



# Tunnel Technical Installations & Testing

# Introduction



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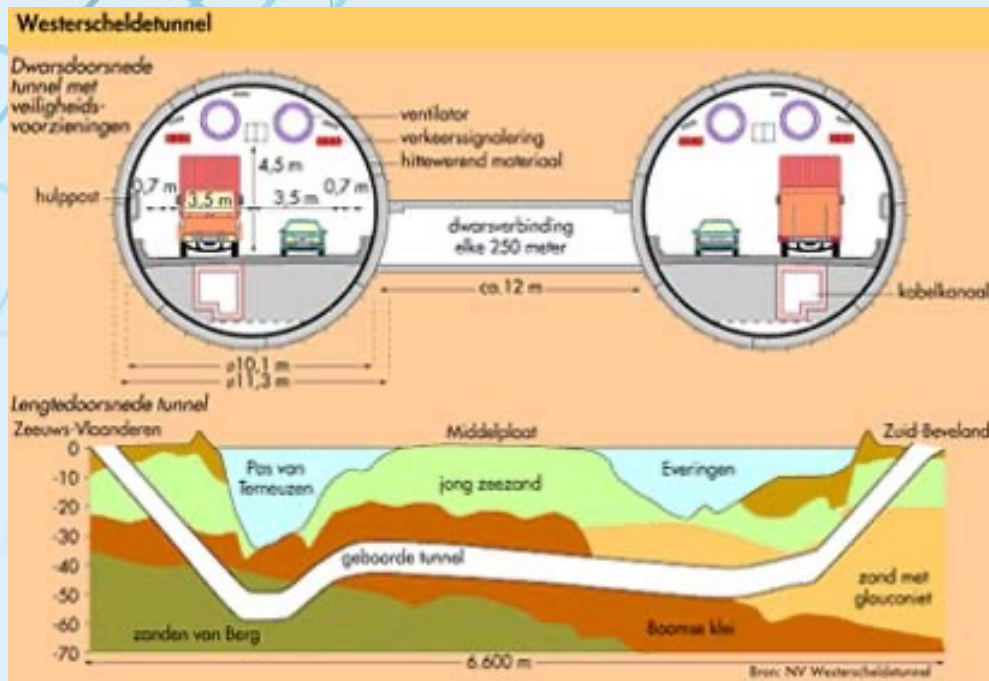
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# Tunnels and safety



Why is a tunnel more dangerous than a normal road?

- More difficult to escape
- More difficult to reach for emergency services
- Natural air flow, chimney effect



# Tunnels and safety

## Major tunnel accidents in Europe

Year	Tunnel	# deaths
1999	Mont Blanc tunnel	39
1999	Tauern tunnel	12
2000	Kaprun skitunnel (railroad)	155
2001	Gotthard tunnel	11





# Tunnels and safety

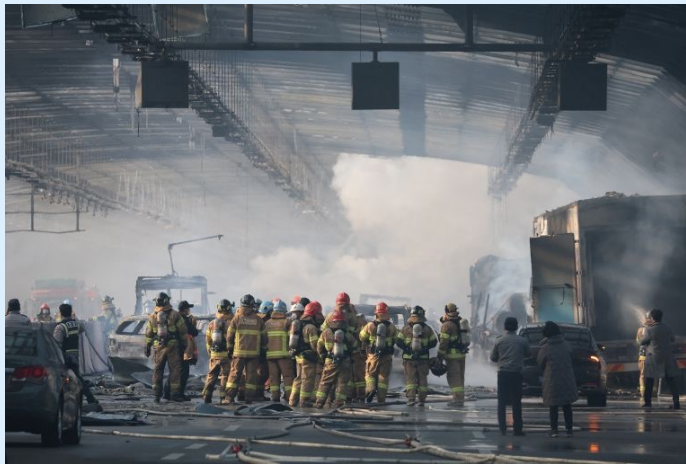
Which effect of a tunnel accident is most dangerous?

- a) Fire
- b) Smoke

# Tunnels and safety

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# Tunnels and safety - Legislation

**DIRECTIVE 2004/54/EG:** European directive with minimum safety requirements for all european roadtunnels >500m

All EU member states have to make specific laws based on the directive. In The Netherlands:

- **Warvw:** Wet aanvullende regels veiligheid wegtunnels (all tunnels > 250m)
- **Rarvw:** Regeling aanvullende regels veiligheid wegtunnels
- **Leidraad Veiligheidsdocumentatie**
- **(Tracewet / Wet Ruimtelijke Ordening)**
- **(Bouwbesluit + regeling bouwbesluit)**
- **(Wet veiligheidsregio's)**
- Specific **NEN-EN-ISO codes**
- Specific **standards** from asset owners
- ...

**Important note: when opening a tunnel, the tunnel-owner has to prove that the tunnel complies with all the legislation**



**STAATSCOURANT**

Officiële uitgave van het Koninkrijk der Nederlanden sinds 1814.



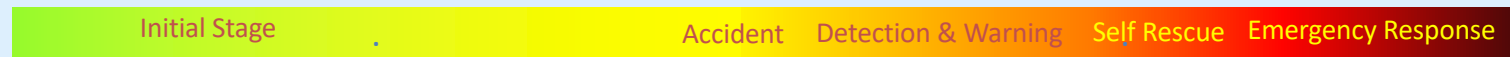
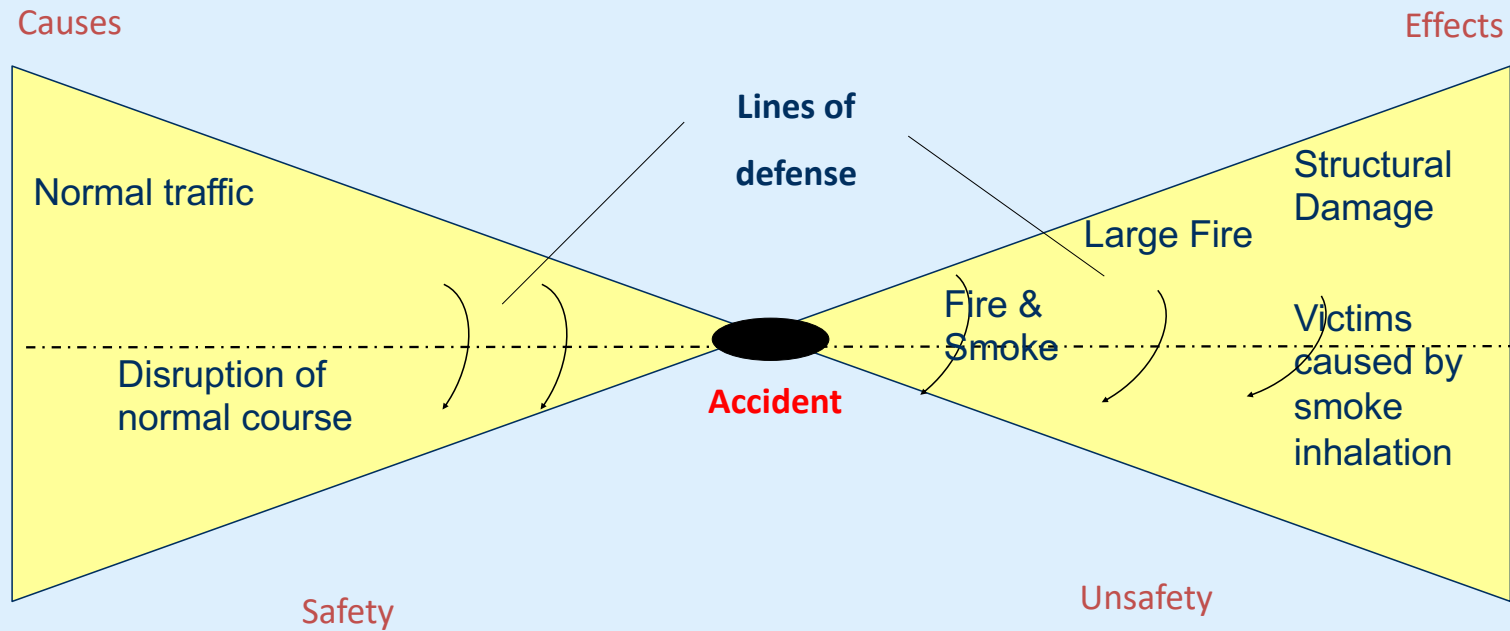


# Main objectives of tunnel safety?





# Tunnel safety



# Tunnel Technical Installations

Wat gebeurt er bij een brand in een tunnel?



**1** MTM-systeem detecteert snelheidsverlaging door file. Borden gaan automatisch op 80 en 50 km/u.



**2** Snelheidsonderschrijdingssysteem geeft melding aan tunneloperator. Camera's tonen locatie van incident. De operator drukt op calamiteitenknop

**3** Tunnelventilatie in incidentenbuis gaat op 'hard blazen' en voert rook in rijrichting af.

**4** Vluchtweg wordt in gereedheid gebracht: inschakelen overdrukventilatie en verlichting middentunnelkanaal.

**5** Verlichting gaat maximaal branden.

**6** Verkeerslichten gaan op rood.

**7** Slagbomen gaan neer.

**8** Ventilatie in nevenbuis in calamiteitenstand zetten.

**9** Contourverlichting en lichtbaken boven deur inschakelen.

**10** Vluchtinstructies uitzenden via speakers.

**11** Vluchtinstructies uitzenden via autoradio.

**12** Hulpverleners arriveren via de nevenbuis.

**13** De hulpverleners betreden de incidentenbuis via de nevenbuis en bovenstrooms door een veilige vluchtdoor voor nadere verkenning.

**14** Na hulpverlening en controle van de installaties en constructie arriveren andere reparatiediensten voor reparaties, inspecties, etc.

Whats happens when a fire starts in a tunnel?



# Tunnel Technical Installations

How many installations does a tunnel have?

- a) 25 – 35
- b) 35 – 45
- c) 45 – 55
- d) 55 – 65

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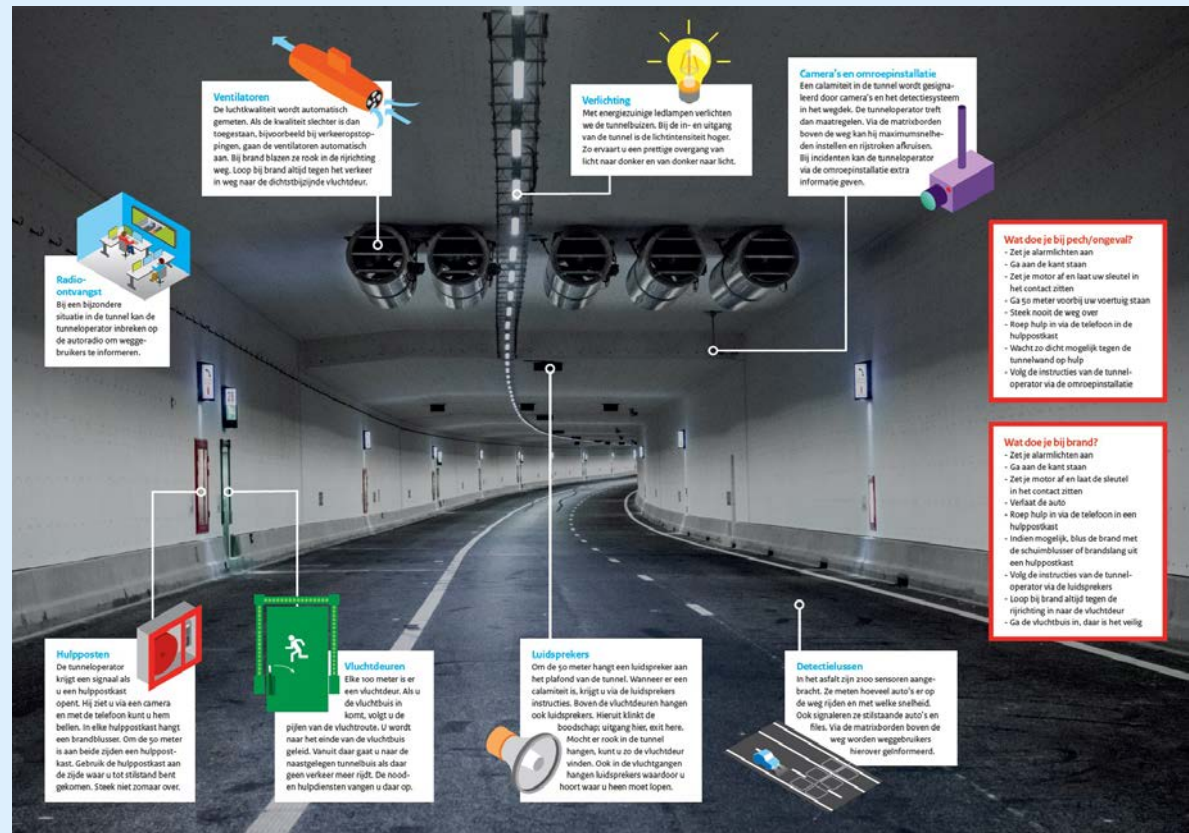
	<b>10 Energievoorziening</b> 11 openbaar nutsbedrijf 12 aardingsinstallaties 13 laagspanningsverdeelinrichting 14 noodstroomvoorziening 15 no-break voorziening 16 middenspanningsinstallaties 17 alternatieve energie	
	<b>20 Algemeen verlichting</b> 21 verlichting verkeerstunnels 22 verlichting middenkanaal (vluchtgang) 23 openbare verlichting	
	<b>30 Drainagepompinstallaties</b> 31 hoofdpompinstallaties 32 middenpompinstallaties 33 hellingpompinstallaties 34 bronpompen in afritten	
	35 Ventilatiesysteem 36 tunnelventilatie 37 meting van luchtverontreiniging 38 overdrukinstallaties pompkamers 39 vluchtgangventilatie	
	<b>40 Verkeersinstallatie</b> 41 rijstrooksignalering 42 verkeerslichten 43 verkeersdetectie 44 hoogtemelding 45 afsluitbomen tunnel+toeleidende wegen 46 beweegbare middenbermbeveiliging 47 bijzondere borden/drips	
		
	<b>50 Brandblusinstallatie</b> 51 brandblusinstallatie in tunnel 52 branddetectieinstallatie in tunnel 53 signaleringen hulppostkasten 54 vorstbeveiliging+verwarming	
	<b>60 Communicatie</b> 61 video/CCTVinstallatie 62 HFinstallatie 63 intercominstallatie 64 luidsprekerinstallatie 65 telefooninstallatie	
	<b>70 Gebouwinstallaties</b> 71 luchtbehandeling;c.v.;overdrukinstallatie 72 beveiliging en bewaking 73 licht+krachtinstallaties 74 brandmeldinstallaties 75 brandblussysteem in gebouwen	
	<b>80 Besturing, bediening en bewaking</b> 81 lokale bediening en bewaking 82 centrale bediening en bewaking 83 noodbediening en bewaking 84 bediening en bewaking voor derden 85 besturingssysteem 86 transmissiesystemen	
	<b>90 Diverse installaties</b> 91 centrale deurontgrendeling 92 kabeltrace's, kabelgoten en ladders 93 liften; roltrappen 94 vluchtwegvoorzieningen, vluchtwegaanduiding; 95 technische uitvoering inrit-lichtrooster	



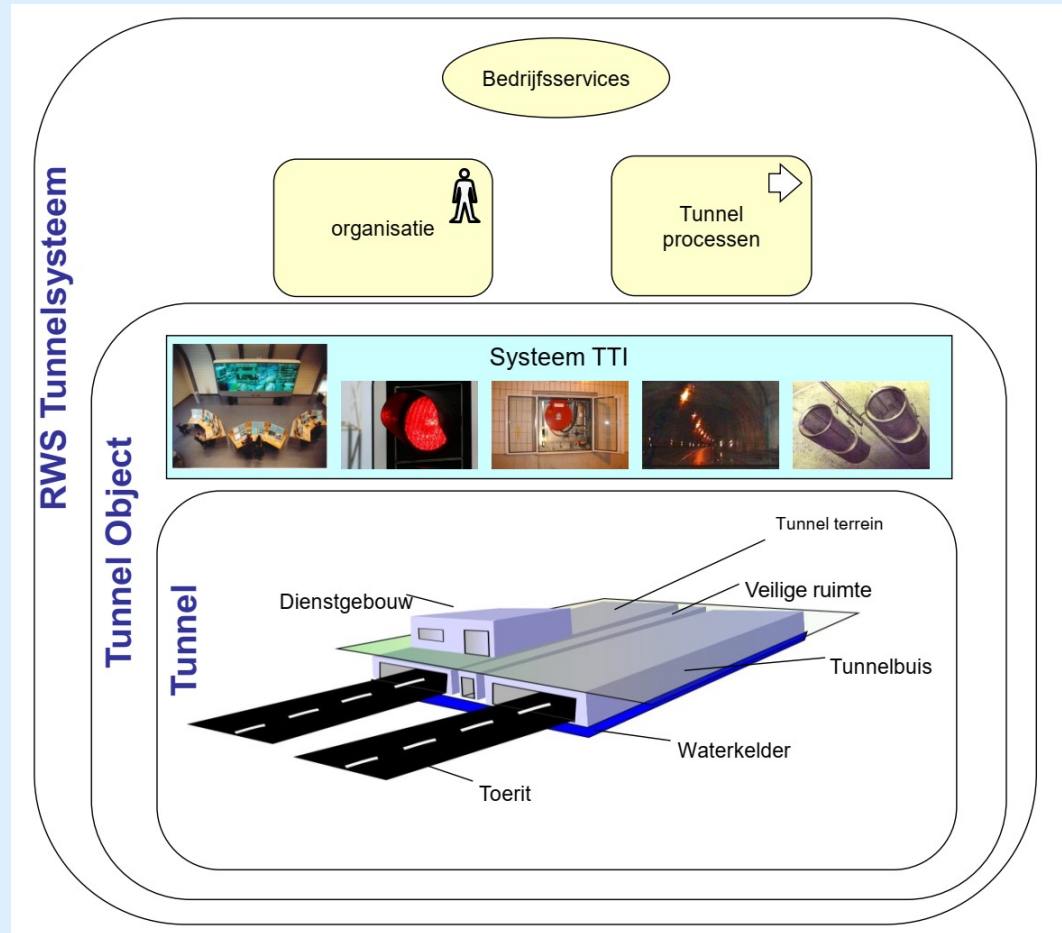
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# Total tunnel system



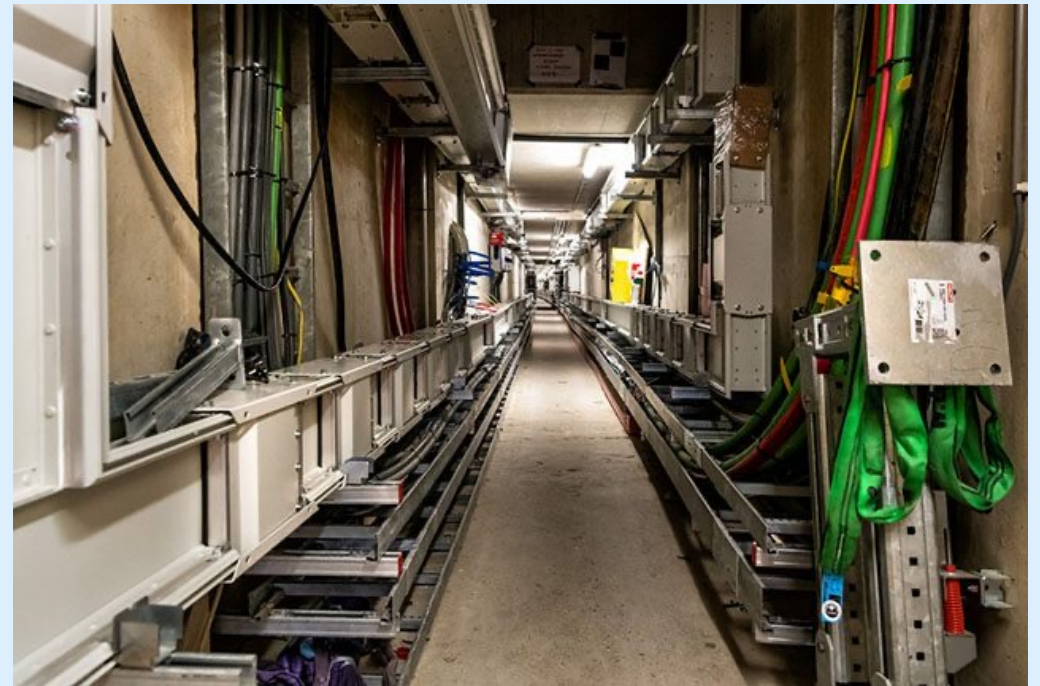
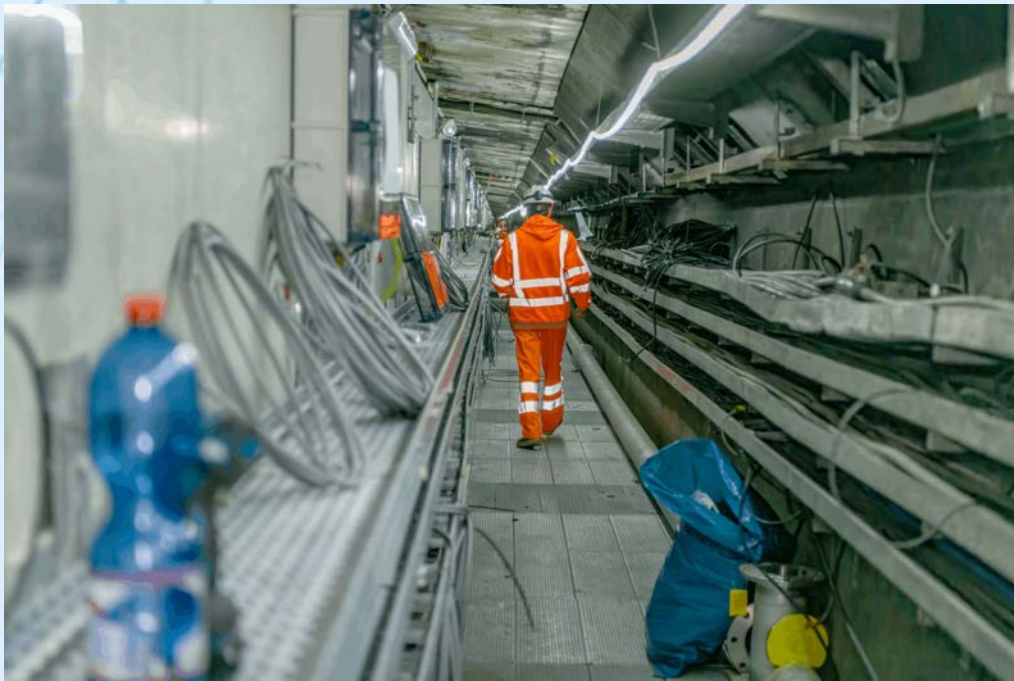
More than technical installations only ..



# Tunnel Technical Installations



# Tunnel Technical Installations



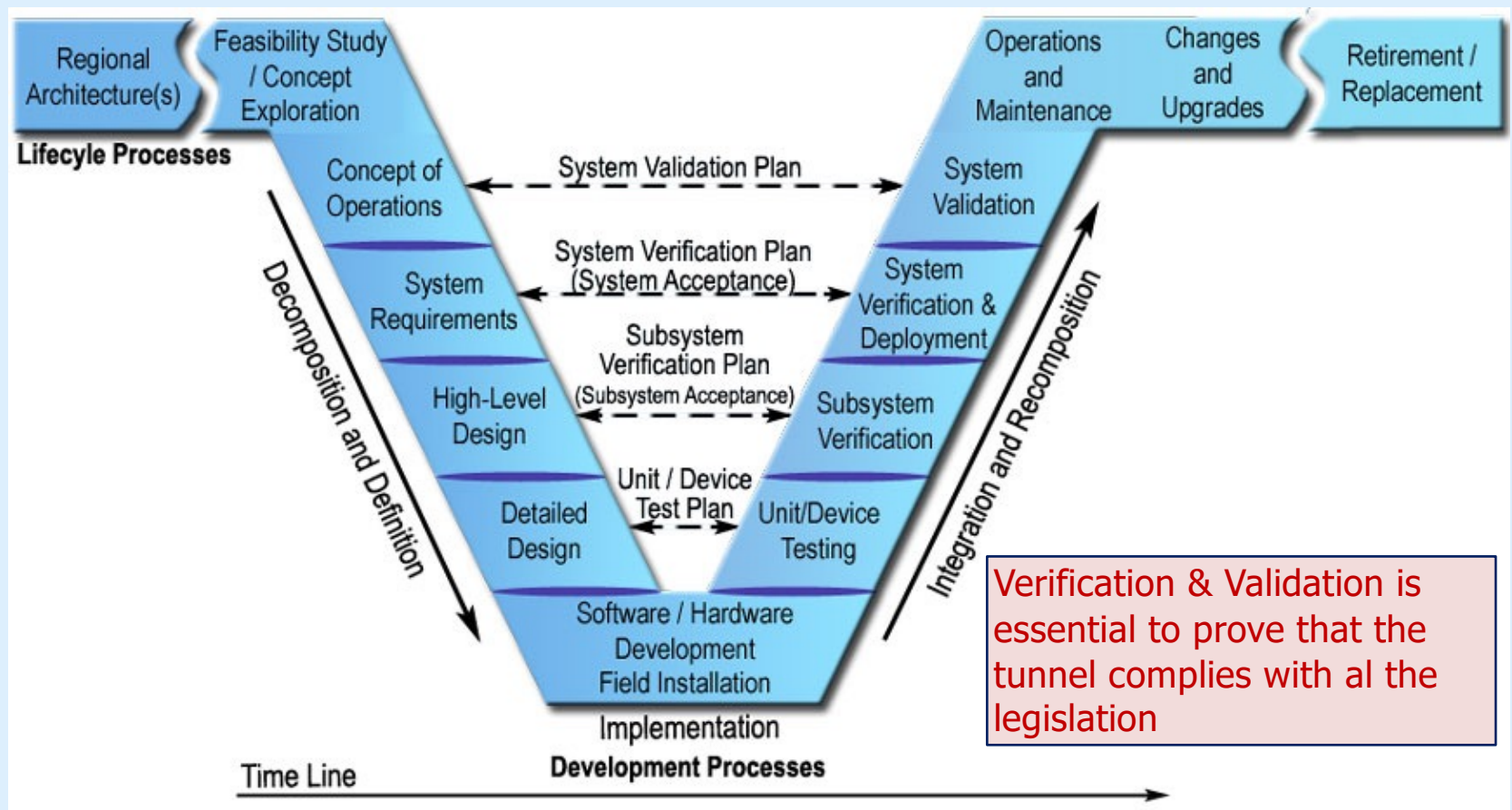


# Tunnel Technical Installations



# Development of TTI

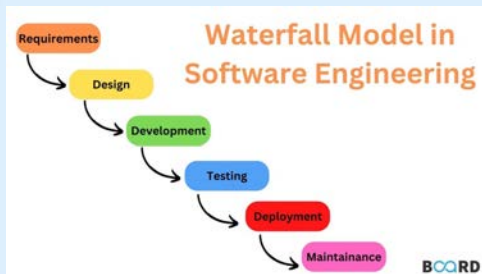
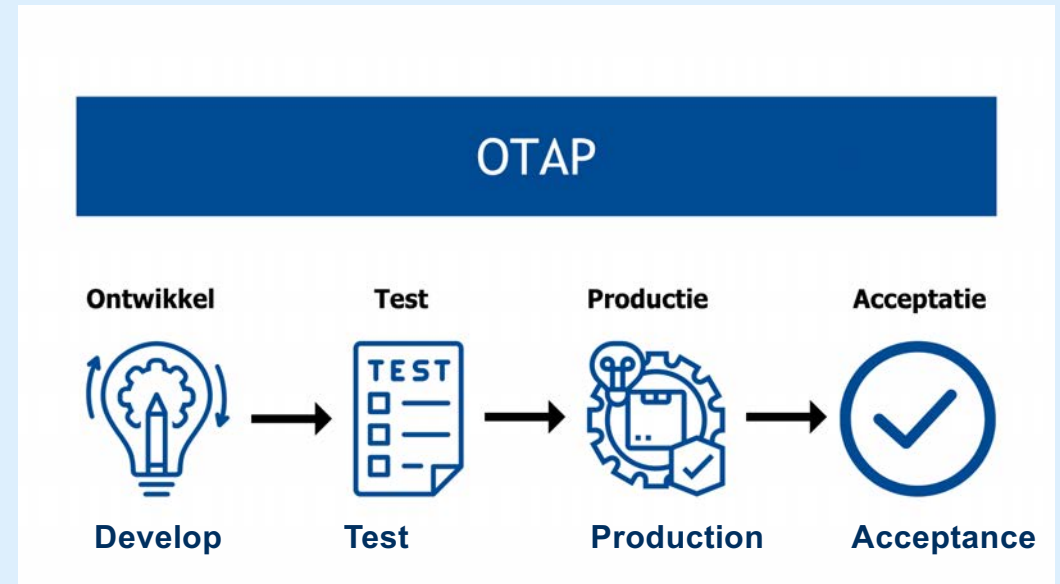
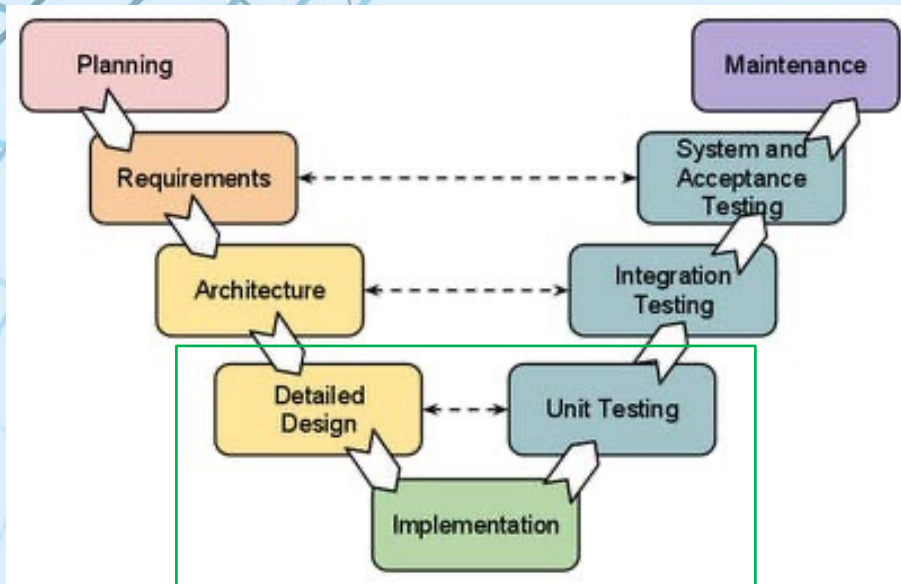
## System engineering, V-model



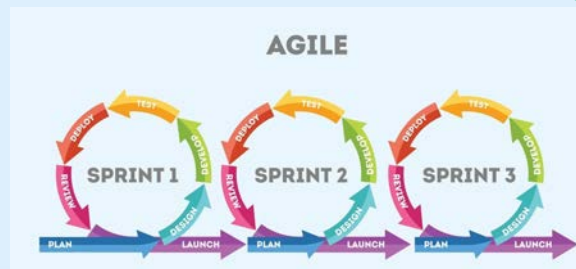


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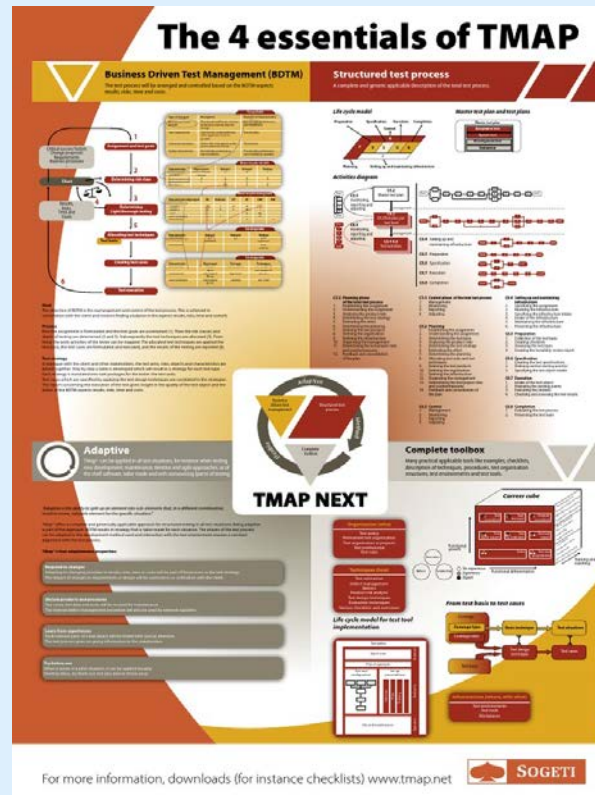
Software development process, OTAP principle



or



# Testing



Testing = prove that everything works as designed

Testing ≠ trial and error!

Structured test process, for example based on Tmap Next

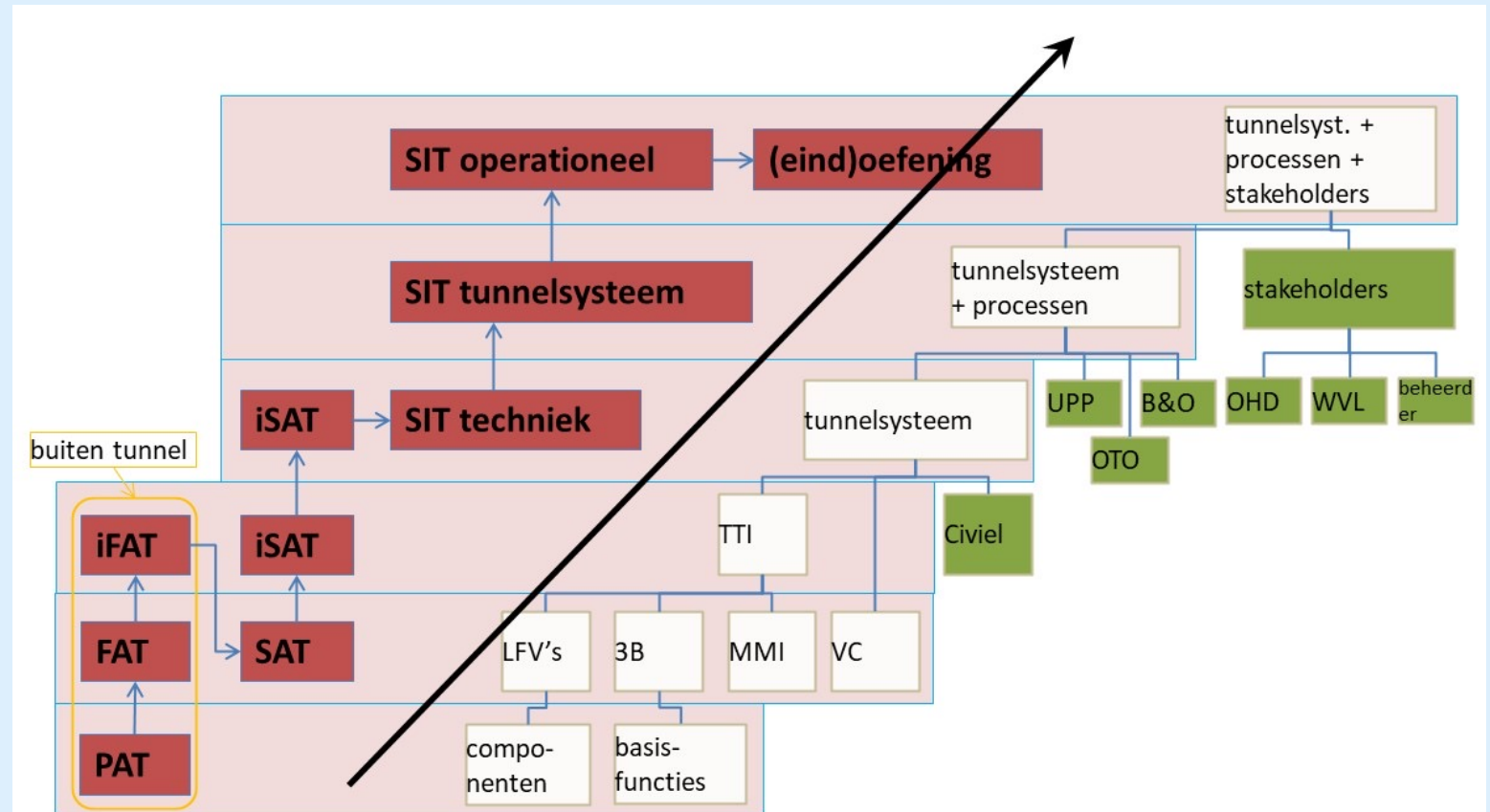
General strategy:

- Test step by step, from small to large
- Testing is risk-based; 100% testing is impossible
- Each test has entry and pass/fail criteria
- Findings are 'weighed'; not every finding is crucial
- Test starts in design, test-engineering
- Execute test as early as possible

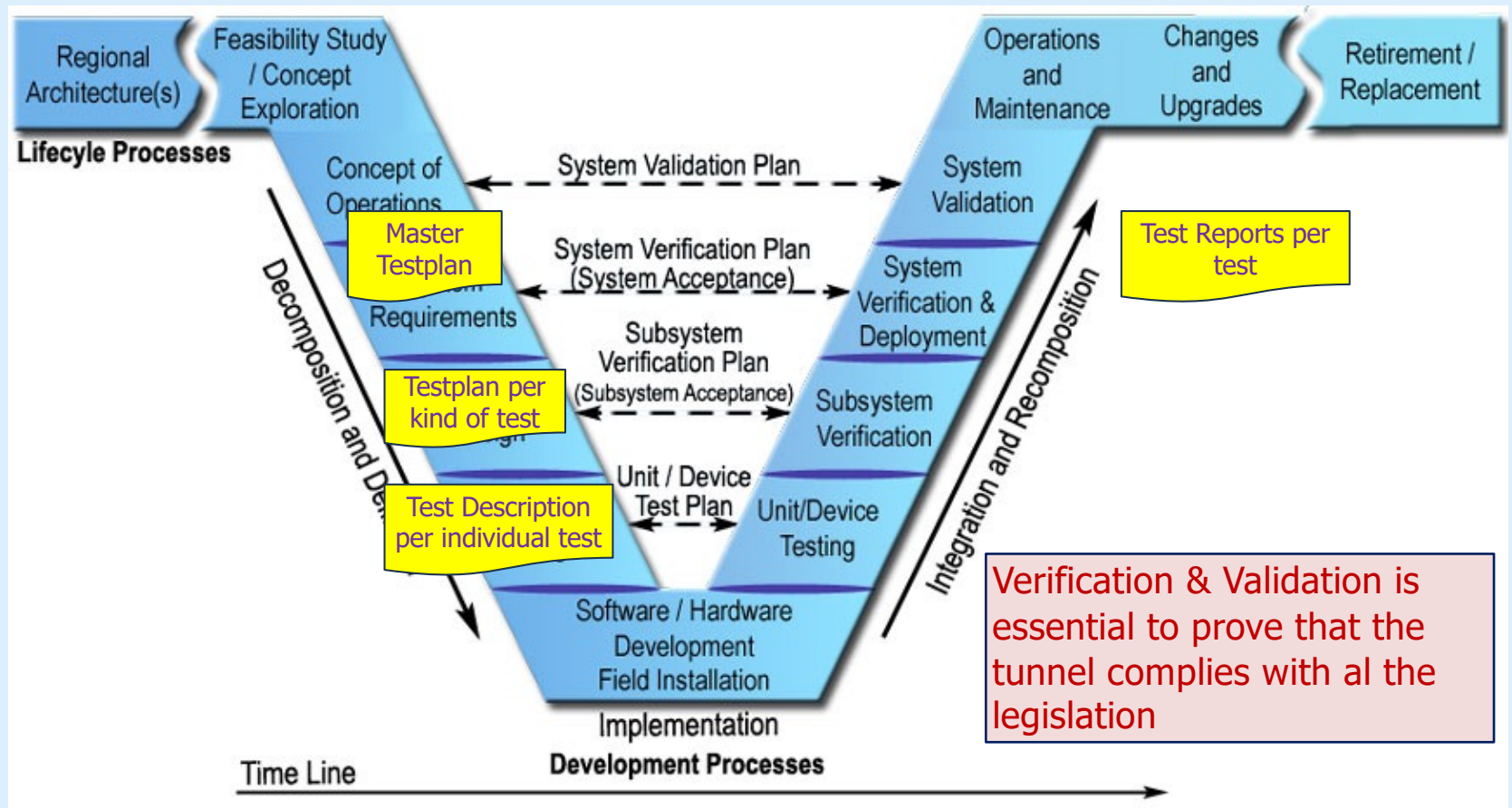


# Testing and integration

System engineering, Test- and integration proces



# Testing Documentation





# Testing

How many documents do we approximately create for testing a tunnel?

- a) 100
- b) 500
- c) 1000





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Note: Depends on customer, scope and teststrategy



# Testing

How many hours do we approximately need for testing a tunnel? Preparation, executing and reporting.

- a) 10.000
- b) 20.000
- c) 30.000

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# Testing off site

Digital and Fysical twins





# Testing off site (FAT)

Factory Acceptance Test



# Testing off site (iFAT)

Integrated Factory Acceptance Test





# Testing on site (SAT/iSAT)

(Integrated) Site Acceptance Test





# Testing on site (SIT-T/SIT-O)

Site Integration Test Technical and Operational

