increased building **energy** efficiency
  - More insulated façades
  - Increased glazing – single, double, triple

- Increased **space** efficiency
  - Architects want to locate living areas close to lift shaft

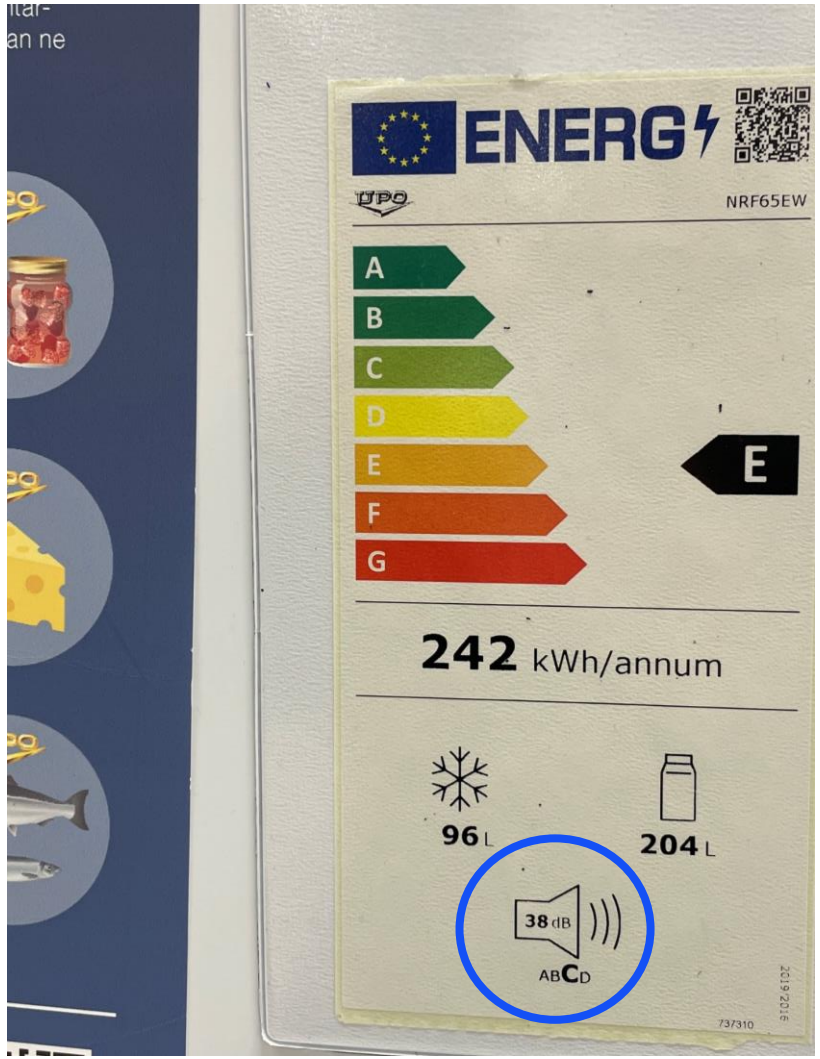
- Acoustics in **sustainability** trends …
  - E.g. BREAM international system :
  - Hea05 - Extra credits for enhanced acoustic performance





Why building noise is becoming more important

- Increasingly internal noise dominated by **internal equipment….**
  - HVAC
  - Lifts
  - Bathrooms, washing machines, etc.
- ….And neighbours…
  - Footfall, pets, doors closing. Music etc.
  - residents become more sensitive to internal equipment noise
  - more time at home
  - More general sleeping issues
  - **Urbanization** … more residents, more risks



Noise & Building Regulations

- Most countries specify max allowable noise in apartment rooms in local building regulations which are:
  - Variable
  - Fragmented
  - Ambiguous
  - Elevator supplier must comply, but builder's responsibility (shaft wall) usually not clear
  - ISO 19488 offers a harmonized classification, but not adopted by many countries

country	norm	Max night time noise (dBA (LaFmax))
EU	EN81-20	Agreement to be clear between Seller and buyer
Finland	C1	33
Sweden	BBR	31
Germany	DIN4109-1	30
Germany	DIN4109-5	27
China	GB50118	37/30
UK	BS8233	25 *
Netherlands	Bouwbesluit section 3,2	30 **

* only for elevator related noise not actively followed yet, but quoted by most state planning offices

**Weighing TBC; Slow time constant

Residential Noise & Sustainability

- Elevator acoustics will be included in all green building schemes sooner or later
  - BREEAM international (HEA05)
  - Leed v4 (so far building only)

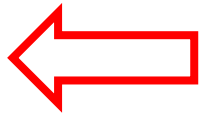
Function	Space type	Installations sound level ($L_{I,A}$/ $L_{I,A,max}$ *)
Office	closed (single) office	≤ 35 dB
	Open plan office / call center	≤ 40 dB
Gathering	Meeting room	≤ 35 dB
	Sleeping area in daycare	≤ 32 dB
Education	Group space in classroom	≤ 35 dB
	Lecture hall	≤ 30 dB
	Music classroom	≤ 30 dB
	Lab room	≤ 35 dB
	Workshop	≤ 40 dB
	Auditorium / main (multi-function) hall in a school	≤ 35 dB or ≤ 30 dB in case used as a theatre hall
	Quiet study space	≤ 30 dB
Hospitality	Living- / bedroom	≤ 28 dB
Sports	Sports hall	≤ 40 dB
Labs	Open workplace	≤ 40 dB
Care facilities	Sitting / sleeping area	≤ 28 dB
* In relation to the octave band with middle frequency 63 Hz to 8000 Hz.		

BREEAM NL is asking for tighter than Building Regs

How Building (acoustics) Regs work

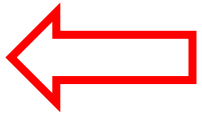
German/Dutch example

- **Building Reg (minimum legal)**
- usually defines
  - Insulation quality of outer façades, internal walls etc.
  - Max allowable noise level in living, sleeping rooms (and other rooms)
  - Min requirements are legal requirements = mandatory



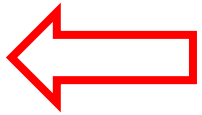
Bouwbesluit30dB
DIN4109-1 (30dBA)
DIN4109-5(27dBA)

  - **Voluntary requirements**
  - Optional High End and sustainability requirements



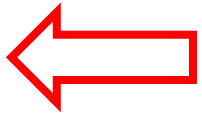
NEN1070
VDI4100

- **Acoustic reference referenced by the Building Regs**
  - How to make the measurements,
  - what setting on the Sound Level Meter,
  - compensation for background noise, reverb



NEN5077
ISO16032
DIN10052

- **Elevator level requirements**
  - These are requirements/guidelines
  - for the elevator/builder to help fulfil Building regs and Building level guidelines



NPR5073 (withdrawn)
VDI2566-1 (MRL)
VDI2566-2 (MR)

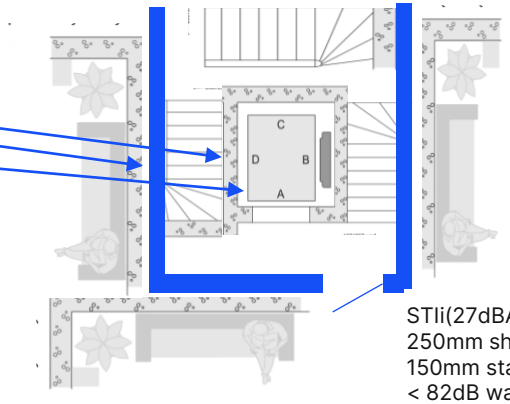
DIN8989 – replacement for VDI2566

- This is a German Guideline
- Introduced august 2019
- Replaces VDI2566-2
- Officially shares responsibility between lift supplier and builder
  - Minimum shaft wall thicknesses
  - Maximum shaft wall vibration requirements
- Refers to 3 standards of insulation
  - STI (30dBA) = DIN4109-1 min building reg
  - Stii (27dBA) = DIN4109-5 increased requirement building reg
  - STIII (24dBA)
- Refers to 3 layout configurations
  - A – lift in stairwell
  - B – lift next to shaft
  - C – buffer room

15

A – lift in stairwell

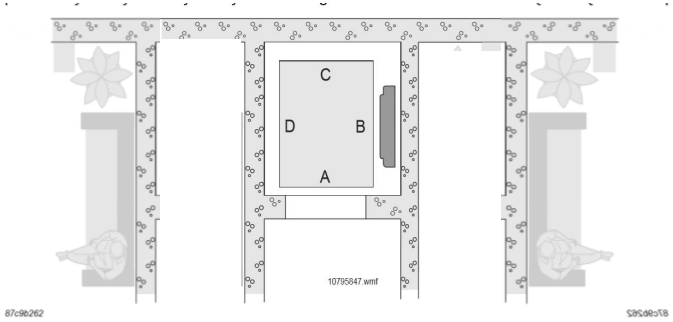
STI(24dBA) needs:
300mm shaft wall
150mm stairwell wall
< 79dB wall accel @ 250hz



STI(30dBA) needs:
200mm shaft wall
150mm stairwell wall
< 85dB wall accel @ 250hz

STIi(27dBA) needs:
250mm shaft wall
150mm stairwell wall
< 82dB wall accel @ 250hz

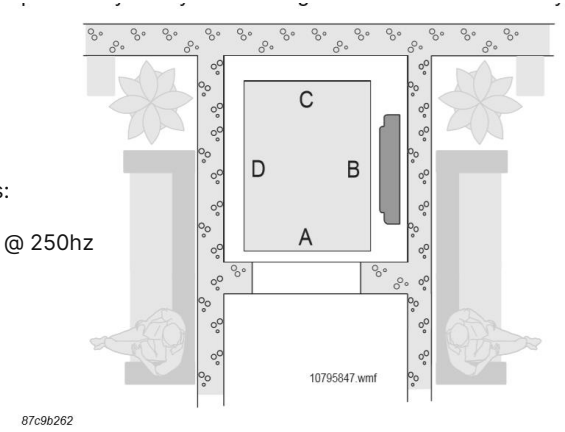
c – lift shaft separated from critical room by buffer space



B – lift adjacent to critical room - Most critical and common

STIi(30dBA) needs:
300mm shaft wall
< 67dB wall accel @ 250hz

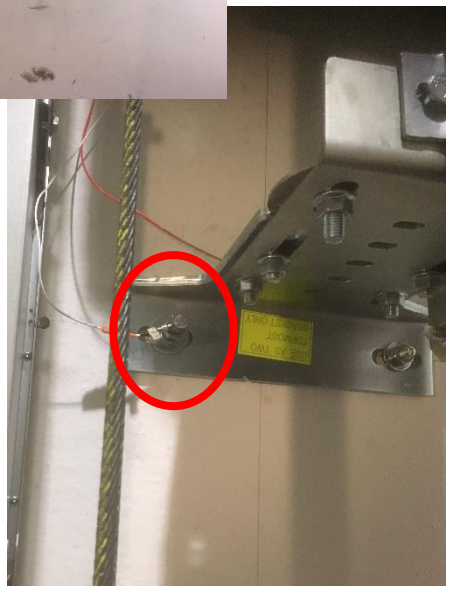
STI(24dBA) needs:
250mm shaft wall
< 64dB wall accel @ 250hz



STI(30dBA) needs:
250mm shaft wall
< 70dB wall accel @ 250hz

Measurement process (in a nutshell)

- Elevator cycle usually defined:
  - one run stopping at every floor, then full run down
- Airborne Measurements
  - In shaft
  - In front of landing (every floor)
  - In apartment (with adjustment for furnishing, background noise, room size)
- Structure borne measurements
  - Accelerations on wall 10cm below motor

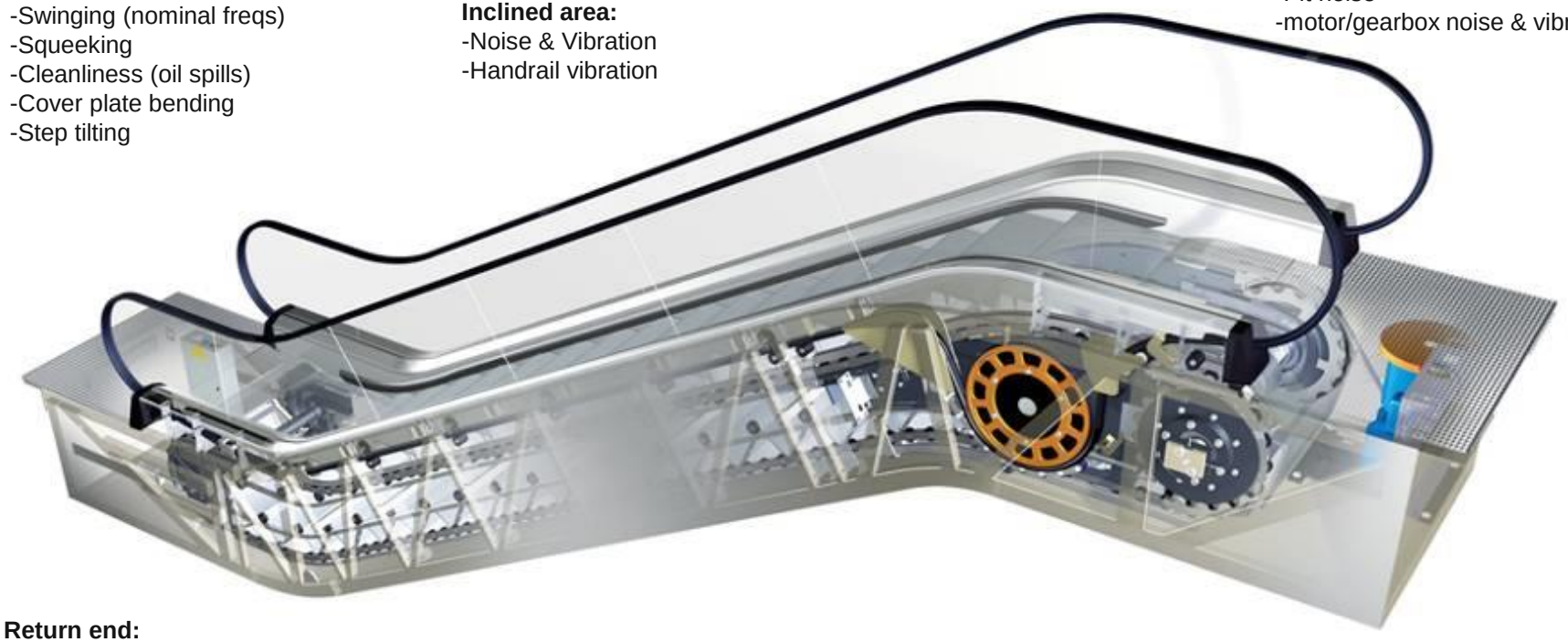


What is Escalator Ride Comfort?

Knock'n'Feel:
-Balustrade bending
-Rattling
-Swinging (nominal freqs)
-Squeeking
-Cleanliness (oil spills)
-Cover plate bending
-Step tilting

Inclined area:
-Noise & Vibration
-Handrail vibration

Top landing:
-Noise & Vibration
-Building interface vibration
-Pit noise
-motor/gearbox noise & vibrations



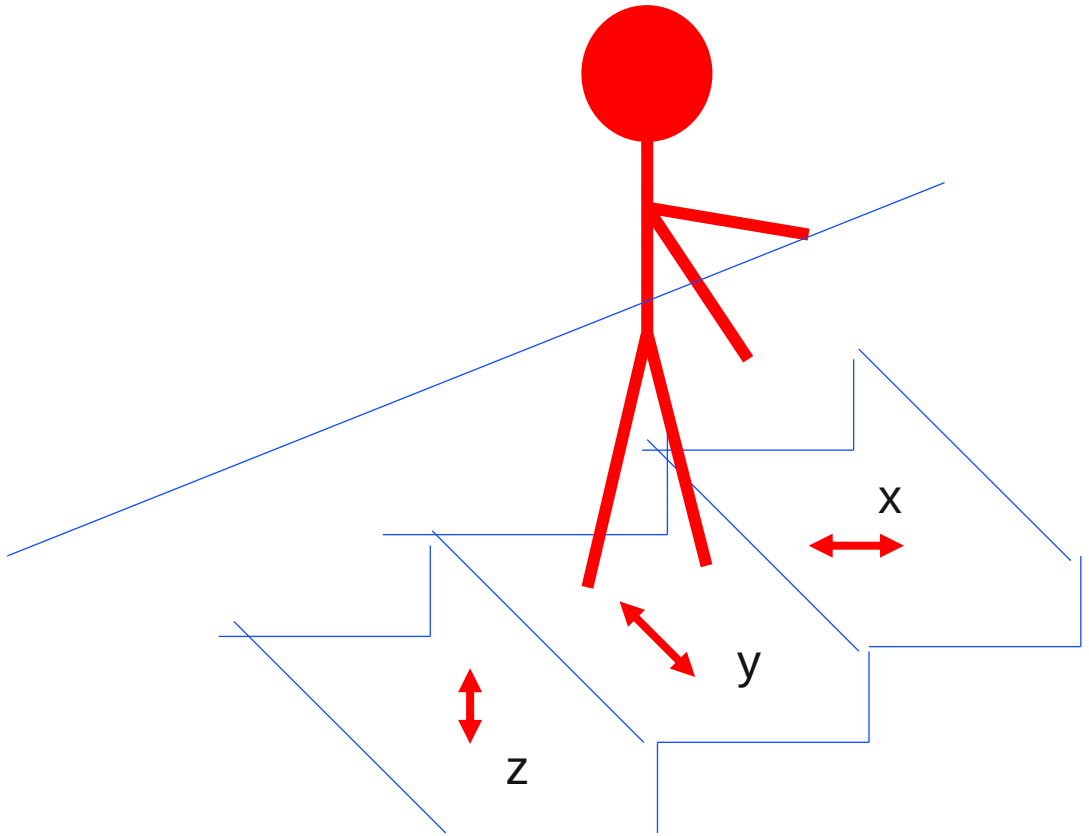
Return end:
-Noise & Vibration
-Building interface vibration
-Pit noise

Escalator **Ride Comfort** is about making **people feel:**

- **safe**
- **comfortable**
- **Non irritated (including non-user residents)**

1.Step vibrations

Moderate- high frequency vibration -> poor quality image
High vibrations at low frequency -> feels unsafe



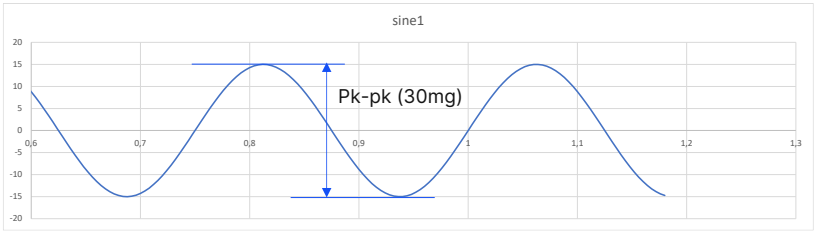
Typical ways of defining vibrations – simple sine wave

Raw trace 4Hz

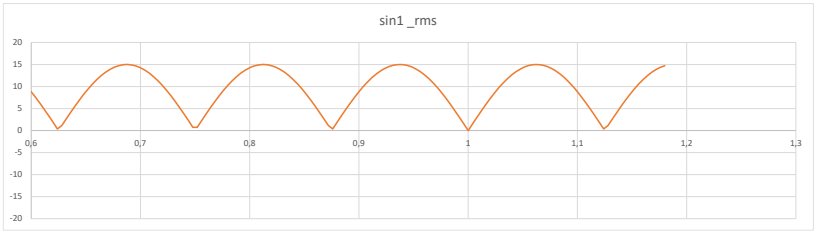
Conventional

Elevator method

(ISO18738-1)



Rectified trace

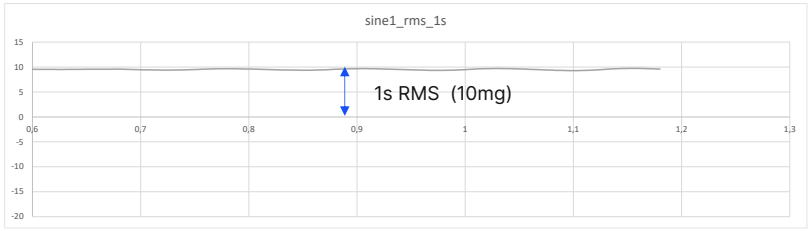


RMS 1s averaged trace

Conventional

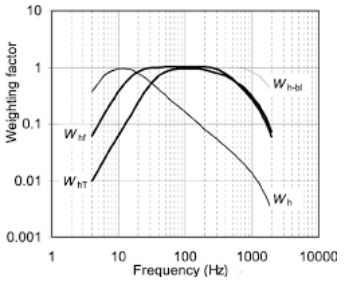
Elevator method

(ISO18738-1)



Escalators use

Different filters to elevators



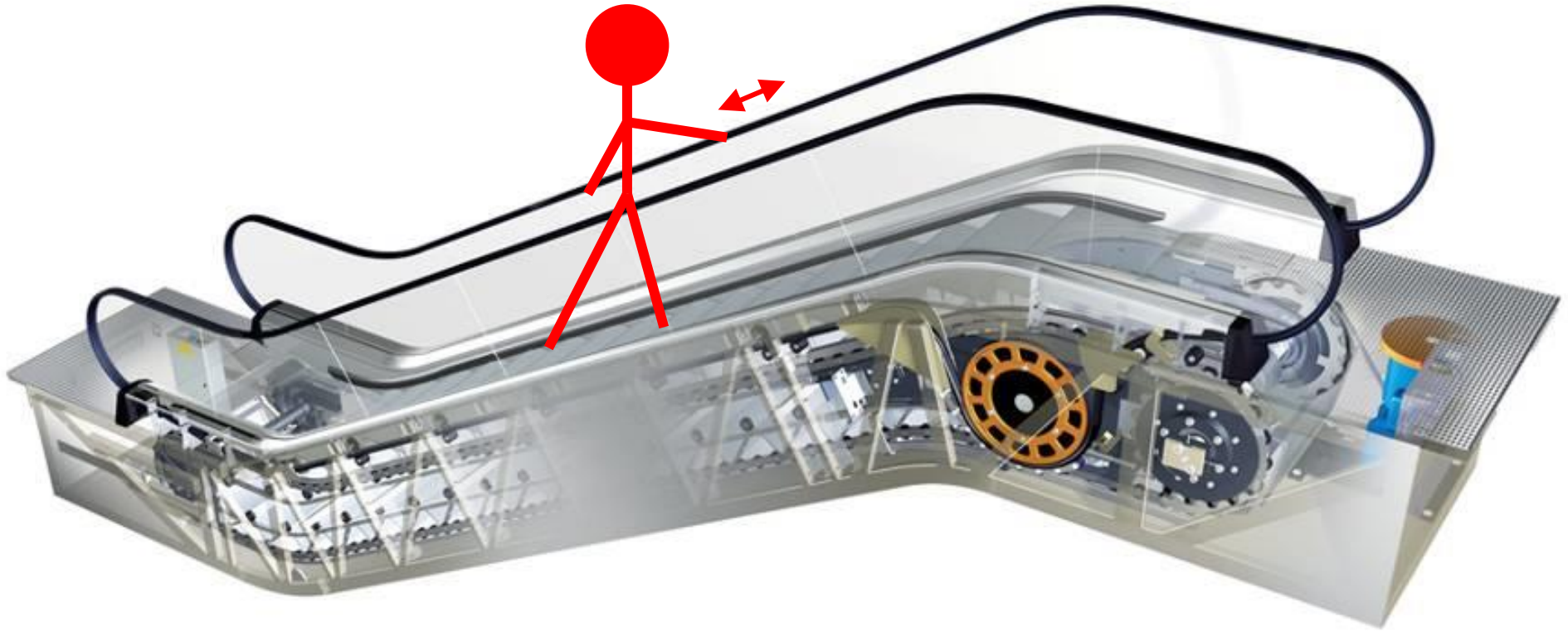
ISO standards use Vector Sum:

$\text{Sqrt}\,(z^2 + y^2 + x^2)$

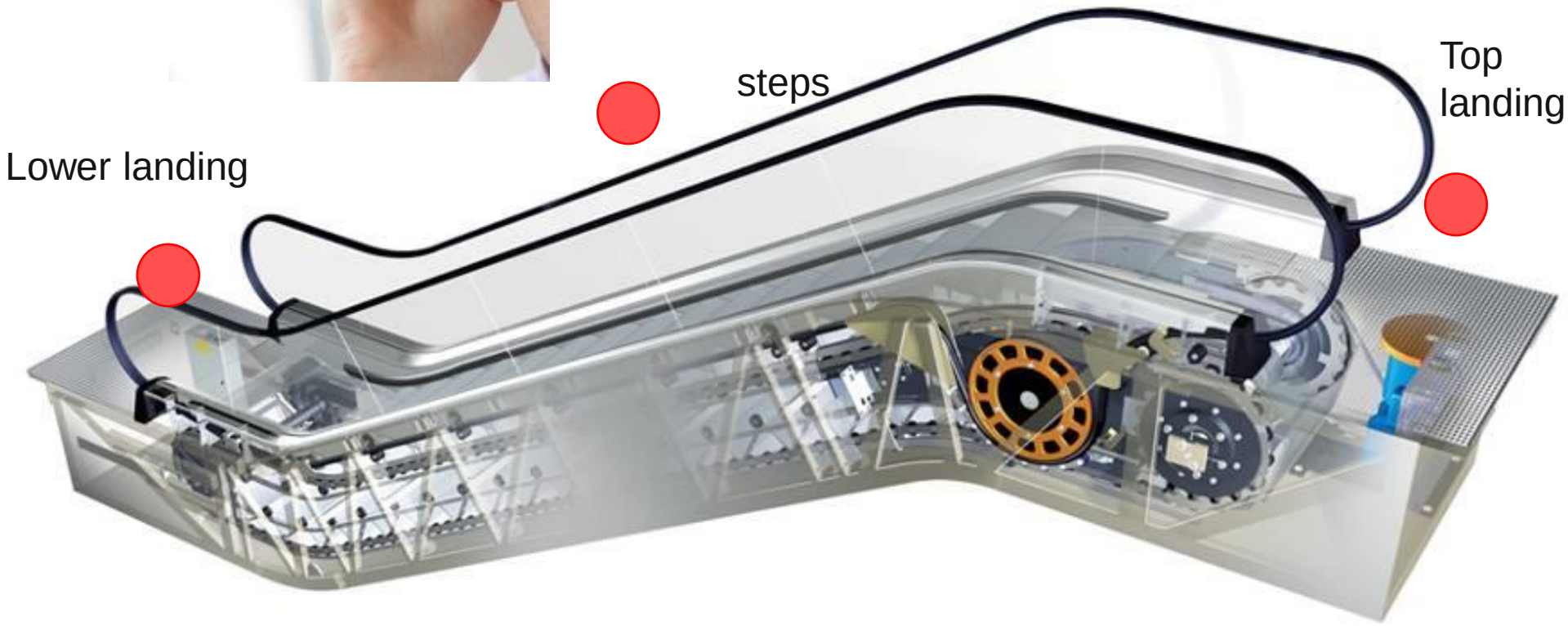
Avoid copy paste elevator specs to escalator specs

2.Handrail vibrations

Moderate-High high freq vibration -> poor quality image
High vibrations at low frequency -> feels unsafe



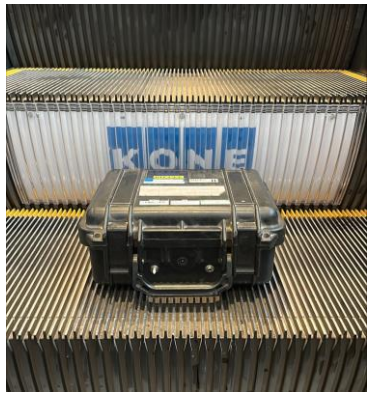
3.Noise



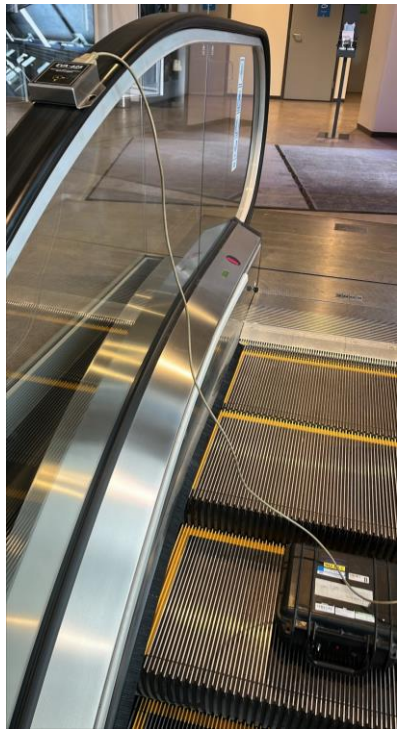
Perception of noise and its irritation very depending on surroundings
Quality commercial and quiet airports are most sensitive
In transit there is often high noise from ventilation masking the esc sound

Esc measurement requirements according to **ISO18738 Part2**

www.pmtvib.com



1 step measurement



2 –handrail measurement

3 noise measurement
Max operational noise levels measured 1,55m above step, or landings

https://www.henning-gmbh.de/

Note – ISO18738 only defines the method of measurements and processing
Not pass/fail criteria – these are defined by customer and internal criteria



Thank you

Dedicated to
People Flow™