Influence of cross-passages temperatures on the life-cycle cost of technical equipment in a railway tunnel
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**Baltic-Adriatic Corridor** of the trans-European-road and railway axes in Central Europe *(1,800 km)*

From the **Baltic seaports** to the **Adriatic ports**

**Industrial regions** of Central and Southern Poland

Czech Republic, Slovakia, **Austria**, Slovenia and Italy

Key railway projects Semmering Base Tunnel and **Koralm Railway Line**
Koralm Tunnel is the sixth-longest railway tunnel in the world

Wettmannstätten to St. Andrä (33 km)

Travel time will be reduced for more than 2 hours (Graz-Klagenfurt)

Two tunnel tubes (external diameter of around ten meters)

Connected with 68 cross-passages (interval around 500 m)
Cross-passages serve as
- escape-ways and
- utility rooms

Technical equipment
- low voltage systems
- medium voltage systems
- transformer systems
- telecommunication systems
Thermal simulations revealed **indoor air temperatures** up to 85°C

Heat release of the **technical equipment**

**Limited heat transfer** with the surrounding rock and with the adjacent running tubes
Reduced service life of telecommunication systems

Arrhenius equation determine the expected lifetime of telecommunication systems

<table>
<thead>
<tr>
<th>Utility room temperature</th>
<th>Service life</th>
<th>Replacement cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>22°C</td>
<td>16 years</td>
<td>3</td>
</tr>
<tr>
<td>25°C</td>
<td>13 years</td>
<td>3</td>
</tr>
<tr>
<td>30°C</td>
<td>9 years</td>
<td>5</td>
</tr>
<tr>
<td>35°C</td>
<td>6 years</td>
<td>8</td>
</tr>
<tr>
<td>40°C</td>
<td>4 years</td>
<td>12</td>
</tr>
<tr>
<td>45°C</td>
<td>3 years</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure: ACTES Ingenieure
Should the telecommunications systems be exposed to higher room temperatures and thereby exchanged at short replacement cycles or

is there an economic advantage if the utility rooms are cooled (ventilated or active cooled) to reach longer replacement cycles of the telecommunications systems
First classification for 22°C
27 active cooled cross-passages and 41 ventilated cross-passages

First approach for LCCA
active cooling of all cross-passages with air-conditioning systems

Terms:
Active cooled = air-conditioning system
Ventilated = ventilation systems
Different installation costs

- First classification – target temperature 22 °C
- All CP active cooled – target temperature 22 °C

Years

Life-cycle Cost in %

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100% 110% 120% 130% 140% 150% 160% 170%
Different operation costs (energy demand) and different maintenance costs
Different construction costs

Replacement cycle of air-conditioning systems (10 years)
Replacement cycle of ventilation systems (20 years)
Different construction costs

Replacement cycle of telecommunication systems (16 years)
**Target temperature 22 °C**

![Diagram of active cooled cross-passages and ventilated cross-passages at 22 °C]

**Target temperature 25 °C**

![Diagram of active cooled cross-passages and ventilated cross-passages at 25 °C]
Target temperature 30 °C

Target temperature 35 °C

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Life-cycle cost in %

- Target temperature 22°C (100 %)
- Target temperature 25 °C
- Target temperature 30°C
- Target temperature 35°C

Years

0 10 20 30 40 50

10% 20% 30% 40% 50% 60% 70% 80% 90% 100% 110% 120% 130% 140% 150% 160% 170%
Target temperature 30 °C

Target temperature 35 °C

Target temperature 35 °C:

Replacement cycle every 6 years instead of 9 years

Higher maintenance costs at higher temperatures

Lower energy demand for cooling
Dominance analysis - Target temperature 30 °C
Dominance analysis - Target temperature 30 °C

Maintenance cost of telecommunication systems

Ventilation systems

Air-conditioning systems

Life-cycle cost

LCCA – 2st CALCULATION RUN

13.09.2019

Dominance analysis

Target temperature 30 °C

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Sensitivity analysis - Target temperature 30 °C

Scenario 3 (S3) – Input parameter: Initial values

- Service life telecommunication systems
- Interest rate
- Rate of price increase
- Adaption, refurbishment and repair cost telecommunication systems
- Adaption, refurbishment and repair cost ventilation systems
- Service life ventilation systems
- Energy price
- Operating hours ventilation systems
- Service life air-conditioning systems
- Rate of energy price increase
- Adaption, refurbishment and repair cost air-conditioning systems
- Operating hours air-conditioning systems
- Operating load scenario air-conditioning systems
Sensitivity analysis - Target temperature 30°C

- Service life – 9 years
- Service life – 14 years
- Service life – 4 years

Scenario 3 (53) – Input parameter: Initial values

Changes of Life-cycle cost in %

- Service life telecommunication systems
- Interest rate
- Rate of price increase
- Adaption, refurbishment and repair cost telecommunication systems
- Adaption, refurbishment and repair cost ventilation systems
- Service life ventilation systems
- Energy price
- Operating hours ventilation systems
- Service life air-conditioning systems
- Rate of energy price increase
- Adaption, refurbishment and repair cost air-conditioning systems
- Operating hours air-conditioning systems
- Operating load scenario air-conditioning systems
Risk analysis - Target temperature 30 °C

Changed input parameters:
- Interest rate
- Rate of price increase
- Energy price
- Rate of energy price increase
First calculation run has shown that the decisive input parameters are the required cooling energy for air-conditioning systems and ventilation systems.

Reduction of cooling energy by other classification resp. by higher target temperatures

Second calculation run has shown that the cross-passage classification for the target temperature 30°C is the most economic scenario over a period of 50 years

At higher target temperatures the difference between the energy demand is too low to compensate the shorter replacement cycles and higher maintenance cost

Dominance analysis has shown that the cost drivers are the maintenance cost of the telecommunication systems

Sensitivity analysis has shown that the uncertainties in the service life of the telecommunication systems affect the life-cycle cost most

Risk analysis has shown that life-cycle cost analyzes are subject to uncertainties
THANK YOU FOR YOUR ATTENTION

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