



Pengembangan Prasarana Perkeretaapian di Indonesia

Sri Atmaja P. Rosyidi, Ph.D., P.E., MIACMAG, MIRDA, MISGE, MPII
Associate Professor, Department of Civil Engineering
Universitas Muhammadiyah Yogyakarta



SRI ATMAJA P. ROSYIDI

- ▶ HP. 08157909887
- ▶ Email: atmaja_sri@umy.ac.id / atmaja.sri@gmail.com
- ▶ Materi: atmaja.staff.umy.ac.id



- ▶ **PENDAHULUAN:**
- ▶ **PENGEMBANGAN INFRASTRUKTUR**
- ▶ **PENGEMBANGAN PRASARANA**
 - ▶ **STRUKTUR JALAN KERETA API: DISAIN DAN KONSTRUKSI**
 - ▶ **GEOTRACK DAN GEOHAZARDS: ANALISIS DAN MITIGASI**
 - ▶ **INSPEKSI DAN EVALUASI: PENGEMBANGAN TEKNOLOGI**
 - ▶ **RAILWAY SAFETY AND RISK ASSESSMENT (RASRIS): SISTEM TEKNOLOGI INFORMASI**



PERAN TRANSPORTASI KERETA API

MENDUKUNG SISTEM TRANSPORTASI NASIONAL - TERINTEGRASI DALAM KONSEP MOBILISASI, LOGISTIK DAN KONEKSITAS

SISTEM TRANSPORTASI NASIONAL

MOBILISASI
PENUMPANG

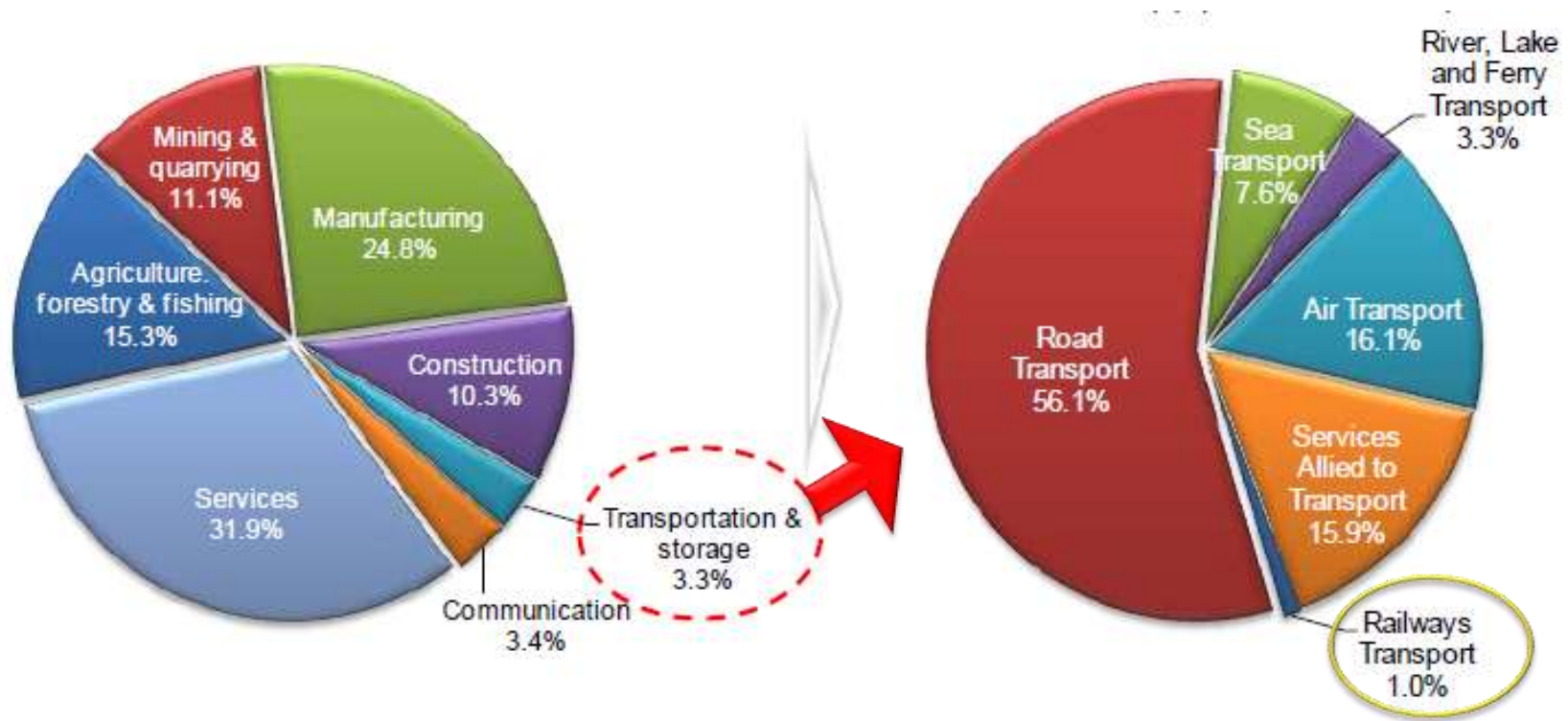
SISTEM LOGISTIK
TRANSPORTASI
BARANG

KONEKSITAS
NASIONAL-
REGIONAL

KERETA API SEBAGAI MODA TRANSPORTASI UMUM
YANG MAMPU MENGANGKUT DALAM JUMLAH BESAR (MASSAL),
EFISIEN, MURAH, TERATUR, TERJADWAL, ANDAL, AMAN DAN
BERDAMPAK LINGKUNGAN RENDAH

PENGUATAN DAYA SAING
DALAM PEMBANGUNAN EKONOMI BERKELANJUTAN





PDB NASIONAL 2011

KONTRIBUSI PERKERETAAPIAN SANGAT KECIL, TETAPI STRATEGIS

- ▶ KONTRIBUSI SEKTOR TRANSPORTASI DAN JASA PENDUKUNG : 3,3% PDB NASIONAL TAHUN 2011 (Rp. 254 TRILYUN)
- ▶ KONTRIBUSI PERKERETAAPIAN KURANG DARI 1% (Rp. 2,3 TRILYUN) DARI TOTAL PDB DARI SEKTOR TRANSPORTASI DAN JASA PENUNJANG



Peran Transportasi Perkeretaapian: RENCANA INDUK PERKERETAAPIAN (RIPNAS 2030)

VISI :

“Perkeretaapian yang berdaya saing, berintegrasi, berteknologi, bersinergi dengan industri, terjangkau dan mampu menjawab tantangan perkembangan”.

ARAH PENGEMBANGAN :

- 1. Pelayanan prasarana dan sarana perkeretaapian yang handal (prima), mengutamakan keamanan dan keselamatan (*security and safety first*), terintegrasi dengan moda lain, terjangkau oleh seluruh lapisan masyarakat serta tersebar di pulau-pulau besar seperti Jawa, Sumatera, Kalimantan, Sulawesi, dan Papua.**
- 2. Teknologi perkeretaapian yang modern, ramah lingkungan, daya angkut besar dan berkecepatan tinggi.**
- 3. Penyelenggaraan perkeretaapian nasional yang mandiri dan berdaya saing, menerapkan prinsip-prinsip “*good governance*” serta didukung oleh SDM yang unggul, industri yang tangguh, iklim investasi yang kondusif, pendanaan yang kuat dengan melibatkan peran swasta.**



RENCANA INDUK PERKERETAAPIAN (RIPNAS 2030)

5 dari 7 Target RIPNAS → **Infrastruktur**

TARGET RIPNAS 2030 :

1. Share angkutan penumpang 11 – 13 % dan angkutan barang 15 – 17 %
2. Jaringan KA 10.000 km, double track dan elektrifikasi pada lintas utama → **Infrastruktur**
3. Jaringan perkeretaapian “Trans Sumatera” → **Infrastruktur**
4. Sebagai tulang punggung transportasi perkotaan → **Infrastruktur**
5. Pengoperasian “Argo Cahaya” (Kereta Api Cepat) di Pulau Jawa
6. Perkeretaapian sebagai tulang punggung angkutan barang di Kalimantan, Sulawesi dan Papua → **Infrastruktur**
7. Pelayanan yang terintegrasi, aman, nyaman, handal dan terjangkau → **Infrastruktur**



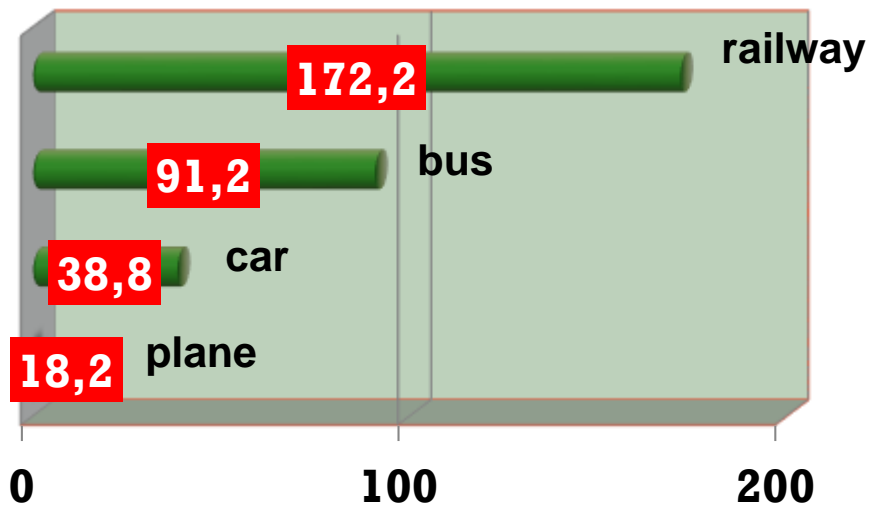
POTENSI (KEUNGGULAN) TRANSPORTASI KERETA API

- ▶ **HEMAT ENERGI**
- ▶ **TRANSPORTASI MASAL → SOLUSI KEMACETAN (ANGKUTAN PERKOTAAN)**
- ▶ **ANGKUTAN BERAT → KAPASITAS BESAR UNTUK BARANG**

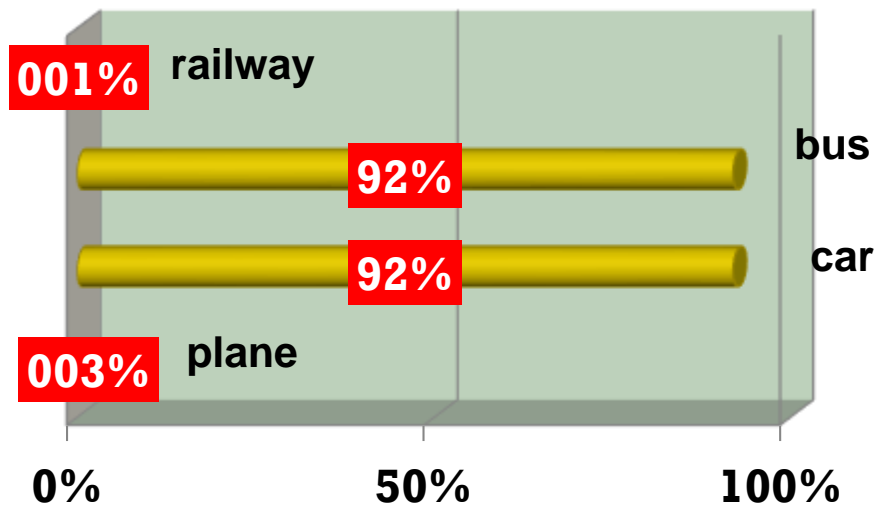


Potensi Transportasi Kereta Api: HEMAT ENERGI

Energy efficiency (pass-km/kg oil eq.)



Greenhouse gases emissions



HEMAT ENERGI DAN RAMAH LINGKUNGAN: MODA KERETA API MEMILIKI KEUNGGULAN KOMPARATIF SEBAGAI ANGKUTAN MASAL YANG HEMAT ENERGI DAN RAMAH LINGKUNGAN. (PEMBANGUNAN EKONOMI BERKELANJUTAN)



PROYEKSI ANGKUTAN PENUMPANG (ORANG/TAHUN)

	2006	2010	2015	2020	2025
Jawa	127.519.723	155.158.347	184.299.294	214.417.082	244.673.991
Sumatera	2.566.924	4.366.143	6.401.799	8.653.562	11.103.851
Kalimantan	-	-	479.468	781.226	1.120.520
Sulawesi	-	-	2.483.369	3.902.371	5.406.375
TOTAL	130.086.647	159.524.490	193.663.930	227.754.241	262.304.737

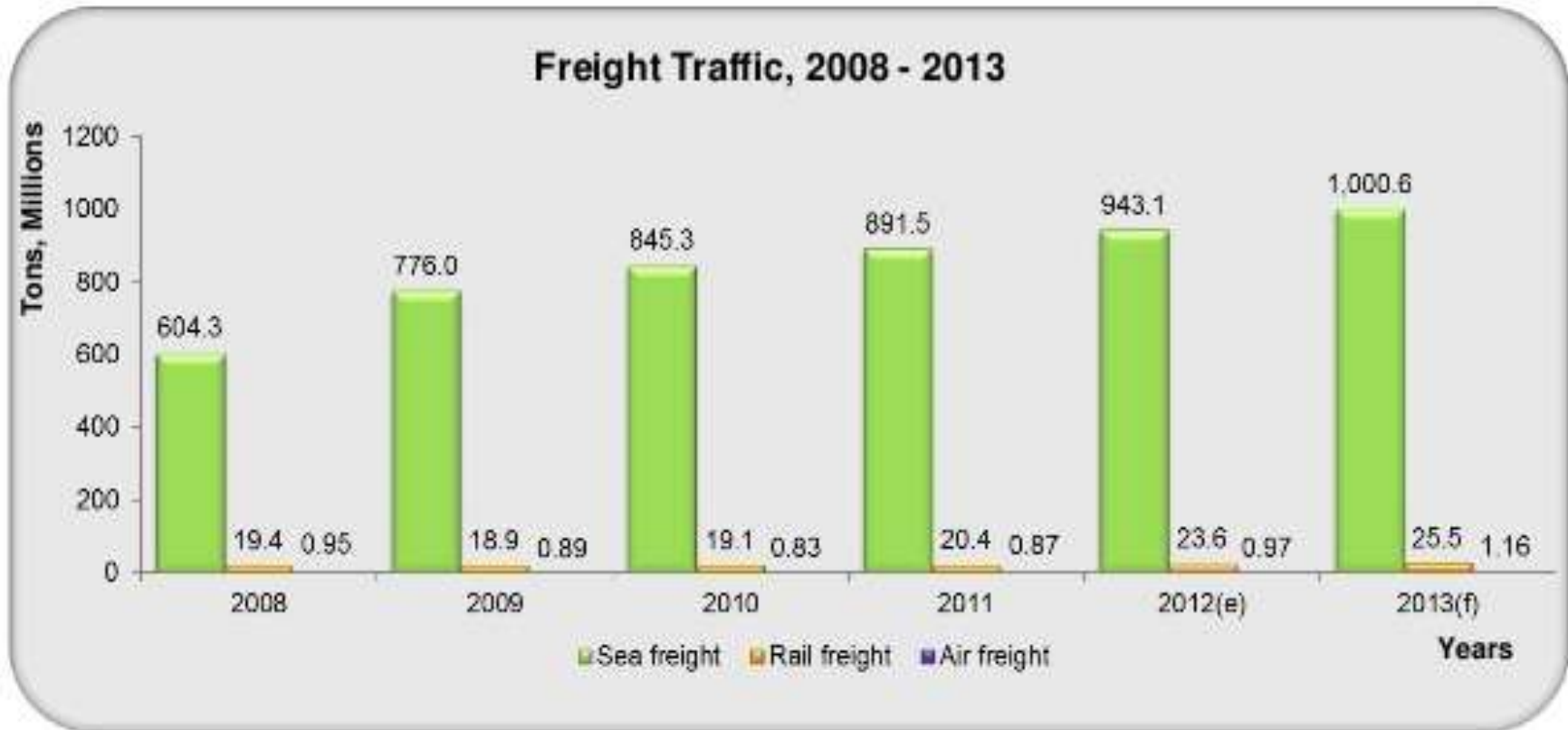
SOURCES : RAILWAYS MASTER PLAN 2009

- ▶ **PADA TH. 2025 INDONESIA MEMILIKI PENDUDUK 273.6 JUTA ORANG.**
- ▶ **PENDUDUK KOTA IN JAWA MENCAPAI 82.2% SEKITAR 120 JUTA.**
- ▶ **PADA GDP PER KAPITA US\$ 13,000-16,000 MOBILITAS MENINGKAT TAJAM.**



JARINGAN LOGISTIK NASIONAL PERKERETAAPIAN

PENGEMBANGAN SISTEM LOGISTIK NASIONAL DIBUTUHKAN PERAN KERETA API



- Seaports handle more than 90 percent of total non-road freight traffic in Indonesia
- Cargo transportation in Java-Sumatra region is still dominated by the freight trucks accounting more than 80 percent for the movement of mining, industrial, plantation and agricultural products



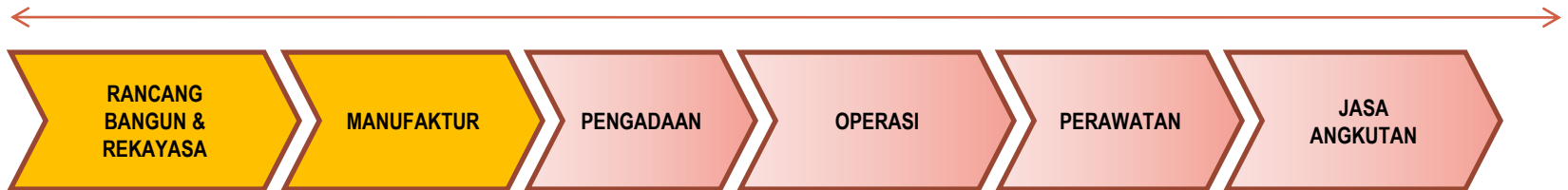
Pengembangan Infrastruktur untuk Jaringan Transportasi Kereta
Api di Indonesia

BAGIAN – 2



PENGEMBANGAN TRANSPORTASI KERETA API

RANGKAIAN SEKTOR PENYELENGGARAAN PERKERETAAPIAN



INDUSTRI MANUFAKTUR

OPERATOR & PENYEDIA JASA



**ANGKUTAN JARAK
JAUH UNGGULAN**



**ANGKUTAN
PENUMPANG
DENGAN
MENUJU
SUSTAINABLE
TRANSPORT**



**ANGKUTAN KOMUTER
/REGIONAL & KOTA**



1

**ANGKUTAN
PENUMPANG
JARAK JAUH**

EKONOMI

2

**ANGKUTAN
PENUMPANG
JARAK JAUH**

EKSEKUTIF

3

**ANGKUTAN
KOMUTER/
REGIONAL**

EKONOMI

4

**ANGKUTAN
PERKOTAAN**

EKONOMI



KOMITMEN DALAM MP3EI – PERKERETAAPIAN

▶ RENCANA NILAI INVESTASI KERETA API Rp. 305.2 TRILYUN

INVESTASI INFRASTRUKTUR PERKERETAAPIAN
SUMATERA : Rp. 43.2 TRILYUN
JAWA : Rp. 222.2 TRILYUN
KALIMANTAN : Rp. 39.8 TRILYUN



■ Pusat ekonomi mega ● Pusat ekonomi ● Usulan lokasi KEK ● Usulan lokasi KEK yang merupakan FTZ

- 1 KE Sumatera
- 2 KE Jawa
- 3 KE Kalimantan
- 4 KE Sulawesi
- 5 KE Bali – Nusa Tenggara
- 6 KE Papua – Maluku



KEBUTUHAN ANGKUTAN EKONOMI KOMUTER & REGIONAL



- MINYAK SAWIT (NO. 1 DUNIA)
- BATUBARA (NO. 2 DUNIA)

ANGKUTAN KOMODITAS
UNGGULAN

PERUBAHAN
BISNIS
ANGKUTAN
BARANG
DENGAN
SOLUSI
TERPADU

ANGKUTAN MULTIMODAL
LOGISTIK NASIONAL



1

ANGKUTAN
BARANG
CURAH PADAT

BATUBARA

2

ANGKUTAN
BARANG
CURAH CAIR

MINYAK SAWIT

3

ANGKUTAN
BARANG
INTERMODA

KONTENER, SEMEN

4

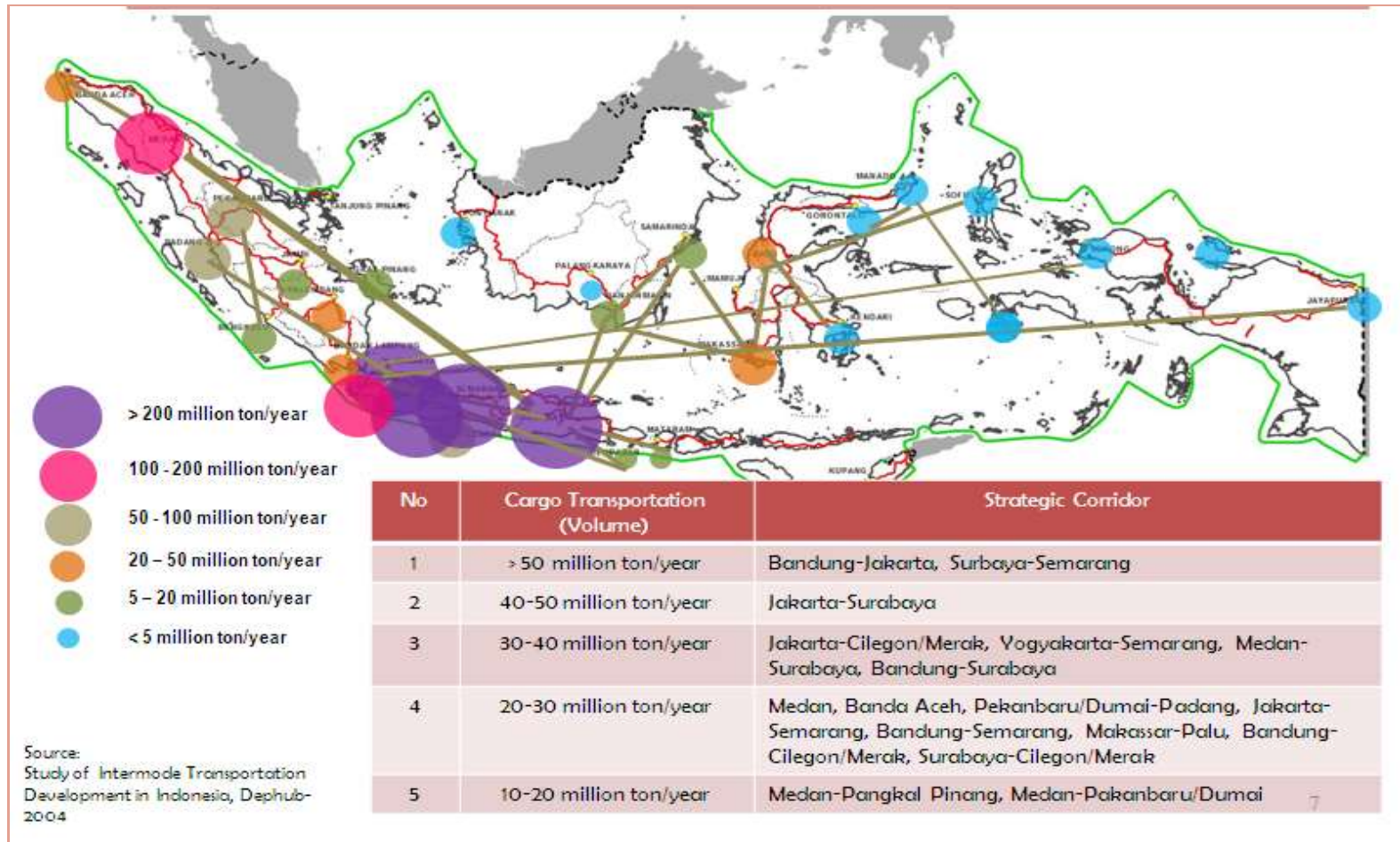
ANGKUTAN
GENERAL
CARGO CEPAT

ELEKTRONIK,
CONSUMER GOODS



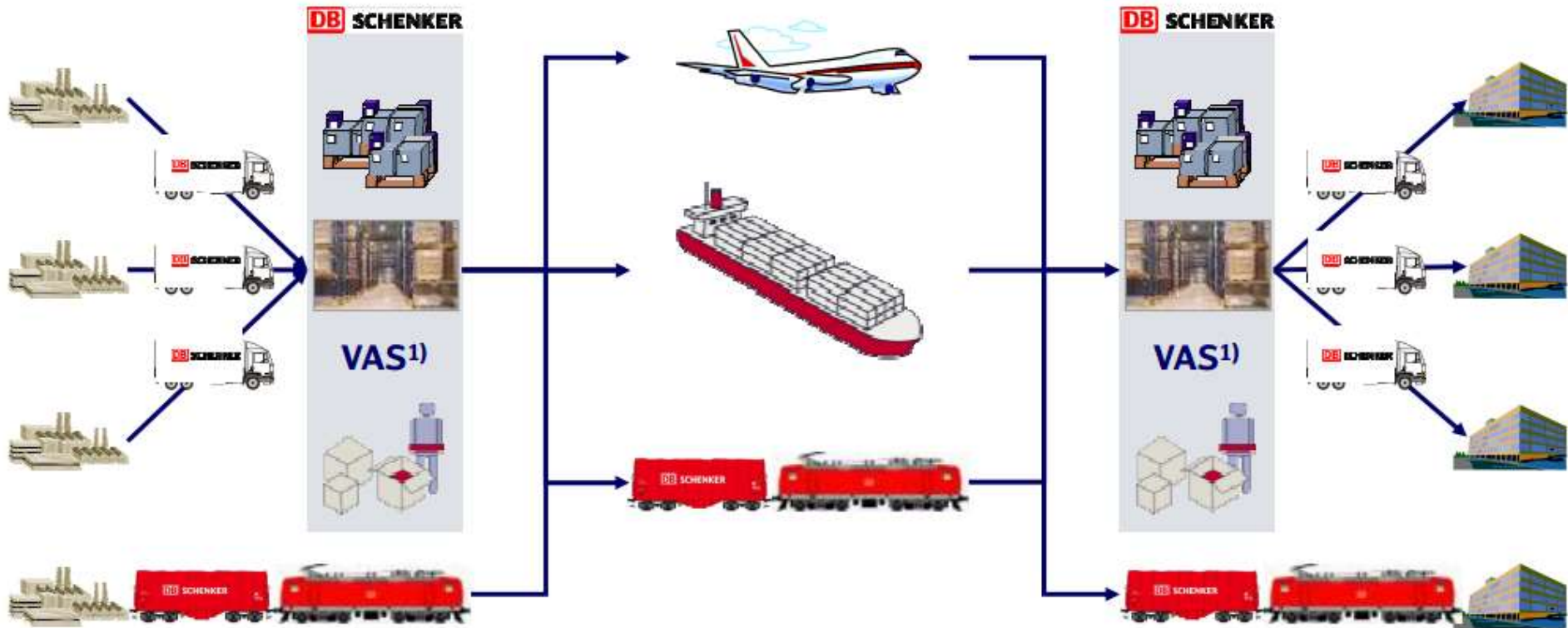
JARINGAN LOGISTIK NASIONAL PERKERETAAPIAN

PENGEMBANGAN SISTEM LOGISTIK NASIONAL KHUSUS UNTUK KORIDOR EKONOMI JAWA SEBAGAI ZONA ARUS BARANG TERPADAT DIBUTUHKAN JALUR KERETA API



PENGEMBANGAN ANGKUTAN KONTENER

INTERMODA DIPERKUAT DENGAN MANAJEMEN LOGISTIK



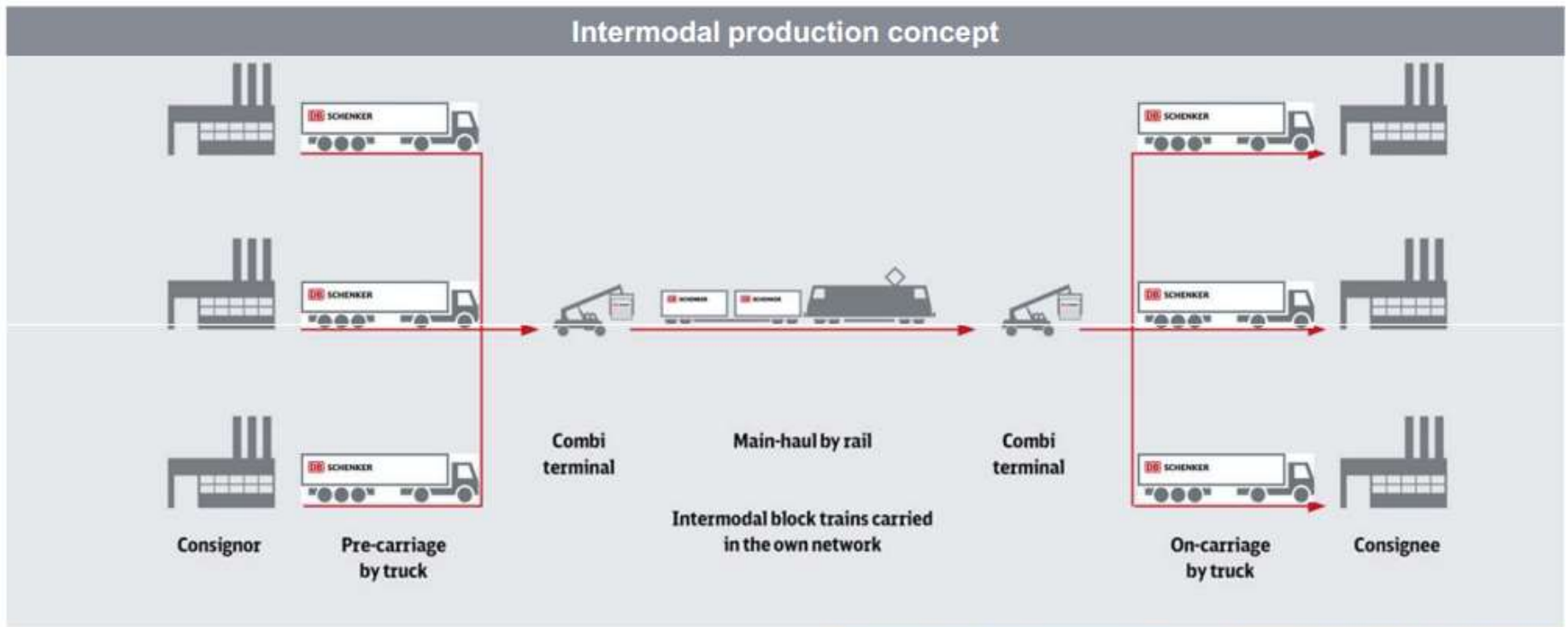
Door-to-door, track and trace

Holistic management of supply chain

Global account management team



KA INTERMODA KONTENER DI JAWA – MANAJEMEN LOGISTIK



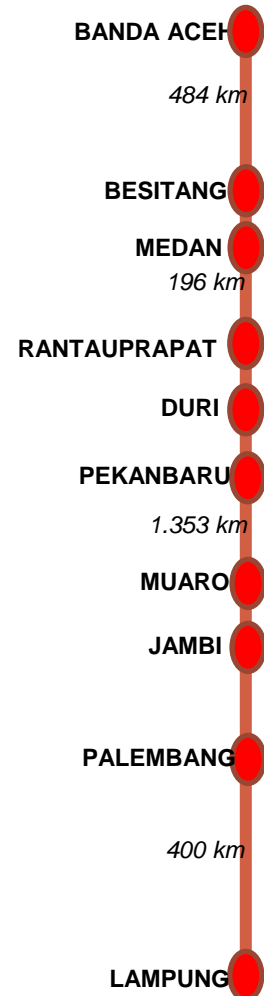
Equipment Details:

- Type: Swap Body & 40' PW HC Container
- Max. Payload: 21'960 kg (Swap Body), 25'000 kg (Container)
 - Length: 13,60 m
- Height / Width / Volume: 2,24 m / 2,43 m / 76 m³

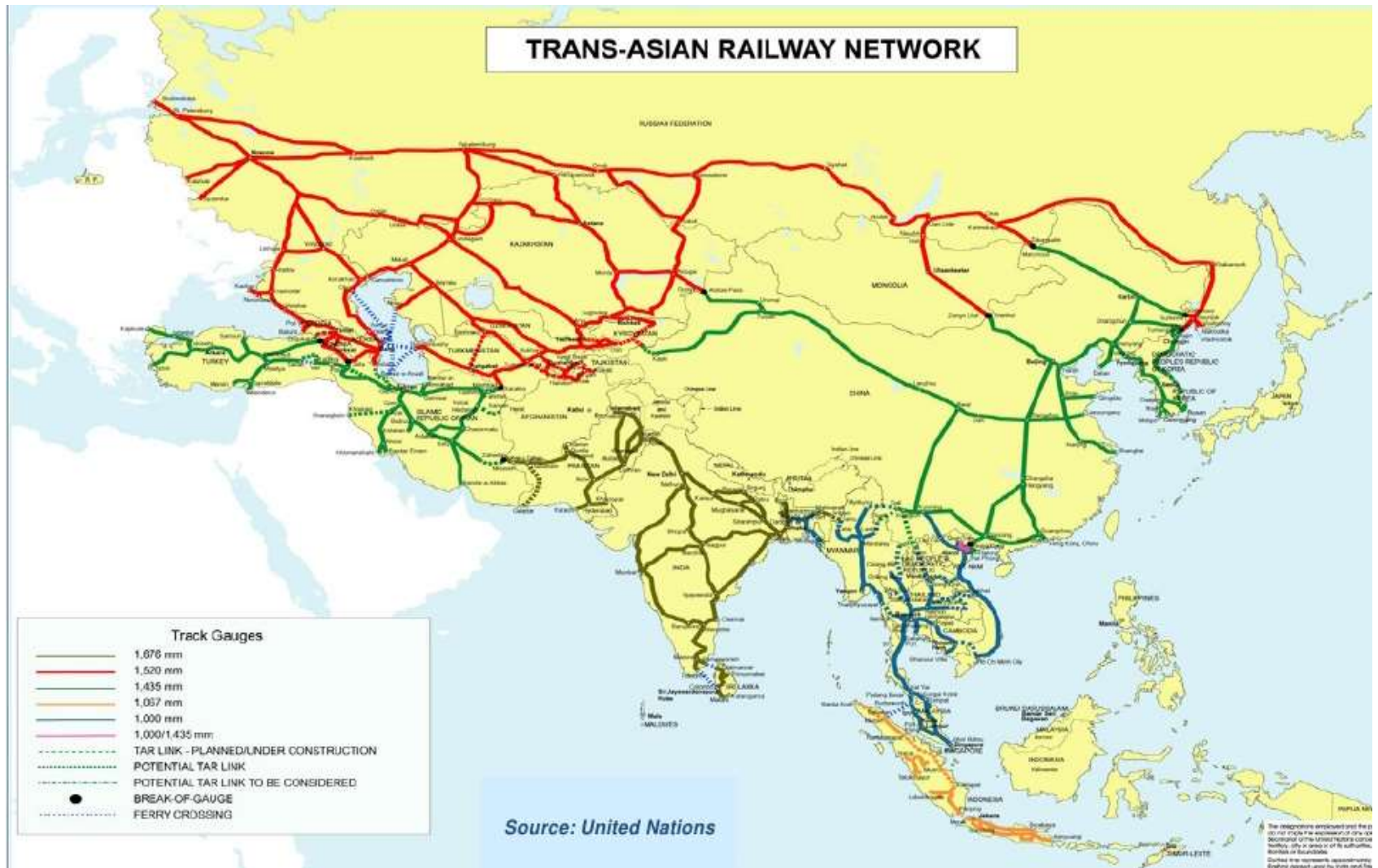


KEBUTUHAN JARINGAN KA SUMATERA

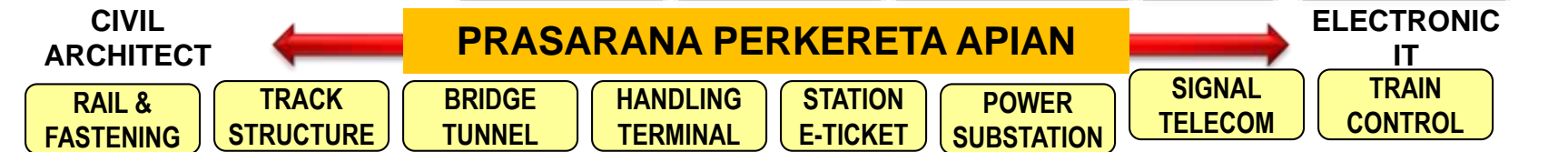
CONTOH: PENGEMBANGAN KA TRANS SUMATERA TERKAIT DENGAN KONEKTIVITAS ASEAN



KONEKTIVITAS REGIONAL ASEAN



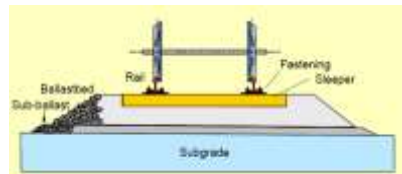
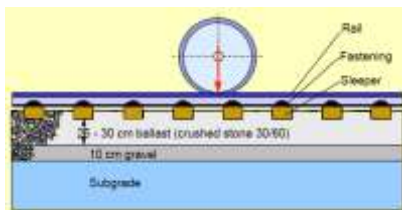
LINGKUP INDUSTRI PERKERETA APIAN



Tantangan Pengembangan Infrastruktur untuk Jaringan
Transportasi Kereta Api di Indonesia

BAGIAN – 3





Struktur Jalan Rel

Disain → ?

- Peningkatan daya angkut
- Peningkatan kecepatan
- Peningkatan struktur

Pemeliharaan ?

Kecelakaan akibat Track ?

Geotrack dan Geohazards

Disain → ?

- Antisipasi variasi perilaku tanah dan bencana geologi

Inspeksi

Sistem inspeksi dan pengembangan teknologi

Risk Assessment

Superstructure

Sub-structure

Bangunan Pendukung

Permasalahan Geoteknik

Bencana Geologi

Sistem Evaluasi

Teknologi

Disain Badan Jalan

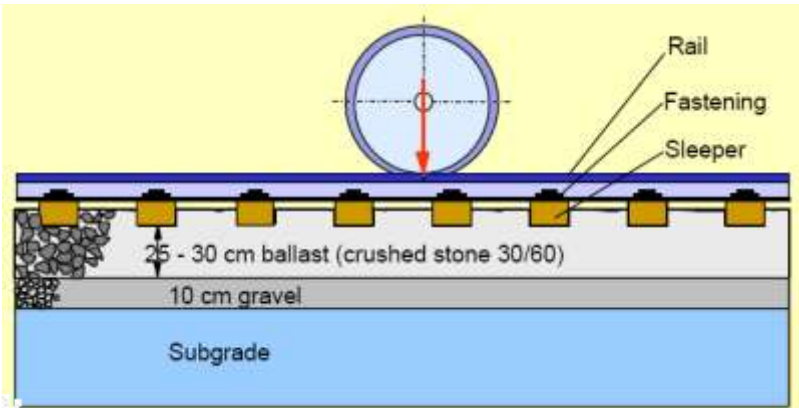
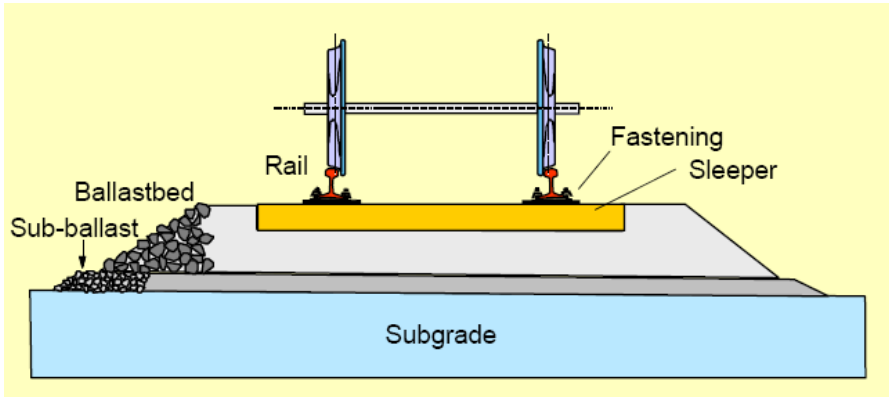
Analisis dan Mitigasi



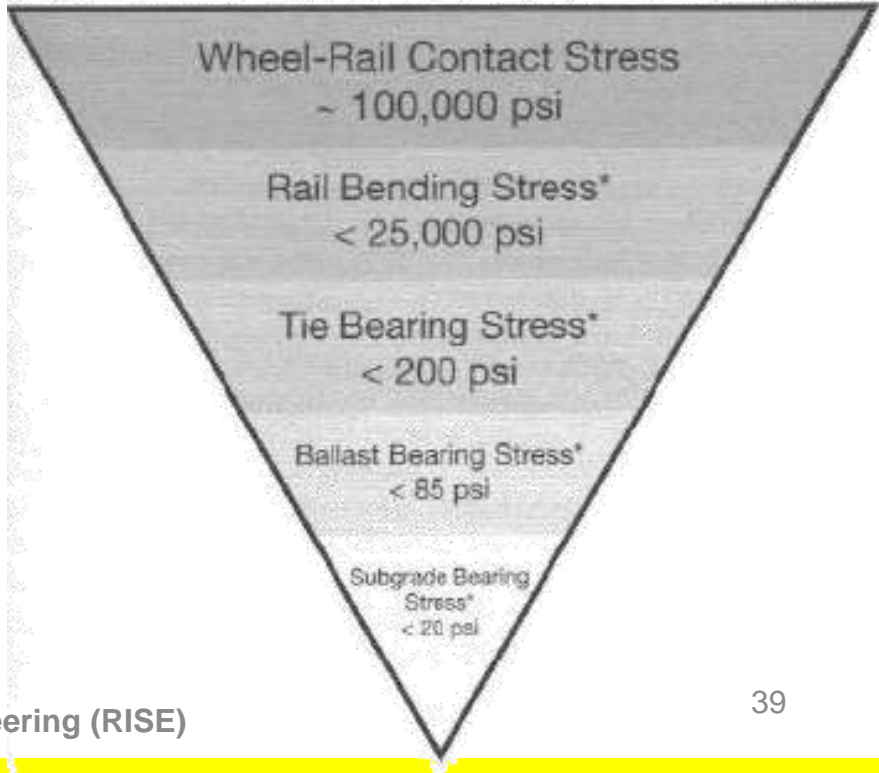
Trilogi – Filosofi Struktur Jalan Rel

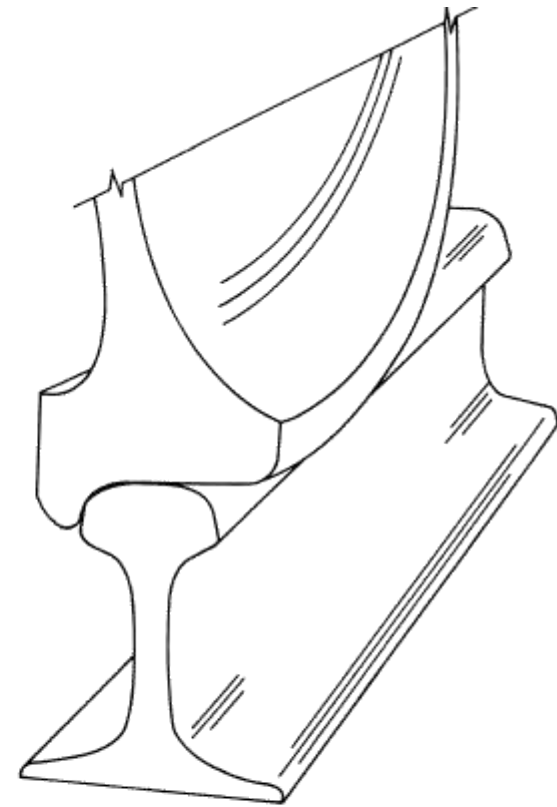
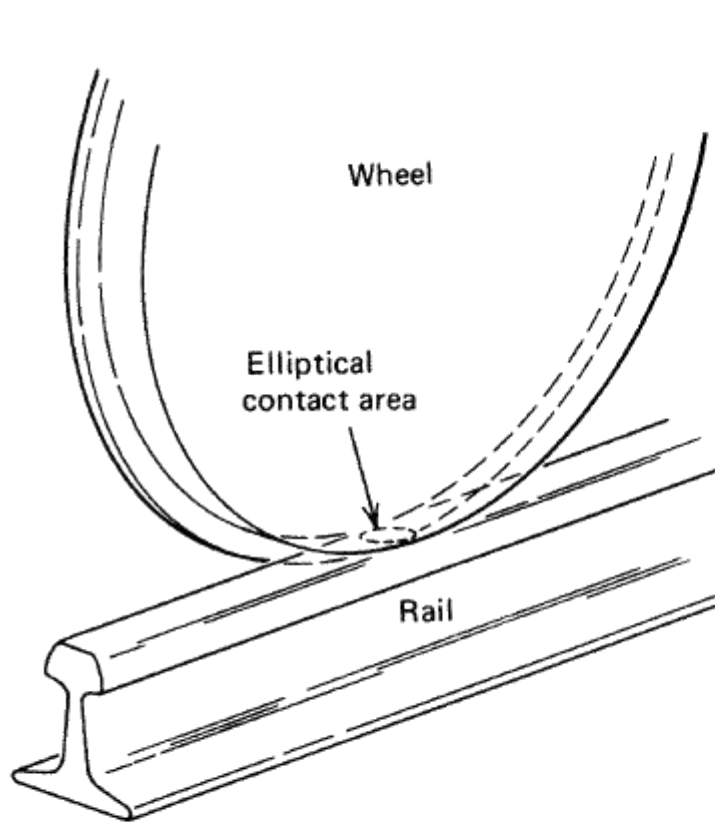


Filosofi Struktur Jalan Rel



Axle Load	Gross Weight of Cars	
Axle load (tons)	Gross weight of cars (lbs)	Type
10	80,000	Light rail transit
15	120,000	Heavy rail transit
25	200,000	Passenger Cars
25	200,000	Common European freight limit
27.5	220,000	U.K. and Select European limit
33	263,000	North American free interchange limit
36	286,000	Current Heavy Axle load weight for North American Class 1
39	315,000	Very limited use; research phase



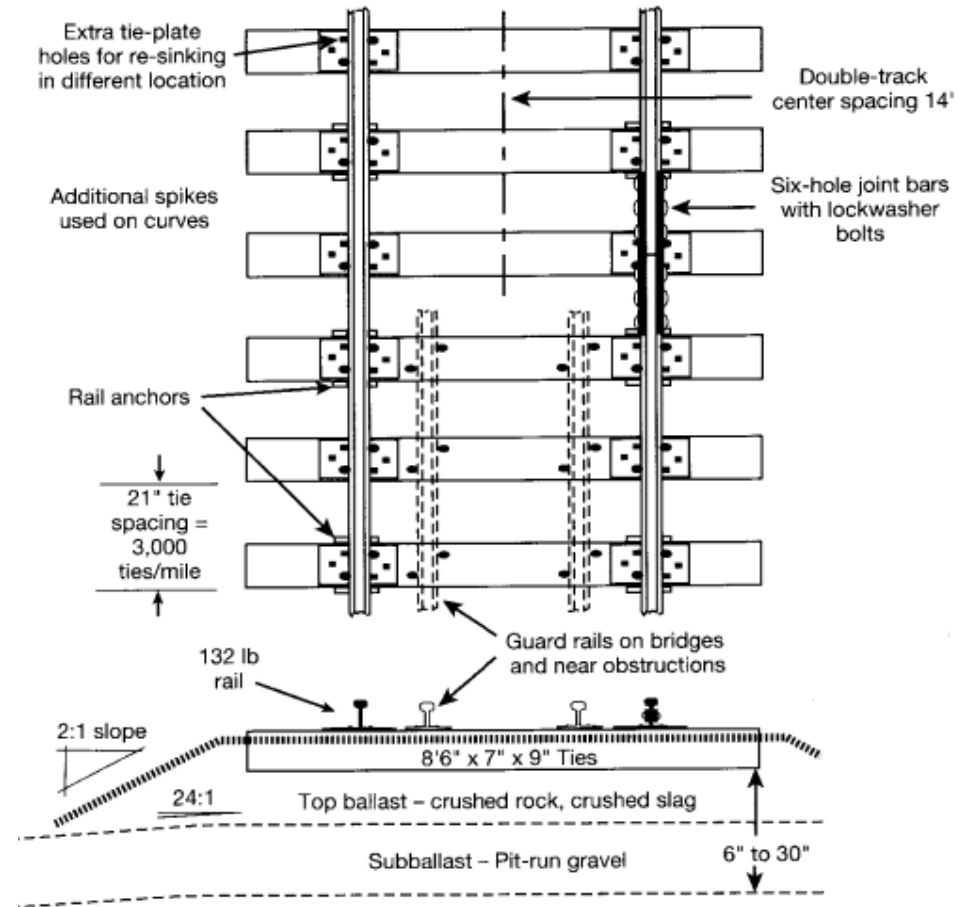


What is the size of the contact patch?



Jalan Rel (**Track**) adalah sistem dinamik komponen-komponen yang saling berhubungan (*interacting*) yang mampu mendistribusikan beban dan menyediakan jalur untuk kereta api berjalan dengan lancar, nyaman dan stabil.

Sistem harus **stabil** dalam arah **vertikal**, **lateral** dan **longitudinal**.



Derivatif **Filosofi** = **Kriteria Struktur**

Stiffness

Resiliency

Resistance to Permanent Deformation

Stability

Adjustability



Disain Struktur

- Metode/pendekatan untuk mendisain struktur:
 - **Coba-Coba** (Trial and Error)
 - **Empirik** – based on trial and error
 - **Empirik/Rasional** – menentukan beban dan sifat material
 - **Rasional** – analisis tegangan-regangan (stress/strain) dan berdasarkan pengukuran (mekanistik-empirik)
- Trackbed (landasan struktur jalan rel) **bukan struktur jalan yang permanen** (permanent way) – sangat bervariasi dan memerlukan disain yang tepat → perlu perawatan secara reguler dan berkelanjutan → sistem pengelolaan (manajemen) jalan rel



Disain Pembebanan

Trackbed (landasan) sangat bergantung kepada variasi beban dan tegangan:

- Beban mati (dead loads)
- Beban hidup (live loads)
- Beban dinamik (dynamic loads)
- Gaya sentrifugal (centrifugal loads)
- Beban lateral (lateral loads)
- Beban termal (thermal loads) – CWR
- Beban longitudinal (longitudinal loads)
- Gerak rangkaian/wave action

Kondisi aktual bahan dan material penyusun struktur jalan rel, khususnya juga untuk landasan jalan rel (tanah dasar dan struktur geologi)

Belum terakomodasi dalam **PM 60 tahun 2012** dan **Peraturan Dinas No. 10 tahun 1986**

Masih mengacu pada **persamaan empirik dan pola pembebanan** (koefisien empirik) lama

Perilaku tegangan-regangan, dinamik dan pengaliran **pada tanah dasar tidak mendapatkan perhatian yang detail.**



1435 mm

b. Lebar Jalan Rel 1435 mm

Kelas Jalan	Daya Angkut Lintas (ton/tahun)	V maks (km/jam)	P maks gandar (ton)	Tipe Rel	Jenis Bantalan	Jenis Penambat	Tebal Balas Atas (cm)	Lebar Bahu Balas (cm)
					Jarak antar sumbu bantalan (cm)			
I	$> 20 \cdot 10^6$	160	22,5	R.60	Beton 60	Elastis Ganda	30	60
II	$10 \cdot 10^6 - 20 \cdot 10^6$	140	22,5	R.60	Beton 60	Elastis Ganda	30	50
III	$5 \cdot 10^6 - 10 \cdot 10^6$	120	22,5	R.60/R.54	Beton 60	Elastis Ganda	30	40
IV	$< 5 \cdot 10^6$	100	22,5	R.60/R.54	Beton 60	Elastis Ganda	30	40



Analisis Reaksi (Beban, Gaya, Momen, Defleksi)

TRACK ANALYSIS:

- Ditentukan beban ijin/allowable loads dan deformasinya
- Ditentukan beban aktual/actual loads dan deformasinya
- Dibandingkan dan disesuaikan (bahan komponen dan tebal)
 - Riset awal : **A.N. Talbot**
 - Pengembangan sistem – Winkler, Westergaard, Boussineq, etc.
 - Sistem komputasi /computer systems (layered analysis)
 - Talbot treated track as a continuous and elastically supported beam

TRACK STIFFNESS:

- Gerak up and down (pumping) akibat beban berulang pada jalan rel merupakan sumber utama kerusakan.
- Disain struktur harus tetap memperhitungkan defleksi minimum.
- Turunan dari gerak ini menyebabkan keausan komponen jalan rel.
- Parameter penting: pengukuran modulus → belum menjadi parameter utama dalam disain struktur jalan rel.



Beban dan Reaksi Tegangan pada Rel dan Bantalan

Kecepatan (km/jam)	120		
Beban gandar (ton)	18		
Beban dinamis	Talbot	Area	Eisnmen
Pd (kg)	16940.3	15922.74	10478.57

Perbandingan beban dinamis menurut teori Talbot (88,23%), AREA (76.91%) dan Eisenmann (16,42 %) lebih besar dari beban statis dengan beban gandar 18 ton.

Kecepatan (km/jam)	120		
Beban Gandar (ton)	18		
Beban dinamis	Talbot	Area	Eisenmen
σ_x (kg/cm²)	1196.027	1124.184	739.8125
Sbase (kg/cm²)	1150.705	1081.584	711.7783

Tipe rel R54 dengan kecepatan 120 km/jam, beban gandar 18 ton, beban dinamis menurut Talbot, Area Eisenmann telah memenuhi syarat tegangan ijin sebesar 1325 kg/cm² dan tahanan momen dasar sebesar 1176,8 kg/cm².

Kecepatan (km/jam)	120		
Beban gandar (ton)	18		
Beban dinamis	Talbot	Area	Eisnmen
Q (kg)	9944.236	9346.907	6151.093

Beban yang di distribusikan rel ke bantalan



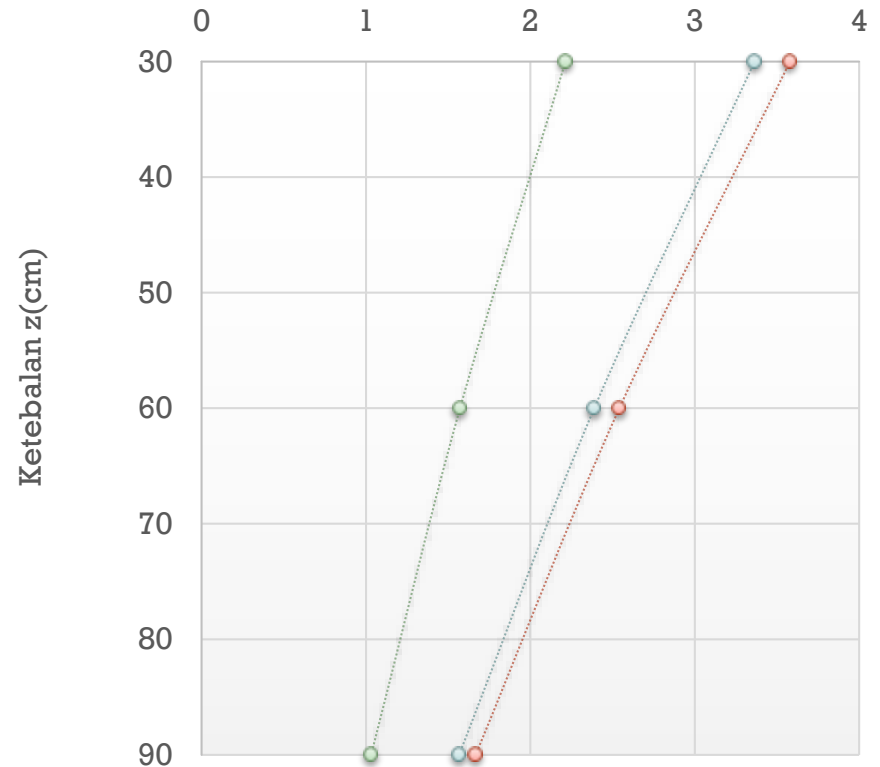
Reaksi Tegangan pada Balas

Kecepatan (km/jam)		120		
Beban (ton)		18		
Beban dinamis		Talbot	Area	Eisnmen
σ_z (kg/cm ²) dengan z (cm)	30	3.57897	3.36399	2.21380
σ_z (kg/cm ²) dengan z (cm)	60	2.54087	2.38825	1.57168
σ_z (kg/cm ²) dengan z (cm)	90	1.66640	1.56631	1.03077

Tegangan Vertikal yang diterima balas dengan Teori Boussinesq

Semakin tebal, balas yang digunakan tegangan vertikal diterima balas semakin kecil.

Tegangan Vertikal (km/cm²)



- V120,B18,Talbot
- V120,B18,Area
- V120,B18,Eisenmenn

Pengaruh tegangan vertikal dengan ketebalan balas model sederhana teori Boussinesq dengan kecepatan 120 km/jam dengan variasi ketebalan balas 30,60,90 cm



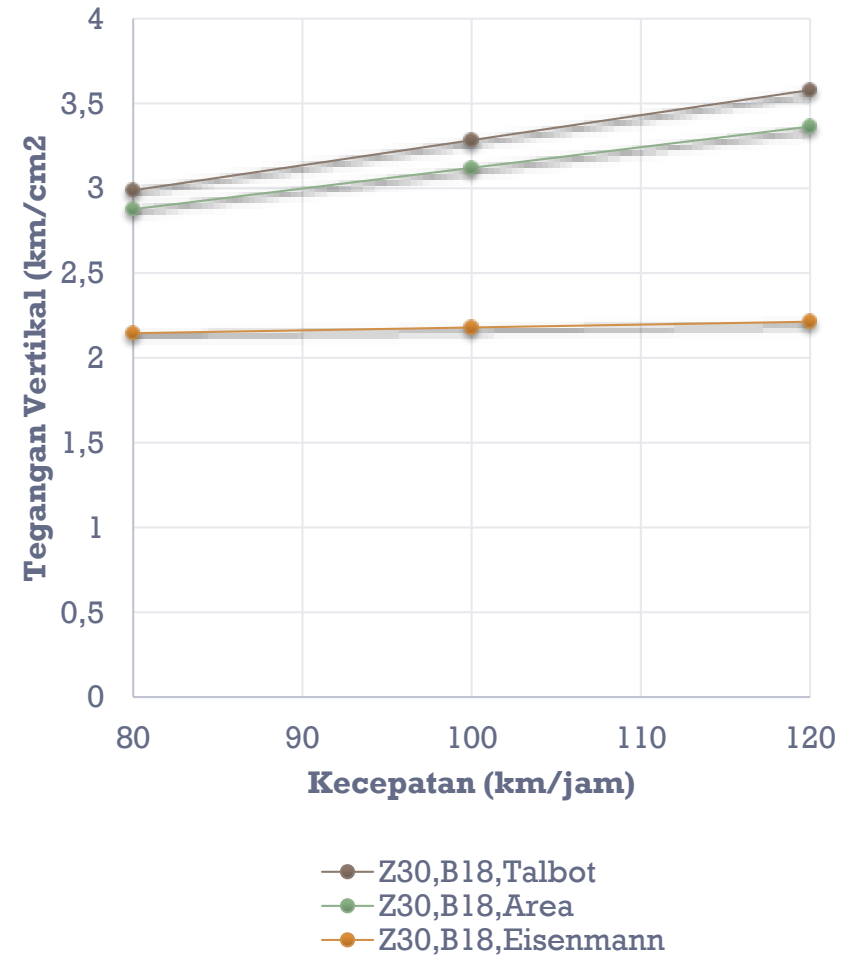
Kecepatan (km/jam)		120		
Beban (ton)		18		
Beban dinamis		Talbot	Area	Eisnmen
σ_z (kg/cm²) dengan z (cm)	30	3.578	3.363	2.213
Kecepatan (km/jam)		100		
Beban (ton)		18		
Beban dinamis		Talbot	Area	Eisnmen
σ_z (kg/cm²) dengan z (cm)	30	3.283	3.120	2.179
Kecepatan (km/jam)		80		
Beban (ton)		18		
Beban dinamis		Talbot	Area	Eisnmen
σ_z (kg/cm²) dengan z (cm)	30	2.988	2.87	2.145

Pengaruh tegangan vertikal dengan variasi kecepatan model sederhana teori Boussinesq dengan kedalaman 30 cm

Semakin tinggi kecepatan semakin besar tegangan vertikal yang diterima.



Reaksi tegangan balas dengan variasi kecepatan



Reaksi tegangan pada ketebalan balas 30cm dengan variasi kecepatan 80,100 dan 120km/jam



Reaksi Tanah Dasar (Tanah Residu Lampung)

Hasil perhitungan tegangan vertikal yang diterima tanah dasar menurut teori BoEf (*Beam on Elastic Foundation*) dan JNR (*Japanese National Railways*) dengan kecepatan 120 km/jam beban dinamis menggunakan teori Talbot, Area dan Eissenmann, beban gandar 18 ton ketebalan keseluruhan balas dan sub-balas 80 cm

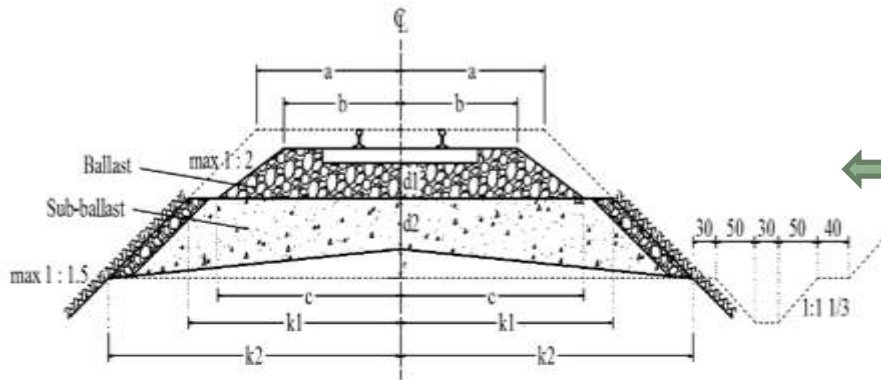
Kecepatan (km/jam)	120		
Beban (ton)	18		
Beban dinamis	Talbot	Area	Eisnmen
σ_2 (kg/cm ²)	0.635876	0.59768	0.39332

Dibandingkan dengan tegangan (daya dukung) tanah ijin setempat sebesar 1,014 kg/cm².



Pemodelan Numerik dan Parameter Material

- Tahap geometri model



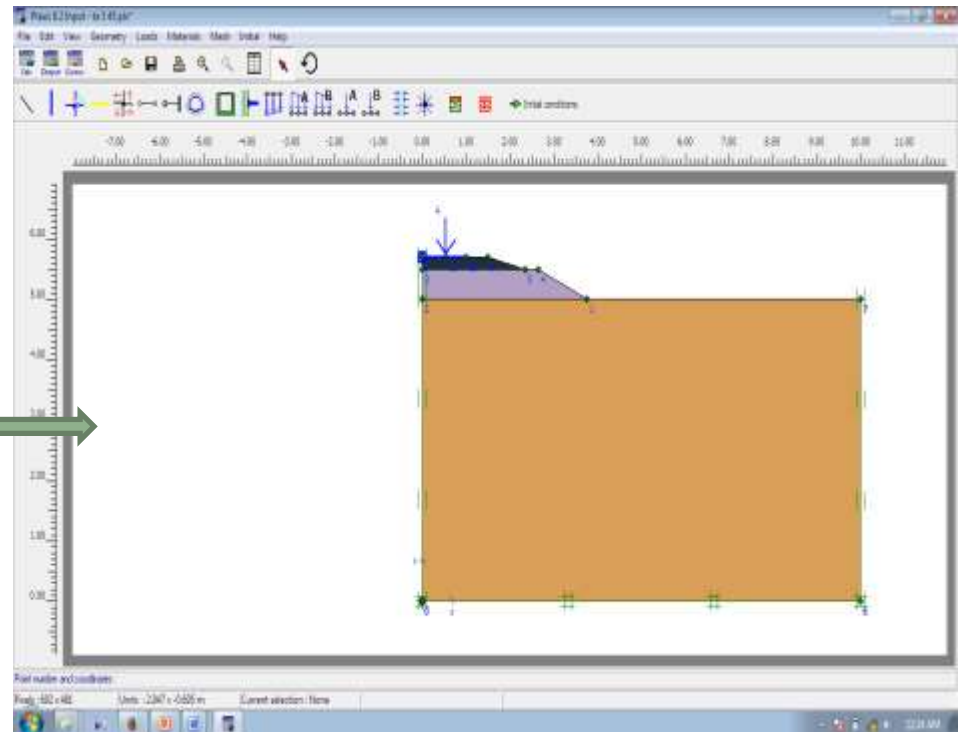
Penampang melintang struktur jalan rel dengan lebar jalan 1067 cm

KELAS JALAN	V Maks (km/jam)	d1 (cm)	b (cm)	c (cm)	k1 (cm)	d2 (cm)	e (cm)	k2 (cm)
I	120	30	150	235	265	15-50	25	375
II	110	30	150	235	265	15-50	25	375
III	100	30	140	225	240	15-50	22	325
IV	90	25	140	215	240	15-35	20	300
V	80	25	135	210	240	15-35	20	300

Sumber : PM No. 60 tahun 2012

Geometri model pada PLAXIS

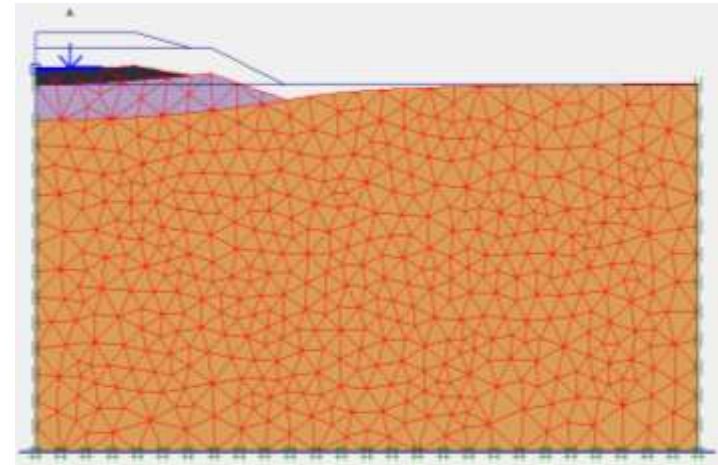
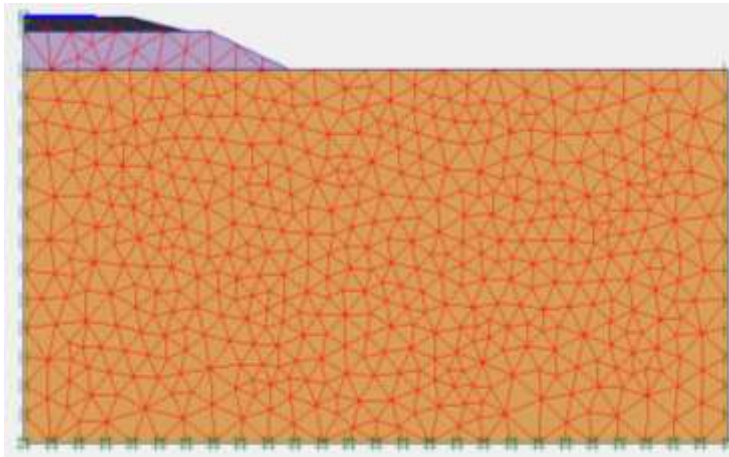
Untuk input dimensi tebal lapisan balas, digunakan variasi tebal lapisan balas 20 cm, 30 cm, 40 cm, 50 cm, dan 60 cm



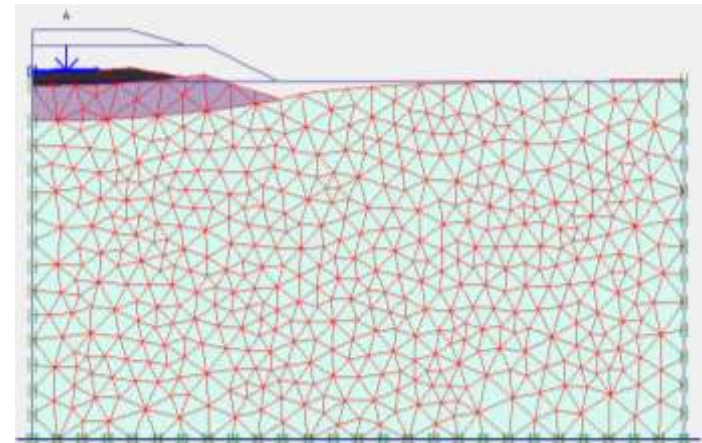
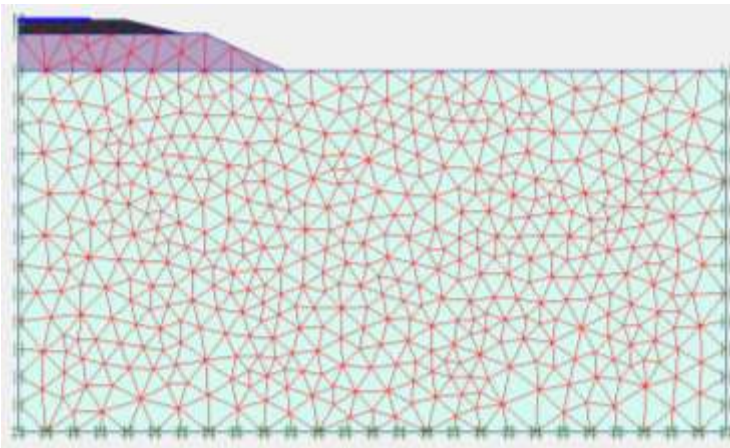
1. Besar Deformasi Akibat Beban Pada Lapis Jalan Rel

- Deformasi vertikal terkecil

Pola deformasi pada KM.117+600 dengan tebal balas 20 cm

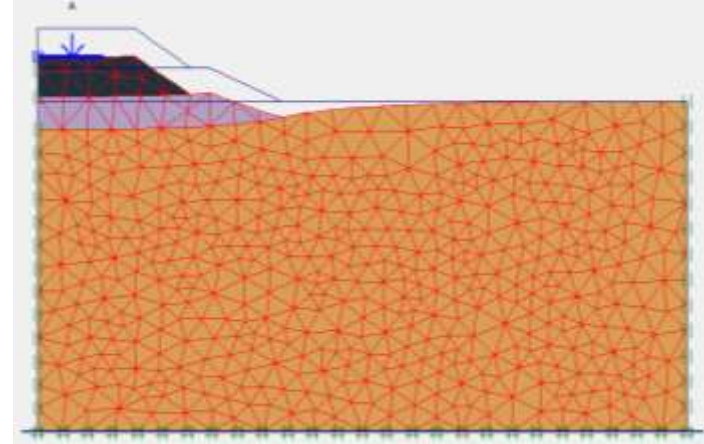
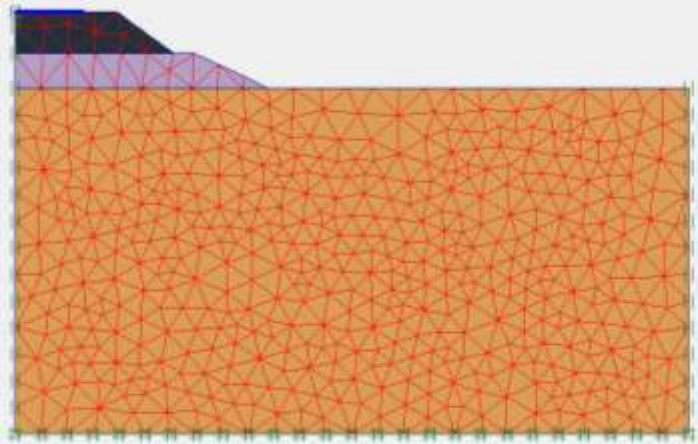


Pola deformasi pada KM.117+800 dengan tebal balas 20 cm

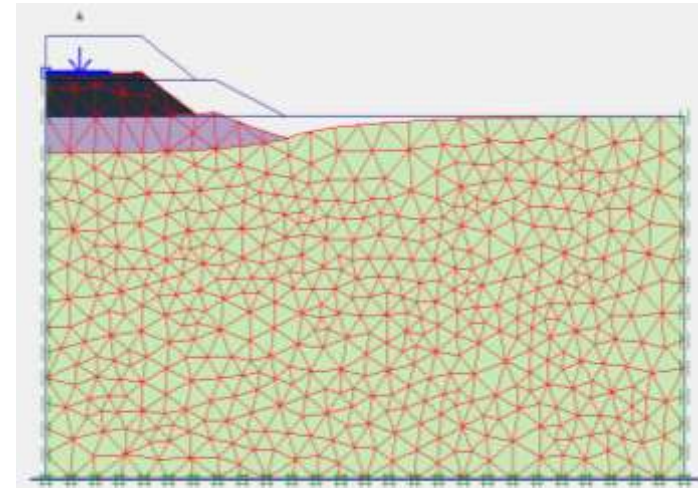
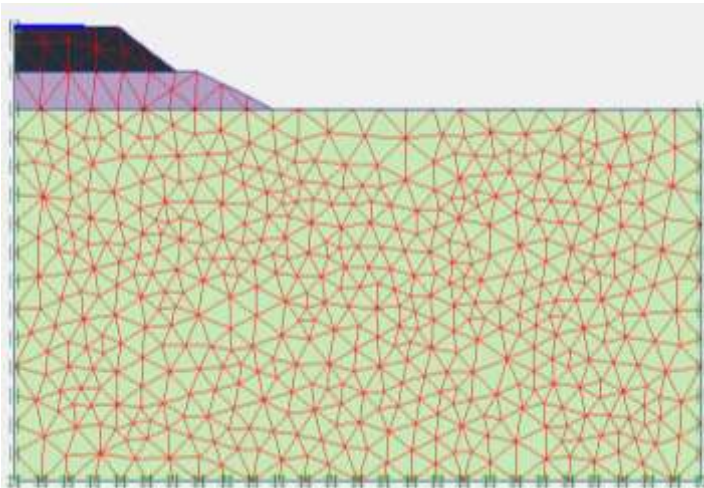


- Deformasi vertikal terbesar

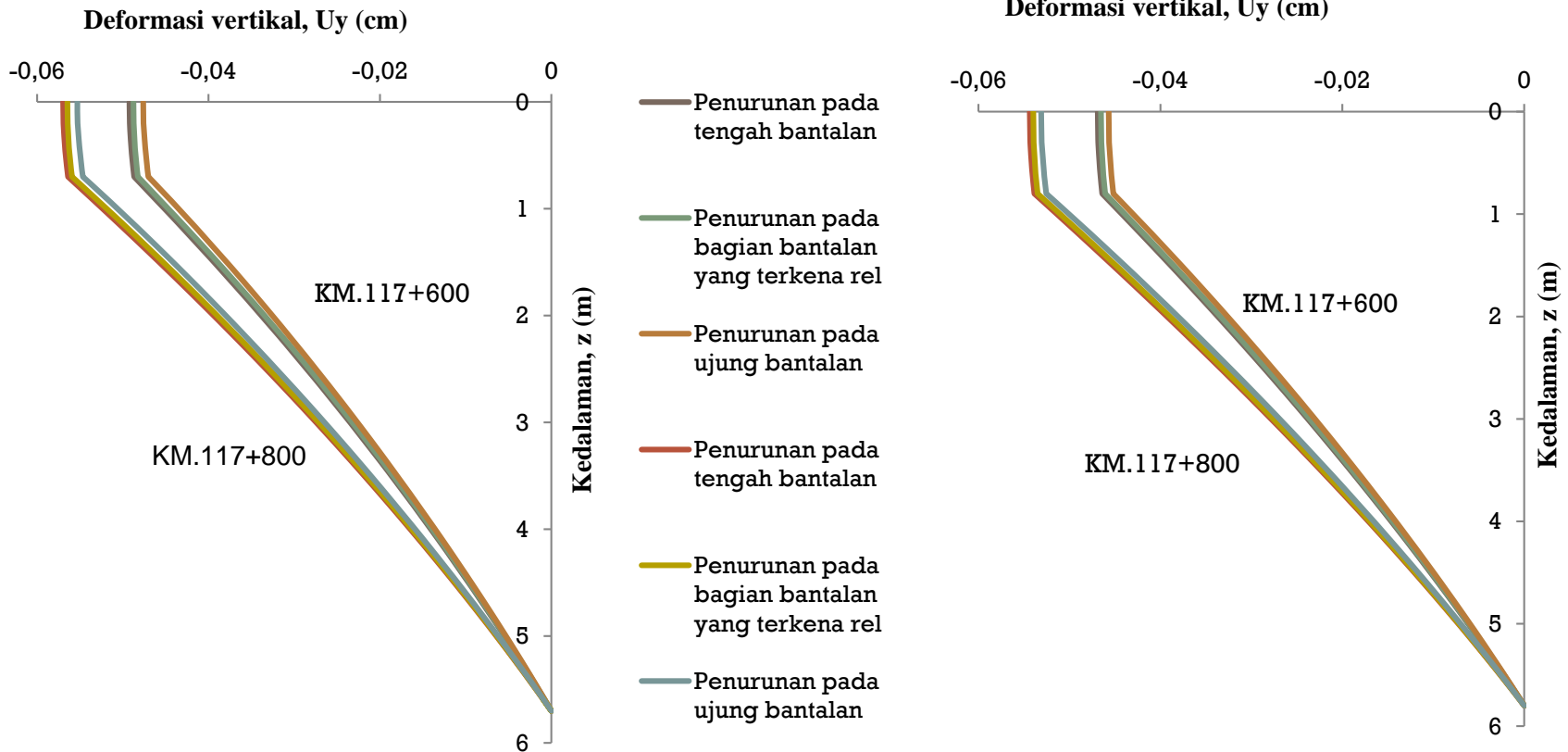
Pola deformasi pada KM.117+600 dengan tebal balas 60 cm



Pola deformasi pada KM.117+800 dengan tebal balas 60 cm



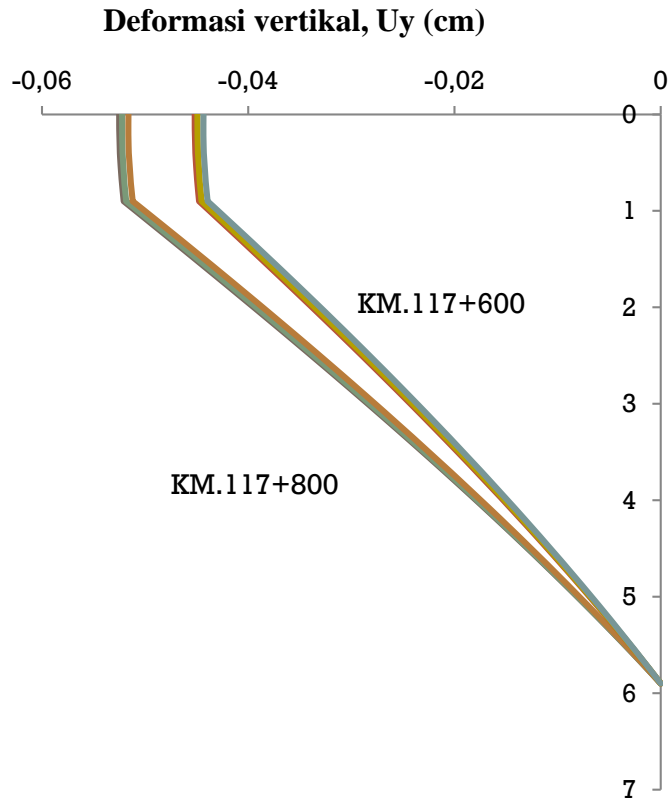
- Grafik deformasi vertikal dengan ketebalan lapisan jalan rel**



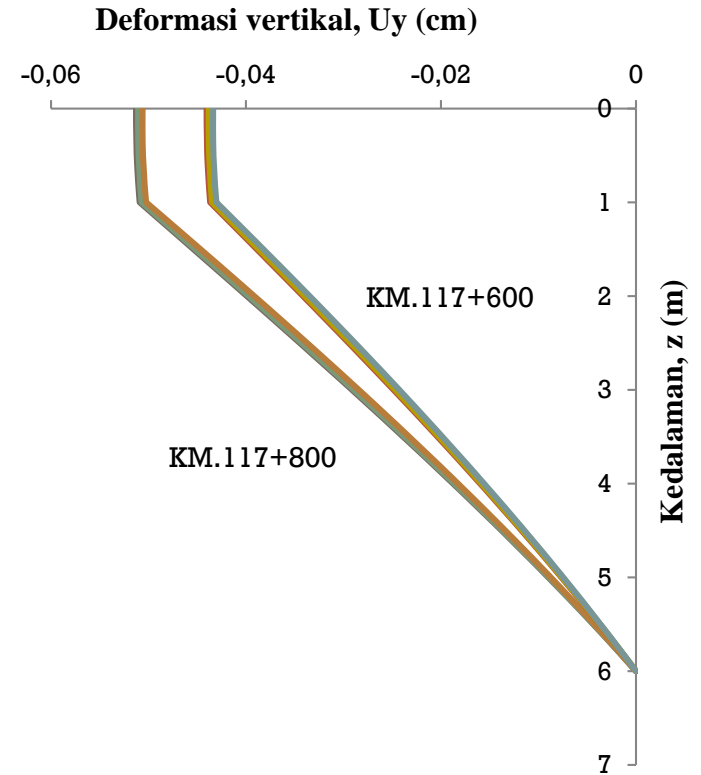
Grafik deformasi vertikal dengan ketebalan balas 20 cm

Grafik deformasi vertikal dengan ketebalan balas 30 cm





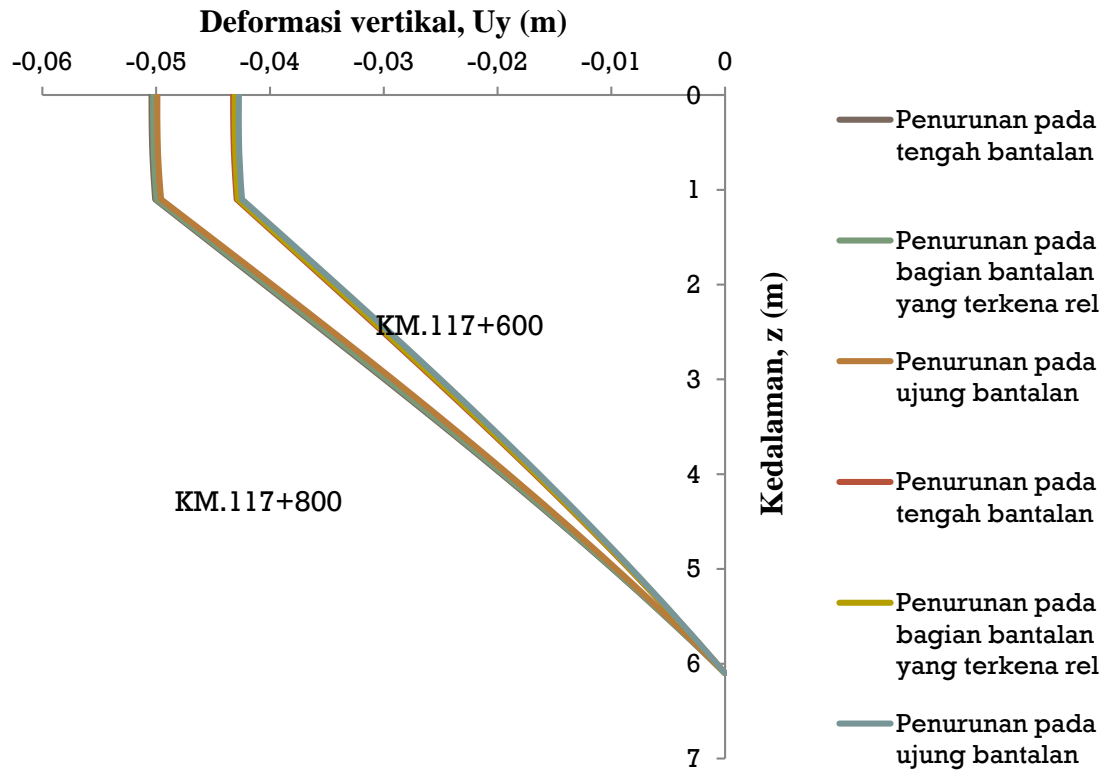
Grafik deformasi vertikal dengan ketebalan balas 30 cm



Grafik deformasi vertikal dengan ketebalan balas 40 cm

- Penurunan pada tengah bantalan
- Penurunan pada bagian bantalan yang terkena rel
- Penurunan pada ujung bantalan
- Penurunan pada tengah bantalan
- Penurunan pada bagian bantalan yang terkena rel
- Penurunan pada ujung bantalan



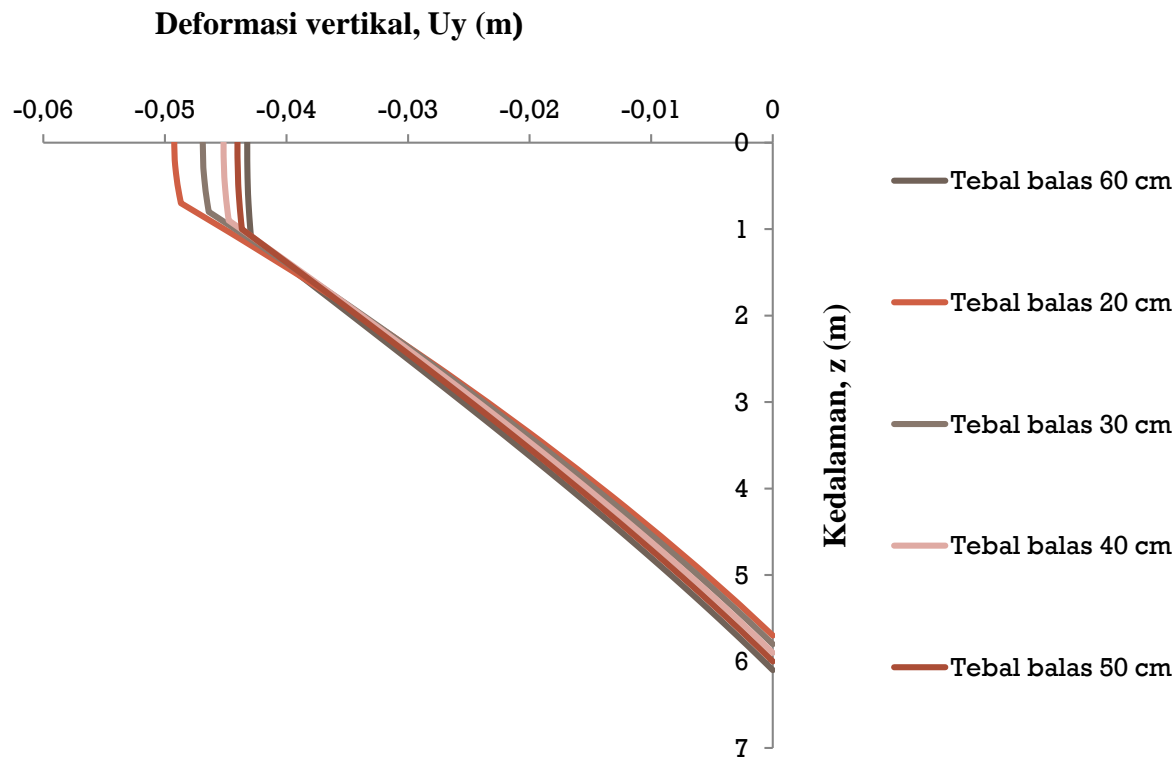


Grafik deformasi vertikal dengan ketebalan balas 60 cm



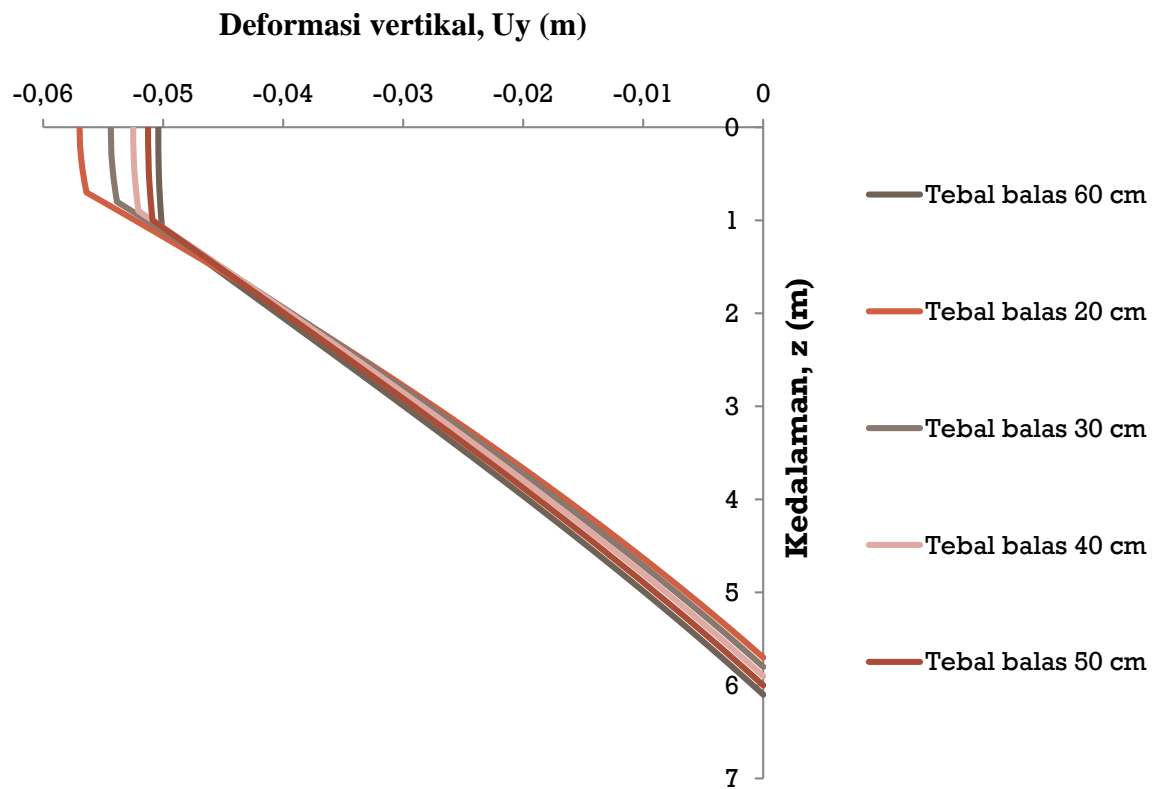
2. Pengaruh Tebal Lapisan Balas (*ballast*) Pada Lapis Jalan Rel Terhadap Deformasi Vertikal

- **Grafik Hubungan antara tebal lapisan balas dengan nilai deformasi vertikal**



Grafik deformasi vertikal pada KM.
117+600





Grafik deformasi vertikal pada KM.
117+800



Subgrade Damage Analysis

- Excessive permanent deformation controls failure
- Deformation is governed by the vertical compressive stress on the top of the subgrade
- Based on Highway experience
- The number of allowable repetitions before failure

$$N_d = 4.837 \times 10^{-5} \sigma_c^{-3.734} E_s^{+3.583}$$



Service Life Prediction

Damage Analysis



Service Life Prediction

Subgrade

- Excessive permanent deformation controls failure
- Deformation is governed by the vertical compressive stress on the top of the subgrade
- $N_d = 4.837 \times 10^{-5} \sigma_c^{-3.734} E_s^{3.583}$

Asphalt

- Fatigue cracking controls failure
- Fatigue cracking is governed by the tensile strain in the bottom of the asphalt
- $N_a = 0.0795 \times \varepsilon_a^{-3.291} E_a^{-0.853}$

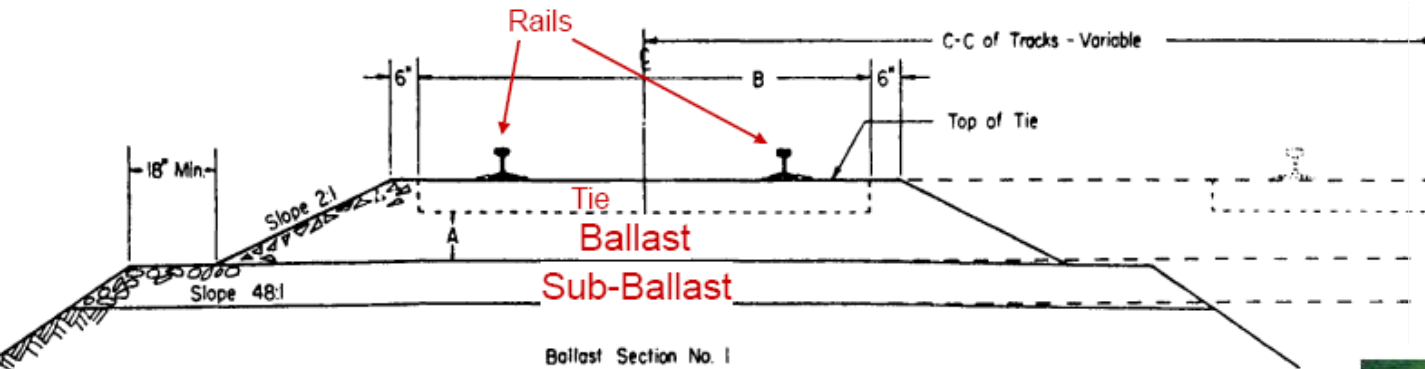
$$L = \frac{1}{\sum_{i=1}^n \frac{N_p}{N_a \text{ or } N_d}}$$

Subgrade Service Life

Asphalt Service Life



Ballast & sub-ballast cross-section*



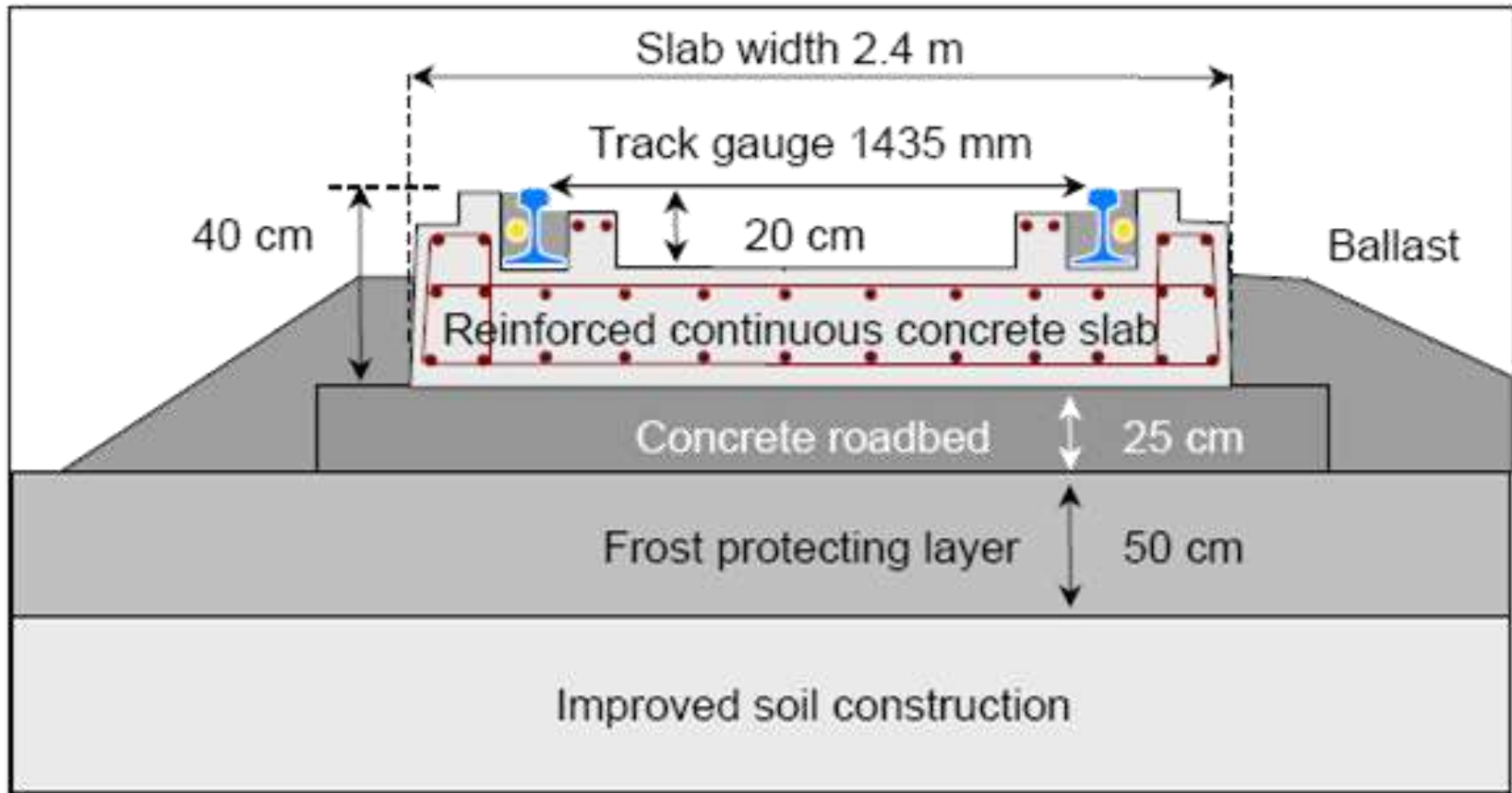
- Ballast and sub-ballast are the final stages in load distribution
- In addition to distributing vertical loads, ballast has a critical role maintaining longitudinal and lateral stability of track.
- Ballast and sub-ballast must provide adequate drainage.
- Ballast is subject to pulverization from loading and unloading as trains pass over, thereby generating fine particles that clog the ballast



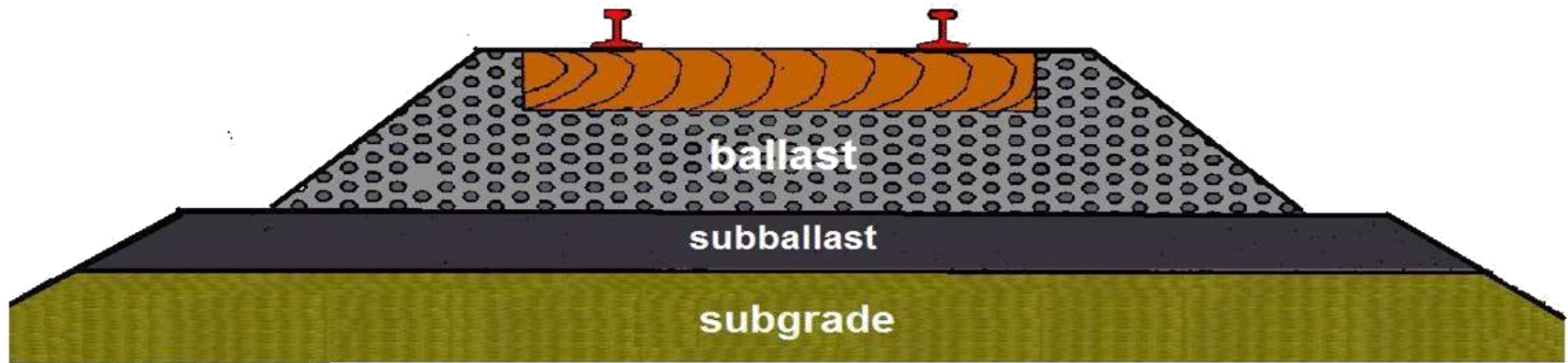
Kualitas tanah (geoteknik) sangat bervariasi dan sangat penting !



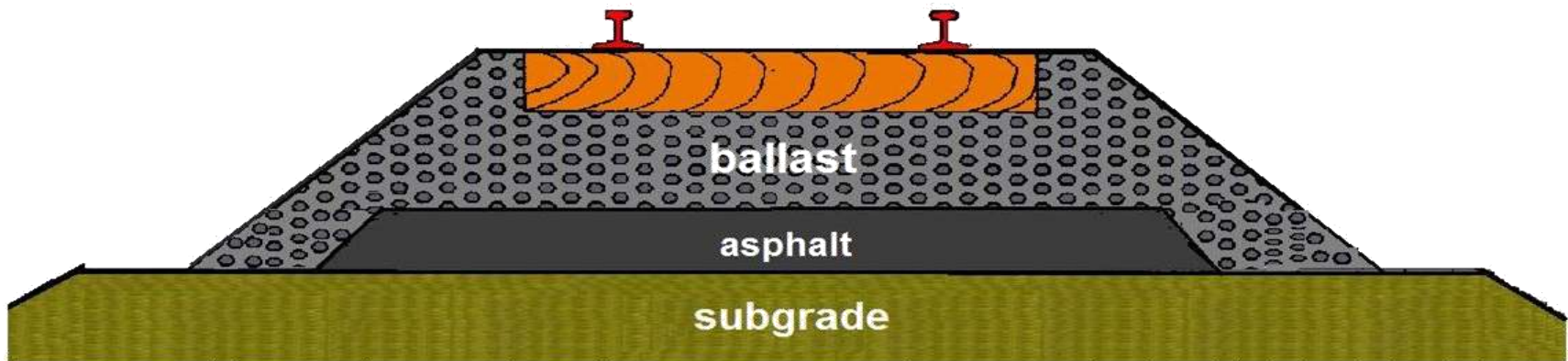
Innovation in Rail Track



TRACKBEDS

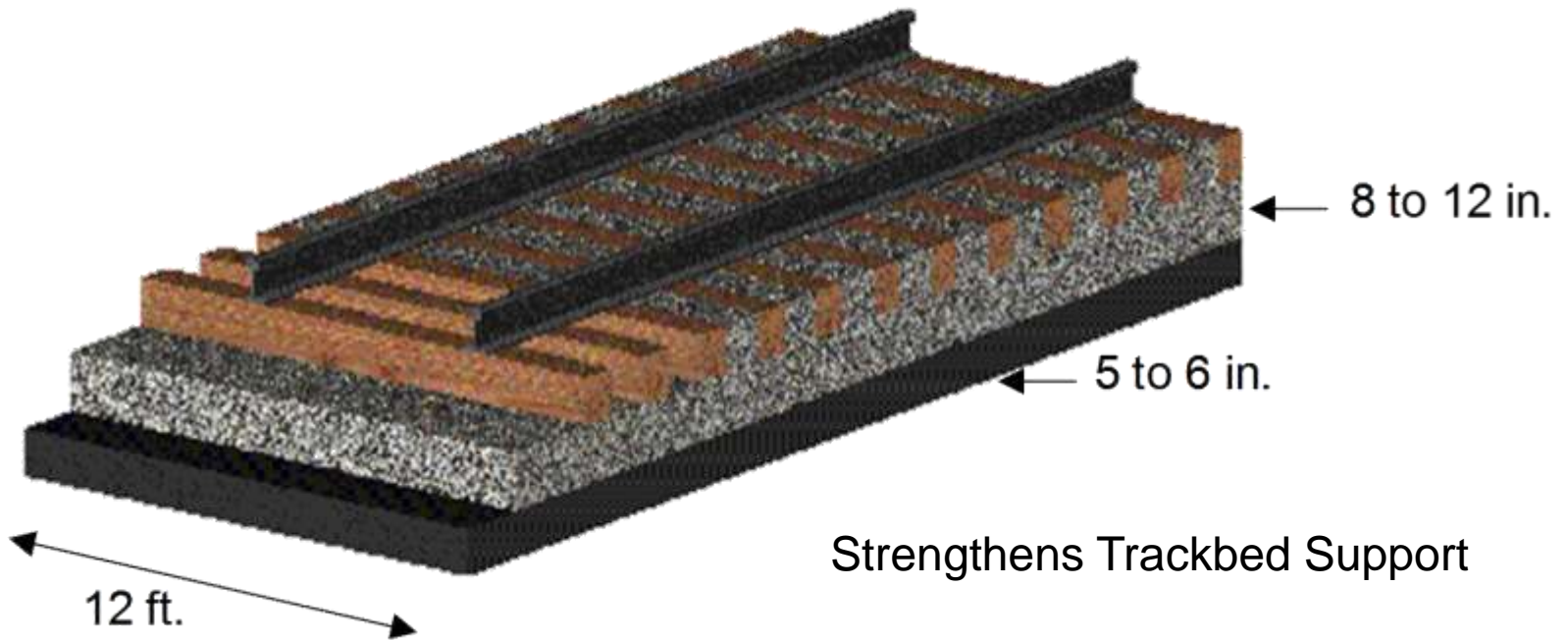


BALLASTED TRACKBED



ASPHALT TRACKBED





Strengthens Trackbed Support

Waterproofs Underlying Roadbed

Confines Ballast and Track



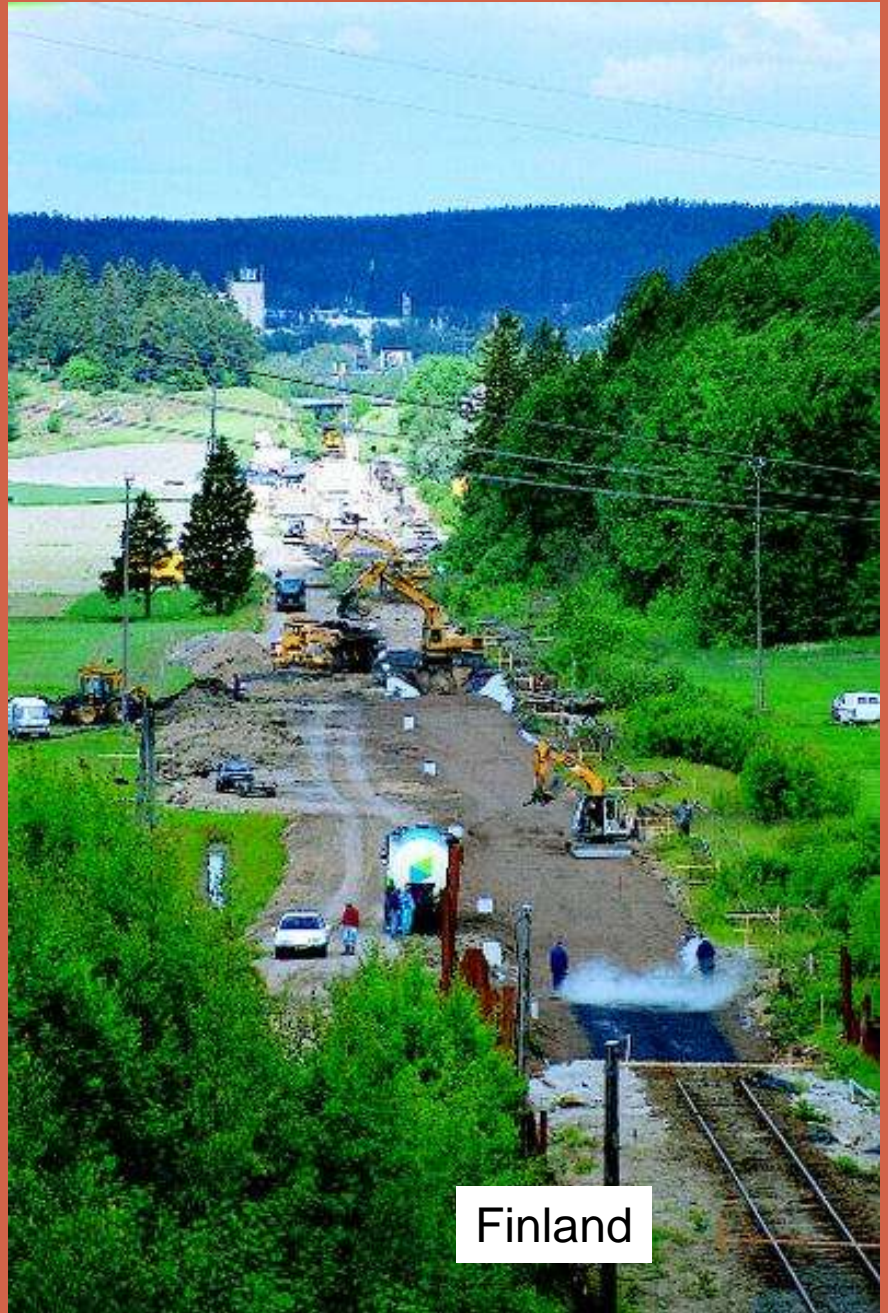




Italy



Germany



Finland









- Kondisi geografis → Iklim Tropis
 - Pengaruh curah hujan dan pergerakan angin
 - Kondisi geologi



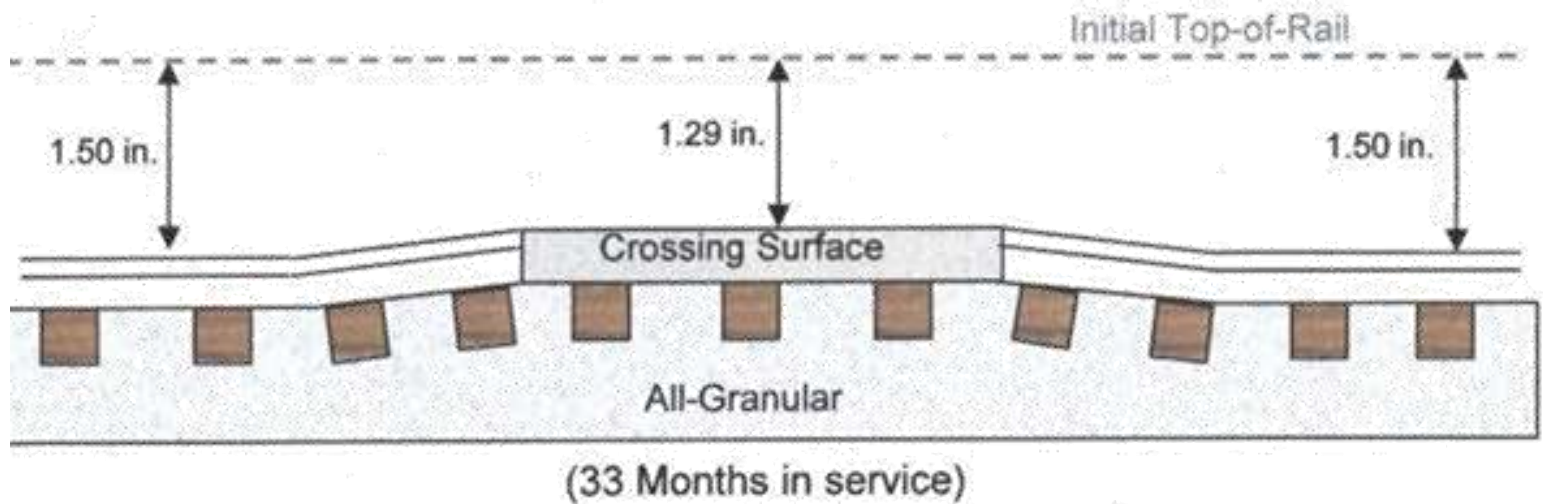
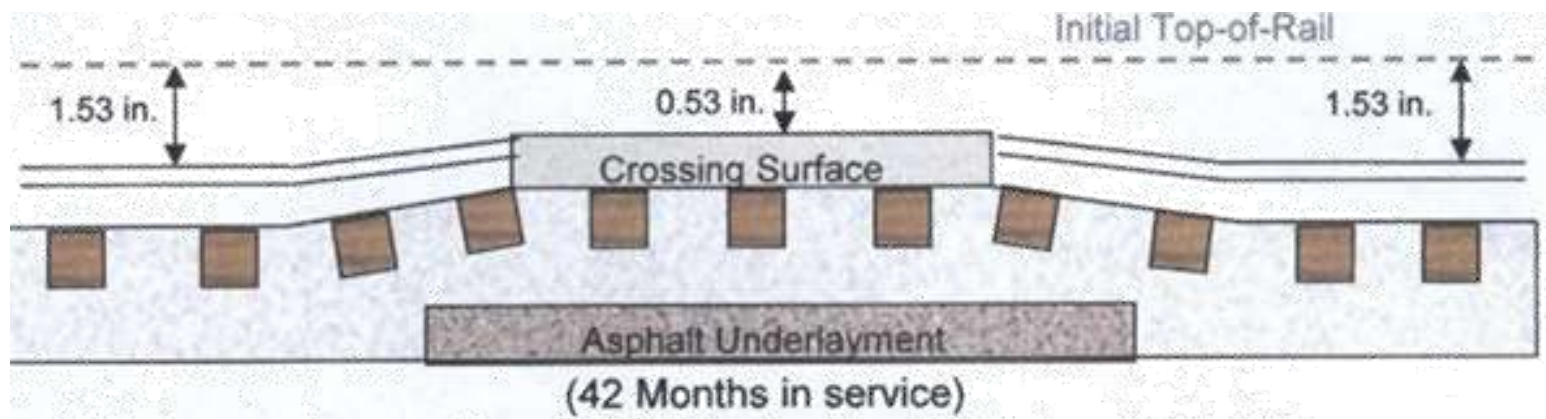
Variabilitas Jenis Tanah



Permasalahan Geoteknik

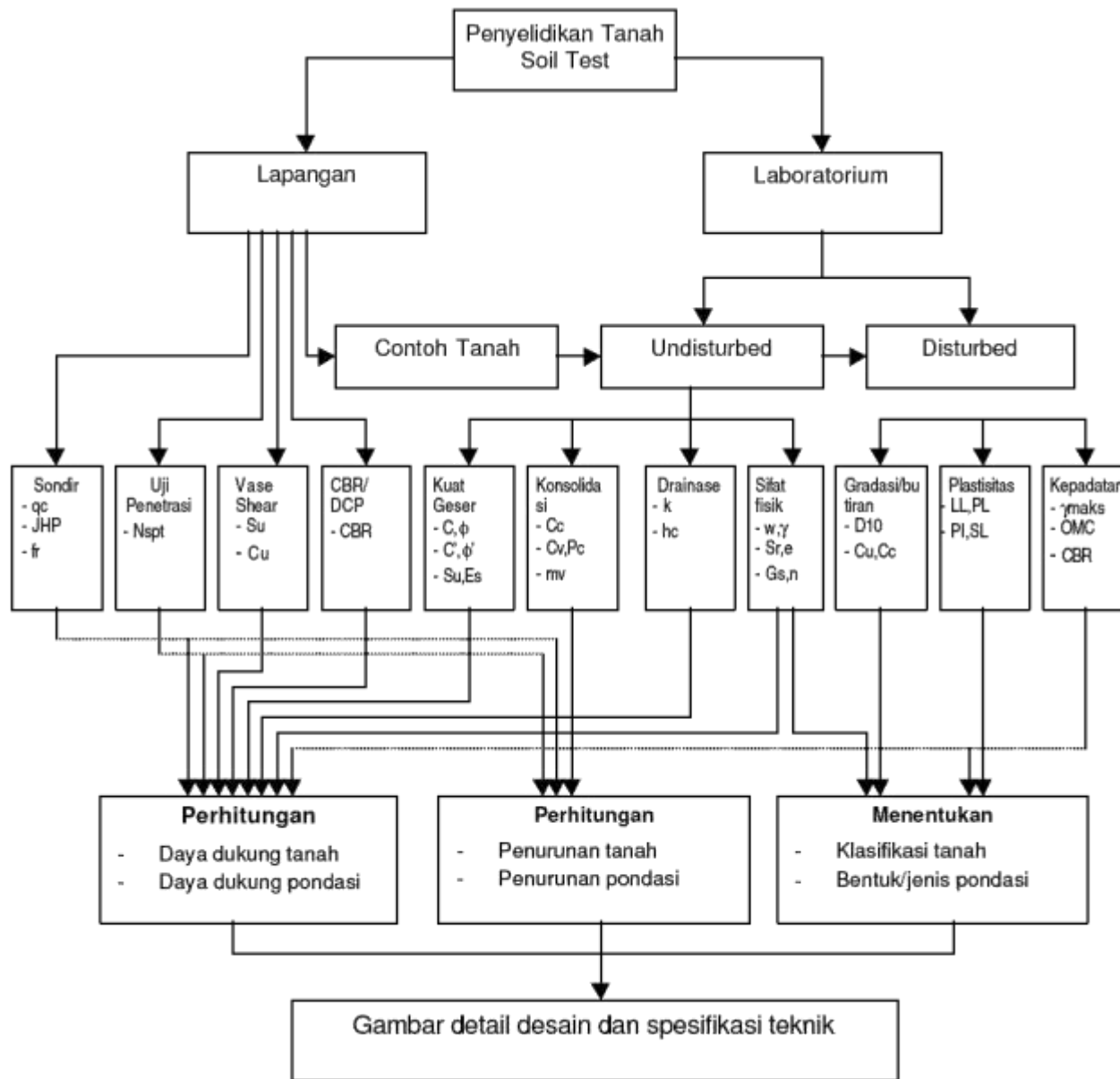
- ▶ Daya dukung tanah yang rendah → salah analisis/disain
- ▶ Badan jalan pada konstruksi timbunan
- ▶ Muka air (pengaliran) dangkal
- ▶ Seepage (rembesan)
- ▶ Konstruksi di atas tanah lunak
 - ▶ Primary settlement dan long-term settlement
 - ▶ Pengaliran
 - ▶ Expansive soil → daya dukung rendah
- ▶ Perilaku dinamik → beban gempa
 - ▶ Penurunan
 - ▶ Likuifaksi – alivium/endapan
 - ▶ Retak/geser
- ▶ Tanah bergerak





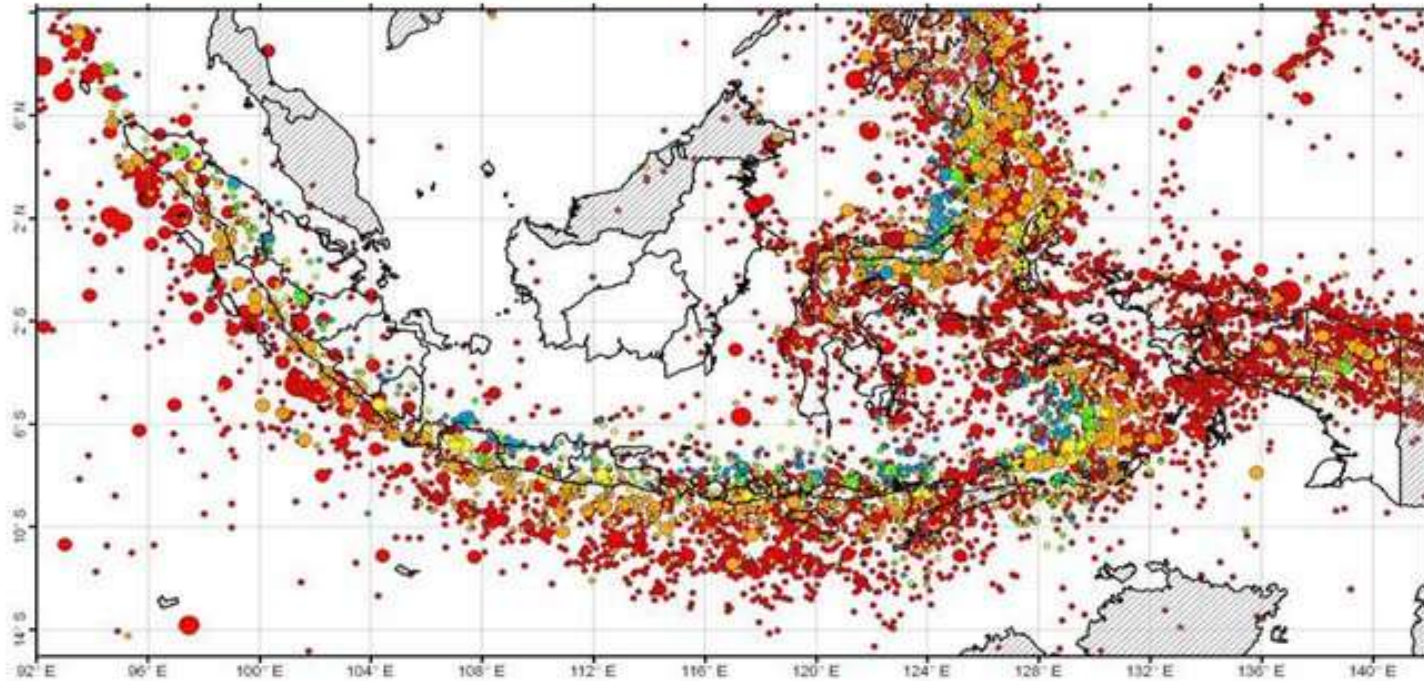
1.0 in. = 25.4 mm





Seismicity of Indonesia

Indonesia is one of the most seismically active countries in the world, it is situated in South-east Asia tectonic regime.

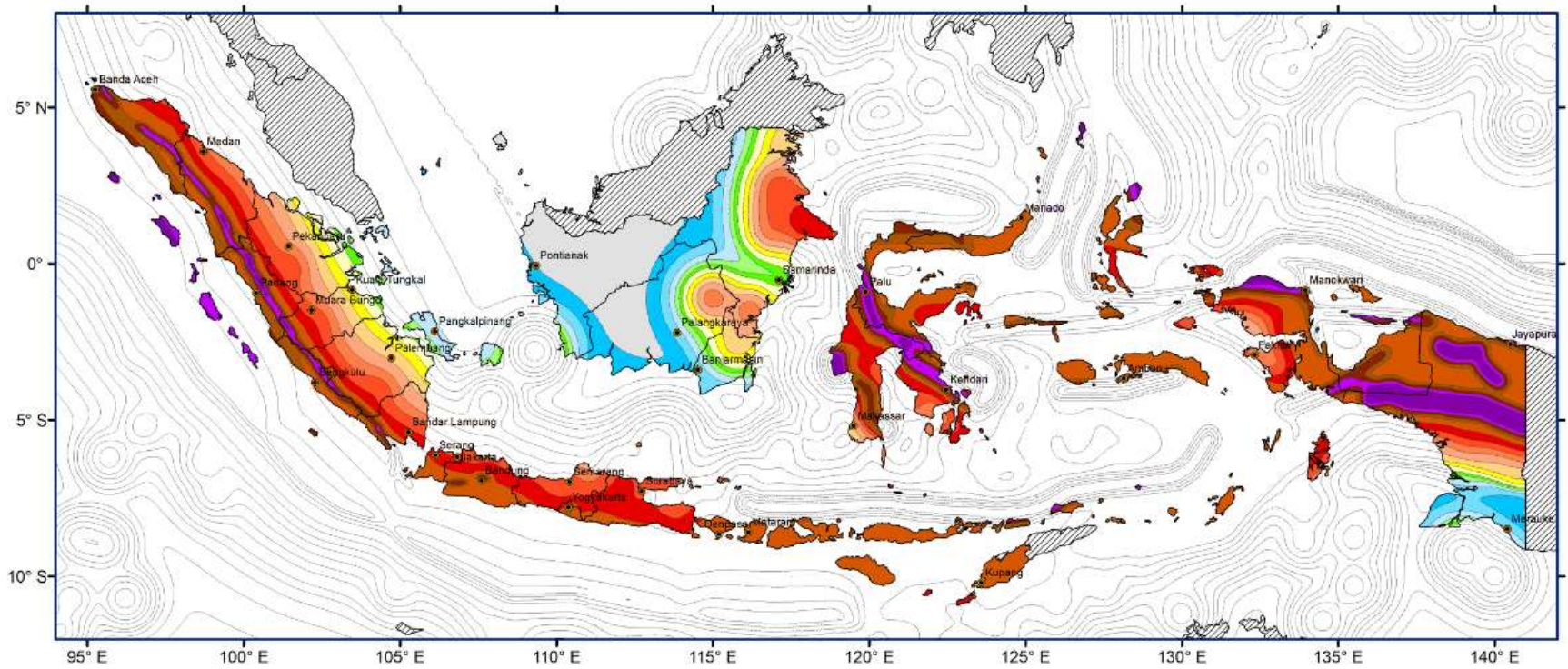


Main shocks only



Irsyam et al., 2010





Spectral response acceleration at short period 5% damped on site class E (soft soil profile)

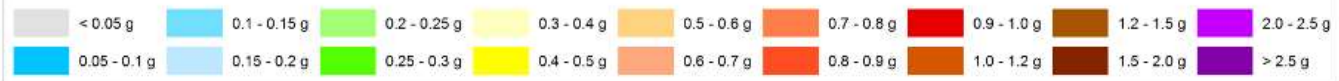
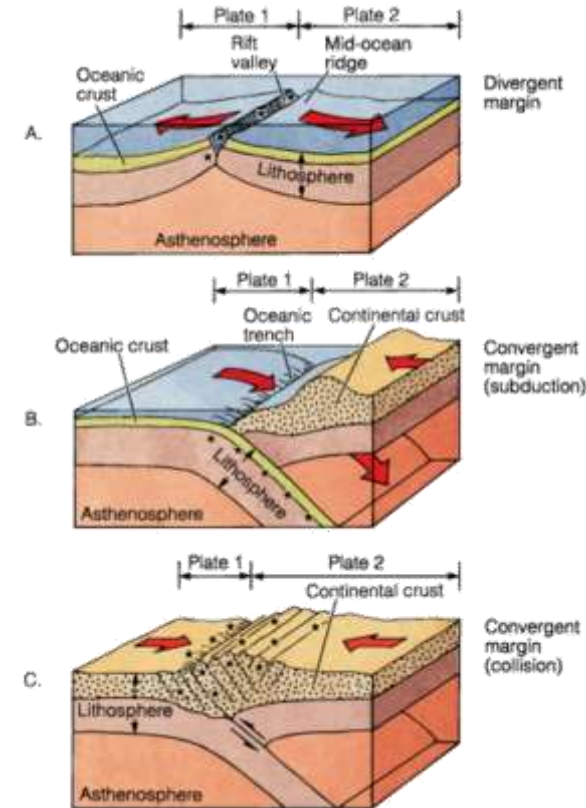
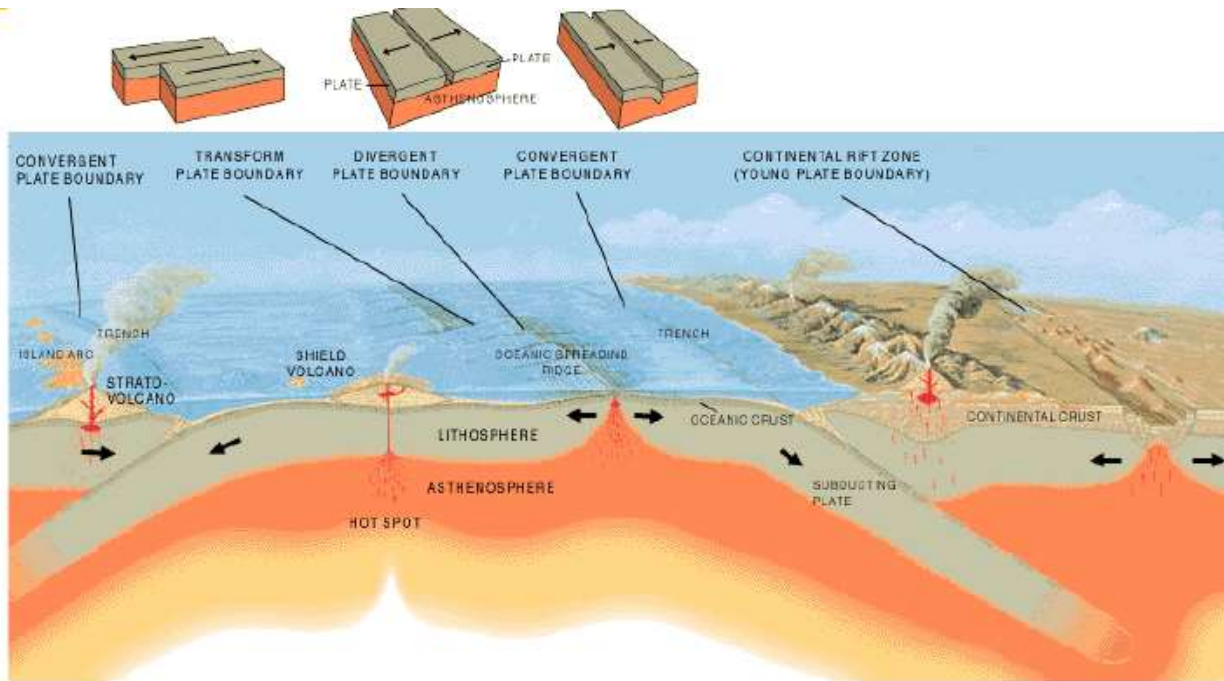
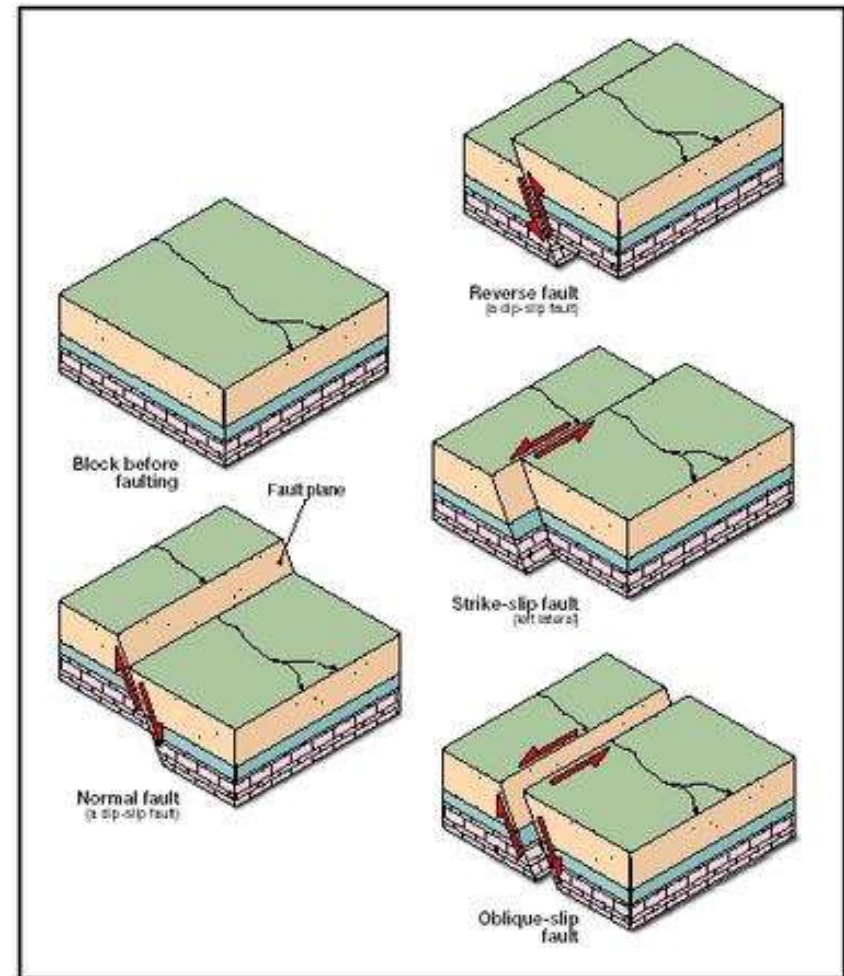
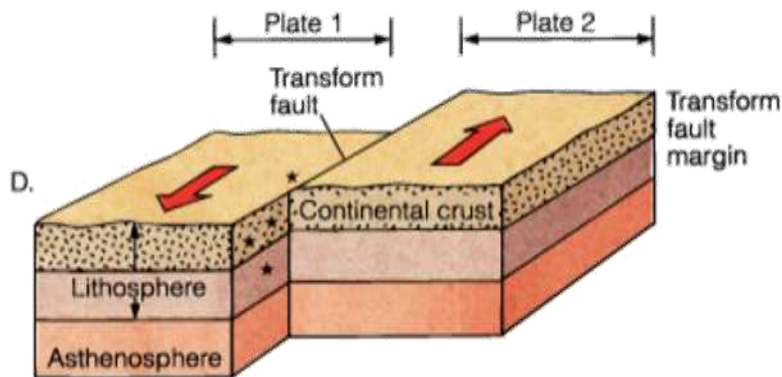


Plate Tectonics

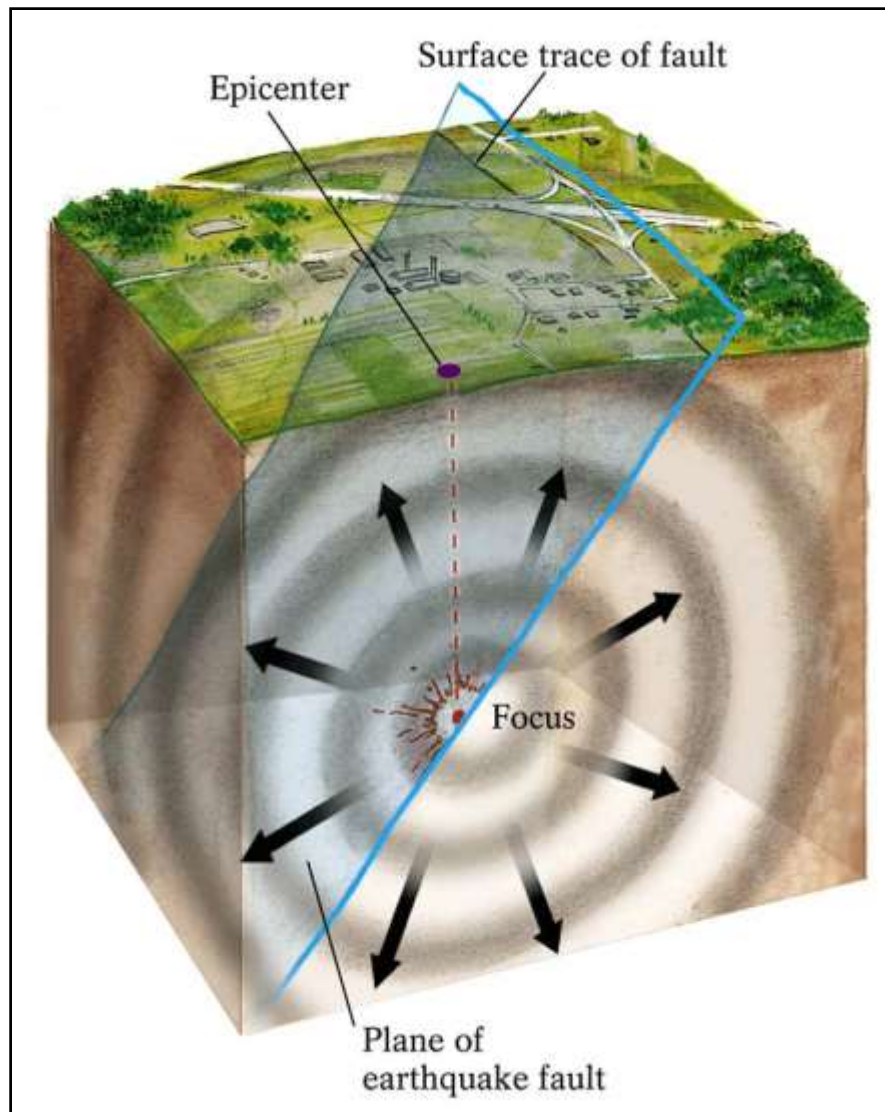


How does the EQ occur?

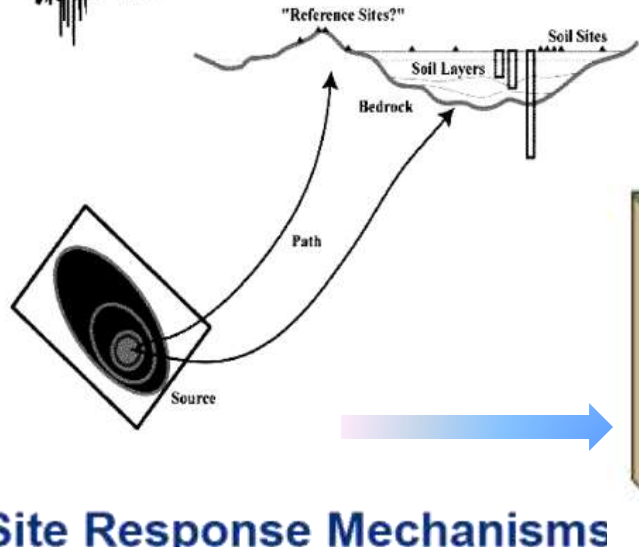
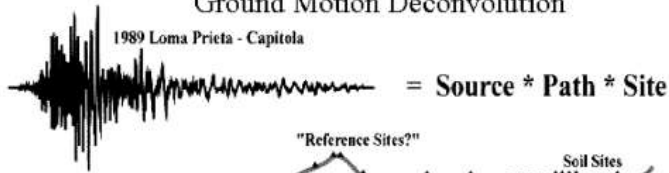
- ▶ Plates moving past each other do so along the **TRANSFORM FAULTS**.
- ▶ Earthquakes occur at **FAULTS**.
- ▶ Fault is a weak zone separating two geological blocks/plates.
- ▶ Tectonic forces cause the blocks to move relative one to another.



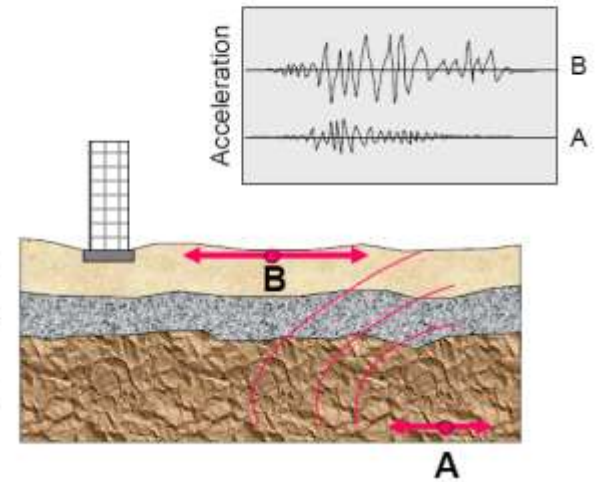
Anatomy of Earthquakes



Ground Motion Deconvolution



Site Amplification Is Common



Site Response Mechanisms

- Constant flux rate – impedance
 $\rho V_s \dot{u}^2 = \text{constant}$
- Resonances within the soil column

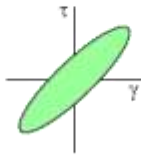


$$f_n = \frac{V_s}{4H}$$

Amplification

- Low-strain damping and apparent attenuation in soil

- Nonlinear soil behavior



Deamplification

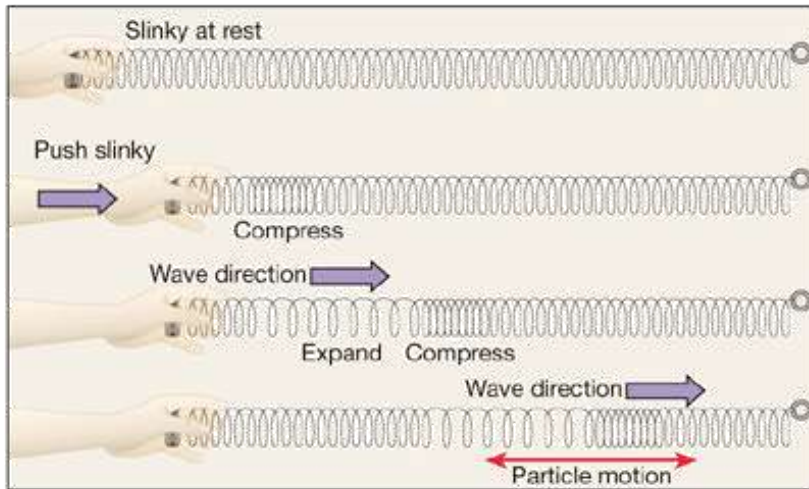
Focus

1	h_1, V_{s1}, D_1, ρ_1	
2	h_2, V_{s2}, D_2, ρ_2	
i		
n	h_n, V_{sn}, D_n, ρ_n	
n+1	$V_{s(n+1)}, D_{(n+1)}, \rho_{(n+1)}$	

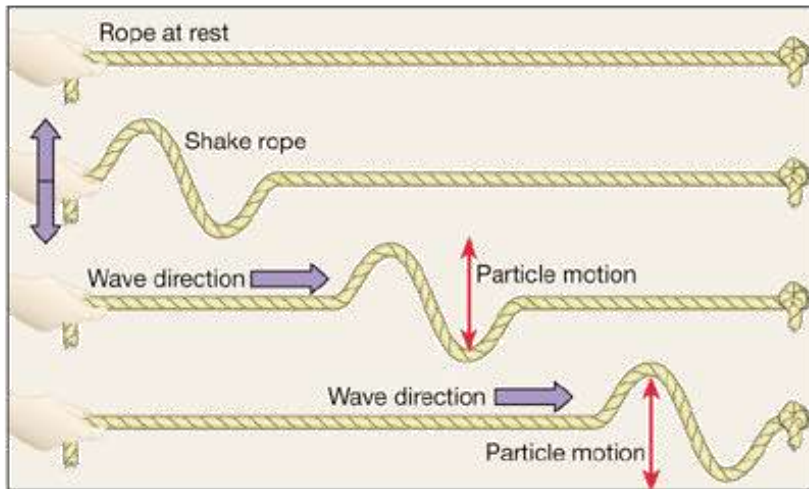
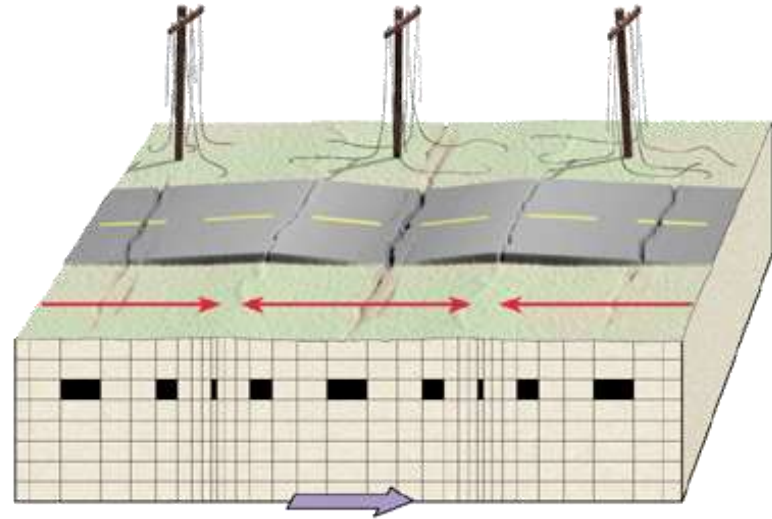
Figure adapted from Rix, G. J., (2001)



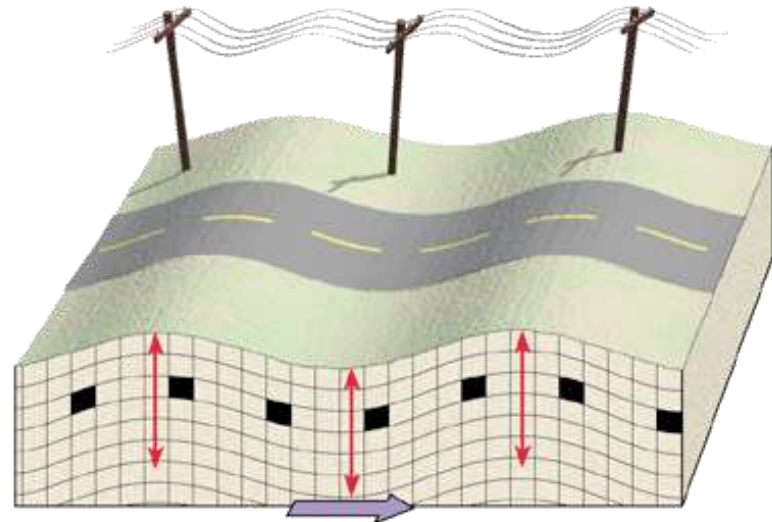
P and S waves



A. P wave

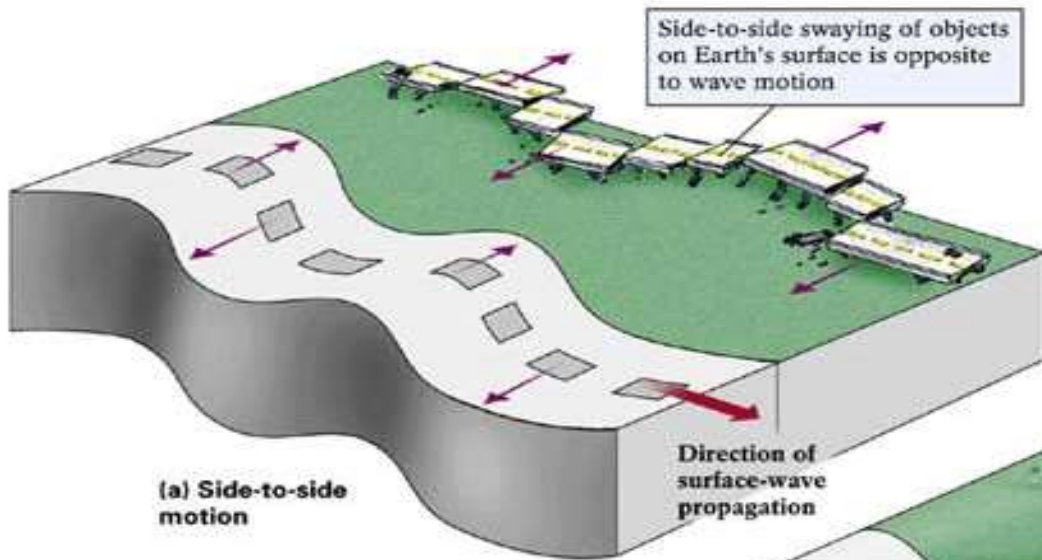


B. S wave

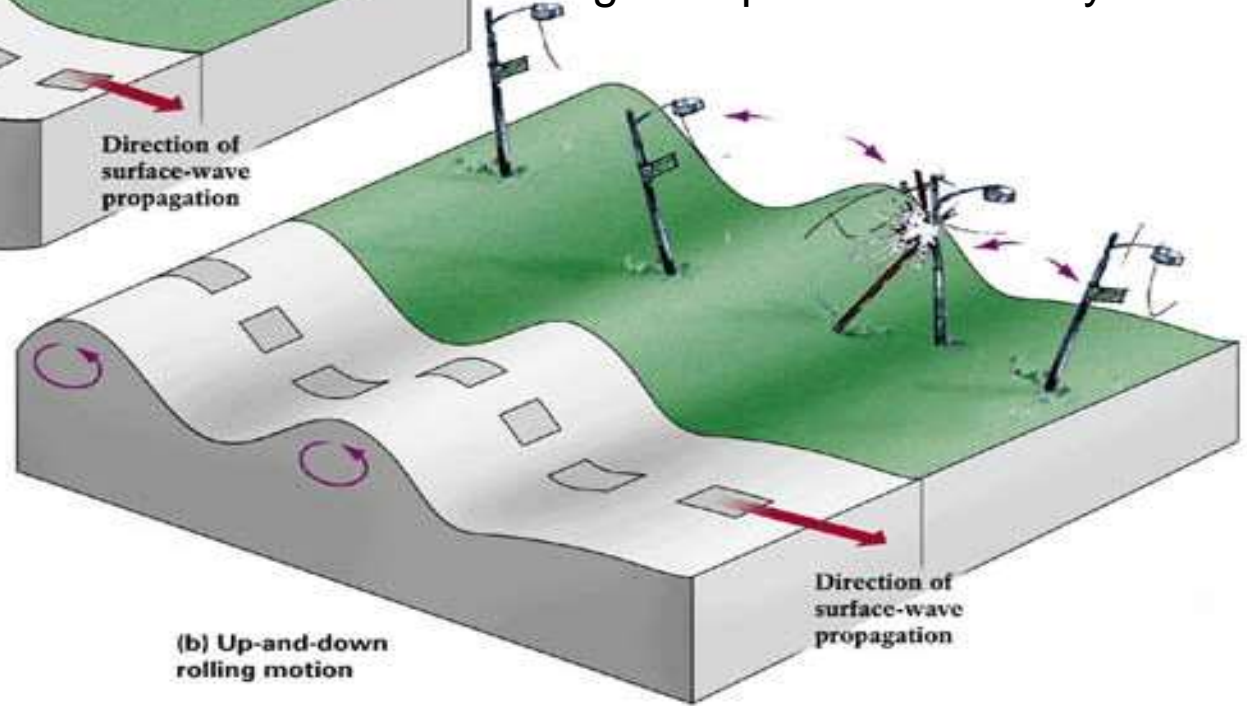


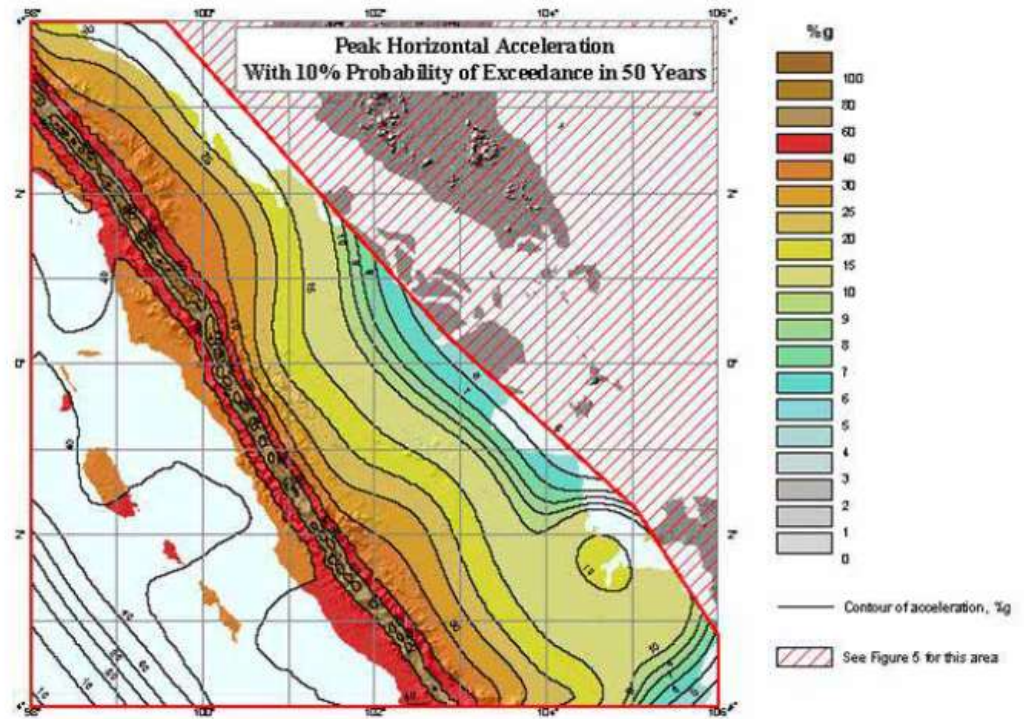
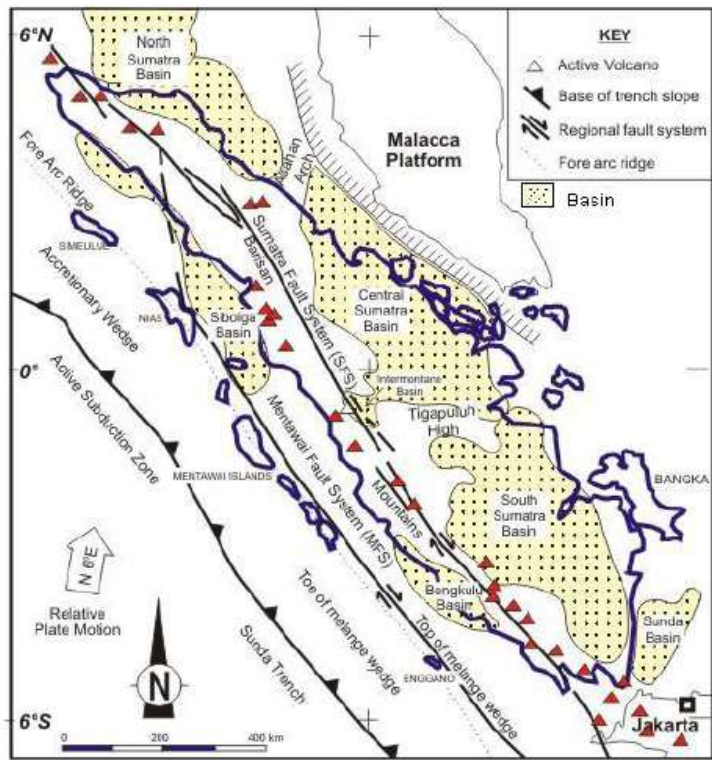
Smaller amplitude than surface (L) waves, but faster, P arrives first





Most of the destruction
Larger amplitude than body waves

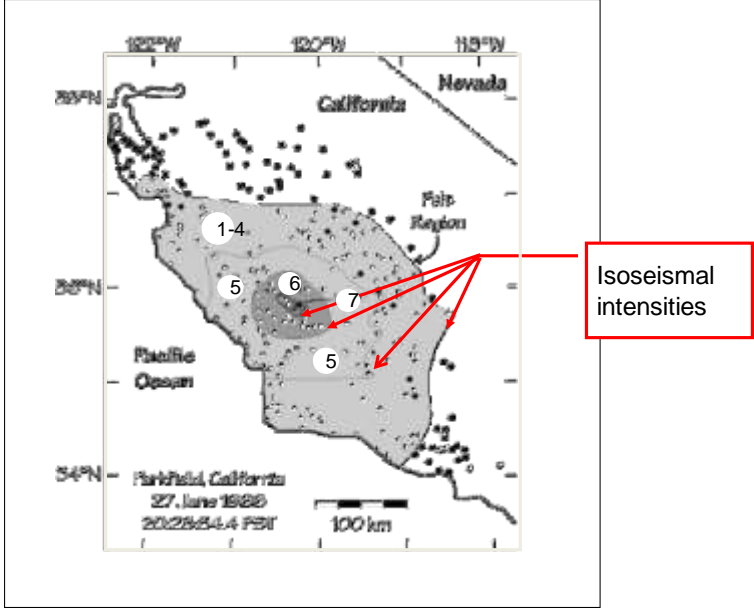
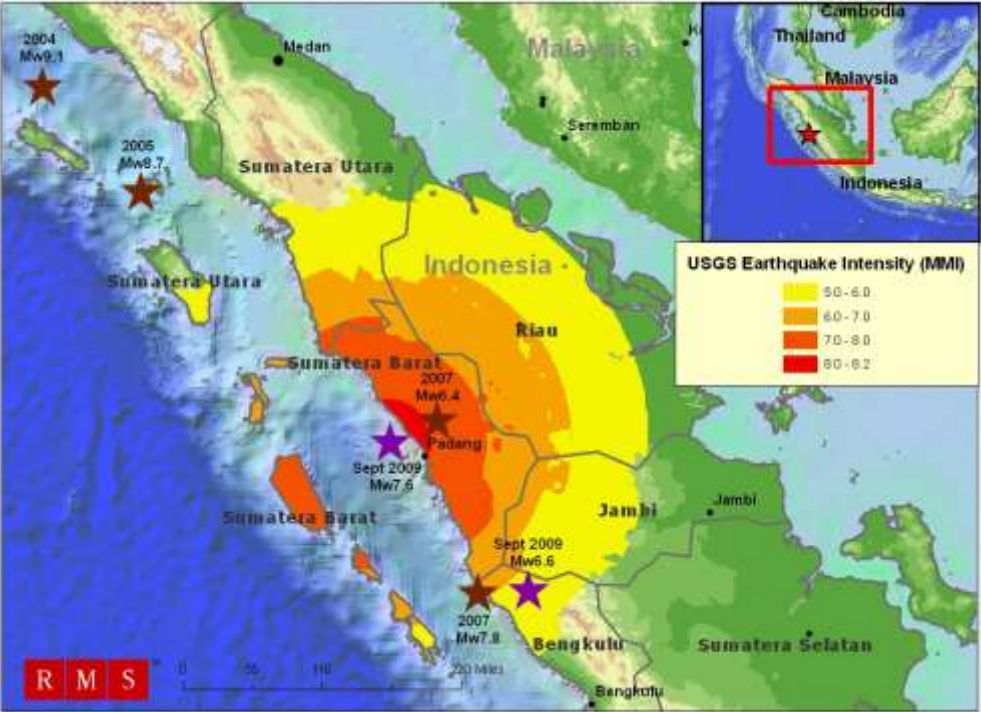




Gambar 8. Peta besar guncangan gempa di Sumatra berdasarkan analisa PSHA. Diambil nilai PGA untuk "10% probability of exceedance" dalam 50 tahun.(dari *Petersen et al* [2004]).



Intensity Patterns and Maps



Liquefaction damage -Niigata, Japan 1964



Soil/Sand Boils



Surface Rupture



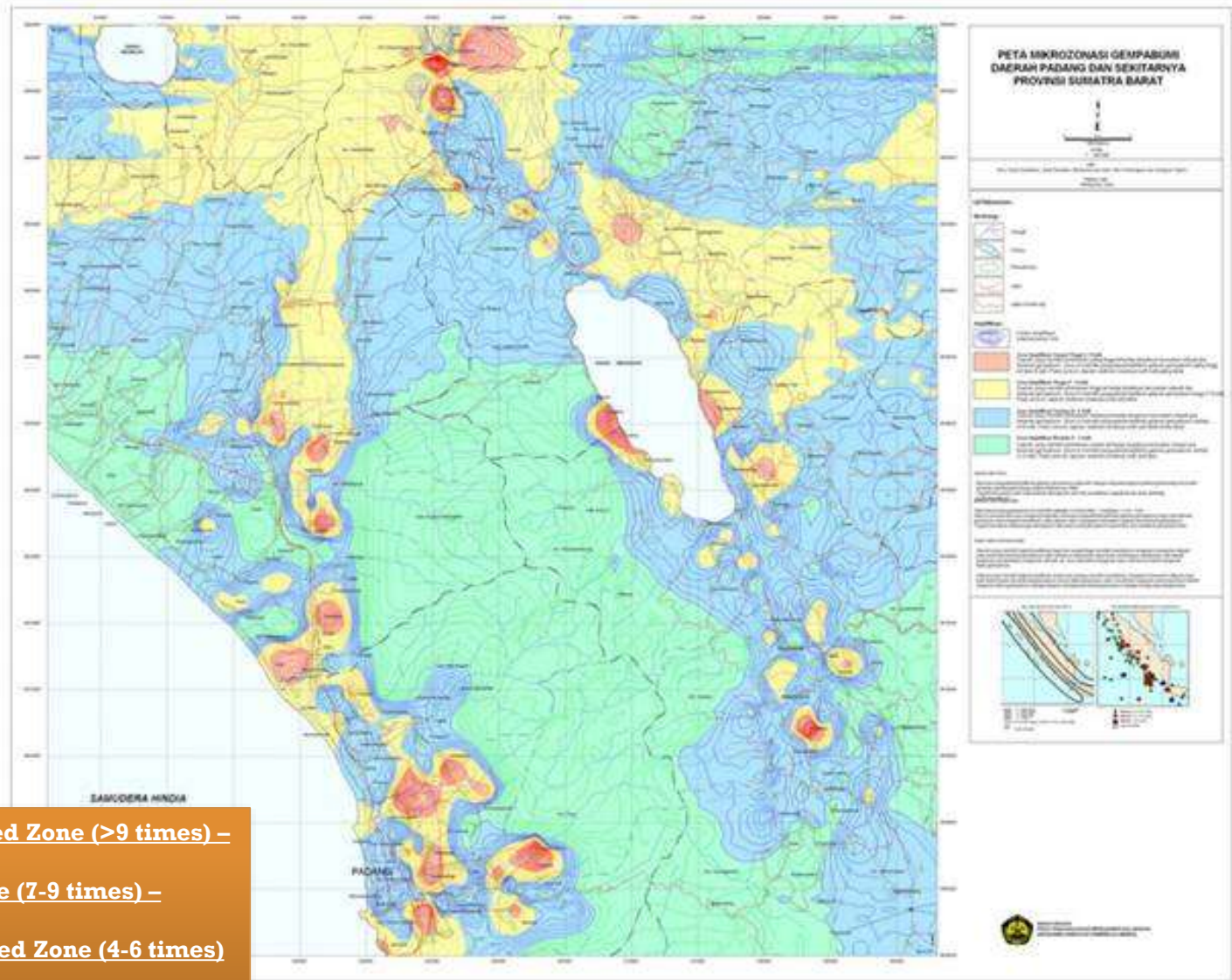
Landslide



El Salvador
January 13, 2001
Magnitude 7.6

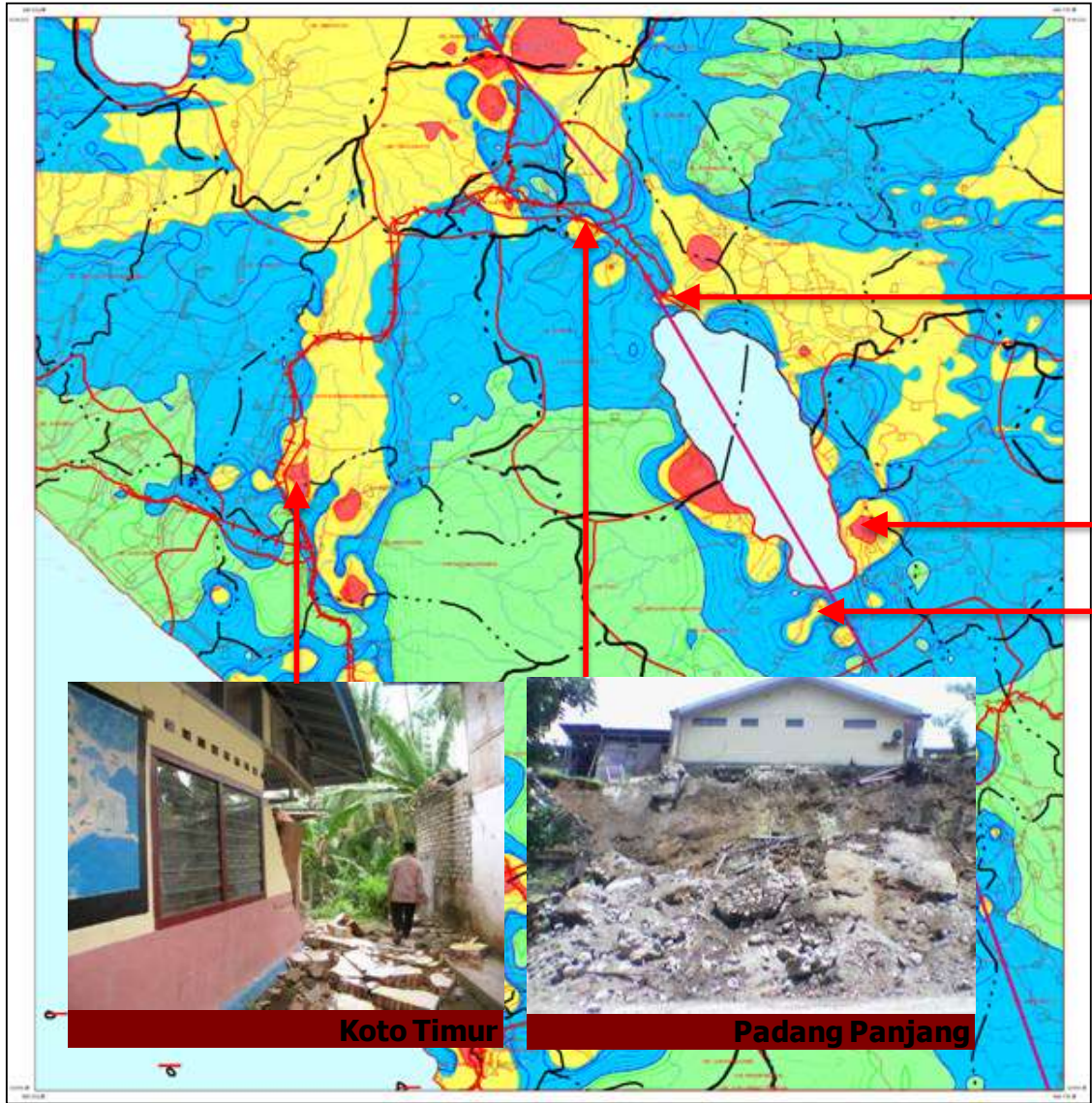
Photo Credit: USGS





VERY HIGH Amplified Zone (>9 times) – RED
HIGH Amplified Zone (7-9 times) – YELLOW
MODERATE Amplified Zone (4-6 times) – BLUE
LOW Amplified Zone (1-3 times) – GREEN





Utara Singkarak



Singkarak



Koto Timur



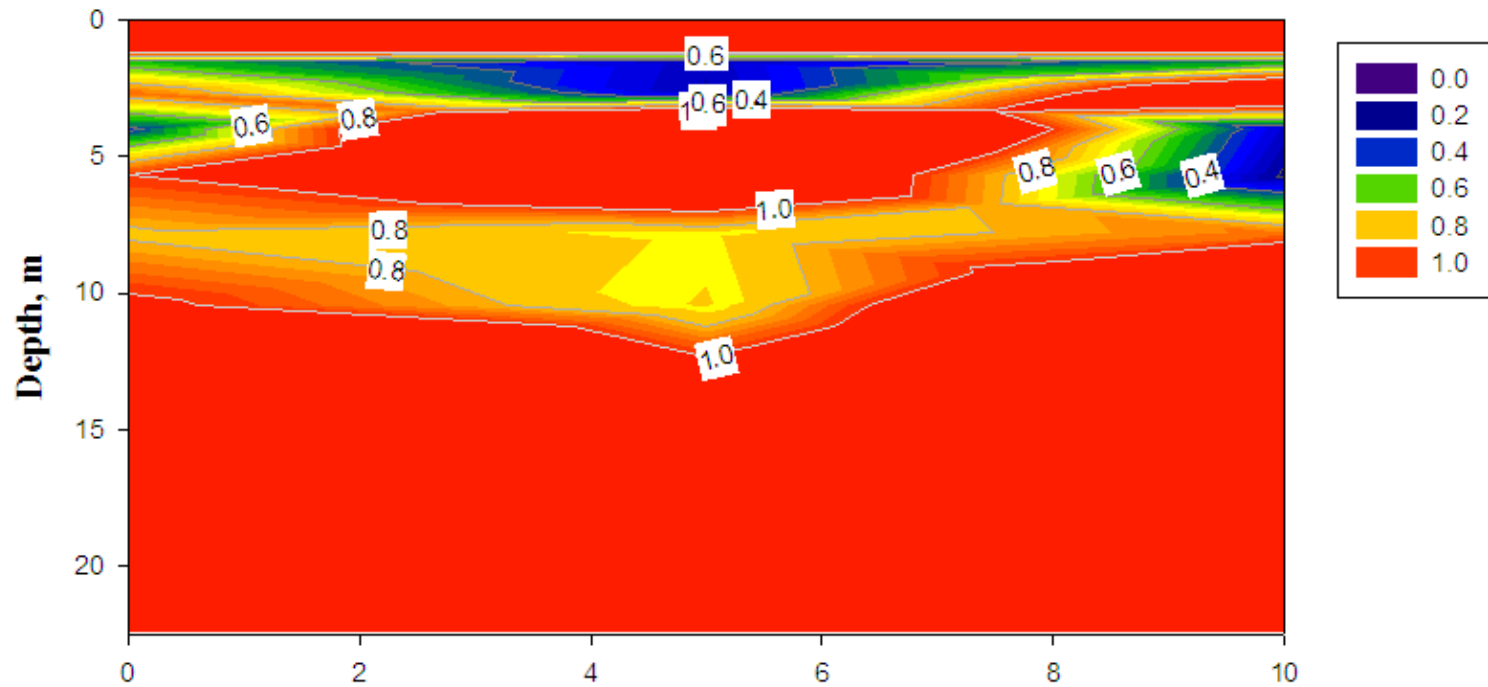
Padang Panjang



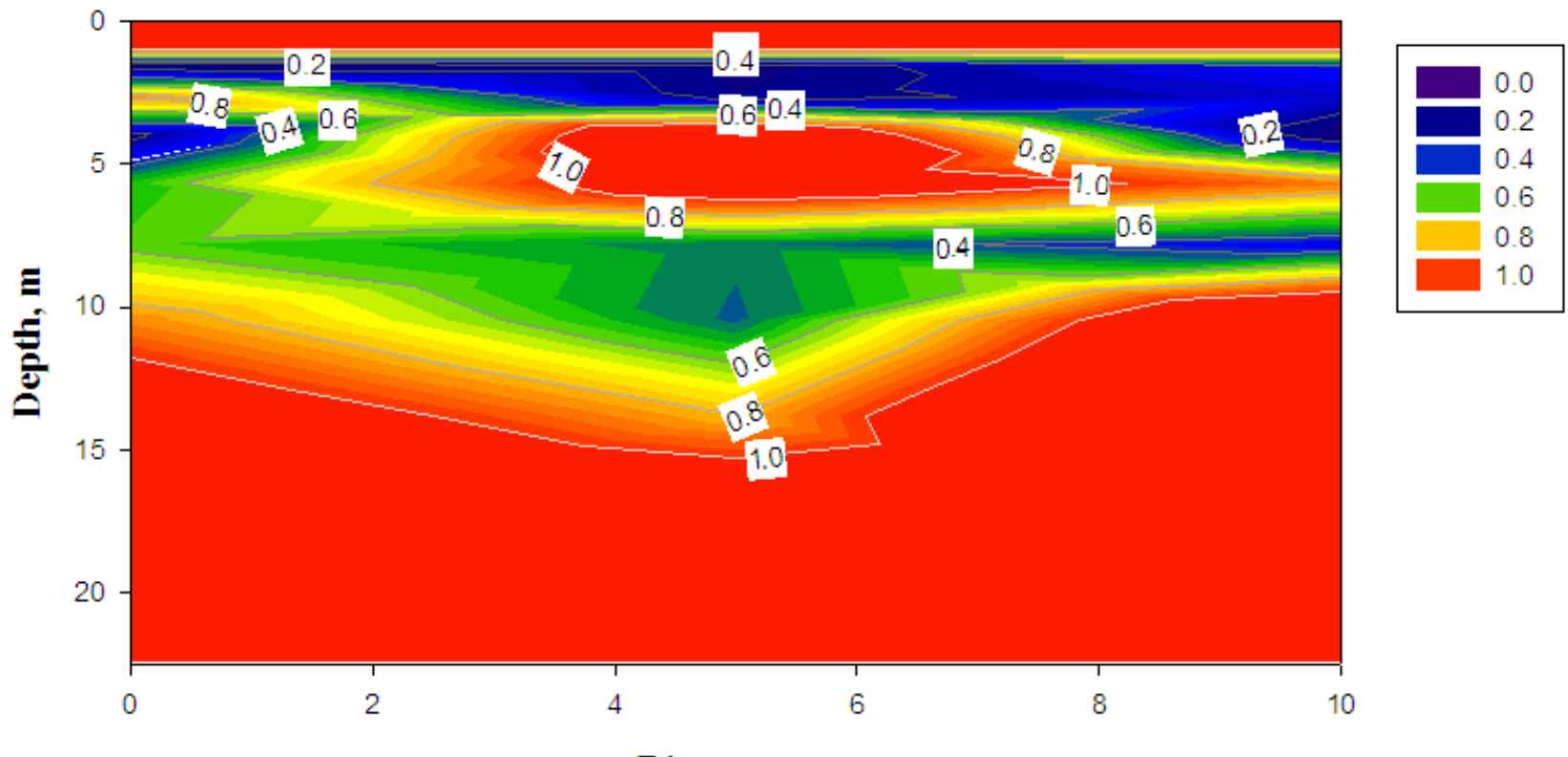
Sumani



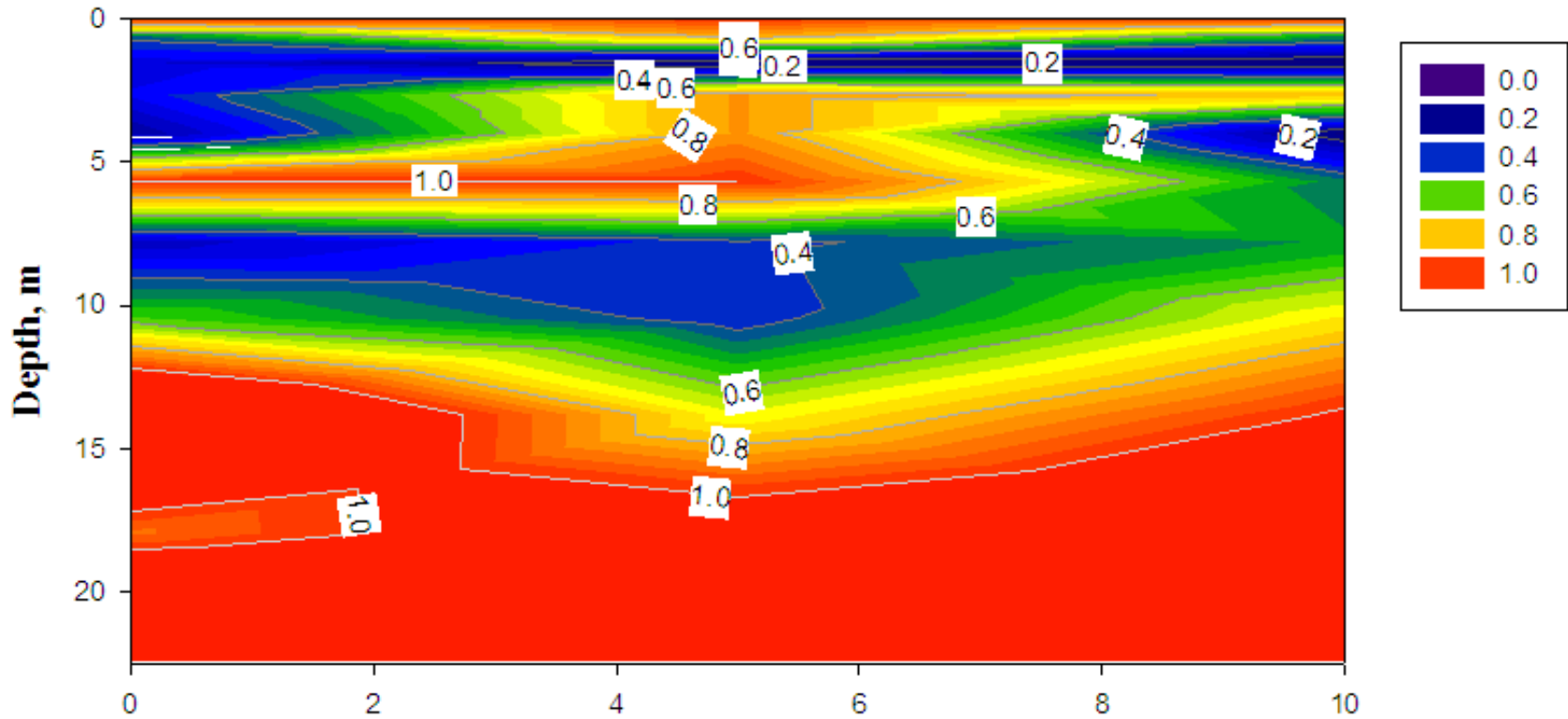
Earthquake scenario, 6.3 Mw



Earthquake Scenario 7.5 Mw



Earthquake Scenario, 8 Mw





Perawatan – Track Maintenance
Inspeksi – Track Inspection
FRA Regulations

“Transportation exists to conquer space and time -”



Importance of Track Inspections

- ▶ **FRA / Transport Canada Required**
- ▶ **First and Last “Line of Defense” against track related derailments**
- ▶ **Initial phase of planning for maintenance activities and future track upgrade programs**
- ▶ **Public and employee safety**



► Hi-Rail Inspection



– Walking Inspection



– Train Inspection



▶ **Hi-Rail**

- ▶ **The hi-rail is a versatile vehicle that allows the inspector to traverse the track in one direction and return by road**
- ▶ **Provides flexibility/versatility**
- ▶ **Most common method utilized for scheduled and special inspections**
- ▶ **Most often one, and sometimes two Inspectors observing the track**
- ▶ **Scheduled per regulatory requirement and/or company policy**
- ▶ **Visual detection of defects**
- ▶ **“Feel” and sound of the track that may indicate the presence of a substandard condition**



Walking Inspections

- Allows for a more detailed look at the track.
- Quantify defects with physical measurements
- Planned at various times of year,
- Regulatory requirement for inspecting turnouts, track crossings and lift rail assemblies or other transition devices on moveable bridges to be performed “on foot”



Train Inspection

- Provides a “feel” of the track under loaded conditions
- Frequency depends on amount and type of train traffic, anywhere from twice annually to monthly



Types of Track Inspection

- ▶ **Normal or Scheduled (Routine)**
- ▶ **Special Inspection**
 - ▶ **Specific Planned (i.e. Culverts, Rail Wear etc)**
 - ▶ **Emergency (Weather related, Incidents/Accidents)**
- ▶ **Specialized Inspection Vehicles**
 - ▶ **Rail Flaw Detection Vehicles**
 - ▶ **Track Geometry Vehicle**



Konsep Perawatan Jalan Rel

- ▶ Kerusakan pada satu komponen **pasti** berimpak kepada komponen lainnya
- ▶ Penggantian setempat dan penggantian (rehabilitasi dan rekonstruksi) lengkap
- ▶ Aktivitas perawatan adalah sistem perputaran



- ▶ Track disturbance can lead to buckling
 - ▶ Dynamic track stabilizer



<http://www.struktonrail.com/en-us/RailInfraStructure/Pages/Stabilizers.aspx>



Track Maintenance

- ▶ Rail grinding – grinding machines or trains equipped with grinding wheels



http://www.flashpointfire.com.au/images/gallery/WEB3_IMG.JPG



http://www.railroad.net/santucci/Grinding_the_weld.jpg

[Daytime](#)

[Night](#)



Rail Grinding



- ▶ Purpose: Remove Surface Imperfections in the Rail & Optimize Rail/Wheel Contact Area
- ▶ Out-of-Face & Switch Multiple Stone Grinders
- ▶ Grinds Main Track Based on Railroad Policy
- ▶ Grinds 6 to 15 MPH



► Vegetation Control – chemical and mechanical



<http://www.homegrowntimber.com/indexrailways.html>



Track Maintenance

- ▶ Stabilization and Drainage
- ▶ Welding



<http://peer.berkeley.edu/publications/nisqually/geotech/liquefaction/lateralspread/index.htm>



http://www.railroad.net/santucci/Flash_Butt_Welding.jpg



Track Inspection

- ▶ Measures the condition of the track
- ▶ Determines where maintenance is needed
- ▶ Visual and specialized



<http://www.ensco.com/index.cfm?page=318>

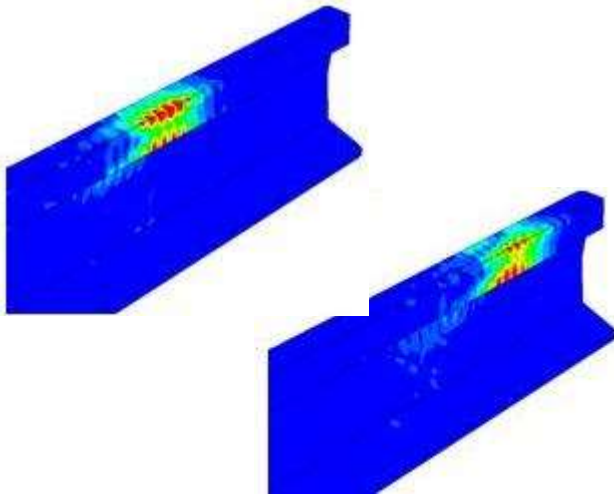
[Inspector at Work](#)



<http://www.ensco.com/index.cfm?page=318>



▶ Rail Defect Testing – Ultrasonic vehicle



http://www.wins-ndt.com/ultrasonic_rail_flaw_detection.php



Track Inspection

- ▶ Gage Compliance - Geometry Cars
- ▶ Gage Restraint Measuring Systems (GRMS)



<http://www.northeast.railfan.net/images/co2.jpg>



http://www.ensco.com/userfiles/file/Products_Services_PDF/07_Rail/Track-Inspection-Systems/04_0204_ENSCO_Rail_Deployable_Gage_Restraint_Measurement_System.pdf



Rail Gang Make-up



Tie Adzer



Galion Crane Laying Rail



Spiker



Rail Heater



Tie Gang Make-up



Production Surfacing



CAT-09 Tamper



MK IV Operator



MK IV Tamper

- ▶ Highly mechanized crews
- ▶ 4 to 20 employees
- ▶ Typical Equipment Includes:
 - ▶ Production Tamper
 - ▶ Jr. Tamper
 - ▶ Regulator
 - ▶ Stabilizer

Surfacing Gang Consist



Undercutting



Prinsip: Risk Management

Risk management can be defined as:

The eradication or minimisation of the adverse affects of risks to which an organisation is exposed.

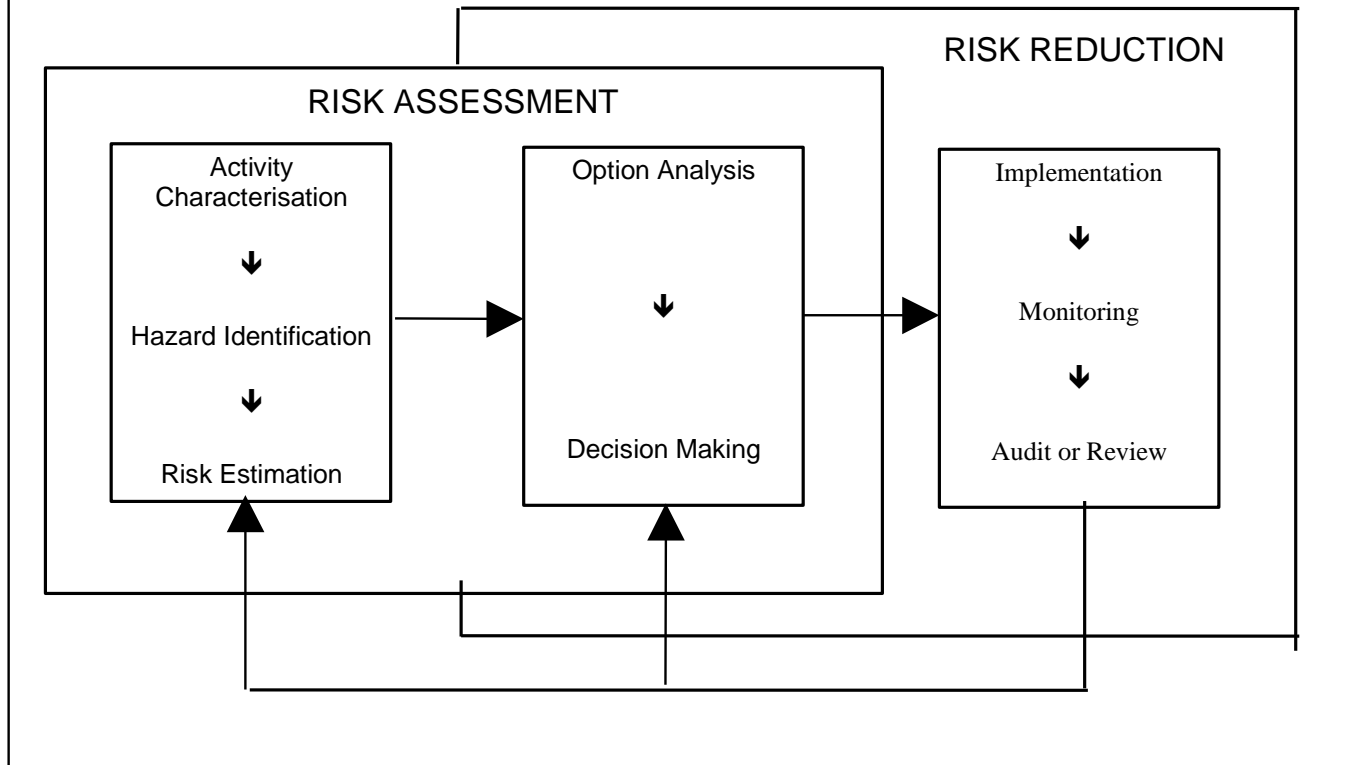


Stages in Risk Management

- Identifying the hazards.
- Evaluating the associated risks.
- Controlling the risks.



RISK MANAGEMENT



Risk assessment can be a
*‘very straightforward process based on
judgement requiring no specialist skills or
complicated techniques.’*

This approach is commonly known as
qualitative or subjective risk assessment.



Major Hazards

- ▶ Major hazards associated with complex chemical or nuclear plants, may '*warrant the need of such techniques as Quantitative Risk Assessment*'.
- ▶ In Quantitative Risk Assessment (**QRA**) a numerical estimate is made of the probability that a defined harm will result from the occurrence of a particular event.



The Risk Management Process

Hazard Identification

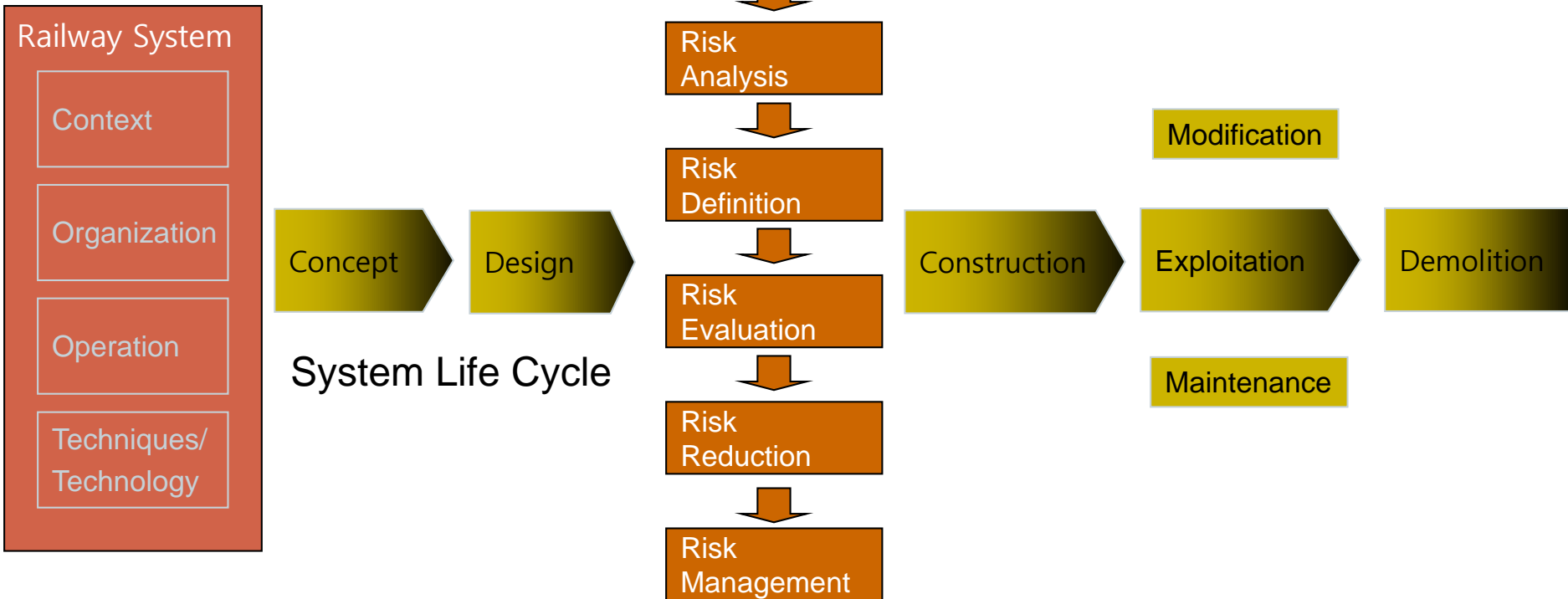
Hazard :

The potential to cause harm. Harm including ill health and injury, damage to property, plant, products or the environment, production losses or increased liabilities.

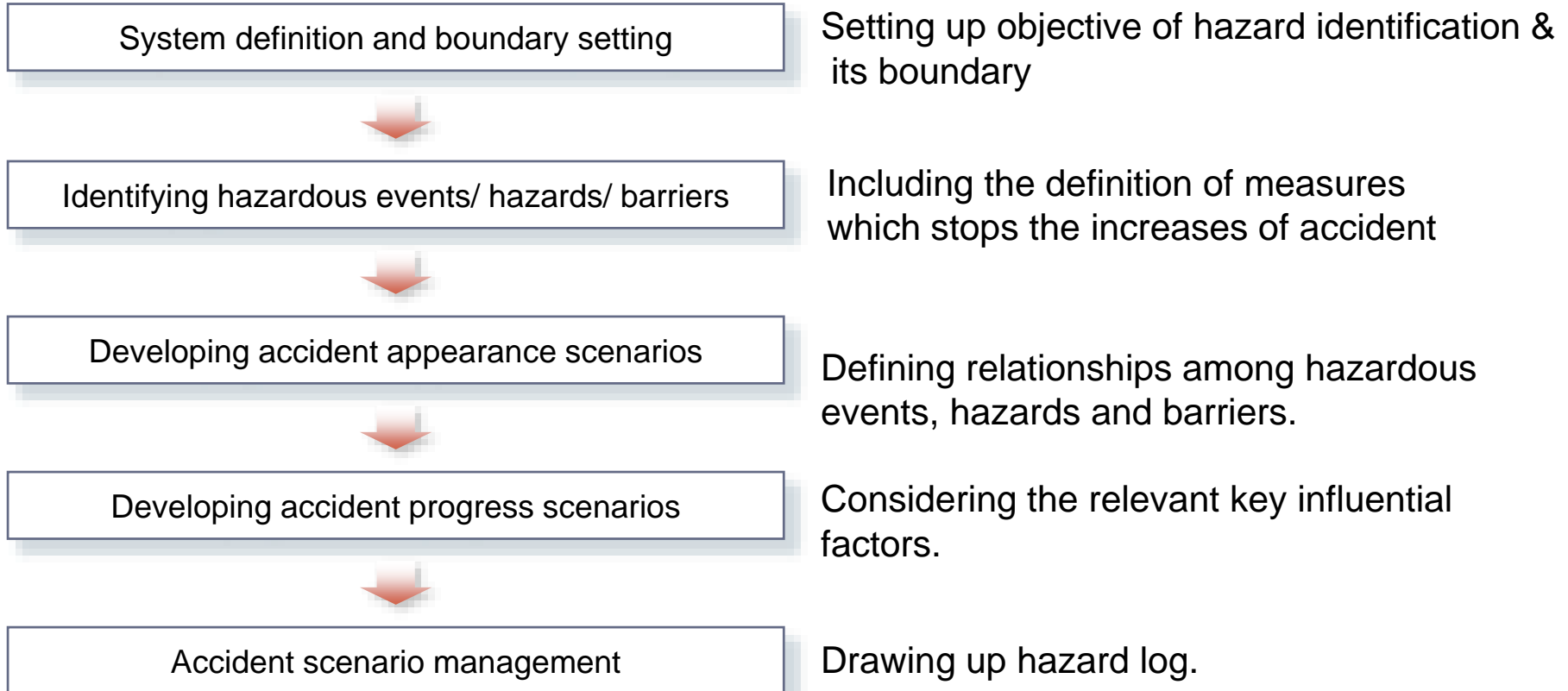


Common Approach Risk Management

Risk Management Process

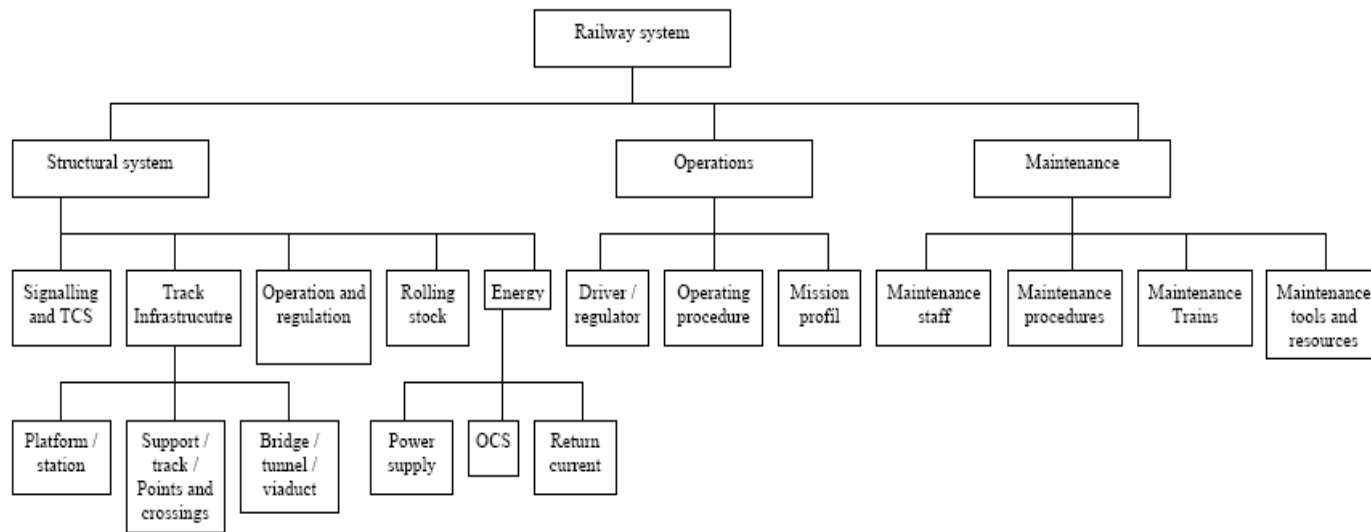


Hazard Identification Procedure



System & Boundary Definition

Typical railway system configuration proposed in SAMRAIL project, South Korea



According to the accident classification of “*Railway Accident Report Regulation*”,
The scenarios were divided into the five main areas

- 1) Train collision accident,
- 2) Train derailment accident,
- 3) Train fire accident,
- 4) Level crossing accident,
- 5) Railway (traffic/safety) casualty accident.



Hazardous Event Identification

Railway Category		Hazardous Events
Train Collision	Misrouted train	Mistaking in dealing points, point faults, mistaking in dealing blockage, interlocking system faults
	Faults in driving	Signal/direction violation, signal fault, mistaking in dealing braking system, braking system fault, over speeding
	Abnormal train	Train separation, car rolling, train stop, backward moving
	Obstacles on the track	External obstacles, parts from train/freight falling, infrastructure collapsing/obstruction
Level Crossing Accident	Being trapped in level crossing	<ul style="list-style-type: none"> -Engine stop -Deviation of pathway -Gangway blocking -Lack of propulsion/braking -Violation entry -Limit interference -Breaking or detour
	Crossing during warning signal	
	Breaking through or detour the barrier	
Railway Traffic Casualty Accident	People struck/crushed	Striking with train, Striking with objects
	Trip/Slip	Trip/slip during train boarding/alighting, Trip/slip by train emergency braking/emergency start
	Falling	Falling from train, Falling from platform during train boarding/alighting
	Caught/Dragged	Caught in a train door, Caught between platform and train
	Others	Electric Shock, Burn, Suffocation



Railway Accident Appearance Scenario

Accident type	Hazardous Event	Immediate Causes	Underlying Causes														
Traffic casualty accident	Falling from train	<table border="1"> <tr> <td rowspan="2">Inside station premises</td> <td>Unauthorized door handling</td> </tr> <tr> <td>Door handling error/malfunction</td> </tr> <tr> <td rowspan="3">Outside station premises</td> <td>door locking system faults</td> </tr> <tr> <td>Train running with opened door</td> </tr> <tr> <td>Holding / jump on to train</td> </tr> </table>	Inside station premises	Unauthorized door handling	Door handling error/malfunction	Outside station premises	door locking system faults	Train running with opened door	Holding / jump on to train	Human Management Factors	Information recognition error	Alcohol					
	Inside station premises	Unauthorized door handling															
Door handling error/malfunction																	
Outside station premises	door locking system faults																
	Train running with opened door																
	Holding / jump on to train																
Falling from platform during train boarding/alighting	<table border="1"> <tr> <td colspan="2">Floor/slipperiness (freezing/oil),</td> </tr> <tr> <td colspan="2">Safety installations (handle/footing) faults</td> </tr> <tr> <td colspan="2">Interruption from floor obstruction</td> </tr> <tr> <td colspan="2">Carelessness</td> </tr> </table>	Floor/slipperiness (freezing/oil),		Safety installations (handle/footing) faults		Interruption from floor obstruction		Carelessness		Circumstantial judgment error	Disease						
Floor/slipperiness (freezing/oil),																	
Safety installations (handle/footing) faults																	
Interruption from floor obstruction																	
Carelessness																	
Safety casualty accident	Falling from rolling stock	<table border="1"> <tr> <td colspan="2">Jump down from train</td> </tr> <tr> <td colspan="2">door handling error/malfunction</td> </tr> <tr> <td colspan="2">door locking system faults</td> </tr> <tr> <td colspan="2">Train running with opened door</td> </tr> <tr> <td colspan="2">Holding / jump on to train</td> </tr> <tr> <td colspan="2">Carelessness</td> </tr> </table>	Jump down from train		door handling error/malfunction		door locking system faults		Train running with opened door		Holding / jump on to train		Carelessness		Human Management Factors	Decision making error	Congestion
	Jump down from train																
	door handling error/malfunction																
	door locking system faults																
	Train running with opened door																
	Holding / jump on to train																
	Carelessness																
	Falling from rolling stock roof	<table border="1"> <tr> <td colspan="2">Falling from rolling stock roof</td> </tr> <tr> <td colspan="2">Falling from rolling stock roof after electric shock with catenary/overhead line</td> </tr> </table>	Falling from rolling stock roof		Falling from rolling stock roof after electric shock with catenary/overhead line		Performance error	Visible/Audible handicap									
	Falling from rolling stock roof																
	Falling from rolling stock roof after electric shock with catenary/overhead line																
	Falling during elevated work	<table border="1"> <tr> <td colspan="2">Falling from a ladder</td> </tr> <tr> <td colspan="2">Falling from a scaffolding</td> </tr> <tr> <td colspan="2">Falling from a railway bridge</td> </tr> <tr> <td colspan="2">Falling to inspection pit</td> </tr> <tr> <td colspan="2">Falling during other elevated works</td> </tr> </table>	Falling from a ladder		Falling from a scaffolding		Falling from a railway bridge		Falling to inspection pit		Falling during other elevated works		Miscommunication	Others			
	Falling from a ladder																
Falling from a scaffolding																	
Falling from a railway bridge																	
Falling to inspection pit																	
Falling during other elevated works																	
Falling from infrastructure	<table border="1"> <tr> <td colspan="2">Falling from outside area (overpass/viaduct) to track</td> </tr> <tr> <td colspan="2">Falling from outside area (overpass/viaduct) to track of road vehicles</td> </tr> <tr> <td colspan="2">Falling from infrastructure inside station premises</td> </tr> </table>	Falling from outside area (overpass/viaduct) to track		Falling from outside area (overpass/viaduct) to track of road vehicles		Falling from infrastructure inside station premises		Procedure/Regulation violation									
Falling from outside area (overpass/viaduct) to track																	
Falling from outside area (overpass/viaduct) to track of road vehicles																	
Falling from infrastructure inside station premises																	
Falling from platform	<table border="1"> <tr> <td colspan="2">Floor/slipperiness (freezing/oil),</td> </tr> <tr> <td colspan="2">Safety installations (safety fence/footing) faults</td> </tr> <tr> <td colspan="2">Interruption from floor obstruction</td> </tr> <tr> <td colspan="2">carelessness</td> </tr> </table>	Floor/slipperiness (freezing/oil),		Safety installations (safety fence/footing) faults		Interruption from floor obstruction		carelessness		Technical Factors	Track/Structure defects						
Floor/slipperiness (freezing/oil),																	
Safety installations (safety fence/footing) faults																	
Interruption from floor obstruction																	
carelessness																	
	Signal control system defects																
	Telecommunication system defects																
	Catenary power systems defects																
	Train/rolling stock system defects																
	Level crossing installations defects																
	Work objects/equipment defects																
		External Factors	Illegal action	Trespass/action													
				Suspected suicide													
				Unauthorized construction /voluntary work													
				Unauthorized installation/placement													
				Terror													
				Other train running interruption action													
		Incomplete climate condition															
		Incomplete circumstance condition															



Risk Measure Method

Risk assessment model

: the form of a cause and consequence analysis

: using fault trees and event trees.

Collective Risk

(Average Number of FWI/year)

=

Frequency

(Average frequency at which the scenario sequence occurs)

X

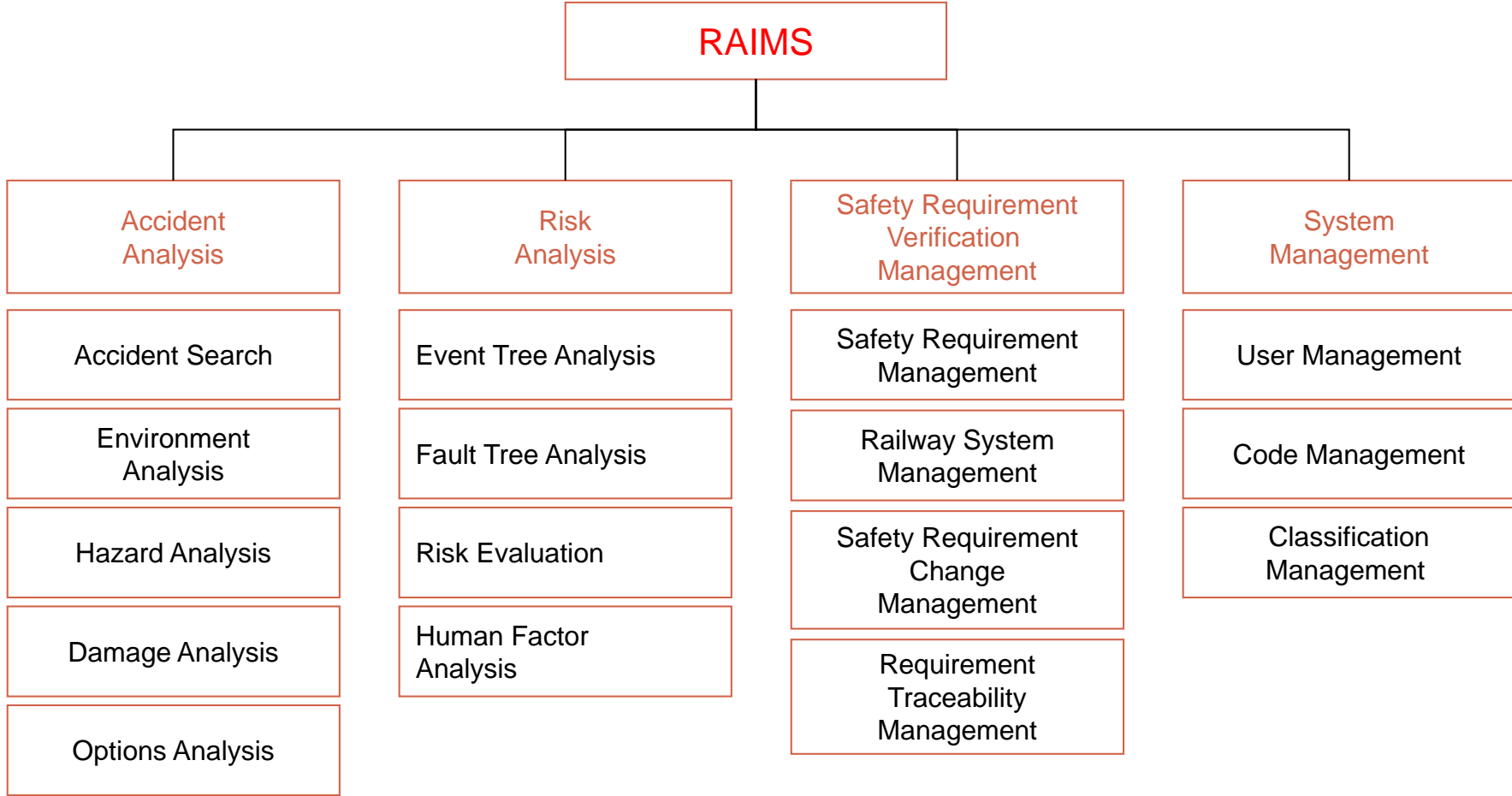
Consequences

(the number of FWI/scenario sequence)

1 FWI = 1 fatality = 10 major injuries = 200 minor injuries



Railway Risk Assessment & Information Management System (RAIMS)



Ada Pertanyaan ?

