



# Tunnelling Asia' 2023

International Conference on  
Climate Change Resilience and Sustainability in  
Tunnelling and Underground Space



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## MAINTENANCE STRATEGIES – INDISPENSIBLE PART OF SUSTAINABILITY IN TUNNELLING

by

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## Why should we think on Maintenance strategies already in an early stage design?

### Maintenance has a tremendous influence on Life Cycle Cost!

As a function over the life cycle, the cost of a project can be divided into the following main groups:

- Construction cost
- Cost during the operation
- Demolition cost
- Object follow-up costs

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## Why should we think on Maintenance strategies already in an early stage design?

**Cost during the operation shall be considered as early as possible**

- **Maintenance costs**
  - Service (fault clearance)
  - Inspection
  - Repair
  - Refurbishment
- **Energy costs**

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## Maintenance

Maintenance is the **combination of all technical, administrative and management measures** during the **life cycle** of an object that serves to maintain or restore its functional condition so that it can fulfil the required function.

## Service

Service cost include, as **part of the maintenance** costs, **all operational measures** (including minor construction measures) **that serve to maintain the target condition** of the facility. For example, cleaning measures, flushing of drainage systems, removal of vegetation, etc. are included. Service measures also **include** the **personnel costs** incurred for this as well as the necessary **operating equipment** (e.g. lights).

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## Inspection

Inspection is understood to be all **measures for evaluating the actual condition** of a structure (testing, checking, continuous monitoring). The necessary measures are to be considered according to the **guidelines of the respective operators** and include not only the **operator's internal personnel costs** but also **costs for external parties**.

## Repair

Repair is understood to be a **large-scale measure** in which an **aged object is restored to its original, functional target condition**.

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## Refurbishment

Refurbishment includes all structural and administrative measures to **increase the load-bearing capacity, safety or performance** of a structure that go beyond the original target condition.

## Energy costs

Energy cost **include all expenses for electrical or thermal energy** (heating, cooling, ventilation, lighting, pumps, etc.) incurred for the safe operation of the building.

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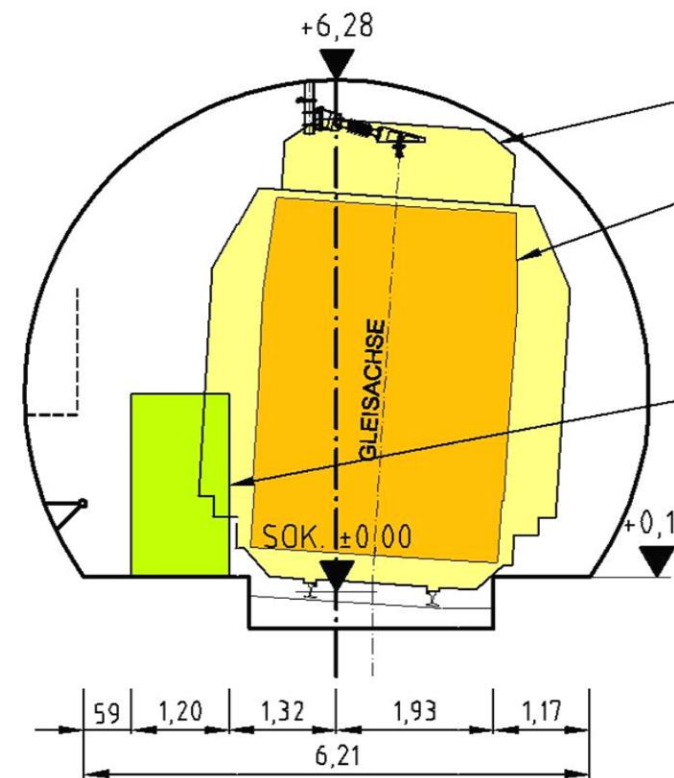
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## Typical objectives

- Safe operation
- Proven constructions
- Service life of at least 100 years
- New requirements
- Cost pressure



Extended clearance  
profile

Clearance profile  
for stopped train

Escape and  
rescue route



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## External effects

- Rock type, rock pressure
- Water chemistry, water pressure
- adjacent buildings
- position in the tunnel (near the portal)

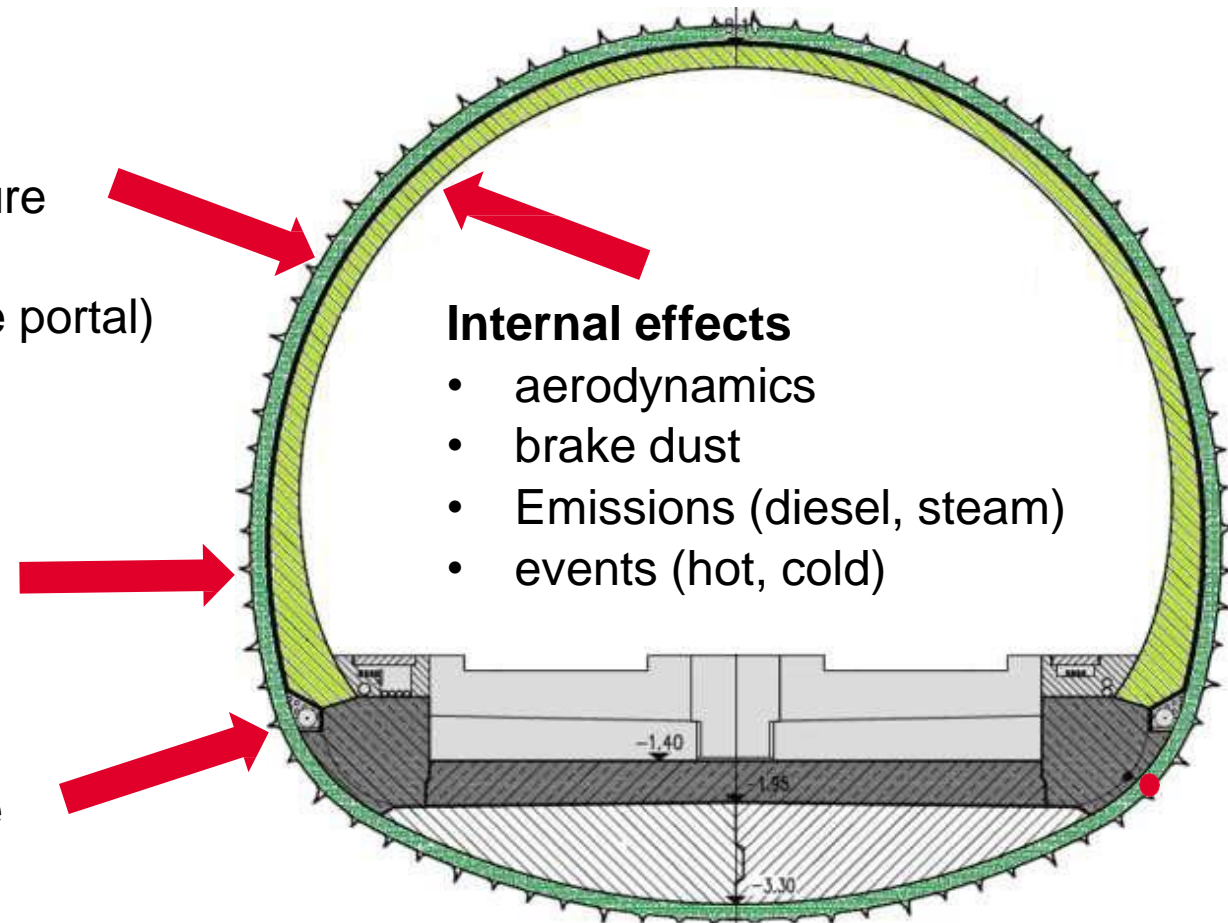
## Structure

- load-bearing effect (type of construction, vault)
- material aging (creep, carbonation)

Drainage  
sintering

## Internal effects

- aerodynamics
- brake dust
- Emissions (diesel, steam)
- events (hot, cold)



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## Structuring of tunnels

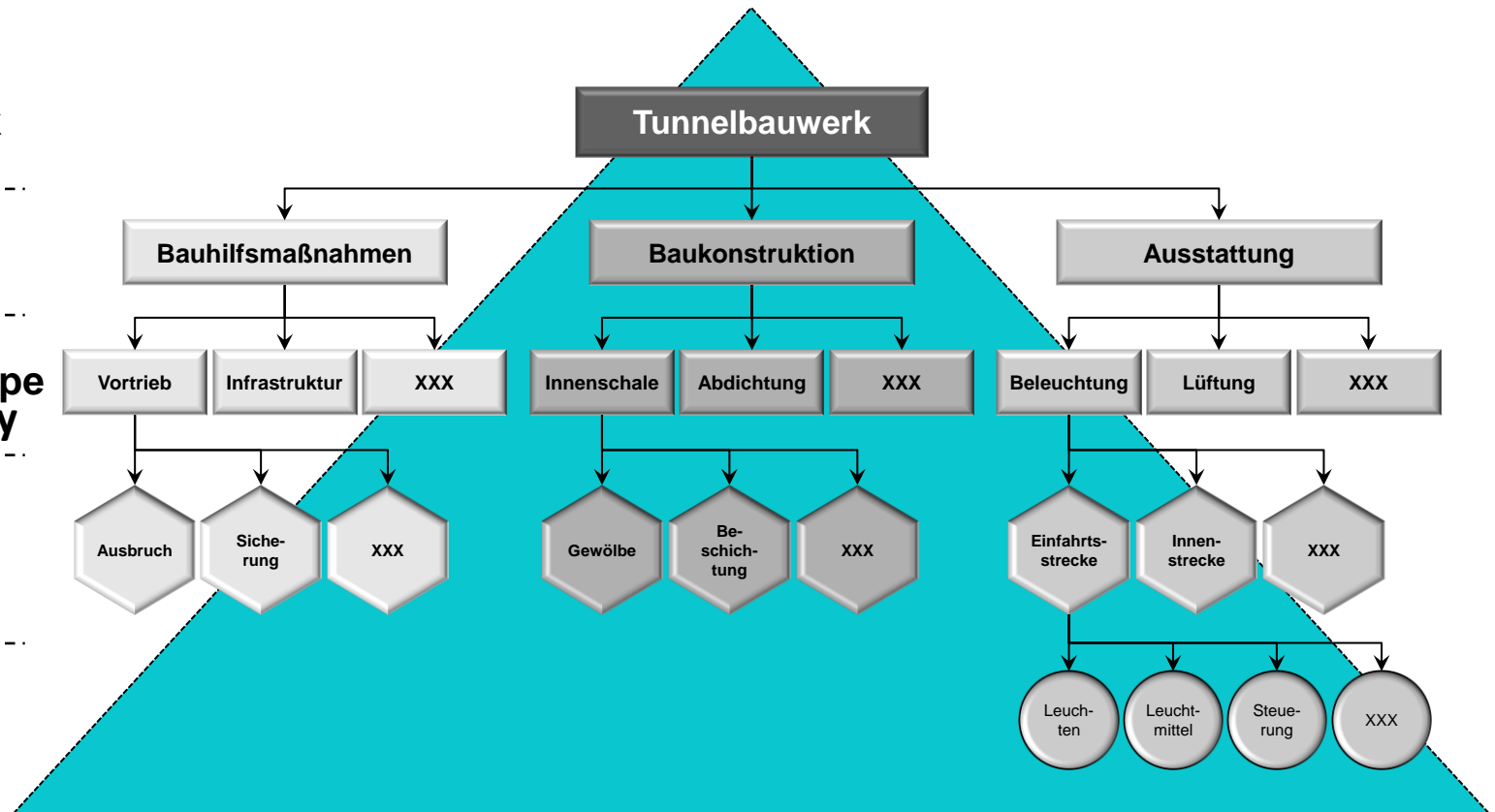
Bauwerk  
building

System  
system

Baugruppe  
assembly  
group

Modul  
module

Element  
element



[Engelhardt]

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**Life cycle assessment of tunnels should be based on  
the List of components which are used in tunnels**

**Questions in this regards are ...**

- average service life?
- acquisition costs?
- replacement cost?
- life cycle relevant? [Y/N]
- maintenance interval?
- synergies feasible?

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## Example Sintering

**Not considering Sinter  
can turn out in a real  
challenge!**



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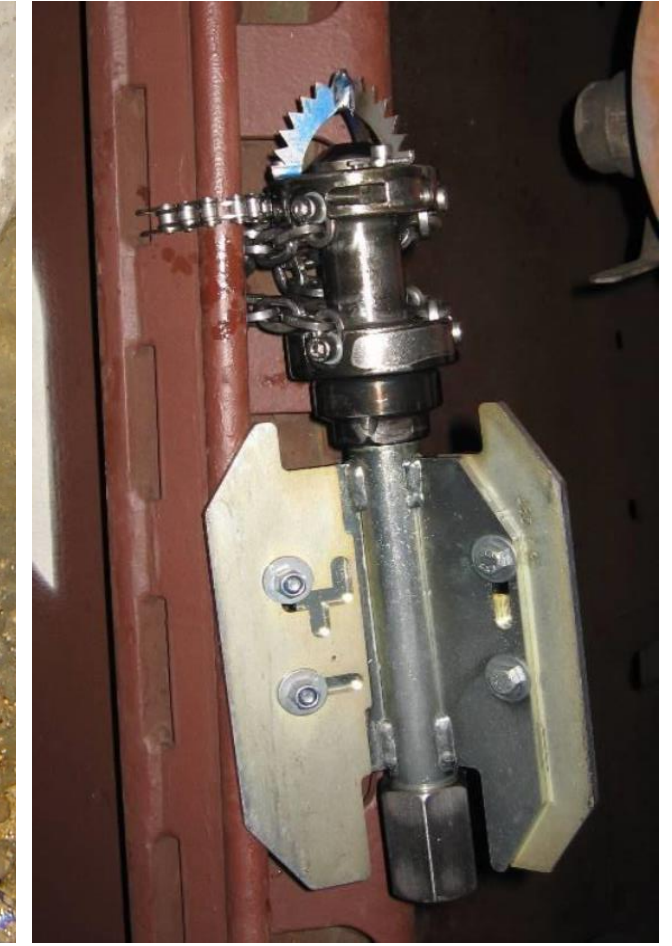
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## Challenge: Cleaning of Sinter



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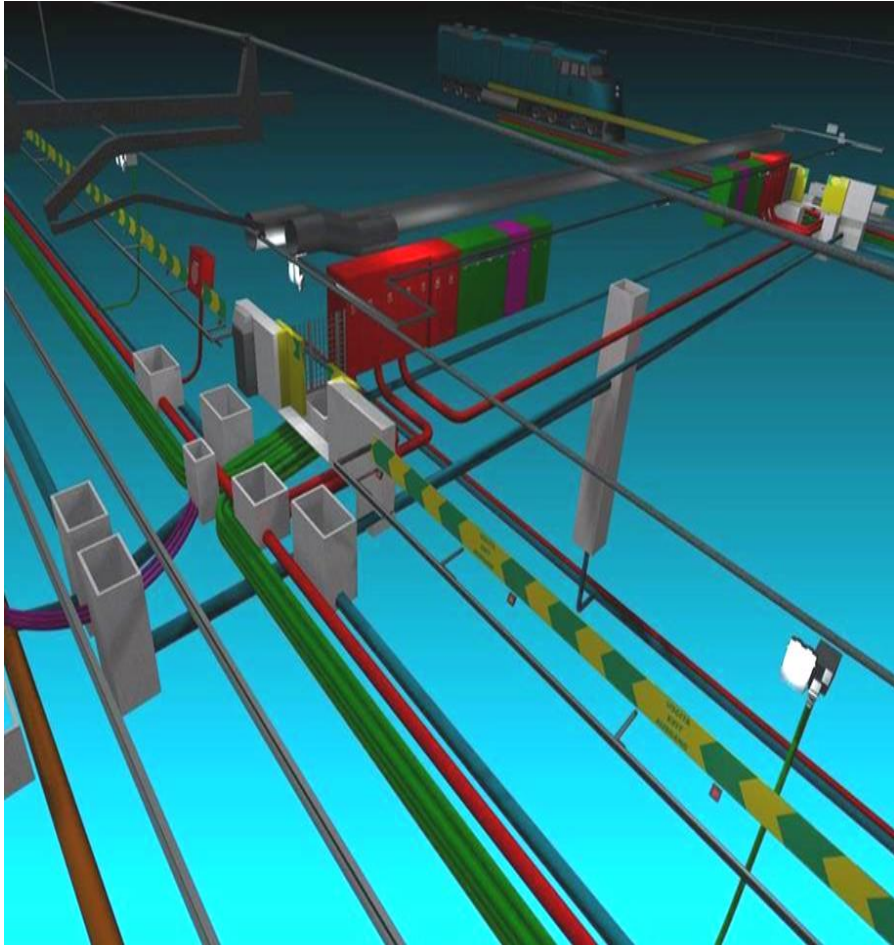
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**A maintenance  
friendly design!**



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## The following further reasons may cause intensive maintenance & repair works

- Imminent loss of stability
- Imminent loss of serviceability
- Necessary safety upgrades
- Clearance profile restrictions or changed requirements
- Maintenance significantly restricts the availability of the underground system

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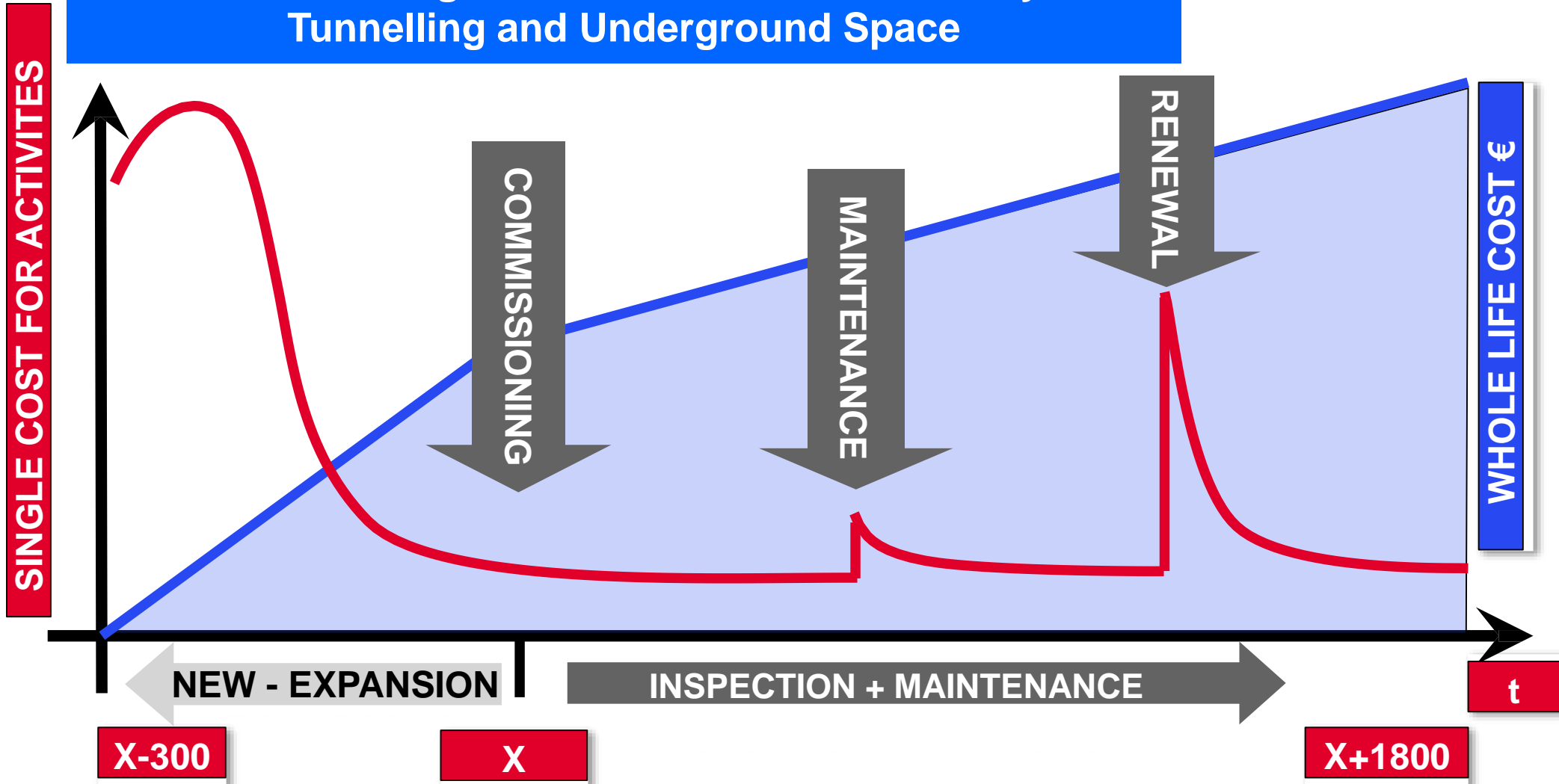


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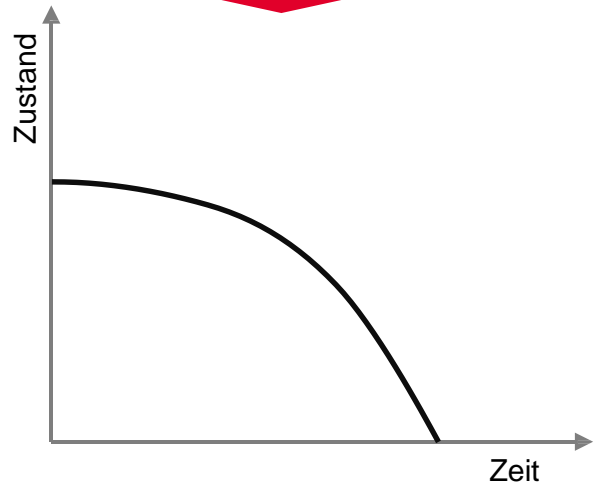
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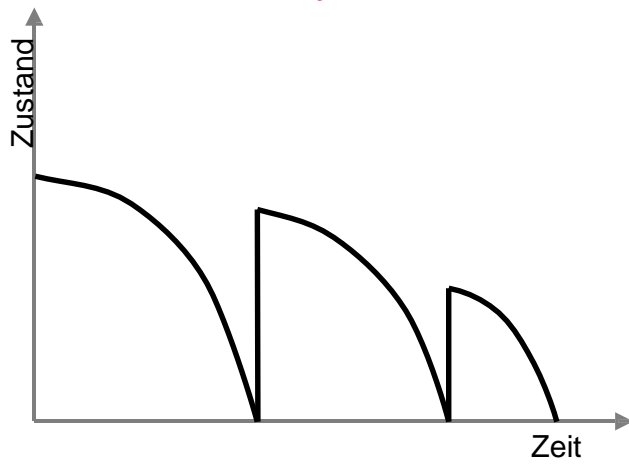
## Maintenance Strategies

**„Do Nothing“- method**



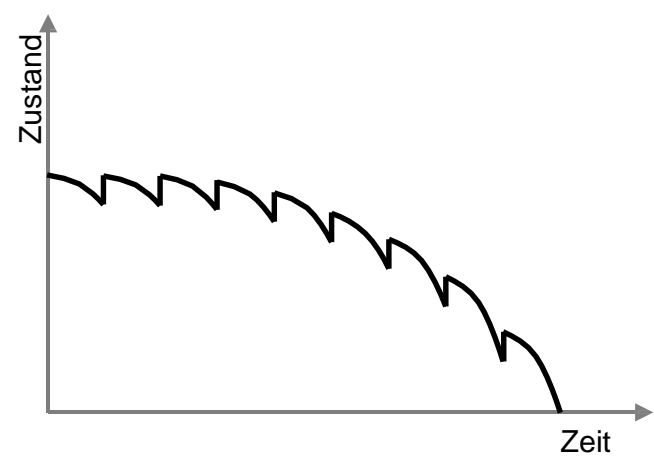
**no track closure**  
**new construction, ...**  
**demolition**

**few big M measures**



**few long locks**  
**few large M measures**

**continuously small M - measures**



**several short locks**  
**several small M measures**





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## Maintenance strategy

From an operational point of view, the main tasks in maintenance are to ensure structural and equipment functionality through

- Forecast of the development of the portfolio
- Verification of future system states through control and testing
- Maintenance and servicing so that life cycles are achieved
- Timely initiation of renovations





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## Life time of constructions

- Civil structures: 50 years
- Bridges: 80-100 years
- **Tunnels: 100-200 years**

## Service life according to EN 1990 (Eurocode 0)

- *Buildings and ordinary structures: 50 years*
- *Monumental buildings, bridges and other engineering structures: 100 years*

## Maintenance cycles:

- e.g., coating system, 10-15 years
- e.g., roadway: 15-20 years



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## Damage Mechanisms of aging

- Concrete corrosion
- steel corrosion
- geomechanical processes
- hydrochemical processes
- fatigue
- fire
- wear



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### Tests and inspections

#### Ongoing monitoring

interval: **every 4 months**  
 implementation: roadside service  
 scope: inspection from the vehicle for defects and damage  
 results: written obligation to report damage

#### Inspection

interval: **every 2 years**  
 implementation: internal experts (trained assistants, HTL)  
 scope: visit and inspections without scaffolding, device  
 results: written documentation of changes to the last inspection; immediate measures

#### Test

interval: **every 12 years**  
 implementation: internal and external experts (HTL, university)  
 scope: Hand inspection of all building elements with equipment (HUB)  
 results: written documentation of all damages and defects, request for repair, measures with time schedule



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## Scope of inspection or testing:

- inner shell (reinforced and unreinforced blocks)
- coating
- roadway and border path
- escape routes, cross cuts
- niches with covers
- intermediate ceiling
- ventilation structures (shafts, towers)
- drainage (sidewall drainage)
- plant components (radio masts, traffic signs, foundations)
- special structures (GSA and pump shafts)
- ground marking, extinguishing system

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[Rainer Kienreich]



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Thanks for your attention!

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Glückauf!

ZaB

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