



Rijkswaterstaat  
*Ministerie van Infrastructuur en Milieu*

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How to manage the  
(increasing) complexity of  
our safety systems?

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# Content

The Dutch situation:

- Road tunnels
- Increasing complexity
- The Paradox
- Example:  
A2 Leidsche Rijn Tunnel, Utrecht
- Analysis and solution
- Role of the Tunnel Safety Officer





## Road tunnels in the Netherlands

Existing tunnels (Trans European Network, TEN):

1.	A22	Velser Tunnel	1957
2.	A4	Schiphol Tunnels	1966/1999
3.	A4	Benelux Tunnels (I & II)	1967/2002
4.	A29	Heinenoord Tunnels (I & II)	1969/1998
5.	A58	Vlake Tunnel	1975
6.	A16	Drecht Tunnel	1977
7.	A15	Botlek Tunnel	1980
8.	A15	Noord Tunnel	1992
9.	A9	Wijker Tunnel	1996
10.	A15	Thomassen Tunnel	2004
11.	A73	Roer Tunnel	2008
12.	A73	Swalmen Tunnel	2009
13.	<b>A2</b>	<b>Leidsche Rijn tunnel</b>	<b>2012</b>



# Road tunnels in the Netherlands

## Planned tunnels (TEN)

1. A4 Tunnel Delft – Schiedam
2. A2 Tunnel Maastricht
3. A9/A6 Tunnel Schiphol-Amsterdam-Almere connection



## Increasing complexity

Developments in the Netherlands:

1. Increasing societal interest in safety
2. Development of traffic management
3. Development of ICT
4. (Changing roles in construction process)



## Societal interest: Influence of accidents

### **Tunnel fires**

Mont Blanc Tunnel (March 1999), truck on fire (38<sup>+</sup>)

- Gotthard Tunnel (October 2001), collision of two trucks (11<sup>+</sup>)
- Chanal Tunnel (November '96 / August '06/ September '08) (0<sup>+</sup>)

### **Fires**

- Kaprun (November 2000), Cable train in tunnel (155<sup>+</sup>)

### **The Netherlands**

- Cafe fire "De Hemel" (December 2000) Volendam (14<sup>+</sup>)

➡ *EU Directive 2004/54/EC* + National Law (Warvw, 2006)



## Actual fatalities (source: SWOV- fact sheet March 2009)

Period	Traffic fatalities	Highways
1996-2001	Ca. 6000	<15%
2001-2006	Ca. 5000	<15%
2006-2011	Ca. 4000	<15%
2010	640	81 In tunnels: 1%



## Traffic management

- Tunnels are no longer autonomous objects but form a part of a traffic network
- The Dutch highway network is more and more subject to traffic management:
  - Specified use of lanes (speed, availability)
  - Rush hour lanes (adaptation of capacity)
  - Diversions (instructions)
  - Accident management (availability)
  - Traffic information
  - Access control





## Increasing number of systems in tunnels

Tunnel = civil structure + limited number of installations  
(light, ventilation, drainage etc.)

Tunnel = civil structure  
+ tunnel installations (light, ventilation etc.)  
+ traffic management installations  
+ systems for operating, control & security  
(+ new: water mist systems)



New tunnels have > 50 systems



## The paradox (tunnel 1.0 → tunnel 2.0)

- Increase of tunnel safety by putting in more systems  
→ Increase of complexity
- Need for ICT to support operational modes:
  - 1) Regular
  - 2) Maintenance
  - 3) Accident(and the transition phases between the modes)
- ICT systems have to be developed (risk)  
(verification & validation required)



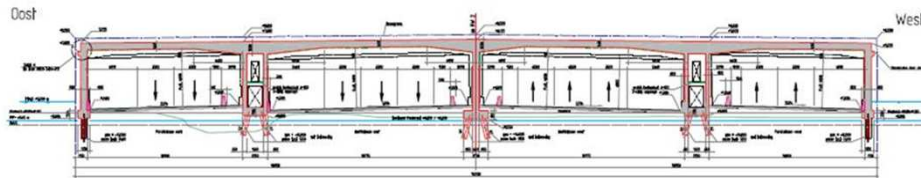
## Problems

- Two major road tunnel projects are delayed due to problems with the tunnel installations (A73 Roermond, A2 Utrecht)
- Other tunnel projects are likely to have same problems if no action is undertaken



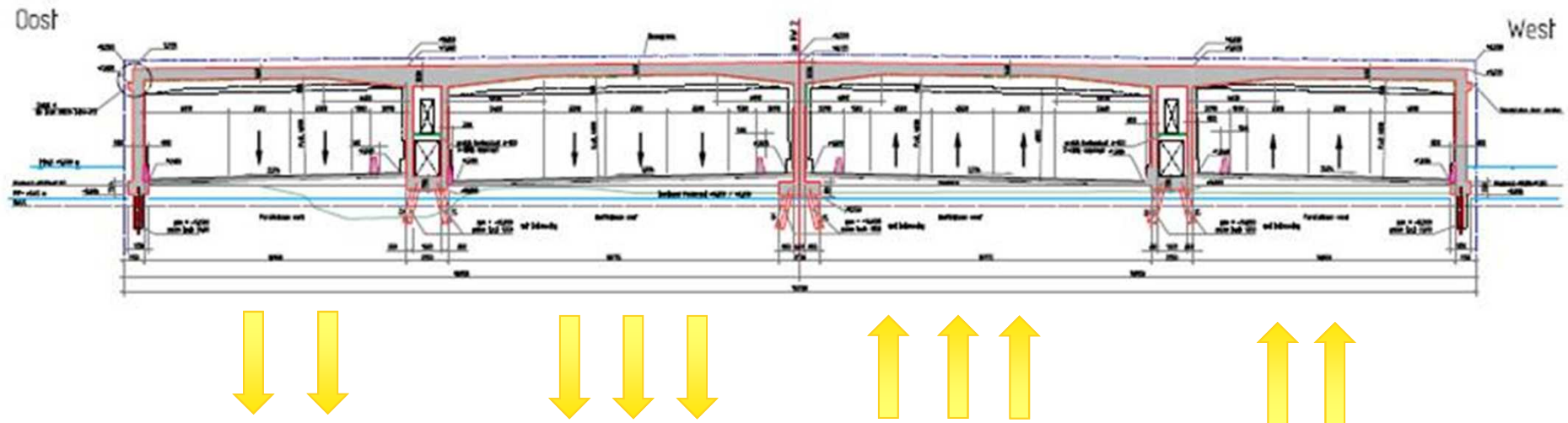


## Example: A2 Utrecht





## A2 Utrecht (Leidsche Rijn Tunnel)



Cross section



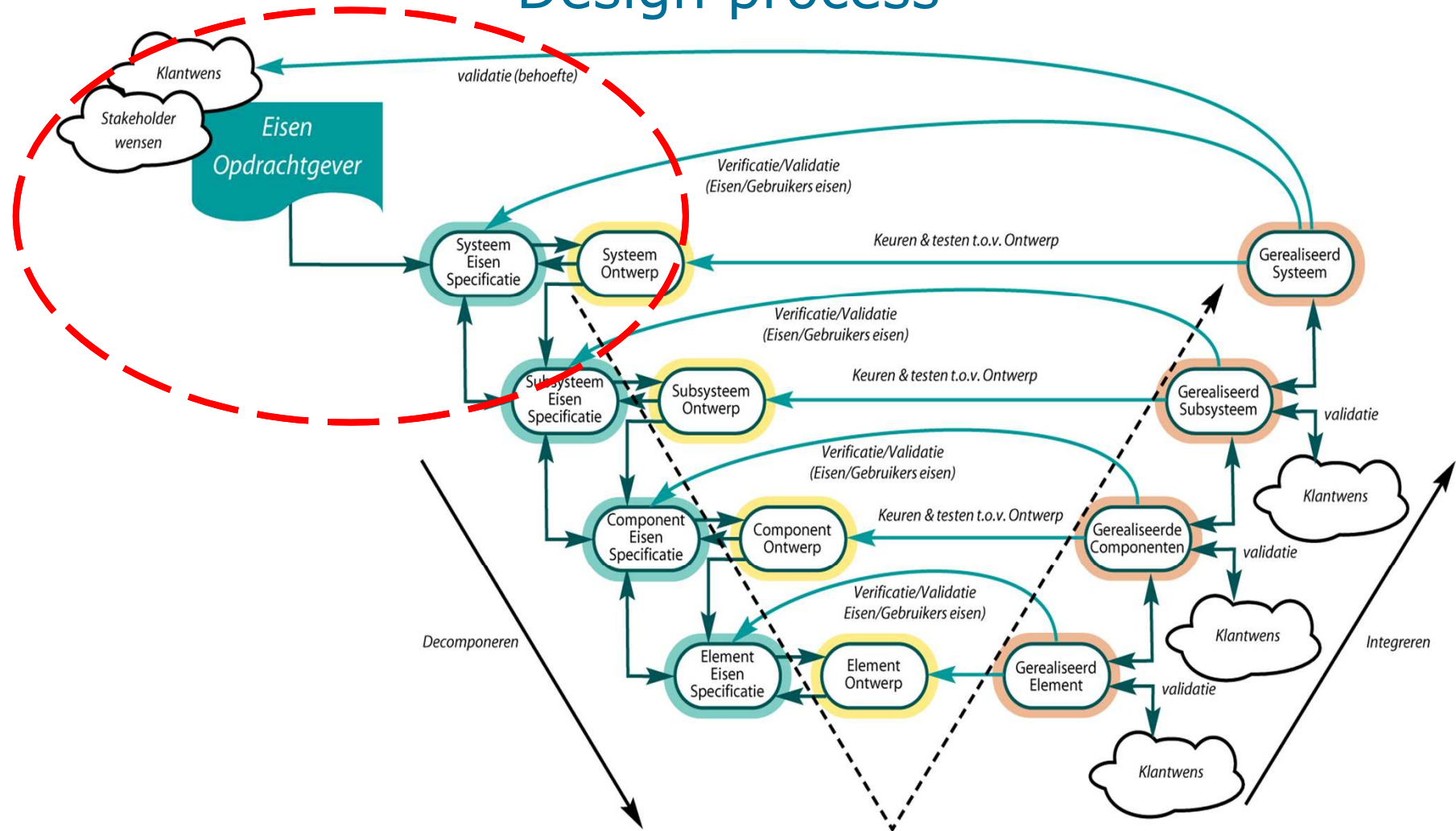


## The Tunnel - April 2011





# Design process





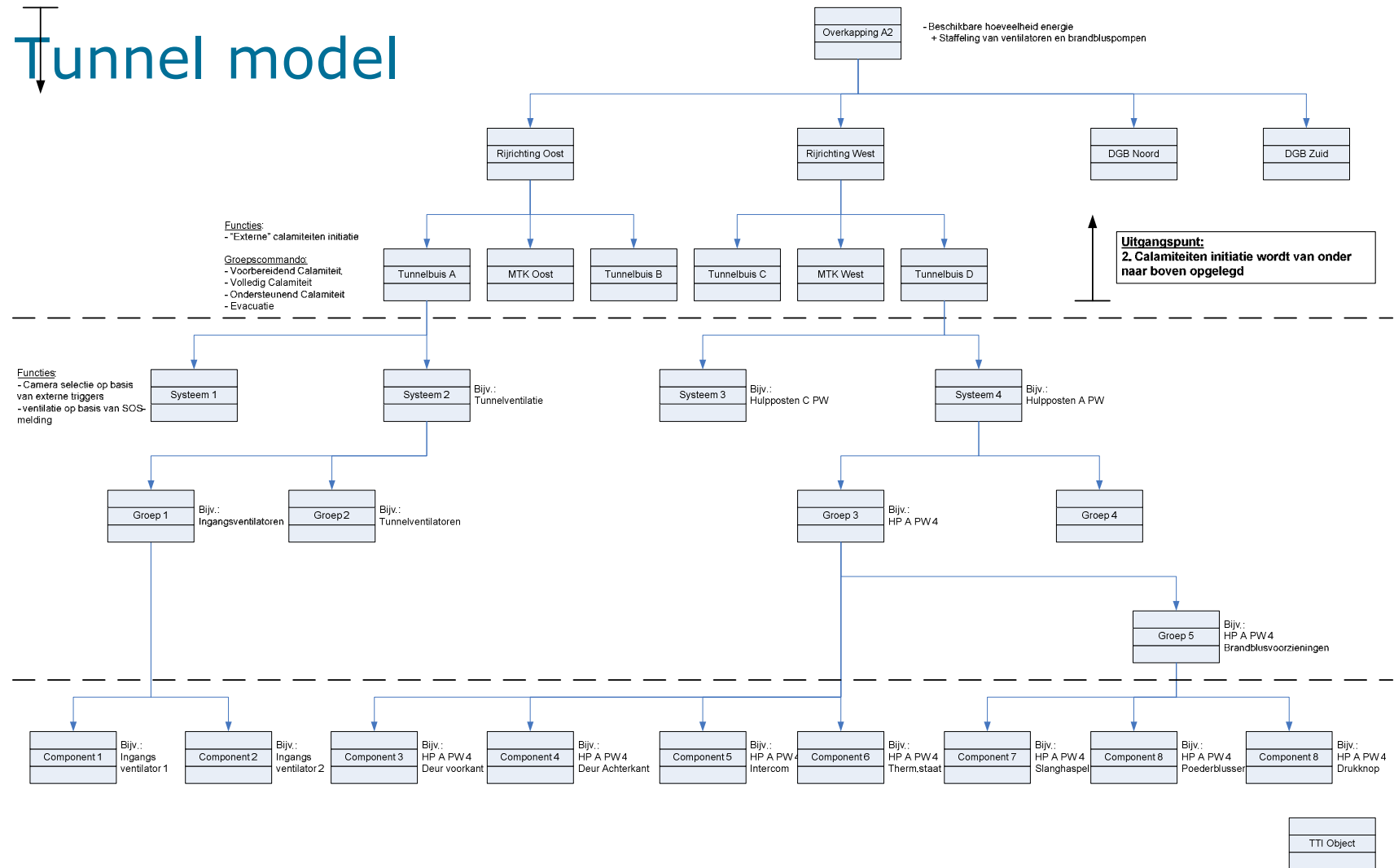
## Technical Installations of Tunnel: issues

- High complexity > underestimated/not understood (three main functions have to be integrated through cooperation of **53** part installations)
- Describing the processes involved in creating software is complex
- No working system without **system integration**





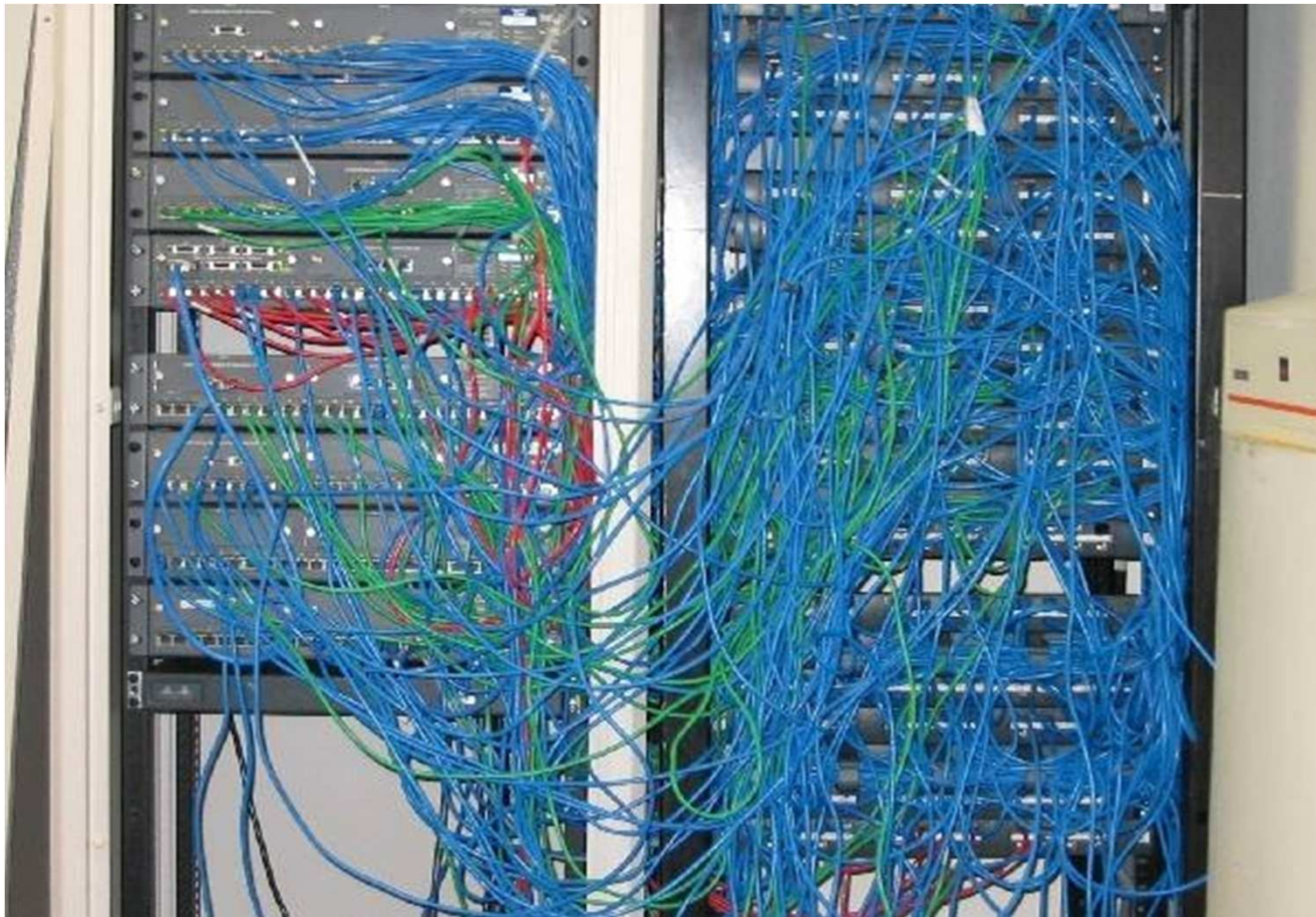
# Tunnel model







## Software is complex (4500 I/Os)





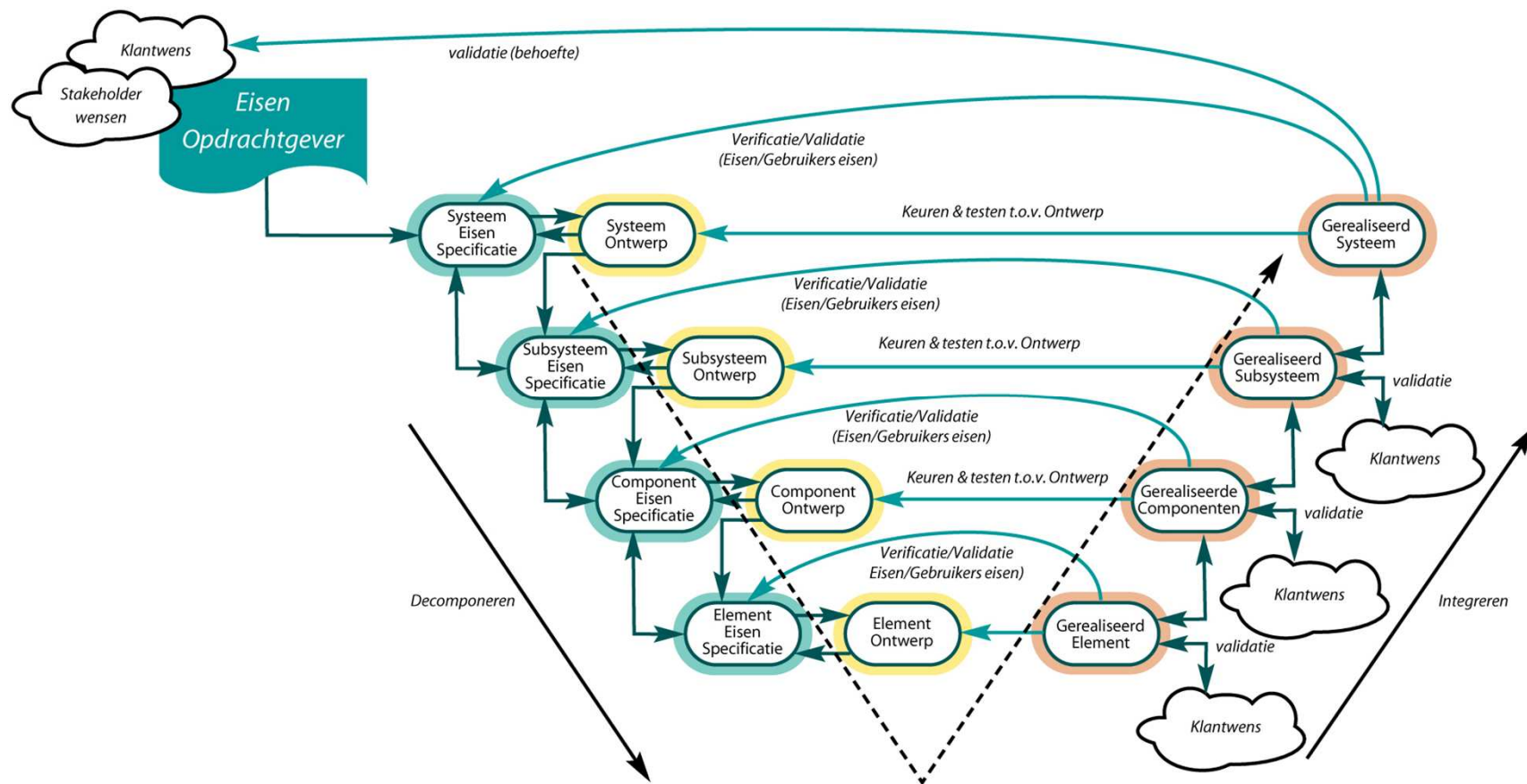
## Lessons Learned at A2 tunnel Utrecht project

- Start sufficiently early with IPM team and internal quality assurance (IPM = integral project team)
- Stakeholder management is essential (scope management)
- Analyze and specify requirements that seem contradictory
- Freeze the scope (internal System Requirement Assessment) and only use proven technology
- Choose a transparent process and keep to it through your milestones/baselines/gateways with go/no-go and external test
- Always take into account Reliability, Availability, Maintainability & Safety (RAMS) and Health.





# How Do I Do The Next Tunnel?





## Analysis (1)

*Dynamics in the governmental process due to:*

- Guideline combined with Dutch law gives no clear definition of what is a safe tunnel
- Decentralization within the administration of providing permissions (building permit and permission to use the tunnel)

Consequence:

Scope is unstable due to ongoing negotiations leading to delays and cost overruns (focus: tunnel safety)



## Analysis (2)

### *Technology:*

- Increasing role of IT
- Increase of demands regarding safety and availability
- Every single tunnel is seen as an unique project



## Solutions (1)

### ***Administration:***

Evaluation of Dutch law that will lead to:

- Modifications of the Dutch law (2012)
- Clear defined position of parties involved
- Clear definition of required safety-level (risk)
- Clear scope with regard to tunnel installations (TEN tunnels)





## Solutions(2)

### ***Technology:***

Focal point of problems: Tunnel Installations (Mechanical & Electrical)

Solution: more **uniformity** and **standardization**

More uniformity and standard solutions in contracts with regard to **installations** as well as the requirements and boundary conditions



## Role of TSO

- New tunnels:
  - Safety is sum of installations (hard-ware), controle system (soft-ware) and organisation (people)
  - Software Validation & Verification is crucial (predictable response to various operational states and conditions)
  - Installation technology requires an other approach compared to civil structures (culture, process steps and testing)

