C4R Workshop on Dissemination
Paris 2015-06-10--11

Dr Björn PAULSSON
Trafikverket, Sweden
Contents of presentation

Contents
• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Do you think the increase will stop 2015?
Do you think the increase will stop 2015?

- **Background and idea**
• **Background and idea**

The problem with overcrowded roads must be solved
Background and idea – existing lines

Background:
• Very few recently built railway lines are built specifically for freight traffic
• Today the trend is that the new built lines are for high speed operations and existing lines are left for freight
• These existing lines are built for the traffic demands from the time they were built
• This means that the railways have to upgrade existing lines in order to meet new demands from freight operators
• **Background and idea – meet demands**

Background:

- Freight operators often come with new proposals but they stop too often due to infrastructure restrictions.
- There are restrictions but also possibilities!
- When we upgrade to meet new demands we don't have any good guidelines or best praxis based on recent research and development.
- D1.1.4 is a guideline to support upgrading based on recent research and development.
- D1.1.5 is an upgraded version including findings from C4R and other new knowledge.
Examples of EU-projects where we have new knowledge that can be used for upgrading

- MARATHON
- AUTOMAIN
- D-RAIL
- INNOTRACK
- RIVAS
- SPECTRUM
- MAINLINE
- SMART RAIL
- SUSTAINABLE BRIDGES
- SUSTRAIL

Research input

CAPACITY4RAIL D1.1.4
Examples of EU-projects where we have new knowledge that can be used for upgrading
Contents of presentation

Contents
• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Objectives

The main objective is to give Infrastructure Managers a guideline so upgrading can be done
• Cost-effective
• Environmentally friendly
• Carried out in a standardised way

The guideline have clear recommendations when possible
Refer to latest knowledge or good real examples
Contents

• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Traffic situations

- Longer trains
- Increased train weight
- Increased axleloads
- Higher speeds
- Increased loading gauge

Input from MARATHON, SPECTRUM, D-RAIL and other EU-projects
Contents of D1.1.4 Methods for assessment and strategies for upgrading infrastructure in order to meet new operation demands

Workflow in 1.1.4

Traffic situations give demands on infrastructure

New demands on infrastructure triggers enhanced maintenance routines
Contents of presentation

Contents

• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Contents of D1.1.4 – **Substructure**

This part is dealt into two parts namely

- Subgrade assessment
- Subgrade improvements

This part is the part where least international research has been carried out historically

- Why? Conditions vary a lot in different parts of Europe due to different substructure conditions and evaluation engineering traditions
- Valuable input comes from INNOTRACK SP2, Eurobalt2, RIVAS and national R&D
• **Contents of D1.1.4 – Subgrade assessment**

• We have evaluated several different methods like geo-radar, track stiffness measurements and other NDT investigation methods

• Assessing substructure condition
  
  • Subgrade condition and track geometry deterioration
  
  • Track stiffness and its impact on track behaviour
  
  • Influence of track stiffness and its variations
  
  • Role of track stiffness measurement in track maintenance and upgrading
• Contents of D1.1.4 – Subgrade assessment
  • Methods for subgrade quality assessment
    • Track substructure stiffness measurement
      • Standstill measurements
      • Rolling measurements
      • Outcome of different measurement techniques
• Contents of D1.1.4 – Subgrade assessment

• Methods for subgrade quality assessment
  • Geophysical inspection of substructure defects
    • GPR (Ground Penetrating Radar)
    • Resistivity profiling
    • Multielectrode method (resistivity tomography)
  • Seismic methods
  • Gravimetry

• Geomechanical investigation of substructure problems
Examples – GRP (ground penetrating radar)

GPR rail-setup with three pairs of 1-GHz horn antennas

The generation of a GPR profile: a) transmission principles; b) single GPR scan
Examples

• Stiffness measured with IMV100S
Motivation

Future traffic demand
• Longer trains
• Increased train weight
• Increase axle loads
• Higher speeds on freight trains
• Increased loading gauges

Problems in the subgrade
• Reduction of stability
• Increase of settlements
• Extensive vibrations
• Increased degradation

Need for improving the subgrade bearing capacity, stability and durability

Negative impact in rail operation:
• Safety
• Reliability
• Economy
• Increased maintenance
Flow chart for assessment, improvement and follow-up of subgrade
D1.1.4 – Section 4.1.2 Subgrade improvements

Decision factors
Total cost of the improvement
• Cost of the strengthening works
• Cost of traffic disruption
• Environmental impact

Two different approaches
1. Improvement from the track
   • Installation between the sleepers (~40cm) -> No or little traffic disruption
   • Remove of the track frame -> Long traffic disruption
   • Other problems: Safety, catenary, cable ducts, polluted ballast, etc.
2. Improvement from sides of railway embankment
   • Minor affection to train operation (train speed and axel load reduction)
   • Need of enough space besides the track

Follow up after installation
• Track geometry, pore pressure dissipation, long-term settlements
## D1.1.4 – Section 4.1.2 Subgrade improvements

<table>
<thead>
<tr>
<th>Method</th>
<th>Scheme</th>
<th>ALLOW</th>
<th>TYPE OF</th>
<th>INCREASE OF</th>
<th>REDUCE OF</th>
<th>REDUCE OF</th>
<th>EXPERIENC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Deep Mixing</td>
<td><img src="image1" alt="Diagram" /></td>
<td>a-1 b-3 c-3</td>
<td>2</td>
<td>3</td>
<td>a-3 b-1 c-2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2 Jet grouting</td>
<td><img src="image2" alt="Diagram" /></td>
<td>a-1 b-3 c-3</td>
<td>3</td>
<td>3</td>
<td>a-3 b-1 c-2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3 Stabilizing berms</td>
<td><img src="image3" alt="Diagram" /></td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4 Stabilizing berms combined with anchored walls</td>
<td><img src="image4" alt="Diagram" /></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5 Compaction grouting</td>
<td><img src="image5" alt="Diagram" /></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
## D1.1.4 – Section 4.1.2 Subgrade improvements

<table>
<thead>
<tr>
<th>Method</th>
<th>Scheme</th>
<th>ALLOW</th>
<th>TYPE OF</th>
<th>INCREASE OF</th>
<th>REDUCE OF</th>
<th>REDUCE OF</th>
<th>EXPERIEN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Precast concrete slab on piles</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Soil nailing</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>a-2, b-3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Vibrocompaction</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Vibroreplacement</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Grouted stone columns</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Vibroconcrete columns</td>
<td><img src="image6.png" alt="Diagram" /></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Other experiences in Spain

1) Hydraulic fracturing with injection of cement grout
Railway line Calatayud-Valencia (208+100 to 208+200)
Mixed traffic: 200km/h passenger + freight trains

2) Injections of bentonite and cement mortar
Railway line Teruel-Sagunto
Conventional passenger traffic

3) Injections of cement mortar and polyurethane resin in karst
Railway line Madrid-Seville
High-speed passenger traffic
Contents of presentation

Contents

- Background and idea
- Objectives
- Traffic situations
- Infrastructure
  - substructure
  - structures
  - rail and S&C
- Maintenance routines
- Conclusions
Contents of D1.1.4 – **Structures**

- Bridges
- Tunnels
- Culverts
- Retaining walls
Example of upgrading

A real example before Sustainable Bridges and MAINLINE Borlänge - Gothenburg line, from 22.5 => 25 tons
Example of upgrading

A real example before
Sustainable Bridges and MAINLINE 1999
Borlänge - Gothenburg line, from 22.5 => 25 tons

- Total number of bridges: 550
- Special inspected bridges: 450
- Number of bearing capacity calculated bridges: 91
- Number of material tested bridges: 35
- Number of strengthened bridges: 48 => 9%
- Number of replaced bridges: 24 => 4%

*) Corresponding figures from the Ore line 10 %
**) Corresponding figures from the Ore line 14 %

of which 10 % were planned to be replaced of other reasons

=> With today's knowledge we would have done this much
more cost-efficient
Contents of D1.1.4 Methods for assessment and strategies for upgrading infrastructure in order to meet new operation demands

Technical principles – define phases for a structured approach

Flow chart for assessment of existing bridges. Three phases are identified: Initial, Intermediate and Enhanced, depending on the complexity of the questions involved. Taken from SB-LRA (2007).
Example from Sustainable Bridges

Concrete bridge – Örnsköldsvik, Sweden

WP3 Inspection and Condition Assessment
WP4 FE-analyses
WP6 Strengthening
WP7 Loading of slab through ballast and loading of strengthened main girders to failure
Examples from MAINLINE

Rautasjokk
20 km NW Kiruna
1902, truss 1962

Åby älv
50 km W Piteå
1894, truss 1957
Åby bridge after failure. It was caused by buckling of the top right girder.

Results from an advanced assessment of the Åby Bridge. It can be seen that the present axle load of 250 kN only represents a small part of the capacity of the bridge.
Conclusions from Sustainable Bridges and MAINLINE

- A majority of today's bridges have a large hidden capacity.
- The approach is to work in defined phases and apply a structured approach.
Chapter about structures

Other parts in this chapter

- Tunnels
- Culverts
- Retaining walls
Latest version of Track Stiffness Measuring

Examples from Germany, Sweden and US

Jährod Tunnel in Germany being enlarged by the Tunnel-in-Tunnel method, Simon (2012).
Contents of presentation

Contents
• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Contents of D1.1.4 – Track and S&C

• Can we use existing track degradation model(s)? Or shall we enhance an existing? Or do we have to create a new?

• We decided to use existing models in a more “intelligent” way!
Track deterioration models, maintenance and cost

- Models for deterioration due to vertical settlement
- Models for deterioration due to wear and contact fatigue
- General deterioration models
- Other models
- Computer aided planning and prediction tools
## Different phenomena

<table>
<thead>
<tr>
<th>Deterioration phenomenon</th>
<th>Main influencing parameters</th>
<th>Important material/component parameters</th>
<th>Time to deterioration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track settlements</td>
<td>Track forces (vertical and lateral)</td>
<td>Ballast (and sub-ballast) resistance</td>
<td>Medium</td>
</tr>
<tr>
<td>Sleeper damage</td>
<td>Vertical (impact) forces, support conditions</td>
<td>Reinforcement, sleeper design</td>
<td>Short if overloaded</td>
</tr>
<tr>
<td>Plastic flow</td>
<td>(Effective) stress magnitude</td>
<td>Yield limit, surface profile</td>
<td>Short</td>
</tr>
<tr>
<td>Wear</td>
<td>Contact load (pressure and frictional), sliding distance</td>
<td>Hardness</td>
<td>Medium</td>
</tr>
<tr>
<td>Plain fatigue</td>
<td>Stress amplitude</td>
<td>Fatigue limit, surface roughness</td>
<td>Medium – long</td>
</tr>
<tr>
<td>Surface initiated rolling contact fatigue</td>
<td>Frictional contact stresses</td>
<td>Hardness, ductility</td>
<td>Medium – long</td>
</tr>
<tr>
<td>Subsurface initiated rolling contact fatigue</td>
<td>Contact pressure</td>
<td>Material defects, fatigue limit</td>
<td>Long</td>
</tr>
</tbody>
</table>
Basic approach

identified need for upgrading

low-resolution analysis
- rough cost estimation
- further identification of potential complications

medium-resolution analysis
- improved cost estimation
- identification of dominating cost areas

high-resolution analysis
- focus on key elements
- detailed cost estimation
- optimized solutions

first identification of potential increases in degradation, safety issues etc

Better cost estimations

potential (cost and/or safety) savings from further investigations higher than costs of investigations?

upgrading plan
- overall actions
- design solutions
- maintenance plan
- mitigating action plan
- evaluation
- etc

upgrading decision

decision on solutions

decision on detailed solutions
Low- / medium resolution analyses

- Difficult part in LCC analysis is to estimate deterioration costs (infrastructure lifetime)
- Often based on Wöhler curve(s)
- Exponential load–life relations > sensitive
- Simplest version: approximate curve for overall deterioration based on experience
- Easy model, but requires extensive calibration data
Medium resolution analysis

• Examples are Network Rail variable track usage charge model, and Trafikverkets DeCays

• Basically consider
  – horizontal track damage (track geometry),
  – vertical track damage (track settlements),
  – RCF / Wear (combined or separate)

• Developed to define track access charges depending on the track friendliness of different vehicles

• Based on Wöhler curves which relate to vehicle parameters and deterioration of different track components

• The analysis gives indications on dominating problem for more refined analysis
Detailed resolution analysis

- Consequences of different types of upgrading
  - Increased speed
  - Increased axle load
  - Increased capacity outtake including longer trains
  - New vehicles
  - Improvement of the track structure
  - Upgraded maintenance procedures

- Different consequences on different parts of the track infrastructure and operative procedures

- Indication of means to predict deterioration / safety risks

- Means to prevent / mitigate upgrading issues

- These are the analyses that will allow for improved solutions and save money!
Contents of presentation

Contents

• Background and idea
• Objectives
• Traffic situations
• Infrastructure
  • substructure
  • structures
  • rail and S&C
• Maintenance routines
• Conclusions
Contents of D1.1.4 – Maintenance routines

A multitude of involved topics, e.g.
- Rail and wheel grade selection
- Grinding
- Wheel lathering
- Lubrication
- Crack detection
- Welding
- Strategies for maintenance
- Increased use of automated maintenance
- Consider use of new innovative maintenance concepts
Conclusions

Upgrading of existing lines is an important way for infrastructure to meet new freight operation and market demands in the future.

To meet these demands in an economical, environmental and structured way there is a need for a guideline with latest research and best praxis.

D1.1.4 and D1.1.5 will therefore play an important role to support Infrastructure Managers to meet new market demands.
Thank you for your kind attention

Dr Björn PAULSSON

Trafikverket
Bjorn.paulsson@trafikverket.se