3D RECONSTRUCTION OF EXISTING STRUCTURES USING OPTICAL METHODS

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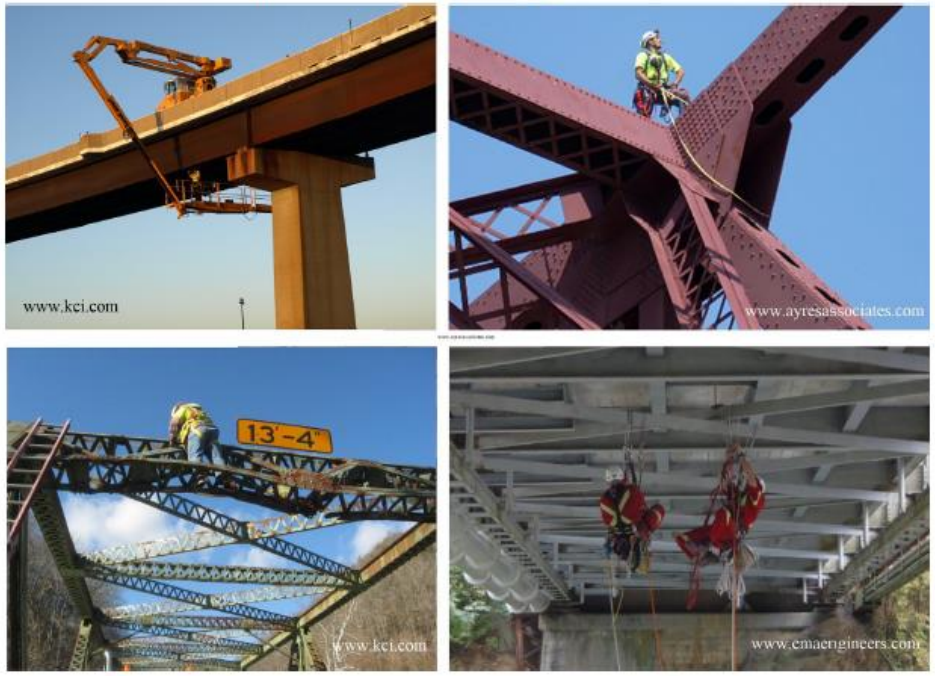
BACKGROUND

- **Visual inspection (most versatile), but:**



- Dependent on the inspector's experience
- Time-consuming data collection
- Subjective information

Problematic knowledge transfer → paper-based format

It started out as a simple analysis, but piled up to information overload.

OBJECTIVES

- Faster, reliable, low-cost alternative is needed
  - Close-range photogrammetry | infrared scanning | Laser scanning
- Six existing concrete railway bridges
  - Varied difficulty
- Analysis
  - Geometric deviations
  - Vizualizations capabilities
  - Level of the inspector’s experience
  - Degree of automation

THE SELECTED BRIDGES

- Six bridges were selected to evaluate the technologies
- Varied difficulties (hard-to-access, high vegetation, deep/rapid waters under the bridge)
- Different weather conditions (from sunny day to cloudy, raining and snowing)

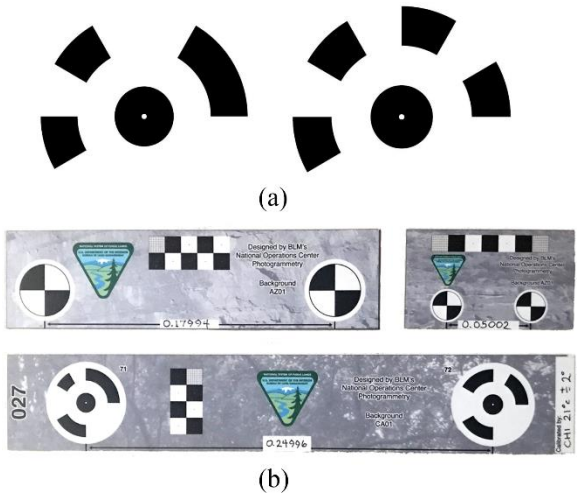
THE SELECTED BRIDGES

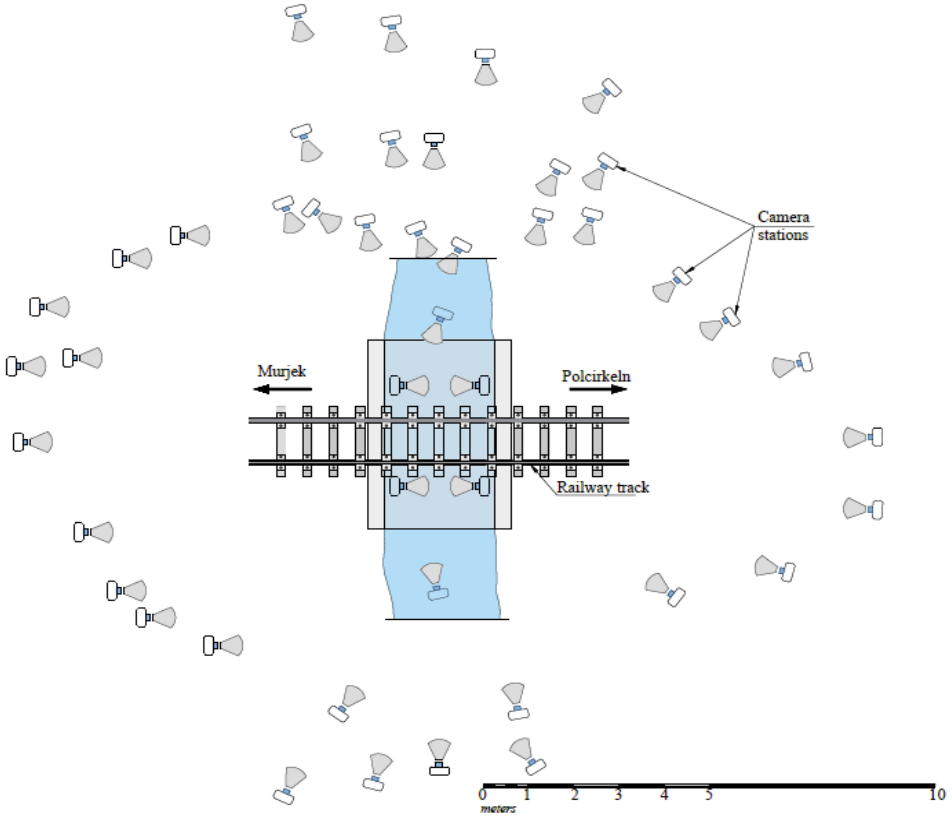
TECHNIQUES AND EQUIPMENT

- **Terrestrial laser scanning**
  - 3D geometry using light detection and ranging technology (LiDAR)
  - long-range, RIEGL VZ-400
  - time-of-flight principle with measurements ranging from 1.5 m to 600 m
  - scan angle ranges are 100° vertical and 360° horizontal

TECHNIQUES AND EQUIPMENT

- Ground-based/aerial photogrammetry
  - Series of images recorded using digital cameras
  - Photos taken with an overlap of about 60-80%
  - Distinct features: natural or artificial (targets)





TECHNIQUES AND EQUIPMENT

- **Team #1**
  - Two MSc students with no prior experience
  - Canon 5D (12.8 MP) + Canon EF 35mm
  - Agisoft PhotoScan Pro
- **Team #2**
  - Two experienced surveyors
  - Canon 5D Mark II (21.1 MP) + Canon EF 24 mm
  - 3DR Site Scan drone
  - Bentley ContextCapture

TECHNIQUES AND EQUIPMENT

- Infrared scanning
  - RGB-D cameras in combination with: infrared camera + infrared projector
  - Matterport Pro2 3D Camera
  - Scan angle range: 360° horizontal and 300° vertical
  - Maximum range 4.5 m
  - Matterport own cloud service

VISUALIZATION CAPABILITIES

- Påunakbäcken bridge

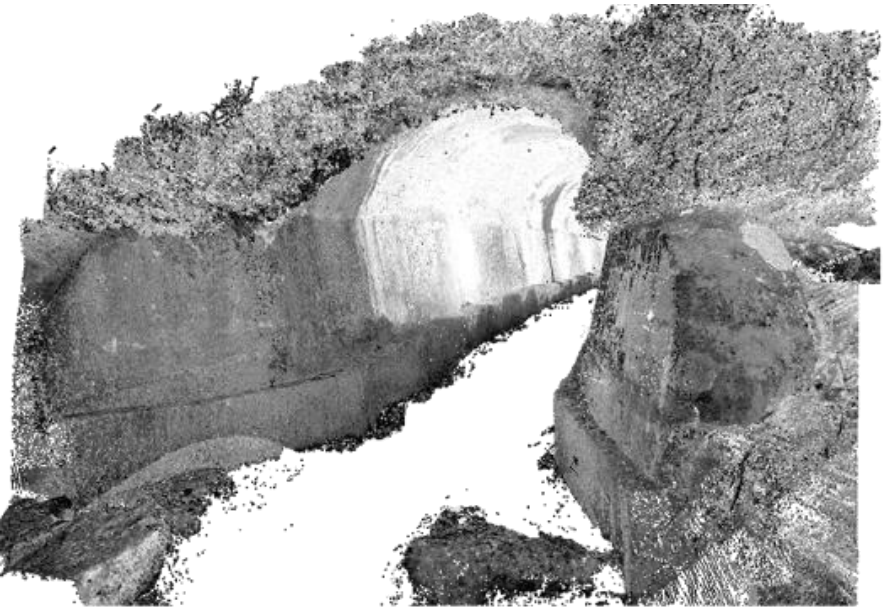
Terrestrial laser scanning

Photogrammetry

Infrared scanning

VISUALIZATION CAPABILITIES

- Kedkejokk bridge



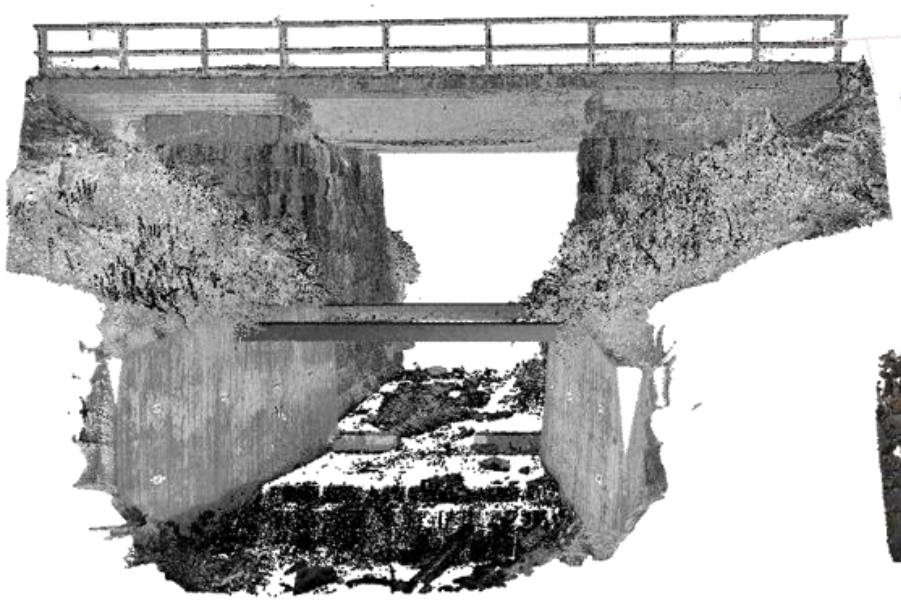
Terrestrial laser scanning

Photogrammetry

Infrared scanning

VISUALIZATION CAPABILITIES

- Juovajokk bridge



Terrestrial laser scanning

Photogrammetry

Infrared scanning

VISUALIZATION CAPABILITIES

- Kallkällevägen bridge

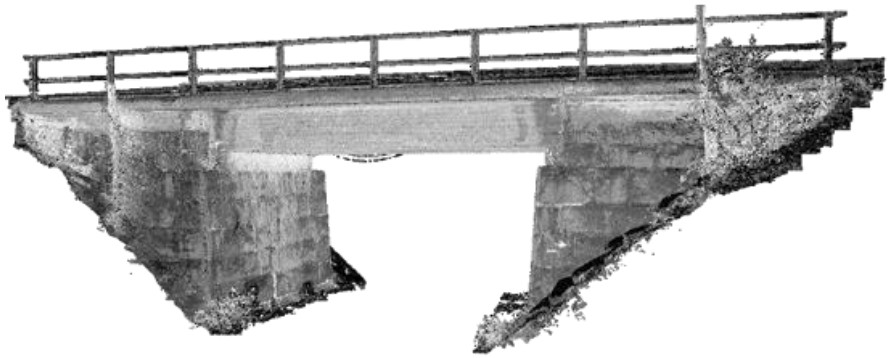
Terrestrial laser scanning

Photogrammetry

Infrared scanning

VISUALIZATION CAPABILITIES

- Pahtajokk bridge

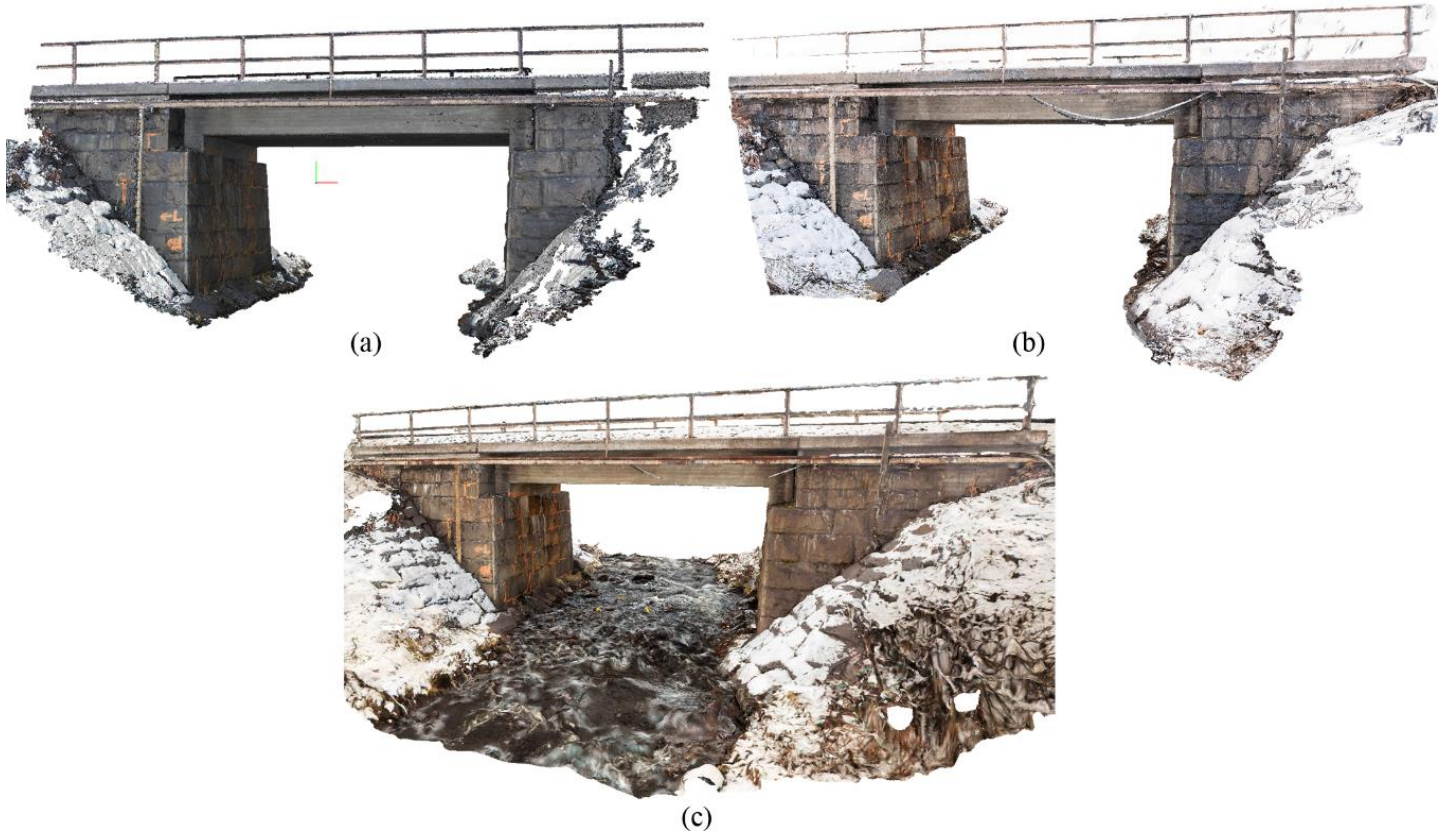


Terrestrial laser scanning

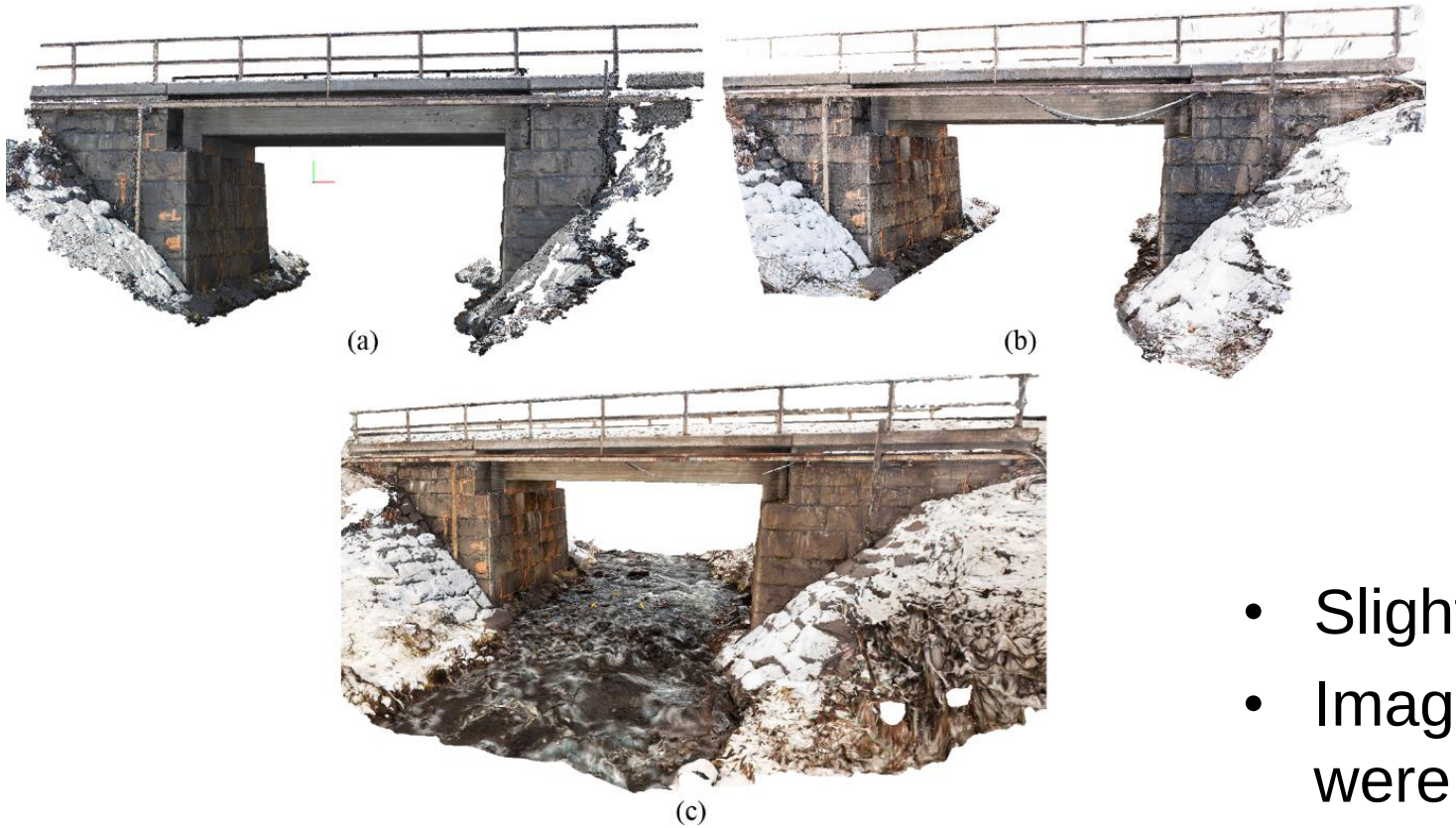
Photogrammetry

Infrared scanning

VISUALIZATION CAPABILITIES



VISUALIZATION CAPABILITIES



Photogrammetry models of Pahtajokk bridge

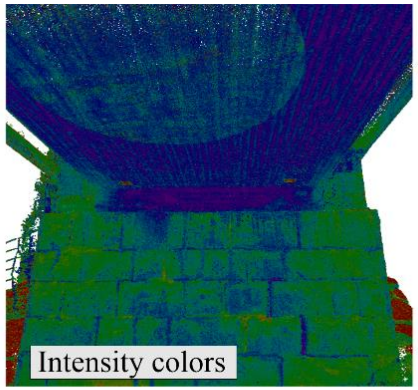
a) Agisoft PhotoScan Pro + Canon 5D
b) Bentley ContextCapture + Canon 5D
c) Bentley ContextCapture + Canon 5D Mark II + 3DR Site Scan drone

- Slight difference in contrast
- Image quality and amount of overlap were sufficient to create the 3D models
- Steepness of its learning curve →affect its rate of uptake

VISUALIZATION CAPABILITIES

- Pahtajokk bridge

Phototograph



Terrestrial laser scanning

Photogrammetry

Infrared scanning

Rendering

- IS and CRP models include RGB information →true-to-life experience

Resolution

- local densities of the point cloud
  - TLS model : 228×103 points/m^2
  - CRP model: 226×103 points/m^2
  - IS model: 14×103 points/m^2

VISUALIZATION CAPABILITIES

- Pahtajokk bridge

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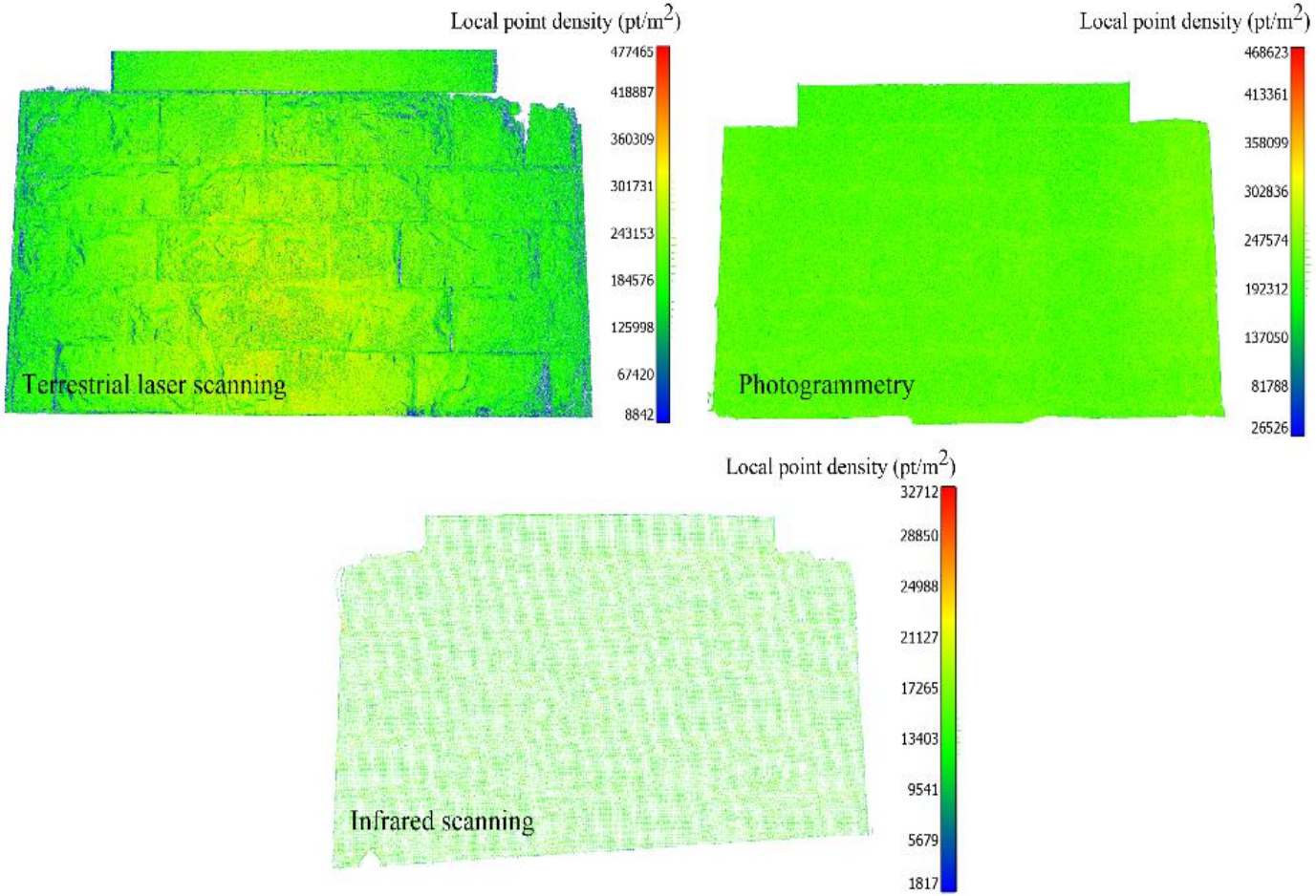

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GEOMETRIC DEVIATIONS

Bridge	As-built dimension	Terrestrial laser scanning	Close-range Photogrammetry	Infrared scanning
	(mm)	%ΔL	%ΔL	%ΔL
Påunakbäcken bridge				
Span	2950	**-0.68%**	**-0.10%**	**1.19%**
Width (deck)	4500	**0.38%**	**0.56%**	**1.02%**
Juovajokk bridge				
Span	5500	**-1.20%**	**-1.60%**	**-0.76%**
Width (deck)	3800	**-0.53%**	**-1.71%**	**-0.53%**
Kallkällevägen bridge				
Central span (interax)	14500	**0.63%**	**-0.22%**	**2.26%**
Width (deck)	4540	**-0.31%**	**-0.66%**	**1.94%**
Diameter (pillar)	1000	**0.00%**	**-2.30%**	**0.90%**

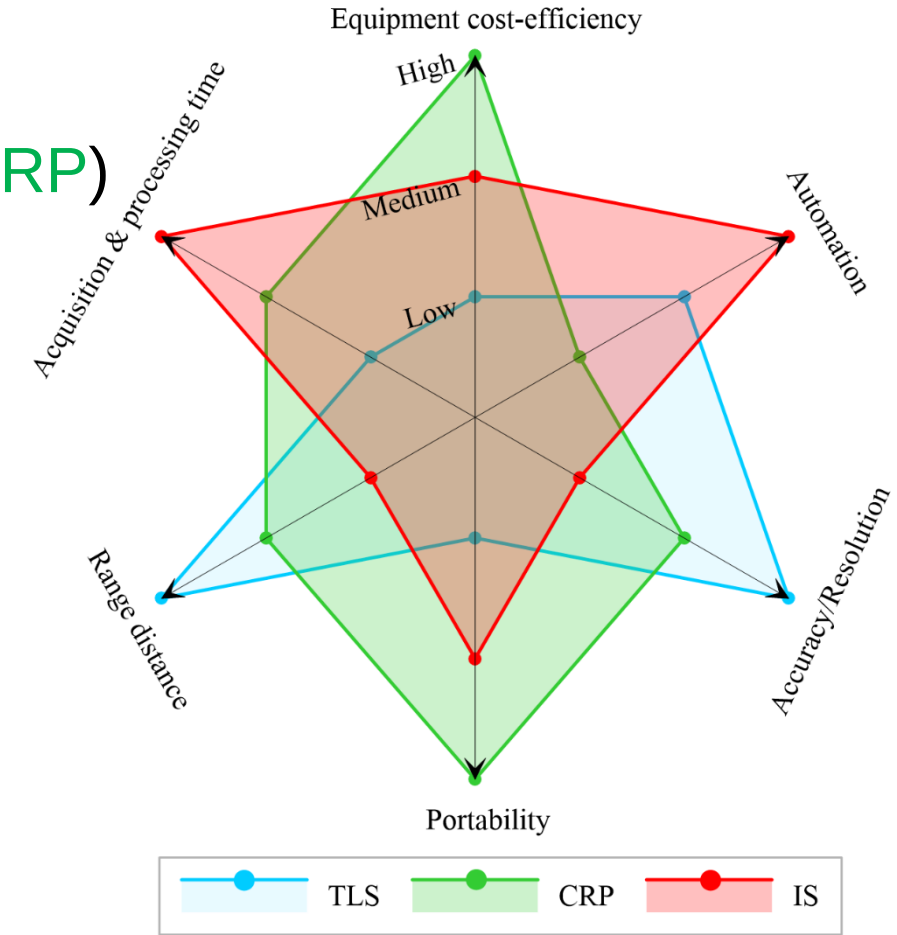
Pahtajokk bridge

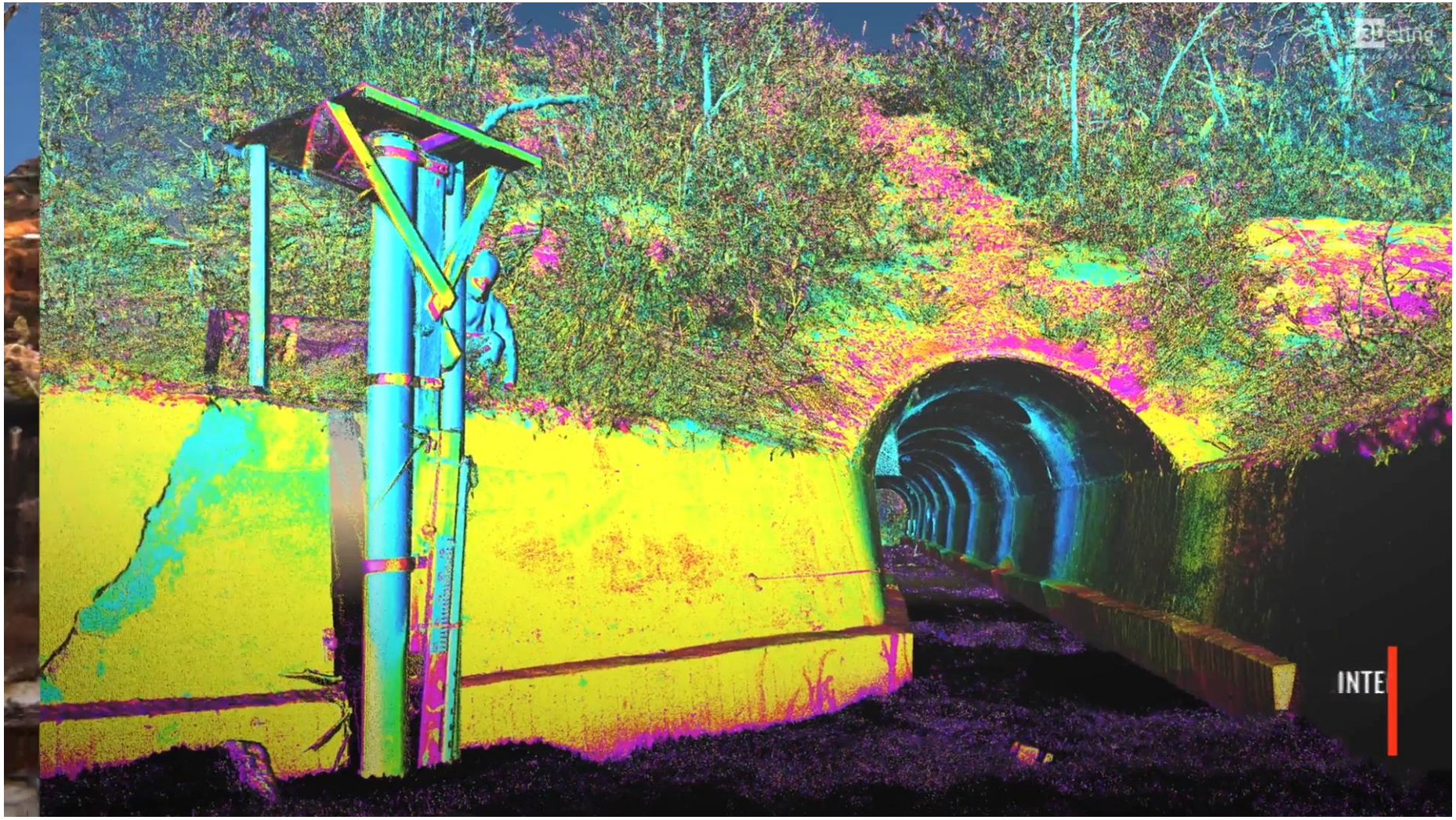
Span: -1.33% vs -1.38%

Width (deck): -1.28% vs -0.18%

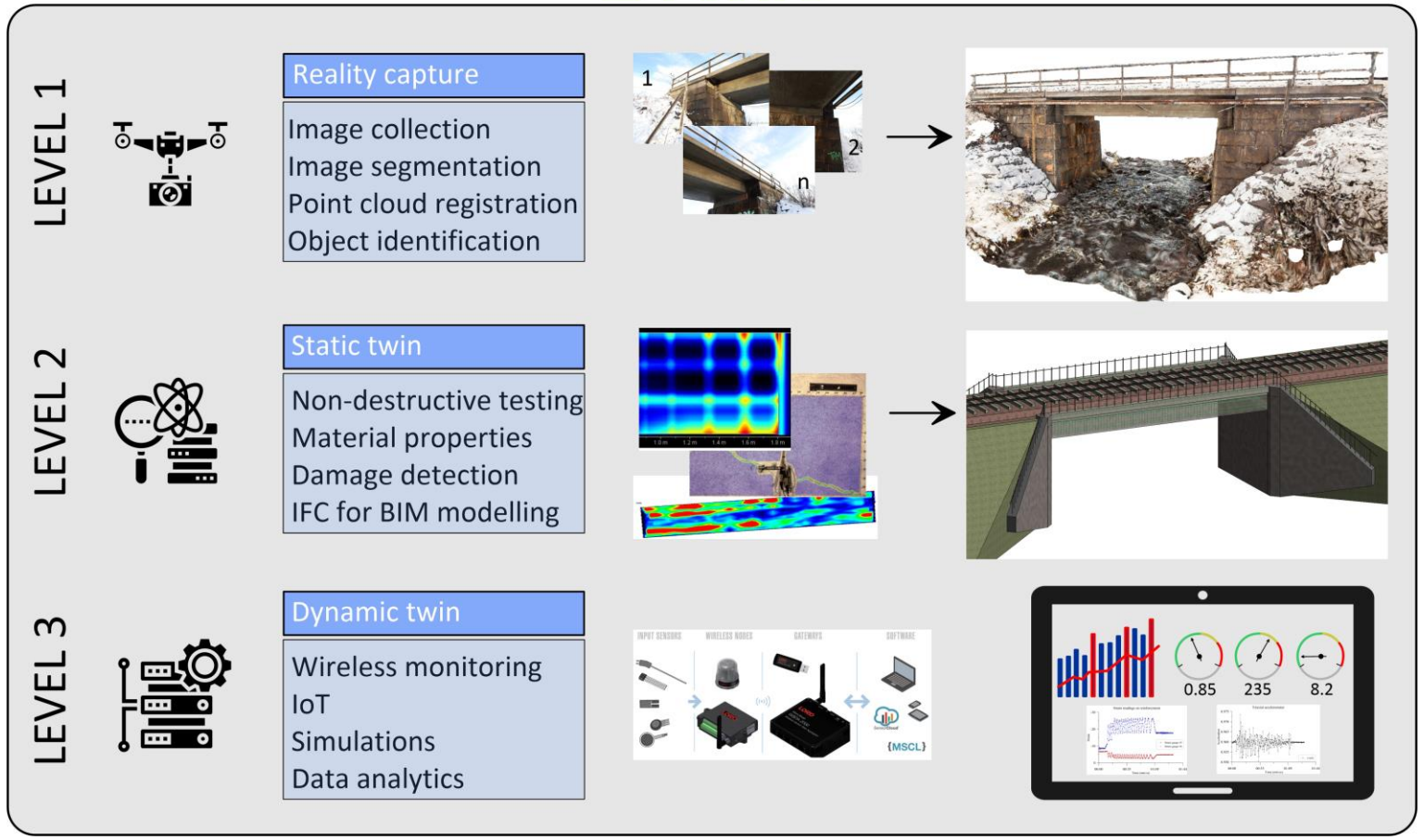
OVERALL COMPARISON

- Costs efficiency
  - 50000 € (TLS) | 4700 € (IS) | 1400 € (CRP)
- Data acquisition
  - 1-2 hours (TLS) | 15 min – 2 h (IS) | 1-4 hours (CRP)
- Post-processing time
  - Up to 7 days (TLS) and (CRP) | 2 days (IS)





THE WAY FORWARD



THE WAY FORWARD

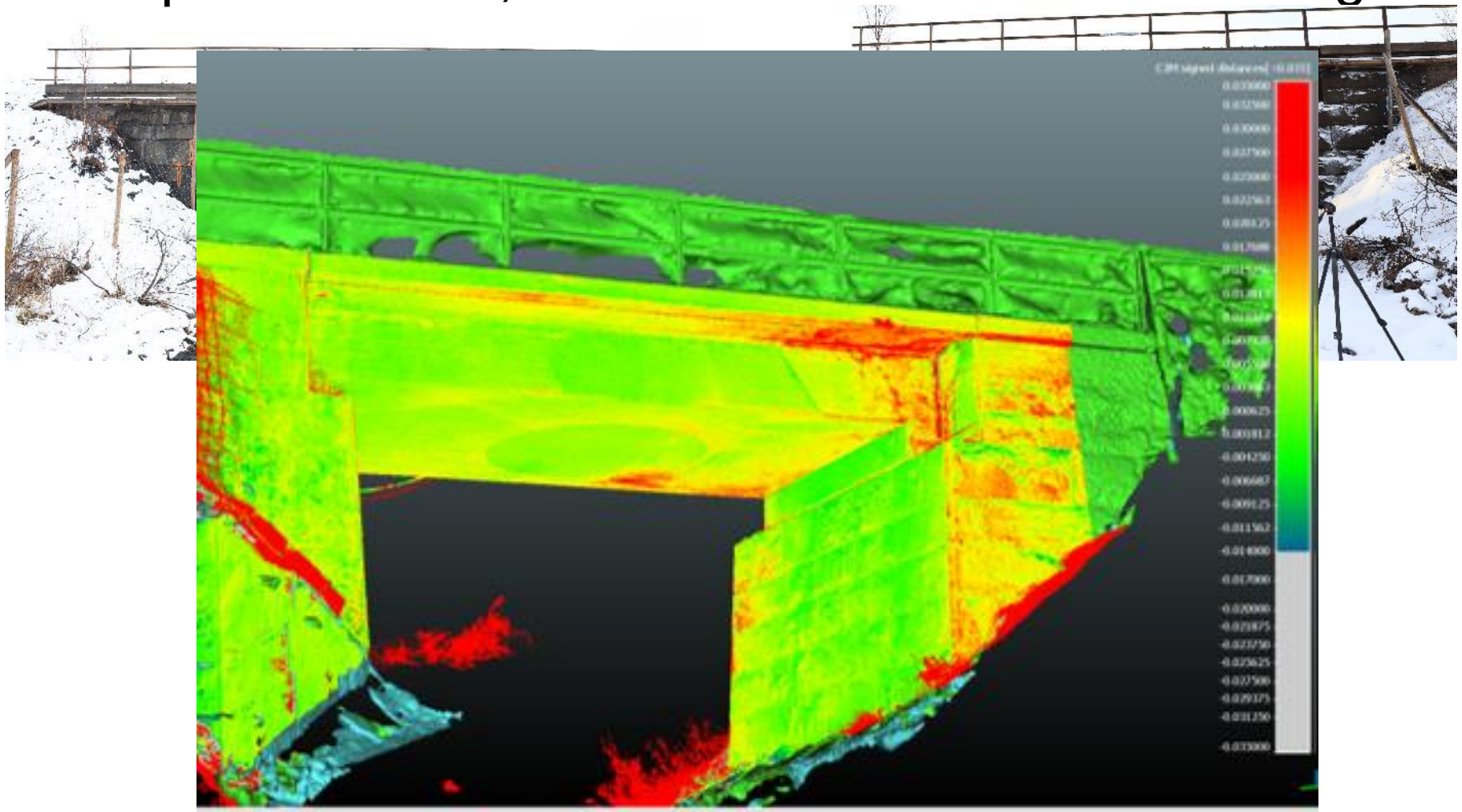
- Follow-up deflections, settlements and surface damages over time

First scanning – year 1

Second scanning – year 2

THE WAY FORWARD

- Follow-up deflections, settlements and surface damages over time



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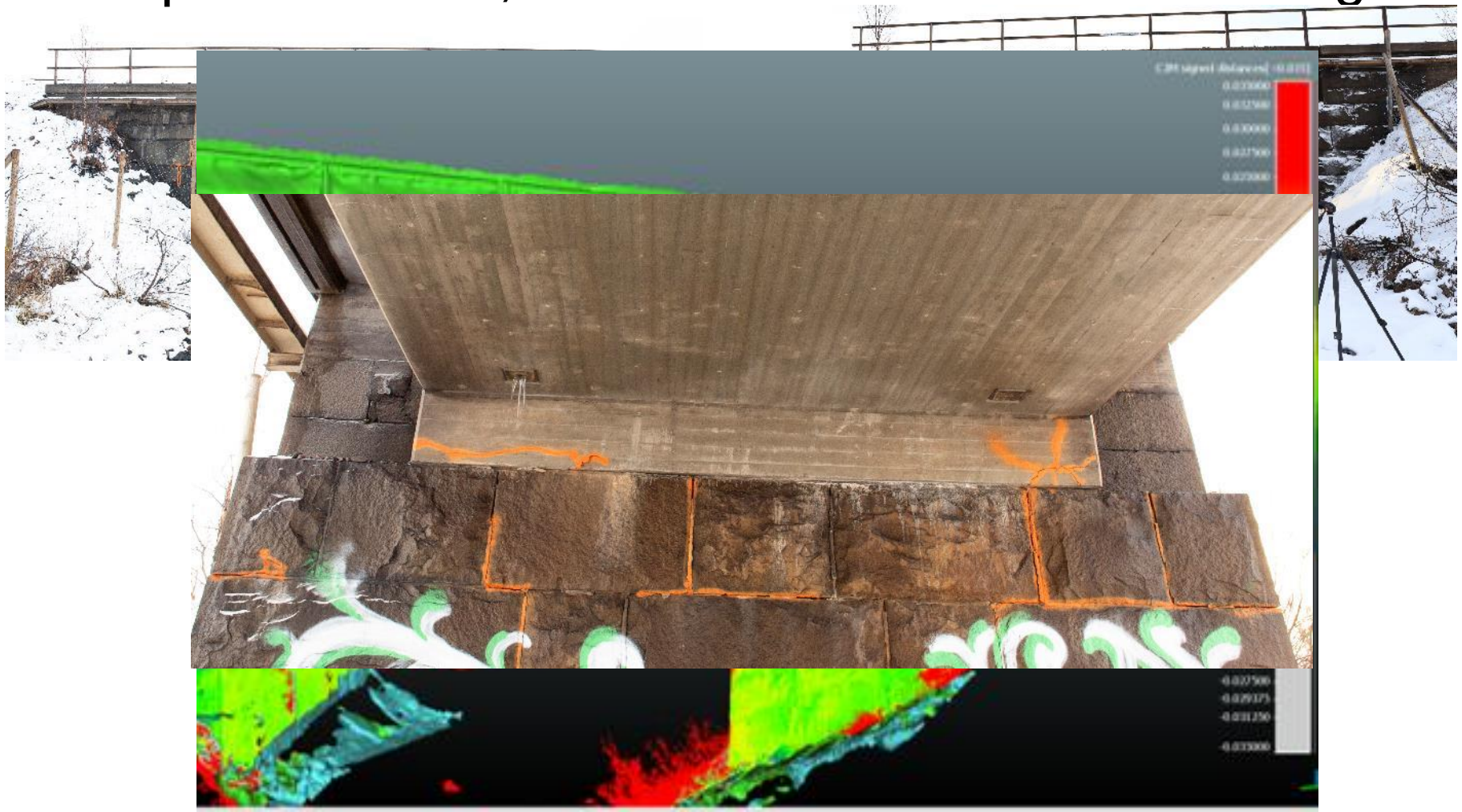
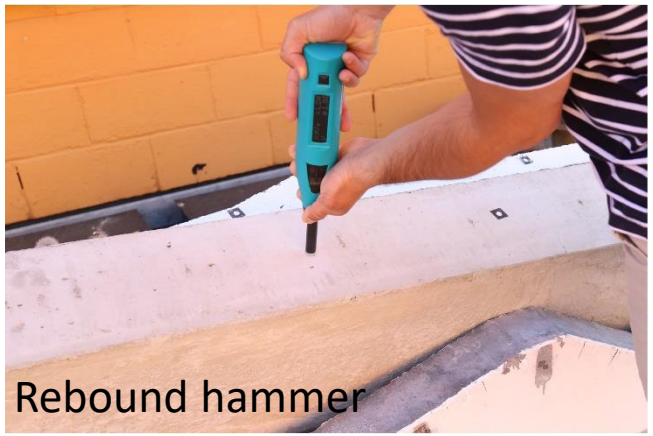
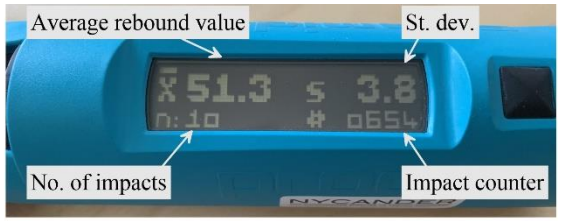
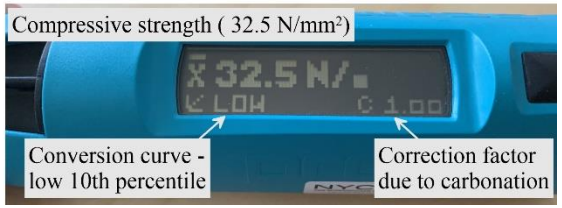


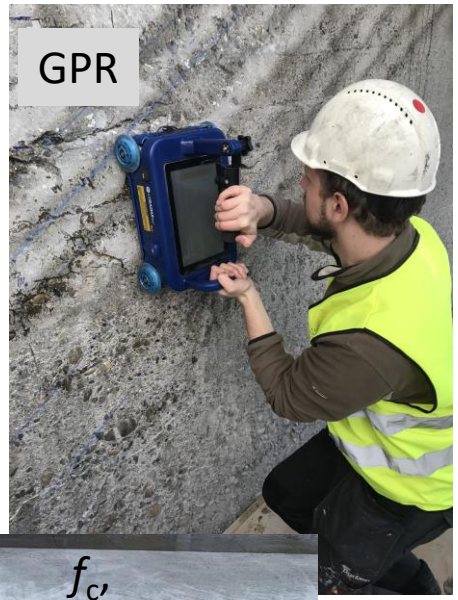
INNER GEOMETRY & QUALITY ASSURANCE

- Non-destructive testing techniques

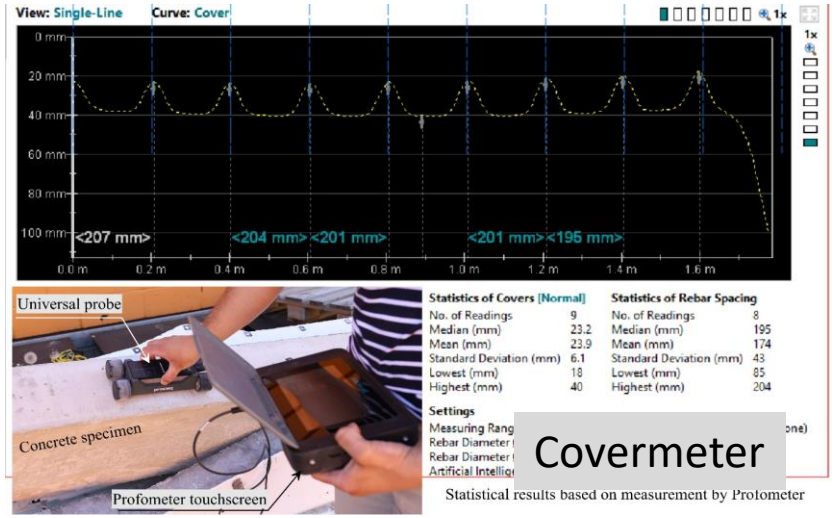

Rebound hammer



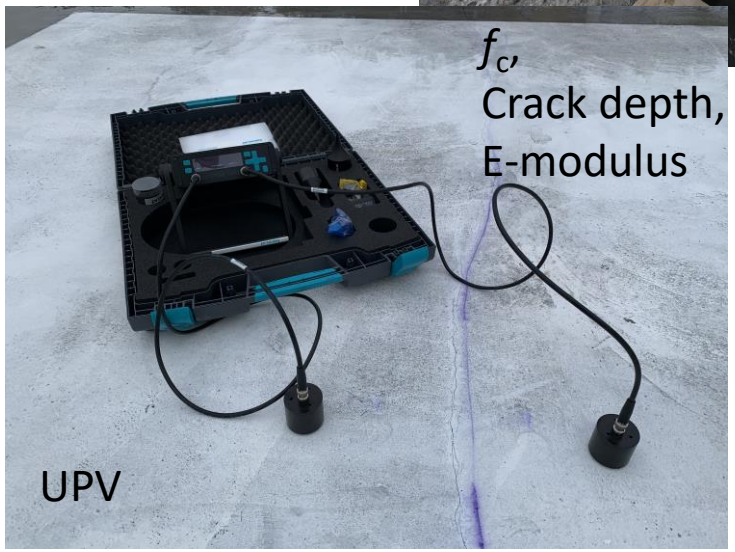



GPR

Pull-off tester



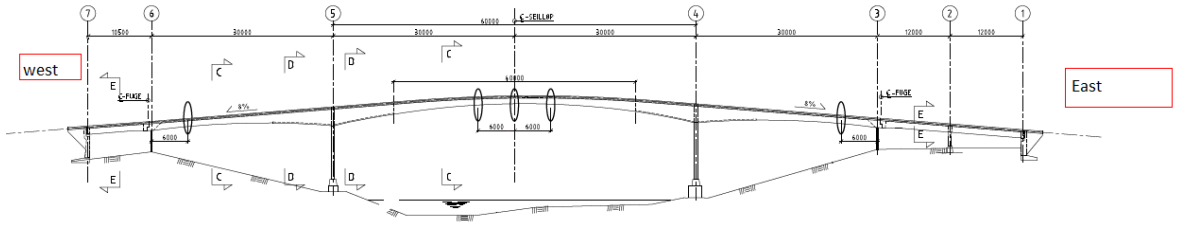
Covermeter

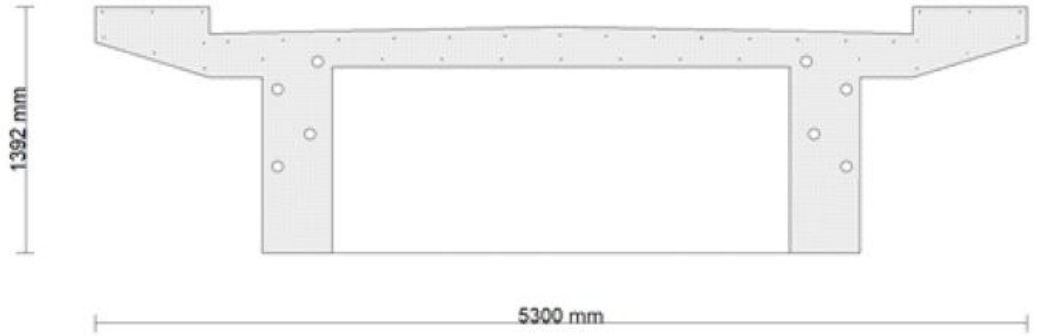


f_c,
Crack depth,
E-modulus

INTERNAL DEFECTS

- For complicated projects, i.e. voids in ducts for prestressing cables, different techniques has to be combined. In addition the post-processing of data is advanced.



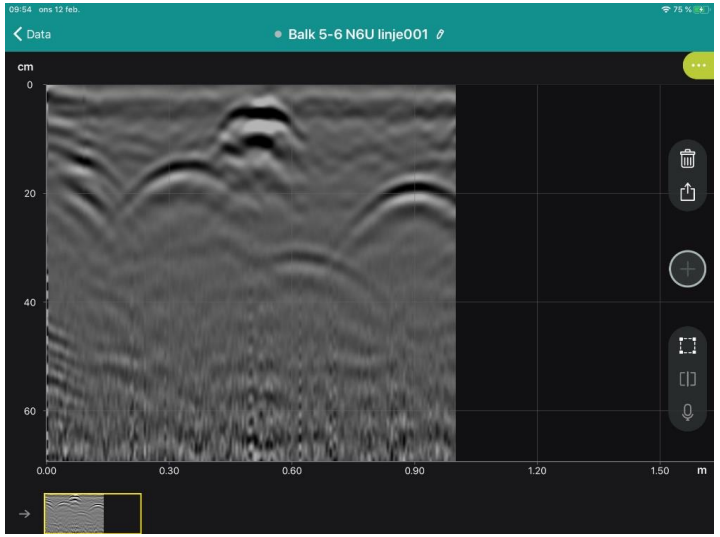


Cover meter + GPR + Tomografi (Ultrasound) + Impact Echo

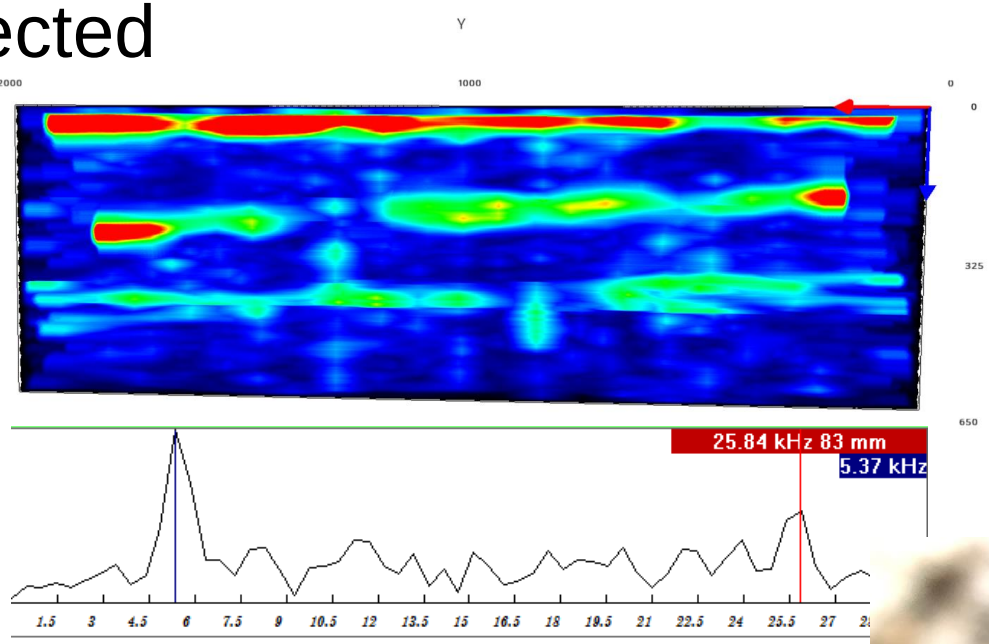
- ✓ **Detection of deep-embedded tendons / cable ducts**
- ✓ **Grouting defects inside of cable ducts**
- ✓ **Delaminations**

INTERNAL DEFECTS

- Grouting defects detected



GPR detecting steel tendons



Processing of Tomografi (Ultrasound) + Impact Echo

CONCLUSIONS

- All methods produced digital models with different levels of completeness
- Good accuracy for geometric measurements
- The methods reduced significantly track possession and provided opportunities to create historical records of the progress of deterioration
- Possibilities to follow-up changes over time
- Non-destructive testing adds a second layer of information (inner geometry and in-depth evaluation)

ACKNOWLEDGMENTS

Research funding

TRAFIKVERKET

Shift2Rail

IN2TRACK2

FORMAS

Automatisk tillståndsbedömning genom bildbehandlig

VINNOVA

Sveriges innovationsmyndighet

Effektivare underhåll av befintliga broar med digitala tvillingar

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