Railway noise and vibrations

Short study

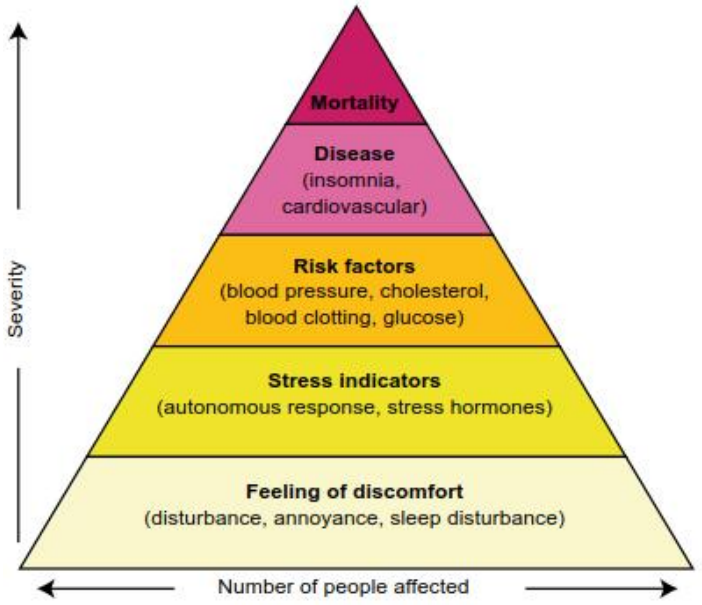
VR Track Oy

Noise

Noise in general

- Loud or unpleasant or disturbing sound may be sensed as noise. Noise can be generated from different sources, for example traffic, industry, construction sites and out door events.
- Exposure to noise may have various effects, depending on the sound level, duration, frequenscy content, source and the attitude and circumstances of the individual experiencing it.
  - Small group of the exposed population may run a risk of developing more serious symptoms including hypertension and stress. These may contripute to a loss of quality of life and healthy life years.
  - More about health effects of noise:
    - https://uic.org/IMG/pdf/railway_noise_in_europe_2016_final.pdf
    - https://www.eea.europa.eu/publications/good-practice-guide-on-noise
- Introduction to noise (in Finnish): http://www.ely-keskus.fi/documents/10191/2073102/Liikonen_Johdatus_ymp%C3%A4rist%C3%B6meluun.pdf

Graph 1. Effect of noise, starting from exposure (under) to health effects (top). After WHO. (Railway noise in Europe 2016)



Railway noise and legislation

- The issue of railway noise concerns both the transport of passengers and freight, but it is much acute for freight wagons. The rolling noise of wagons results, firstly, from the roughness of the surface of wheel and rail and secondly, from the type of tracks the wagon is rolling on. Effective reduction can be best achieved by addressing both elements in parallel. Core measures include "silent brakes" (composite brake blocks) and acoustic grinding of tracks.
- The railway noise has also its interoperability dimension as country-specific restrictions on noisy wagons without addressing the issue in a wider context could potentially undermine competitiveness of railway sector vis-à-vis other transport modes.
- EU has noise legislation that can be found from http://ec.europa.eu/environment/archives/enlarg/handbook/noise.pdf
- EU also has other related directives and regulations:
  - DIRECTIVE (EU) 2016/797 of the European Parliament and of the Council of 11 May 2016 on the interoperability of the rail system within the European Union
  - Directive 2008/57/EC on the interoperability of the rail system within the Community (repealing Directives 96/48/EC and 2001/16/EC from 19 July 2010);
  - DIRECTIVE 2014/106/EU of 5 December 2014 amending Annexes V and VI to Directive 2008/57/EC of the European Parliament and of the Council on the interoperability of the rail system within the Community
  - Directive 2014/38/EU of of 11 March 2014 amending Annex III to Directive 2008/57/EC of the European Parliament and of the Council as far as noise pollution is concerned
  - Directive 2013/9/EU of of 11 March 2013 amending Annex III to Directive 2008/57/EC of the European Parliament and of the Council on the interoperability of the rail system within the Community
  - Commission Recommendation 2014/897/EU [59] of 5 December 2014 on matters related to the placing in service and use of structural subsystems and vehicles under Directives 2008/57/EC and 2004/49/EC of the European Parliament and of the Council (DV29bis), repealing Commission Recommendation 2011/217/EU
  - Directive 2011/18/EU of 1 March 2011 amending Annexes II, V and VI to Directive 2008/57/EC of the European Parliament and of the Council on the interoperability of the rail system within the Community
  - Directive 2009/131/EC of 16 October 2009 amending Annex VII to Directive 2008/57/EC of the European Parliament and of the Council on the interoperability of the rail system within the Community
  - Technical Specification for Interoperability (TSI) on Noise - Regulation (EU) No 1304/2014
  - Noise charging - Regulation (EU) 2015/429
  - Connecting Europe Facility - Regulation (EU) 1316/2013
  - Directive 2002/49/EC relating to the assessment and management of environmental noise (the Environmental Noise Directive – END) is the main EU instrument to identify noise pollution levels and to trigger the necessary action both at Member State and at EU level.
  - Directive 2012/34/EU of the European Parliament and of the Council establishing a single European railway area (recast)

Noise measurements

- EU noise measurements follow ISO standard
  - Standard ISO 1996-2:2017 Acoustics -- Description, measurement and assessment of environmental noise -- Part 2: Determination of sound pressure levels
- In Finland railway noise measurements follow two guides from Finnish Environmental authority (only in Finnish):
  - https://julkaisut.valtioneuvosto.fi/bitstream/handle/10138/42692/Ymp%c3%a4rist%c3%b6melun%20mittaaminen.pdf?sequence=1
  - https://helda.helsinki.fi/bitstream/handle/10138/41691/Ymp%C3%A4rist%C3%B6opas_97.pdf?sequence=1

Noise management

- The approach to outdoor noise problems is to migitate some of three options depending on situation:
  - The source (usually most cost effecient)
  - The propagation path (barries or increase the distance)
  - The receiver (e.g. sound proof windows)
- With rolling noise the control should be based on the system that consists of the vehicle and the tracks
- More information about noise management and reduction can be found from
  - https://uic.org/IMG/pdf/railway_noise_in_europe_2016_final.pdf
  - https://ec.europa.eu/transport/sites/transport/files/modes/rail/doc/2016-01-05-cswc-rail-noise-reduction.pdf

Train-induced ground vibration

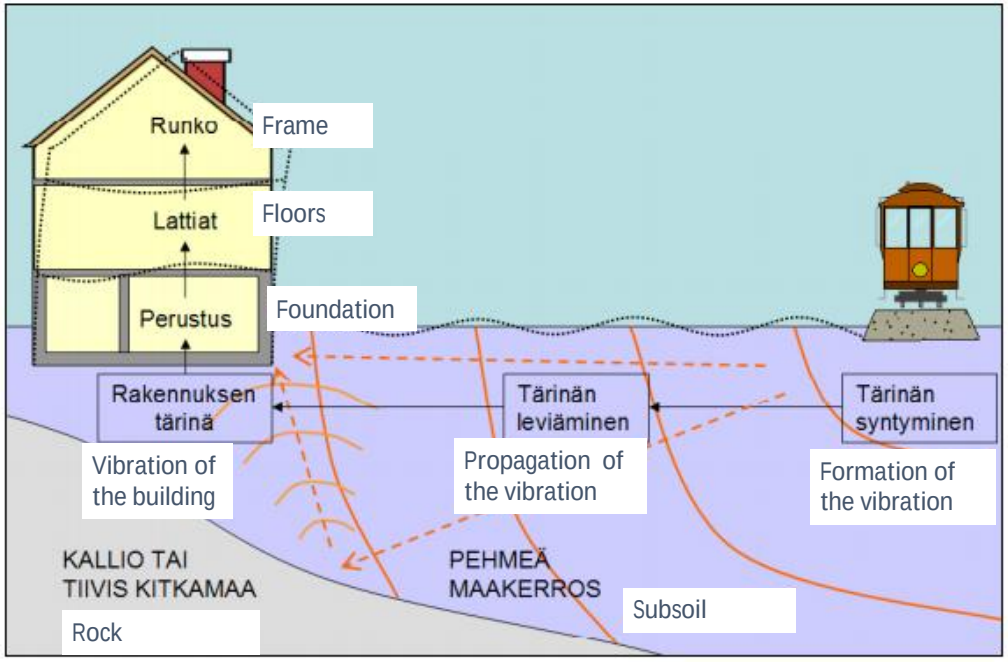
Train-induced ground vibration

- Train-induced ground vibration is a complex phenomenon that depends on many different factors
- Predicting is difficult and requires a professional
- Three different mechanisms that cause problems: high-speed trains (does not concern this project), heavy freight train and structure-borne noise (common with underground trains)

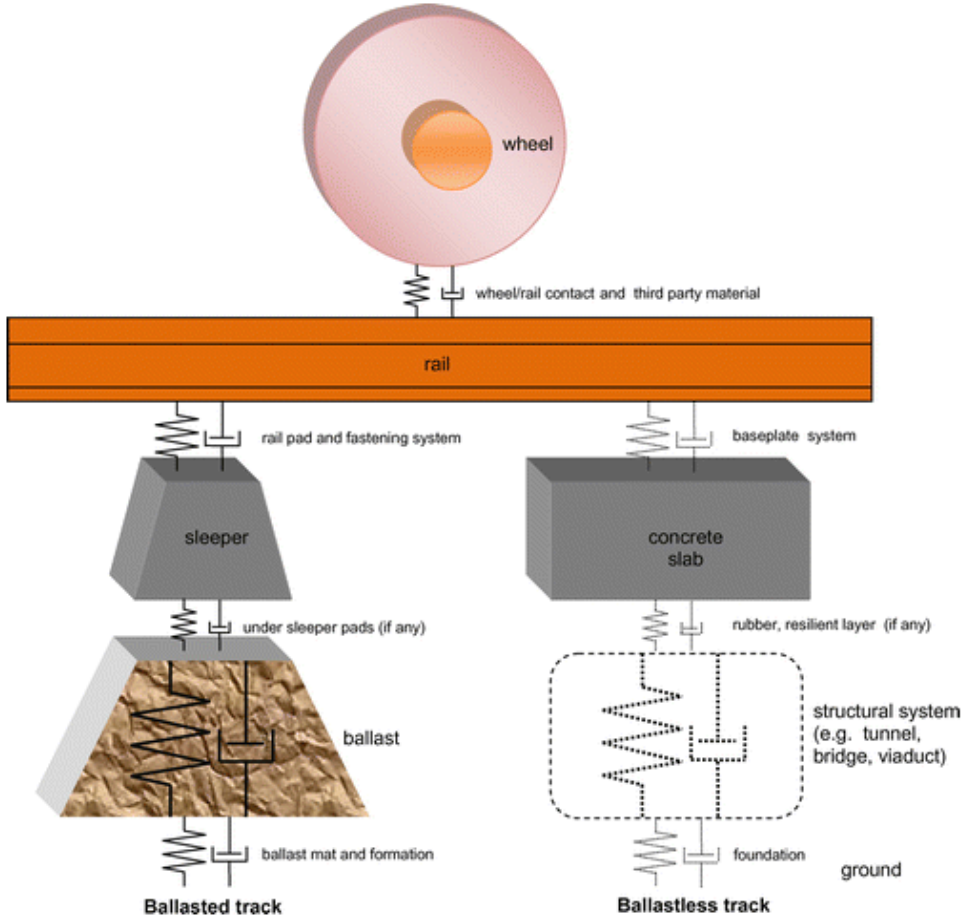
- This project deals with heavy freight trains à the mechanism causing problems is highly depended on characteristics of the soil

Vibration caused by heavy freight trains

- Basic principle: Irregularities on the track make the train to vibrate, vibration propagates to the track and ballast and eventually to the ground. The vibration propagates in the ground and can propagate to a building and make the building to vibrate. Vibration wave can also reflect from the bed rock to the buildings.



Train and track/rail interaction causes the vibration



Generation of vibration depends on

- Soil
  - Vibration can propagate far on soft soil
  - Vibration damps quickly on hard soil
- Track
  - More irregularities, more vibration
- Vehicle
  - Train weight, train speed, train condition
- Buildings
  - Characteristics of the building define how it receives vibration
  - If vibration's frequency is the same than house's structures' resonance frequency, it can multiply the vibration

Factors increasing vibration risk

- The most important factor is the soil
  - Soft soil (clay, silt, peat)
  - High soil moisture content
- Irregularities on the track
- Heavy trains, high speed, poor condition of the vehicles
- 1-2 stories high wooden houses

Estimation of the impact distance

Study report

TUTKIMUSRAPORTTI VTT-R-04703-14

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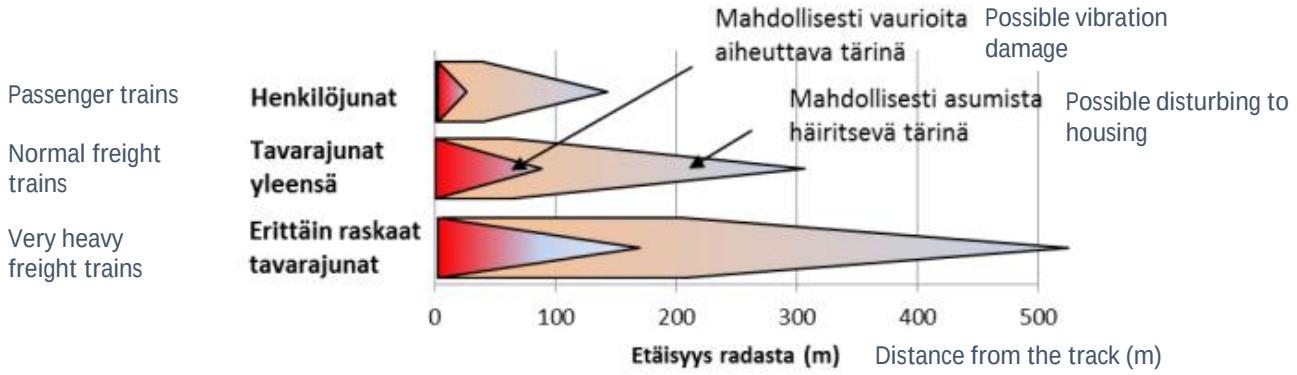
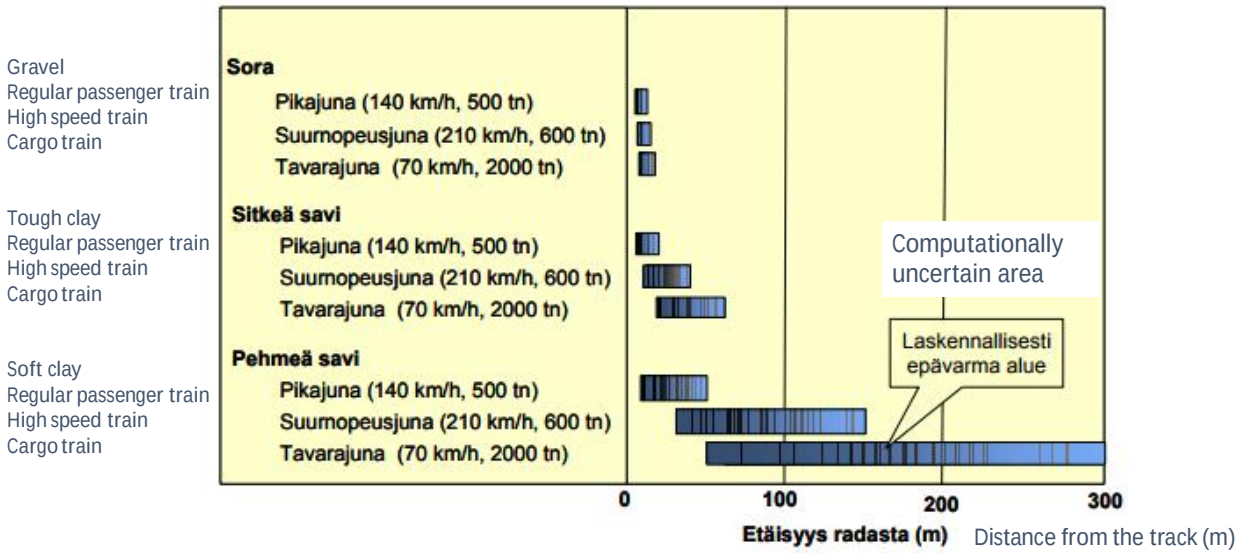


Kuva 3. Suuntaa antava arvio suurimmasta etäisyydestä, jolla tärinä voi häiritä asumista ja tai aiheuttaa vaurioita.

An indicative estimate of the maximum distance at which vibrations may affect housing and / or cause damage

Estimation of the impact distance on different soils



Kuva 4. Suuntaa-antava arvio etäisyydestä eri maalajeilla, jolloin junista aiheutuva tärinä voi olla haitallinen. Varjostetut alueet kuvaavat laskennallisesti epävarmaa aluetta.

An approximate estimate of the distance between different types of land, whereby the train's vibration may be harmful. The shaded areas represent a computationally uncertain area.

Evaluating the harmfulness of vibration

- Two different approaches:
  - Does the vibration damage buildings?
  - Does the vibration annoy dwellers?
  - à Usually two different ways of evaluating vibration!

- Vibration that damages buildings is much higher than vibration that people feel annoying

Human exposure to train-induced ground vibration

- The annoyance of the vibration depends on many factors:
  - Magnitude [mm/s]
  - Frequency [Hz]
  - Duration of vibration (how long does a single train passing last)
  - Amount of passings in a day (how often the trains pass)
  - Time of day (vibration during night-time disturbs sleeping)

- People experience vibrations differently and some people are more prone to feel the vibration annoying
- It is impossible to set an absolute value when vibration is annoying and when it is not à different kinds of methods have been developed to evaluate when vibration the majority of people think that vibration is annoying

Human exposure and frequency of the vibration

- People experience different frequencies of the vibration differently
- People experience high frequencies more annoying
- Train-induced ground vibrations are low frequency vibration, typically 1 – 20 Hz
  - à measured values have to be weighted to correspond the human experience

Impacts of vibration to the nearby dwellers

- Reduced comfort
- Disturbance of sleep
- Disturbance of concentration
- Fear of damage to the buildings (actual damages usually require much bigger values)

- Long-term impacts are hard to study but long-term exposure to traffic vibration is considered to harmful to health

European standards for evaluating vibration annoyance

- European countries have their own standards for railway-induced vibrations and they all use a different value to evaluate vibration and the disturbance to residents
  - Finland has a recommendation for limit values but the recommendation is not legally binding (http://www.vtt.fi/inf/pdf/tiedotteet/2004/T2278.pdf, in Finnish)
  - Finland's recommendation is based on a Norwegian standard NS 8176
  - Other countries have their own standard, for example
    - Germany DIN-4150-2
    - Sweden TDOK 2014:1021
  - It is impossible to compare the limit values of different countries because they all use different methods of frequency weighting

Norwegian standard NS 8176, basic priciples

- The standard is used to evaluate how annoying the vibration is to the dwellers, not how harmful it is to the buildings
- The standard uses a statistical maximum value for weighted velocity v_{w95} (mm/s) to evaluate the annoyance of the vibration
- At least 15 single passings of a train must be measured at each measurement position
- The measured values are weighted by a frequency weighting function to correspond the human experience of vibration
- Statistical maximum value is calculated from the weighted velocities
- Finland's practice follows these same principles

International ISO standards and vibration

- ISO standards 2631-1 and 2631-2 handle mechanical vibration and shock and they evaluate human exposure to whole body vibration
- They are used to evaluate all kinds of vibrations, not just train-induced ground vibration
- They include basic principles of evaluating the annoyance of vibration

à Evaluating annoyance of the train-induced ground vibration requires national standards, many of the national standards are based on the principles presented in ISO standards

Measuring vibration

- Magnitude of vibration can be measured in
  - Vibration velocity [mm/s]
  - Vibration acceleration [mm/s2]
  - Displacement [mm]

- Measurements should be done by a professional
  - Data must be processed before any evaluation of the annoyance

- Usually vibration is measured at three different distances from the track to see how it decreases

Mitigation measures

- Vehicle
  - Smooth wheels
  - Maintenance
- Track
  - Track smoothness
  - Installing rubber pads between rail and sleepers (works only with hard soil!)
- Ground (these are used in soft soil!)
  - Walls embedded in the ground, for example sheet-pile walls, soil stabilization etc
    - Experiments in Finland, effectiveness uncertain, needs more studying
  - Trenches
- Traffic
  - Reducing train weight
  - Reducing train speed
    - Reducing train speed from 80 km/h to 40 km/h makes a significant difference