Testing of complex tunnel systems

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Introduction

• Background Norwegian standards
• The Knappetunnel
• Preparations during design
• Example SAT
Background

- Norwegian public road administration
- Road traffic central, region west
  - 250 tunnels
  - 2 – 6 operators on duty
  - Low tolerance for alarms
Stages of testing

• Factory Acceptance Test
• Suppliers Test
• Site Acceptance Test (SAT)
• User Acceptance Test
The Knappetunnel

- 6.4 km highway tunnel
- Two construction stages
- 6 tunneled slip roads
- 10 tunnel portals
- Joint system with the Lyderhorntunnel
Photo: Statens vegvesen
The Knappetunnel

• 2730 objects
  • VMS signs
  • Ventilation
  • Automatic barriers
  • Automatic incident detection
  • Traffic plan generator
  • Automatic response to wrong way driver and queue
• Large amount of objects
• Complex system

What can we do to ensure satisfactory and efficient testing, while keeping a good overview?
Design and contract

• Plan for testing in early stage
• Design documents used for testing
  • List of objects
  • Requests for programming
List of objects

• Standardized description for process interface
• Detailed description of objects types
## Status emergency cabinet

<table>
<thead>
<tr>
<th>Status bit</th>
<th>High</th>
<th>Low</th>
<th>Ok/comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Door open</td>
<td>Door closed</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Door blocked</td>
<td>Door enabled</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Telephone receiver lifted</td>
<td>Telephone receiver in place</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Fire extinguisher removed</td>
<td>Fire extinguisher in place</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fire extinguisher blocked</td>
<td>Fire extinguisher enabled</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Telephone receiver blocked</td>
<td>Telephone receiver enabled</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Telephone error</td>
<td>Telephone ok</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Error on telephone blocked</td>
<td>Error on telephone enabled</td>
<td></td>
</tr>
</tbody>
</table>
## Specifications for object

- Tag
- Object type
- Status bits
- Command bits
- Parameters
- Values
- Comments
- Columns for testing

<table>
<thead>
<tr>
<th>Tunnel navn</th>
<th>Telleromr.</th>
<th>Pls.</th>
<th>Seriellsn.</th>
<th>ID hinterfelt til PC</th>
<th>Objekt type nr</th>
<th>Bit Statusord</th>
<th>Bit kommandord</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1</td>
<td>A51</td>
<td>AS1</td>
<td>10</td>
<td>10016om551</td>
<td>10</td>
<td>0,1,2,3,4,6,7</td>
<td>0,1,2,3,5,7</td>
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<td>A51</td>
<td>AS1</td>
<td>10016om552</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS1</td>
<td>A51</td>
<td>AS1</td>
<td>10015om510</td>
<td></td>
<td></td>
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<tr>
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<td>A51</td>
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<td>10015om511</td>
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<td>10016om561</td>
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<td>10016om563</td>
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</tbody>
</table>

Columns for testing:
Requests for programming

- Separate document
- Detailed description
- Unique and verifiable requests

<table>
<thead>
<tr>
<th>Request No.</th>
<th>Request</th>
<th>Approved</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3.1</td>
<td>“Description”</td>
<td></td>
<td>XX</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Position “3” has priority over position “2” which has priority over position “1”.</td>
<td></td>
<td>XX</td>
</tr>
</tbody>
</table>
• List of objects
  • Supplier signed every object
  • Signed during SAT
  • Overview and documentation

• Requests for programming
  • Unique and verifiable
  • New document in construction stage 2
  • Useful for follow-up
Site Acceptance Test

• Approach described in article

• Reliable response to SCADA system

• Example
Reliable response

- Reliable response to the SCADA system
- VMS signs
  - Test button
- Ventilators
Traffic plans
Traffic plans

- Automatic response in the Lyderhorntunnel
- Swift changes
- Incompatible combinations
- “Unexpected” commands
• Verify feedback to SCADA system
• Traffic plans
  • Transitions
  • Stress test
Conclusion

• Discovered faults at all stages
• Design and contract
  • List of objects
  • Requests for programming
  • Expectations for testing clear to supplier
  • Good overview
  • Follow-up on errors