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The magazine for civil & structural engineers

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ETSH

Management of Existing Railway Tunnels Using Digital Strategies and Technologies

September 28, 2022

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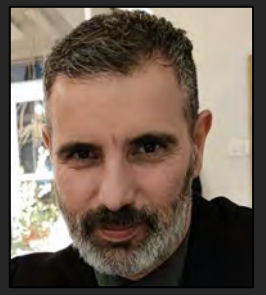
Introduction

Federico Foria
Manager, Geotechnics, Geology and Hydraulics Department; and Research & Development Department
ETS



Emanuele Moschetti
Architect, Geotechnics, Geology and Hydraulics Department
ETS

Mario Calicchio
Infrastructure Engineer, Geotechnics, Geology and Hydraulics Department; Specialist, Research & Development Department
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Product Manager, Civil Engineering
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Who we are: to be, to do, to inform

ETS is a civil engineering company that offers infrastructural and architectural design services, surveying services, mobile mapping and geotechnical-geological studies.

ETS is at the forefront of railway and road projects. Our expertise concerns structural and geotechnical engineering, architecture, seismic vulnerability studies, mobile mapping, rock slope mapping, hydraulic studies, bathymetric surveys

ETS is the owner of ARCHITA, a unique and innovative system for mobile mapping surveys. From design and engineering to construction and management, ETS aims for delivering specialized services across the entire project life cycle.

ETS develops their projects with the support of BIM (Building Information Modelling), in compliance with the standards of the UNI 11337, the BS 1192 and PAS 1192-2: 2013 guidelines with the return of the Data Base, composed of a Confederate Data Model and related Information Contents.

CREDITS & PARTNERSHIP

FT 1000 Europe's Fastest Growing Companies 2018 statista

LE FONTI AWARDS FINALIST 2018

Technical Product/Equipment Innovation FINALIST ITA TUNNELLING AWARDS 2019

REPORT 2020 on the Italian Construction, Architecture and Engineering Industry

GROUND ENGINEERING AWARDS 2020 WINNER

GROUND ENGINEERING AWARDS 2021 FINALIST

DITECFER Railway Innovation Leader 2021 MIRET ETS

AGI Associazione Geotecnica Italiana

SIG

iBIMi institute for BIM Italy

buildingSMART Italy

ASSOCIATO oice CONFINDUSTRIA

FONDAZIONE BRUNO KESSLER

POLITECNICO MILANO

STVDIVM VRBIS

HIPPOCRATICA CIVITAS STUDIUM SALERNI

UNIVERSITAS ATHESINA STUDIORUM

UNIVERSITAT ROVIRA i VIRGILI

Vision

Infrastructure is a social value

Maintenance is a strategic need

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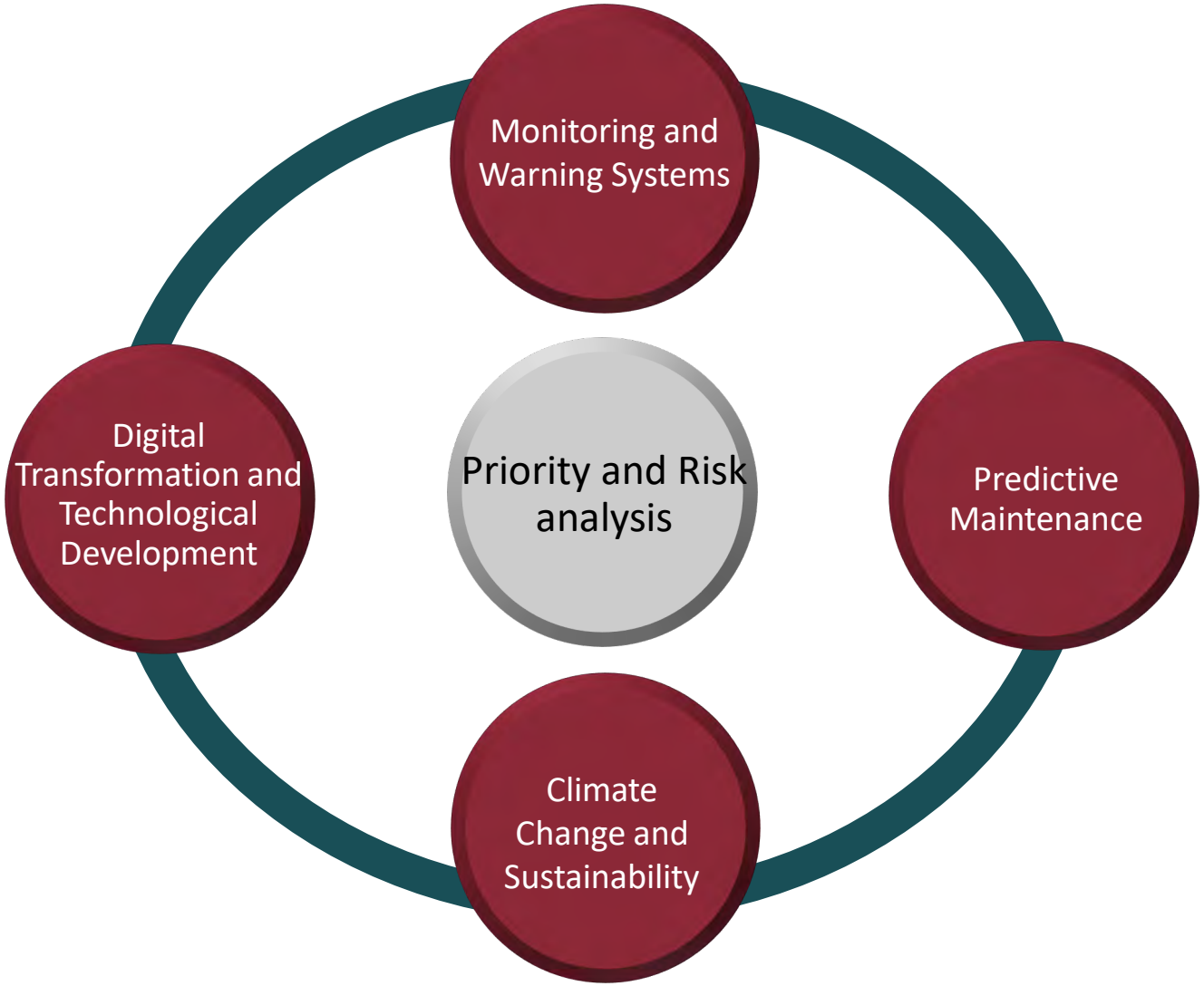
Mission



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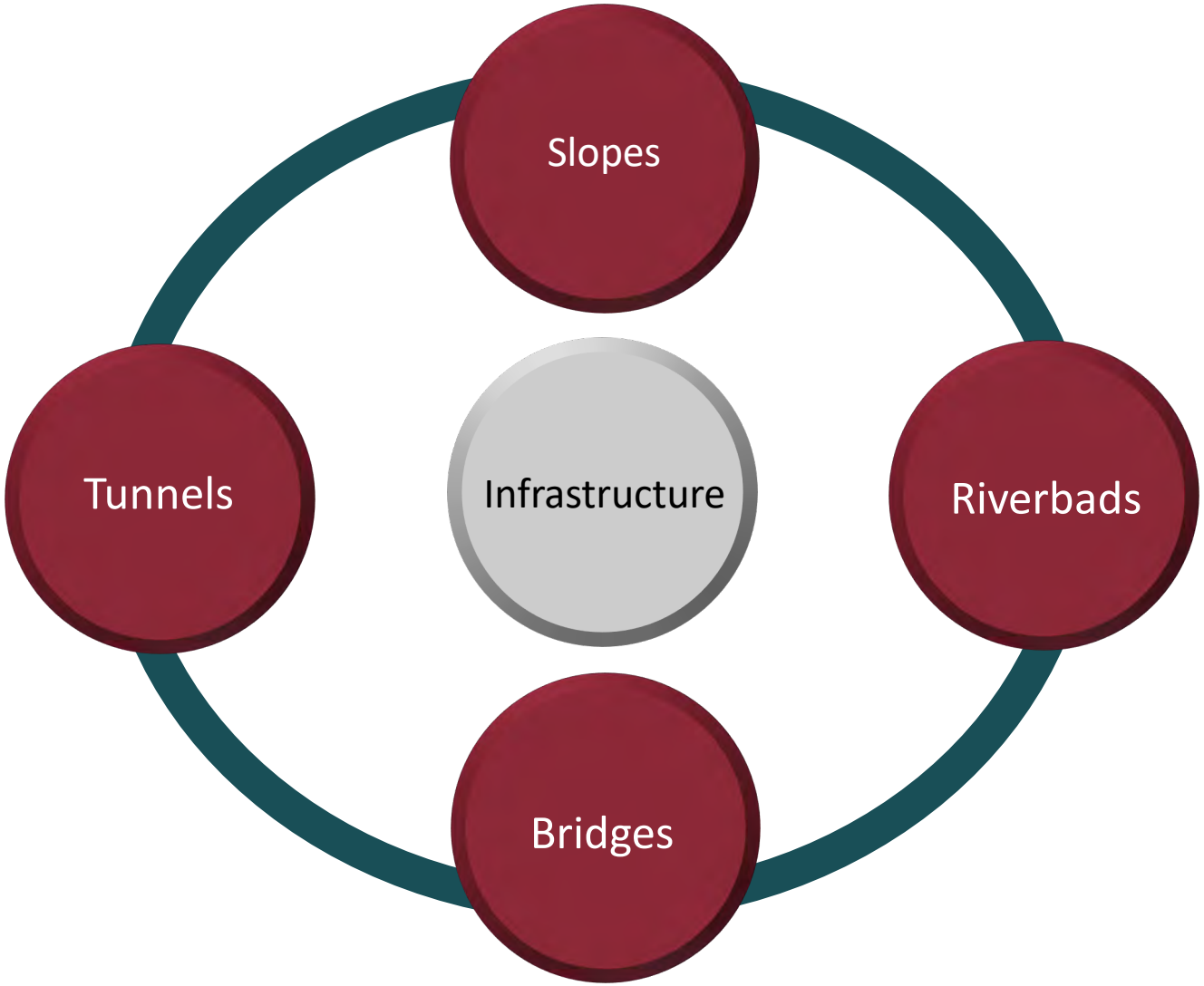
Mission



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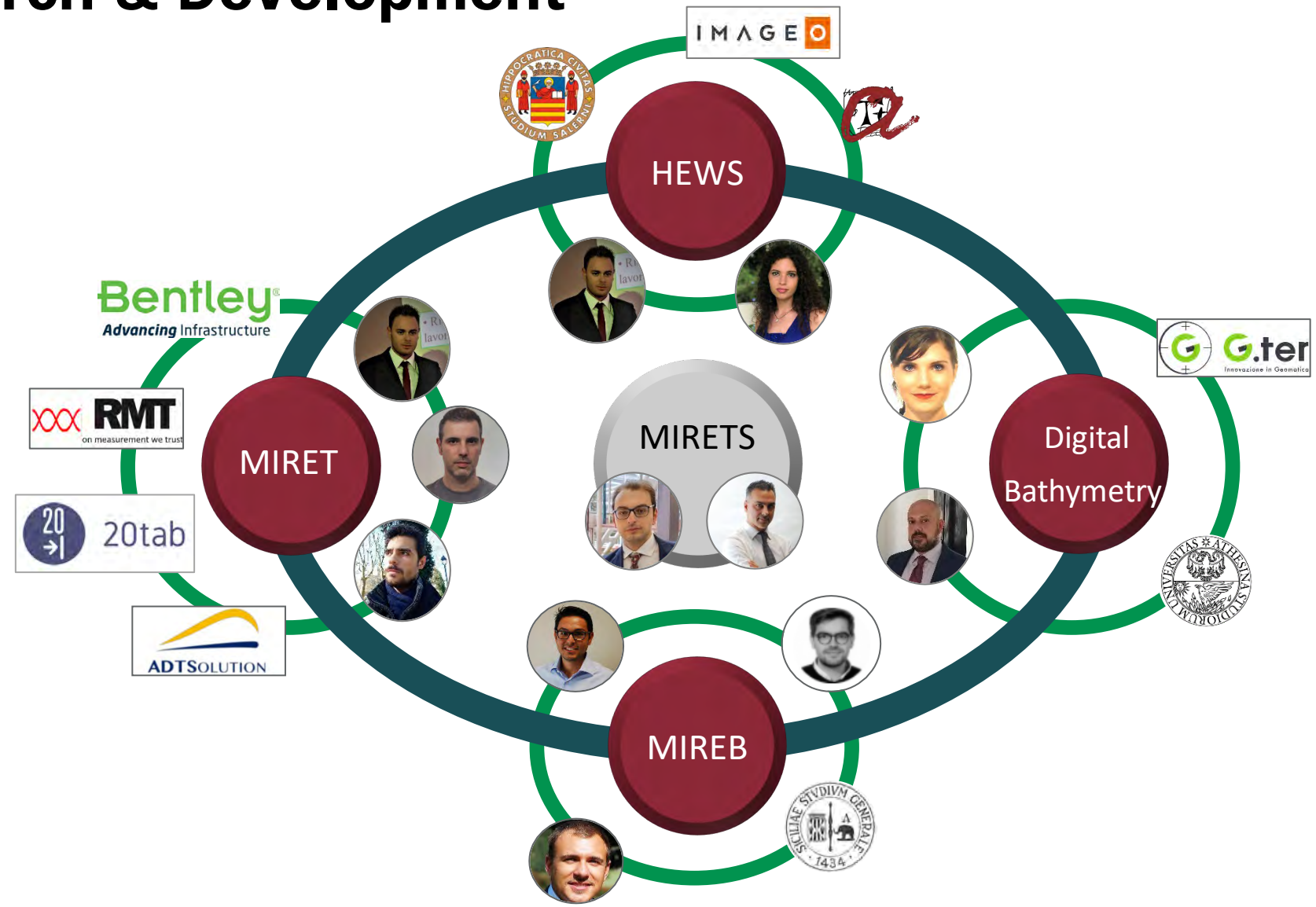
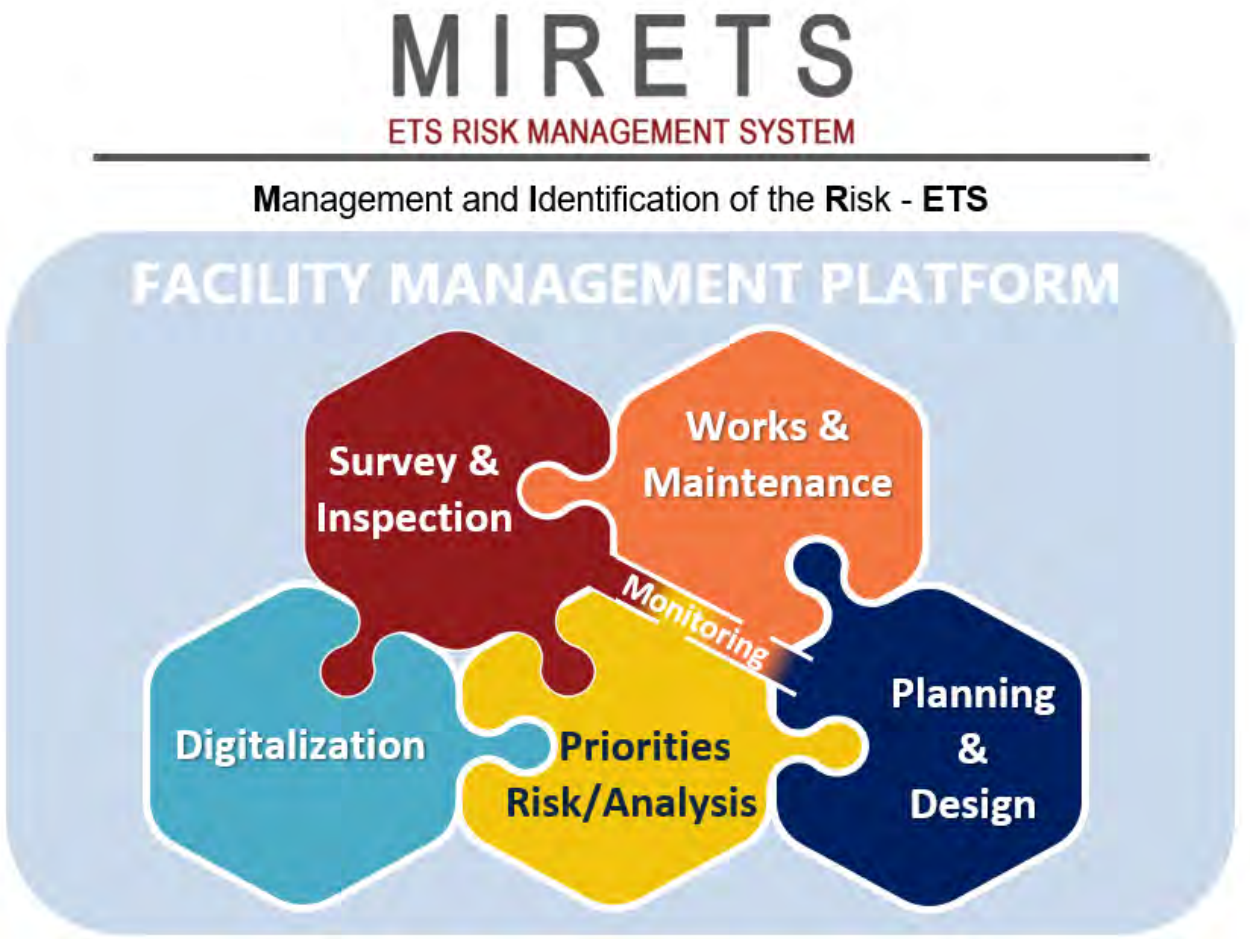
Research & Development



MIRETS: General Approach and Workflow



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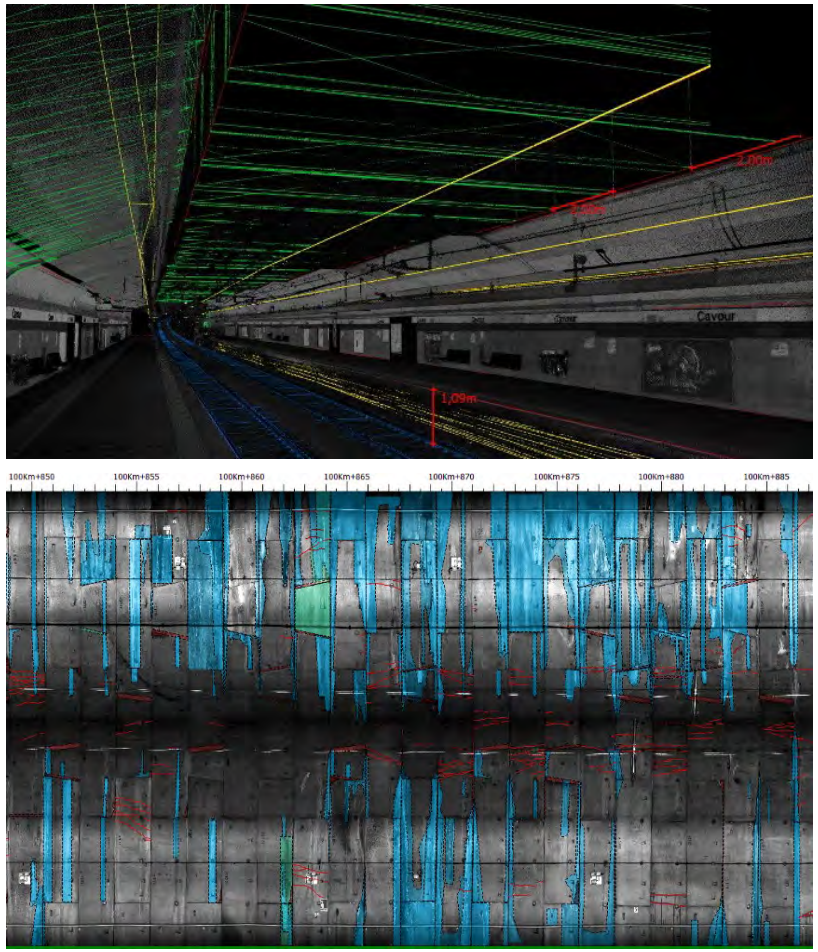
Survey & Inspection: Mobile Mapping and NDT Big data

Tunnels (MIRET), Slopes and Artworks (MIRETS) Mapping

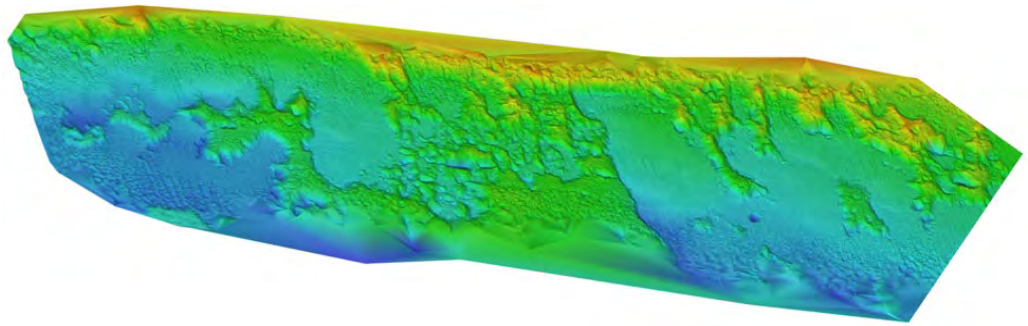
Bathymetries (MIRETS)

Digitalization: Big data, Informative Models and CDE

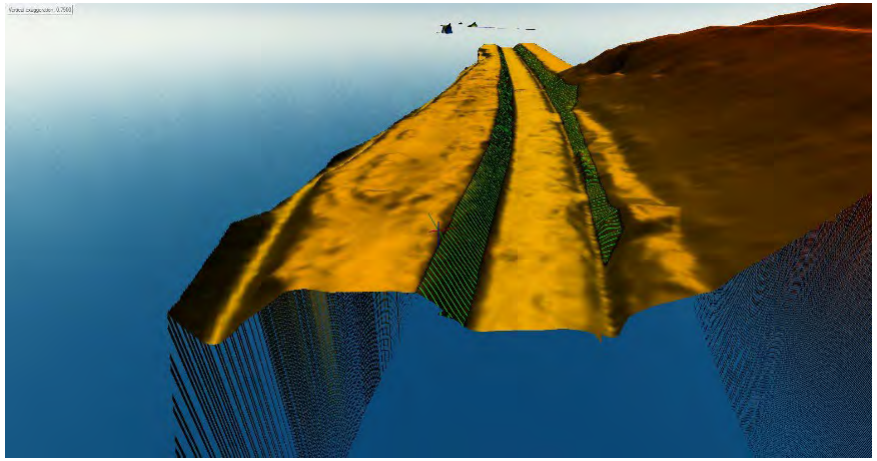
Tunnels (MIRET)



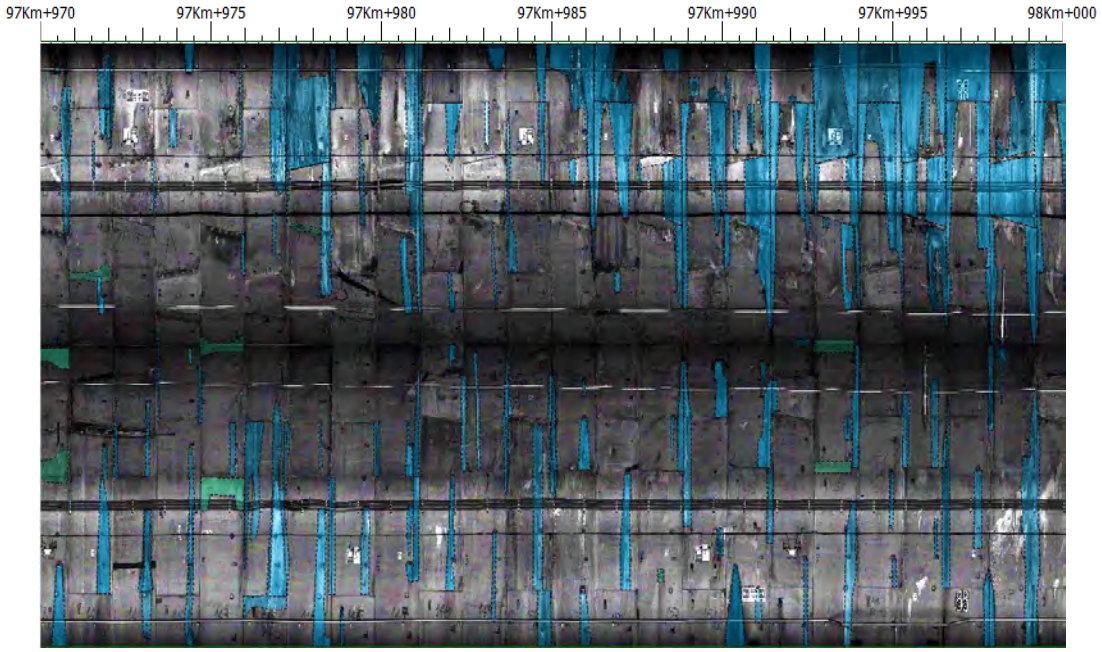
Bathymetries (MIRETS)



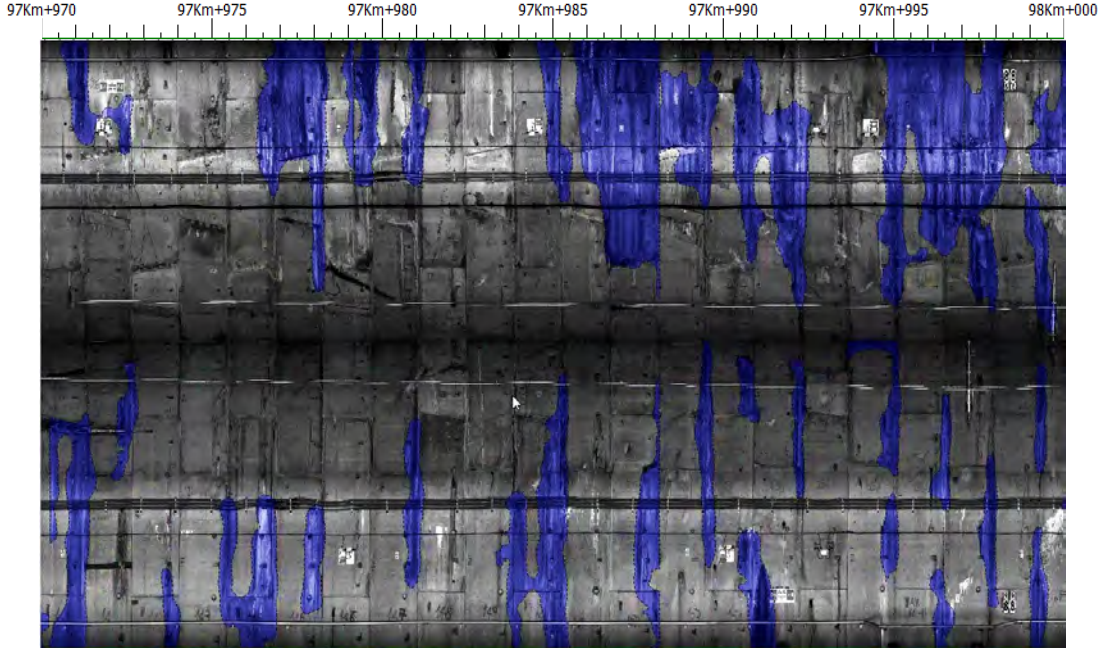
Slopes and Artworks (MIRETS)



Priorities & Risk Analysis: Artificial Intelligence vs. NDT Big Data



Manual detection (days/weeks)



Automatic detection (minutes/hours)

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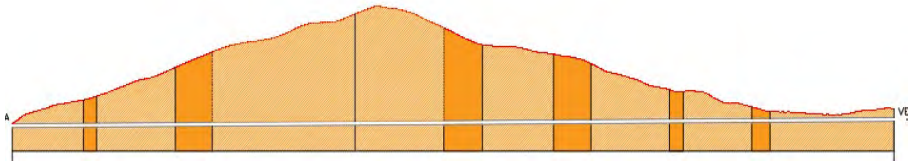
Priorities & Risk Analysis: Automatic Multidisciplinary Approach

Seismic Hazard and Vulnerability → Micro-Seismic Mapping

Geological Hazard → Geological Susceptibility Mapping

Geological Hazard → Detailed Hazard Mapping

Geotechnical Hazard and Vulnerability → Geotechnical Profile



Structural Vulnerability → Defect Mapping

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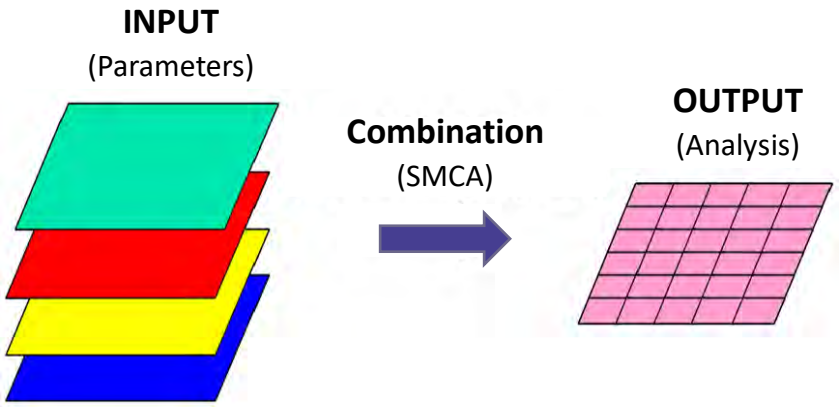
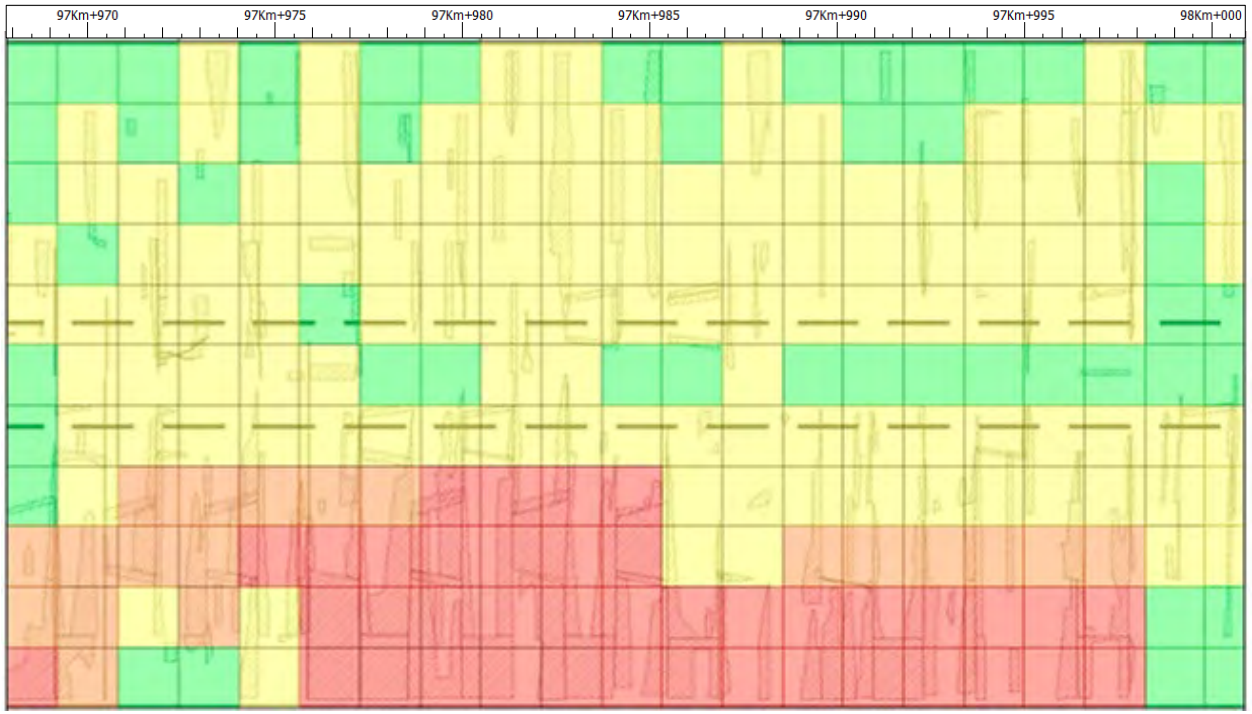
Priorities & Risk Analysis: Spatial Indexes





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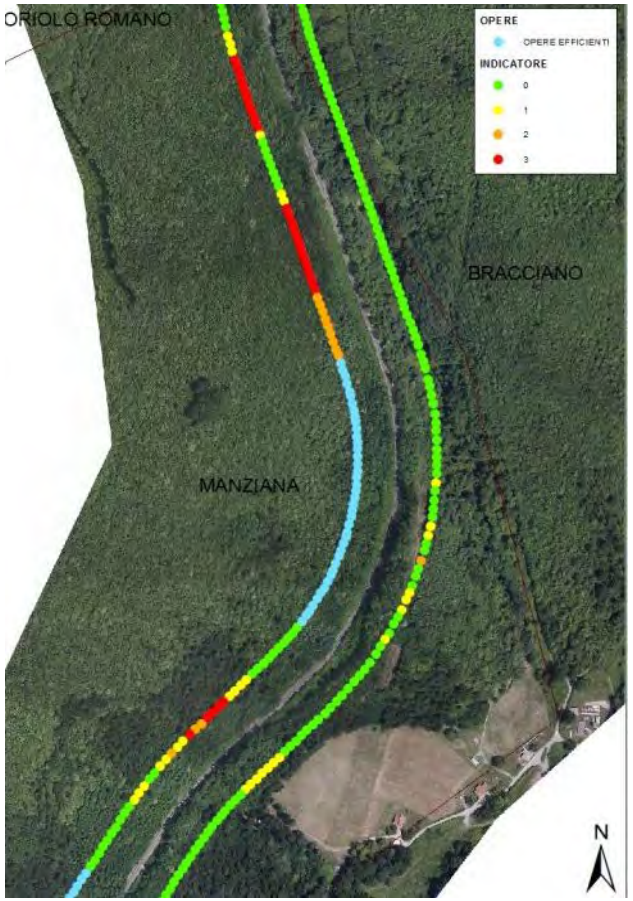
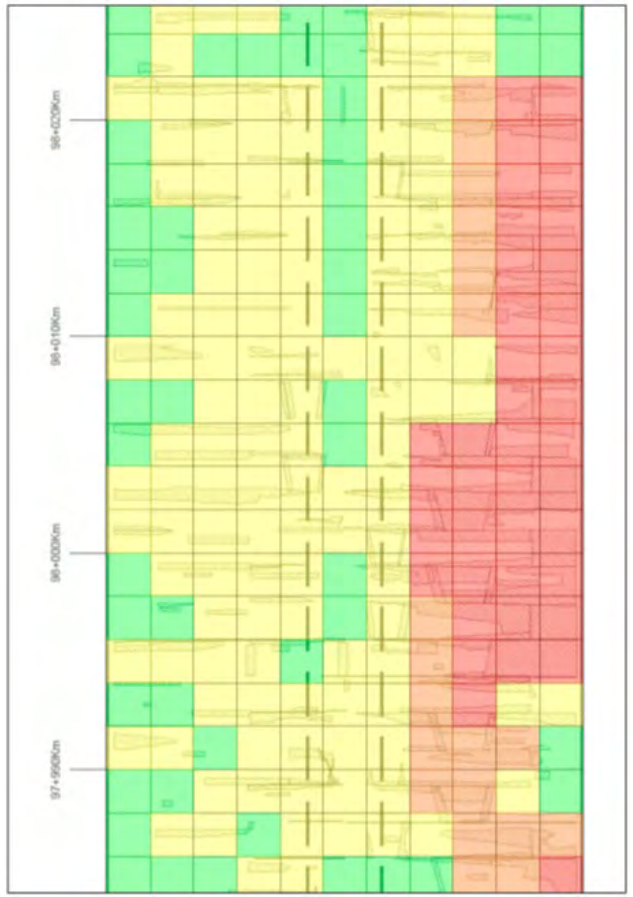
Planning & Design: Indexes and Scaling

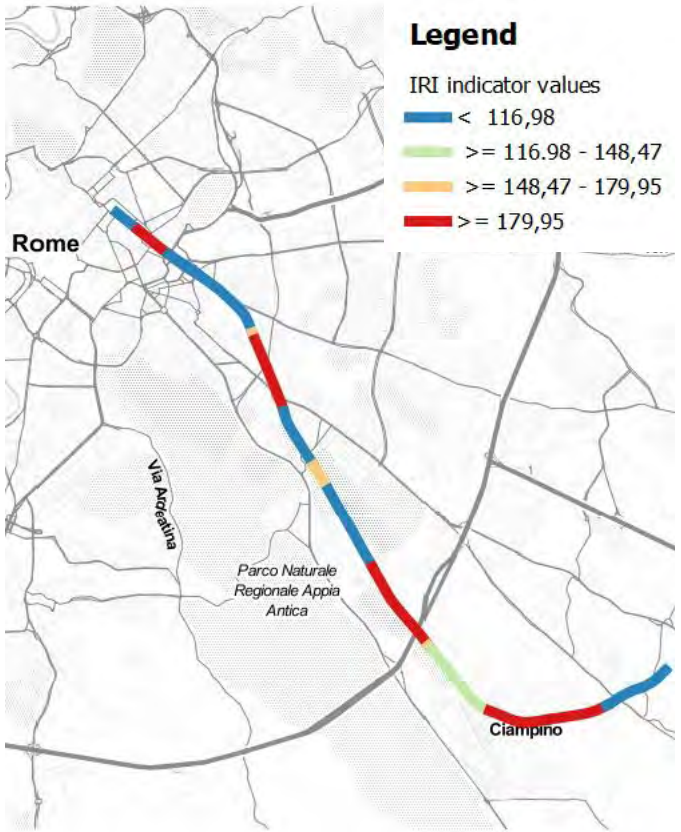
Priorities (Infrastructure)



Tunnels (MIRET)



Priorities (Climate Change)



Planning & Design: Indexes Analysis and Scaling

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Planning & Design: Indexes Analysis and Scaling

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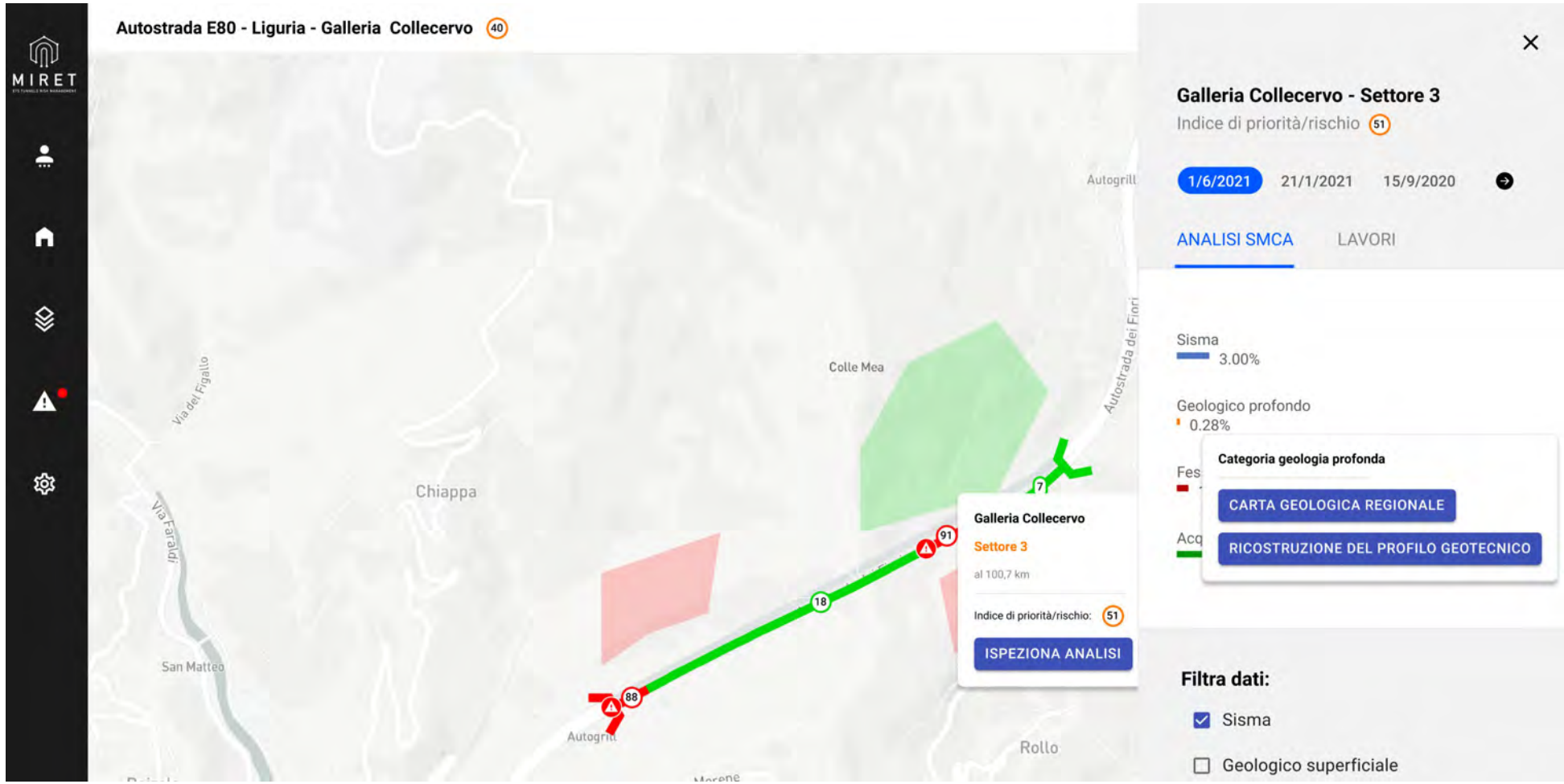
Planning & Design: Indexes Analysis and Scaling (Tunnel Example)



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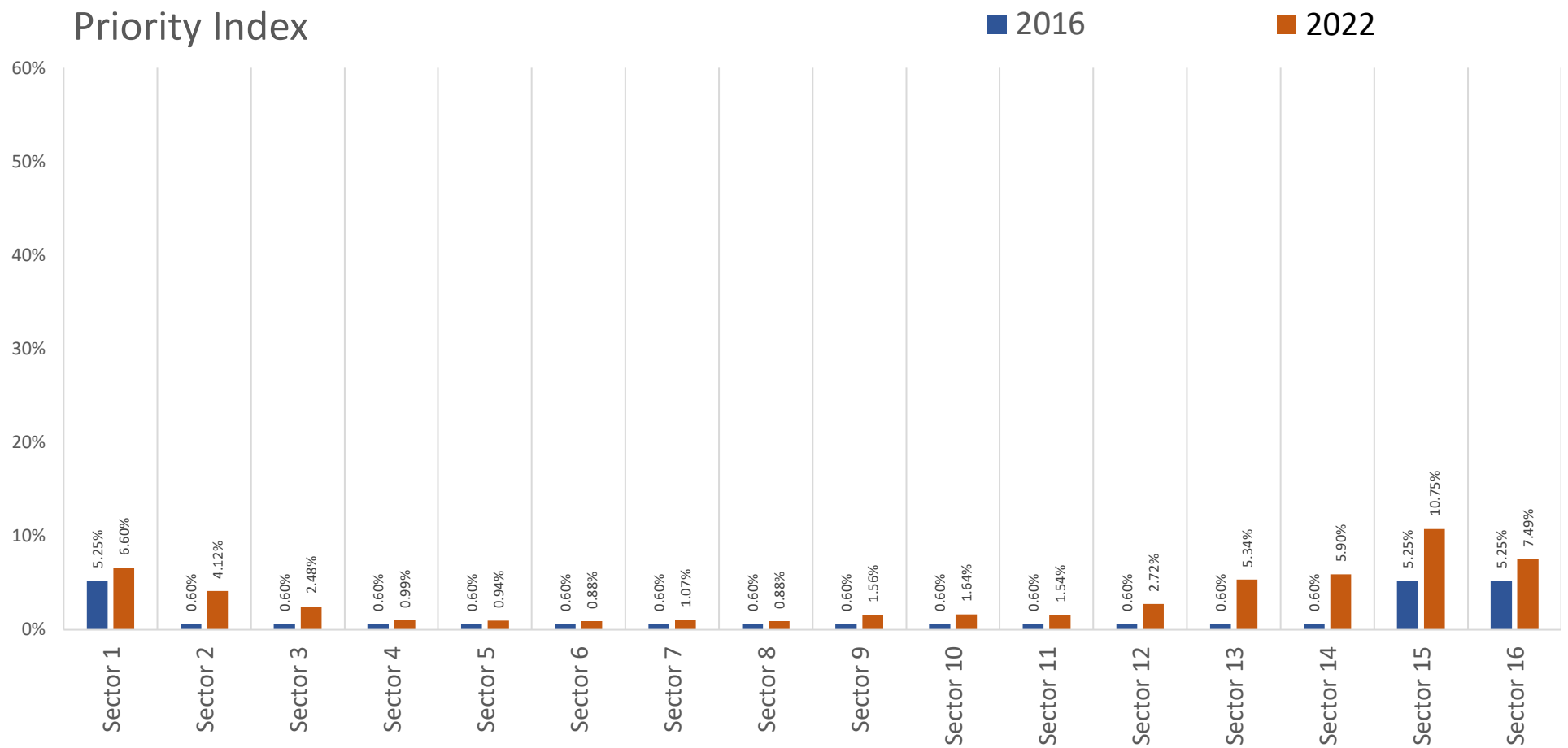
Planning & Design: Indexes Output (Tunnel Example)



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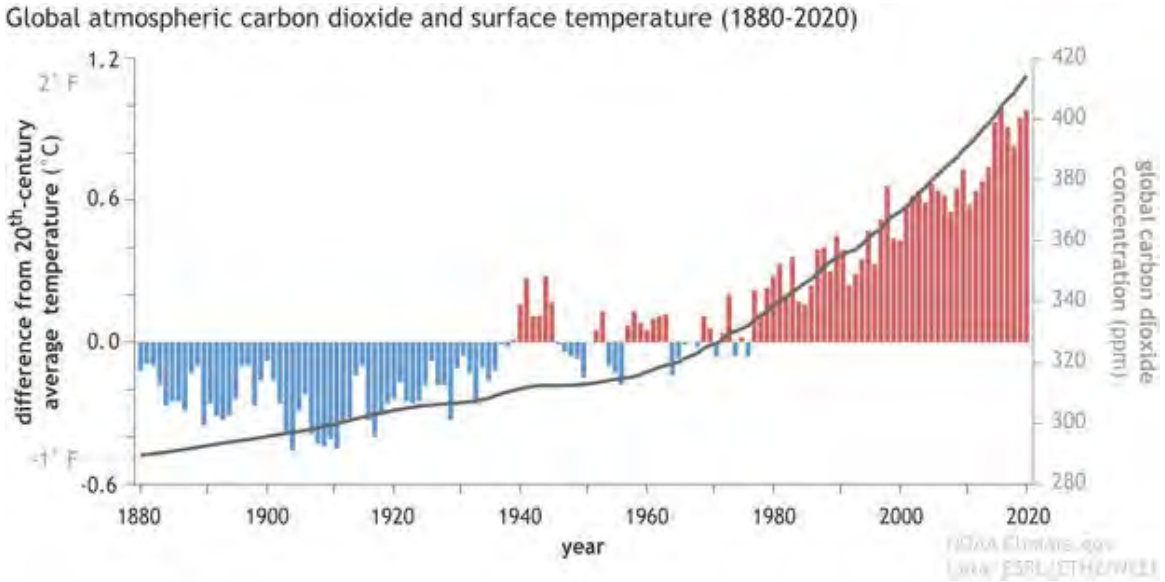
Planning & Design: Multi Scenario Analysis

Sustainable Development Goals of the United Nations Agenda



Data Source: Global ABC (UN)

Building and Construction 36-38% of energy related CO2 emissions

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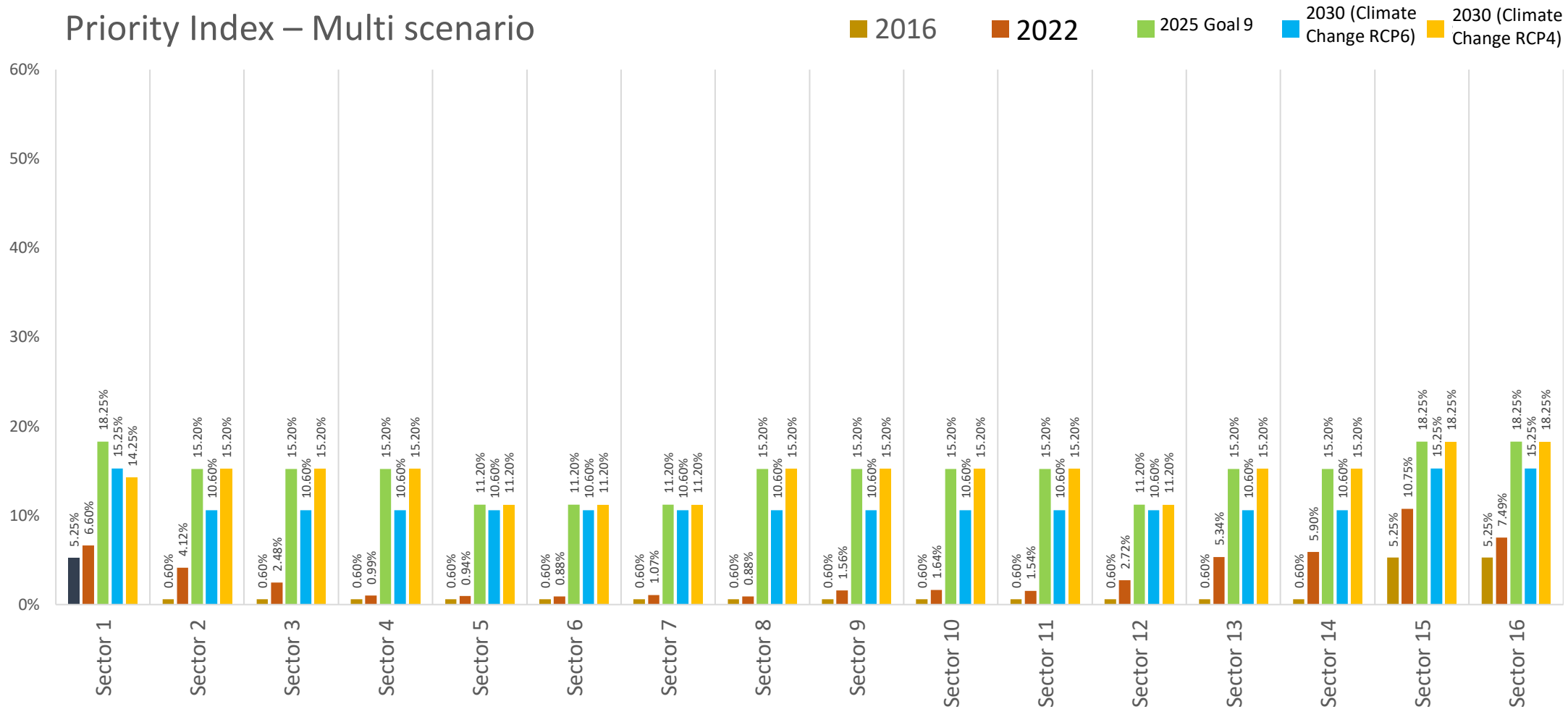
Planning & Design: Multi Scenario Analysis (Tunnel Example)



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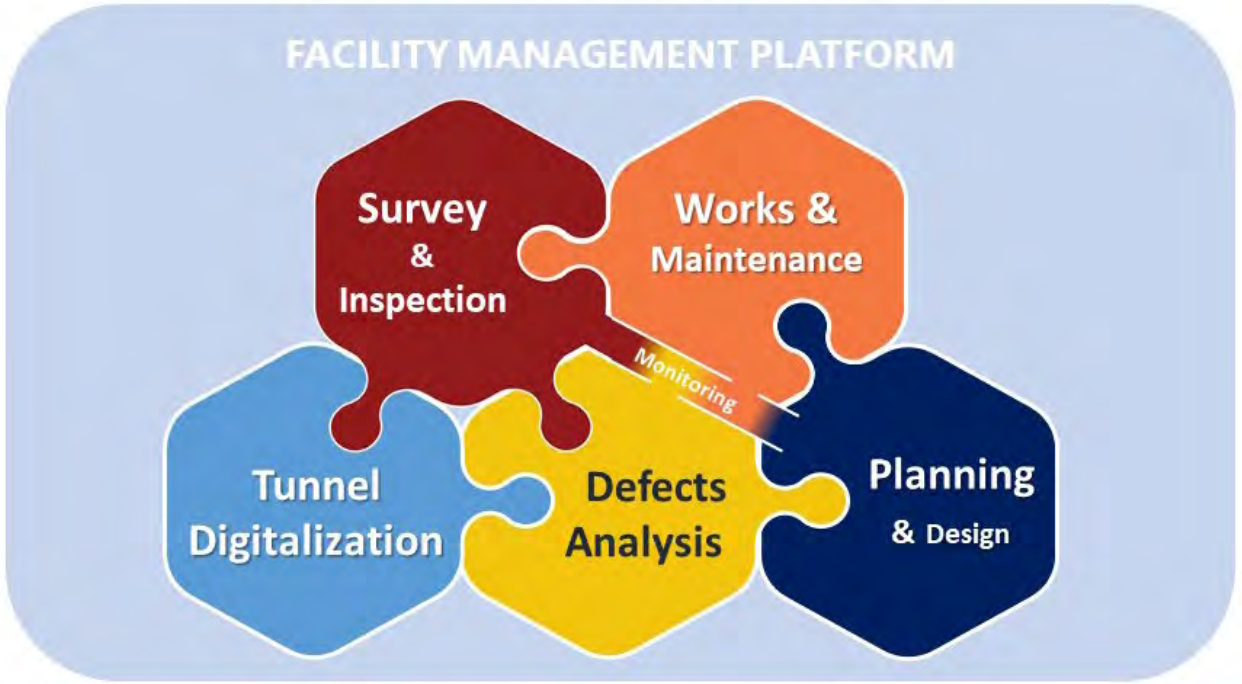
MIRET: General Approach and Workflow

MIRET
ETS TUNNELS RISK MANAGEMENT



CONTINUING EDUCATION AIA
DITECFER Railway Innovation Leader 2021 MIRET ETS
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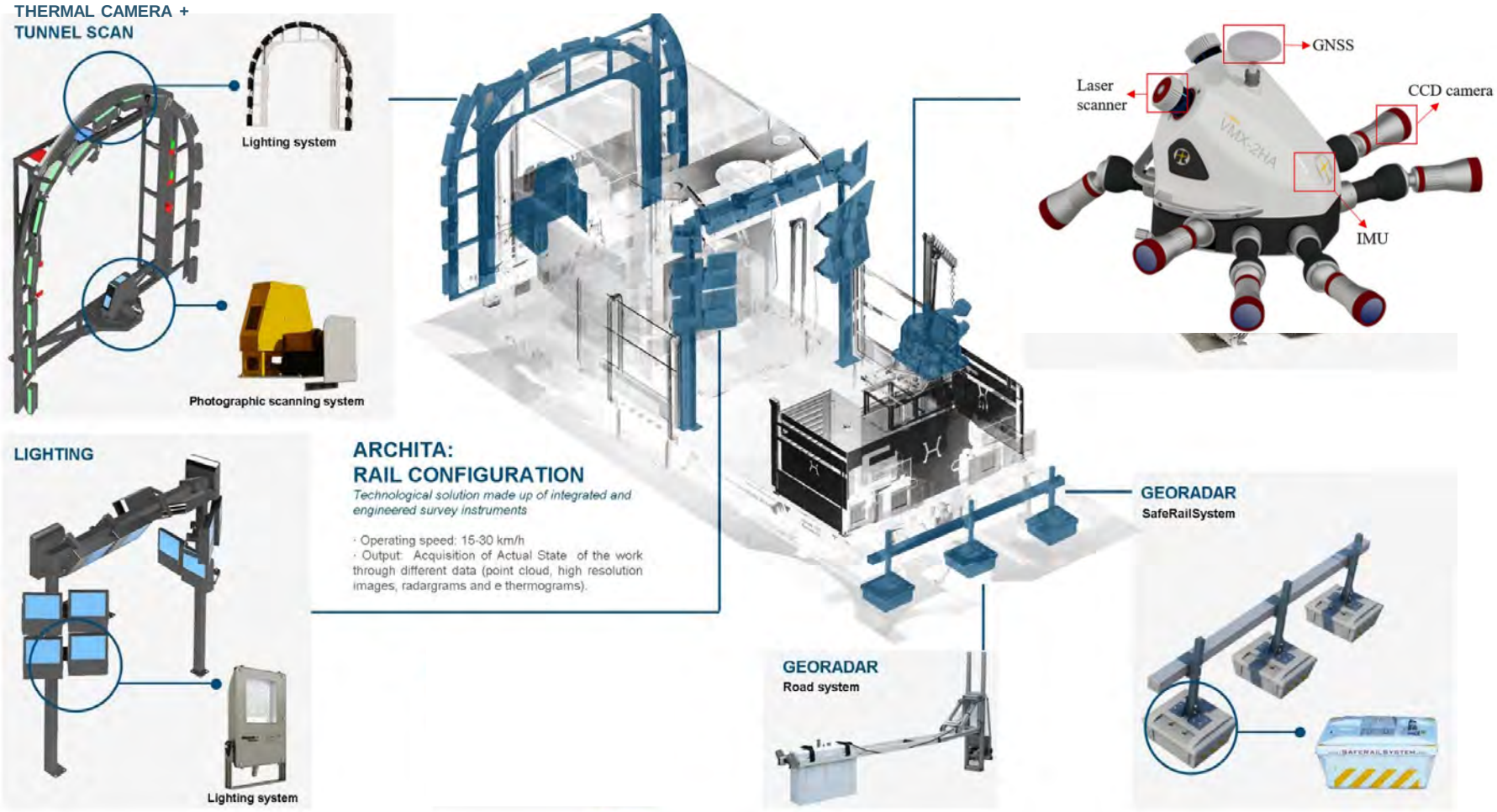
Survey & Inspection: ARCHITA

ARCHITA is a multi-dimensional mobile mapping system developed by ETS

Key advantages of the ARCHITA's approach:

- To avoid intrusive structural surveys
- To minimize the time of traffic disruption
- To increase operator's safety
- To improve back-office capabilities

Survey & Inspection: ARCHITA



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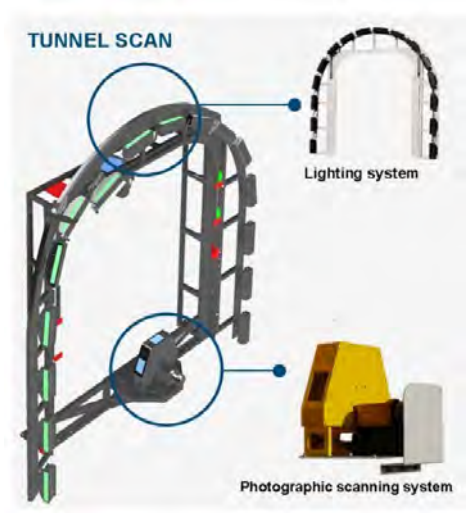
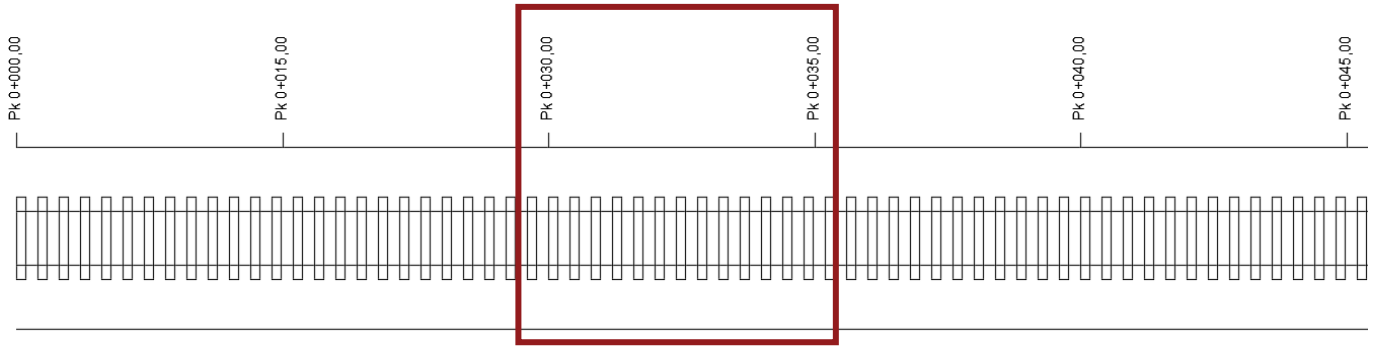
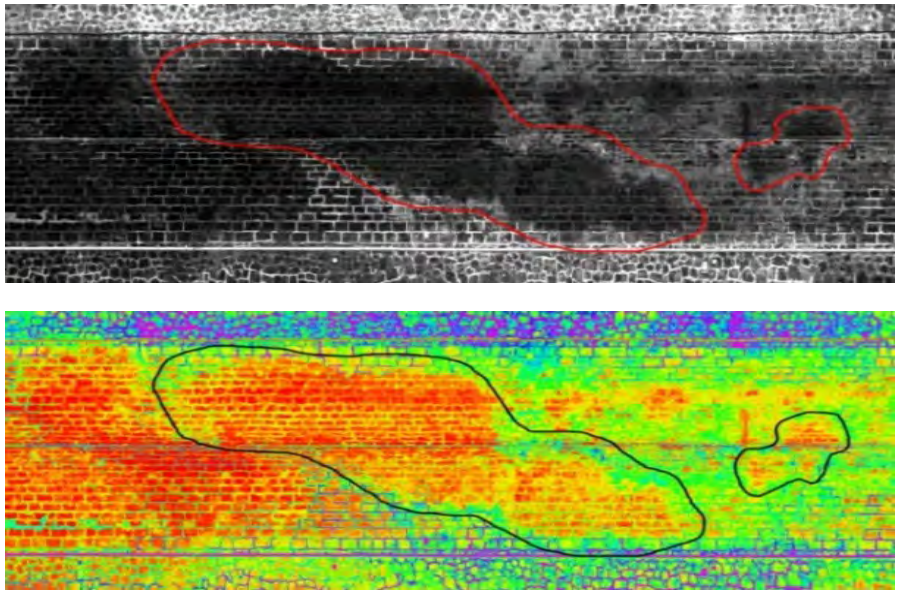
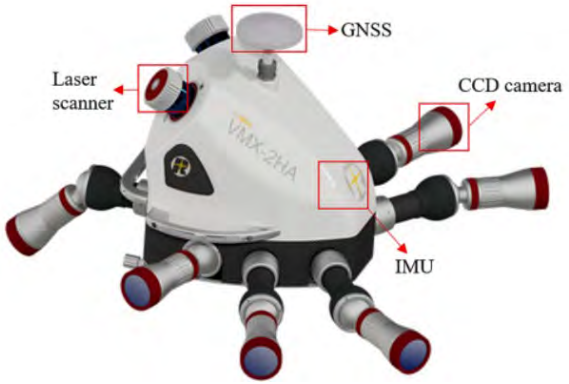
Survey & Inspection: ARCHITA

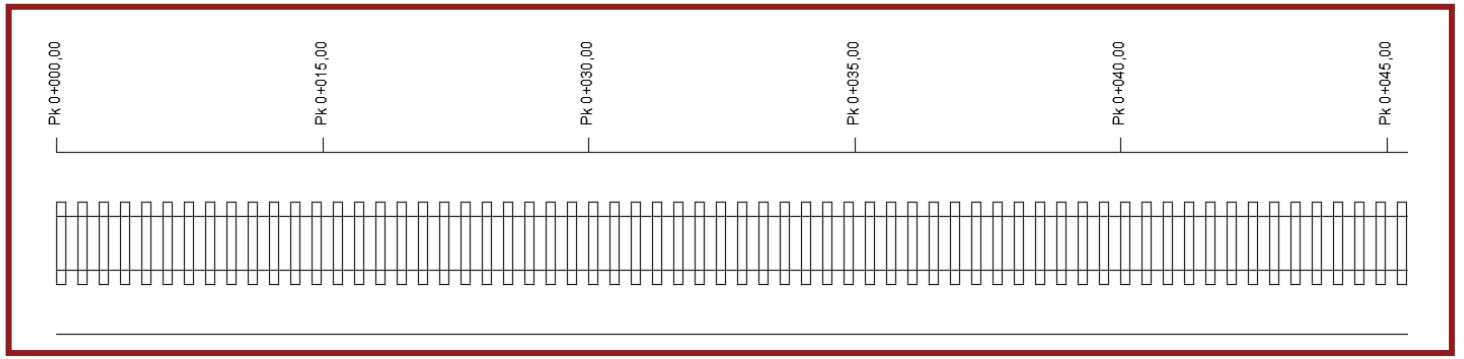


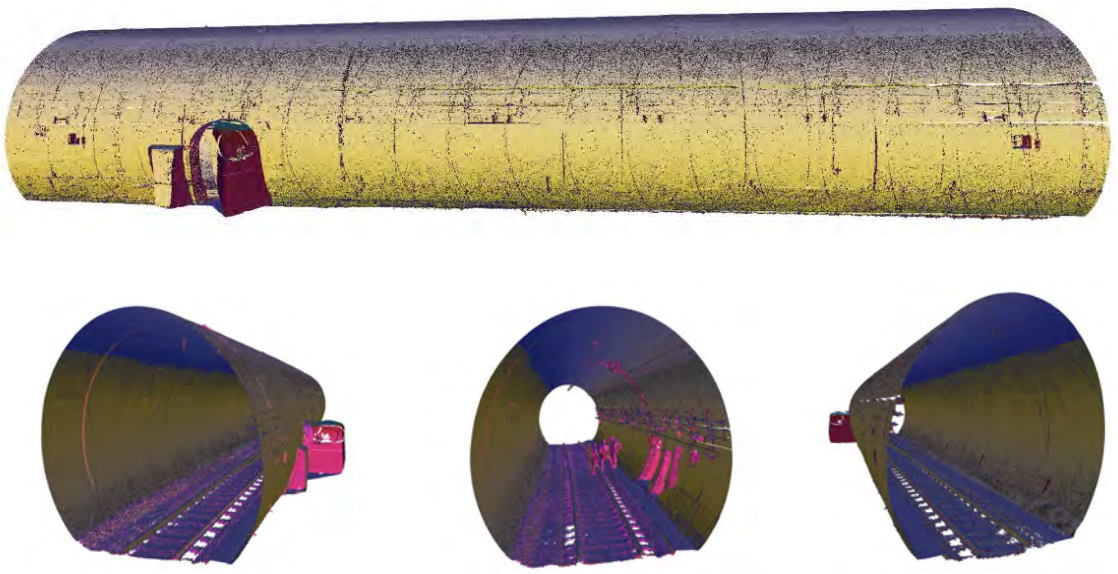




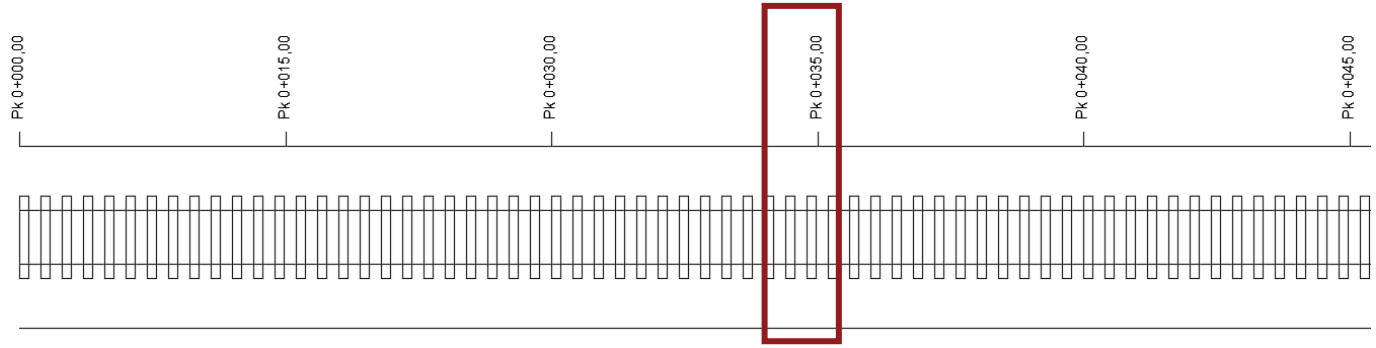
Survey & Inspection: ARCHITA

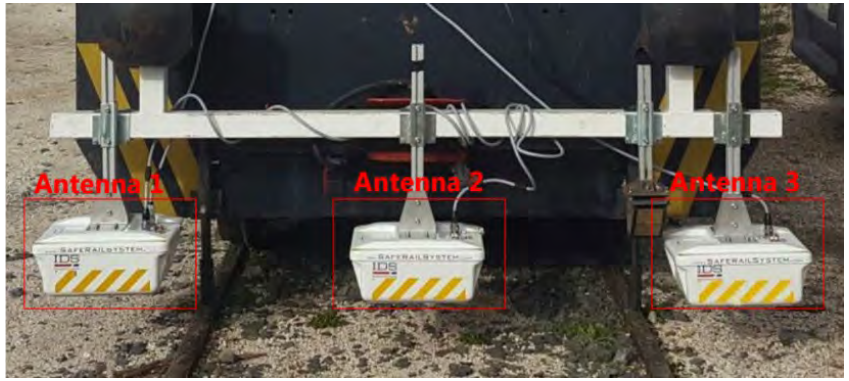


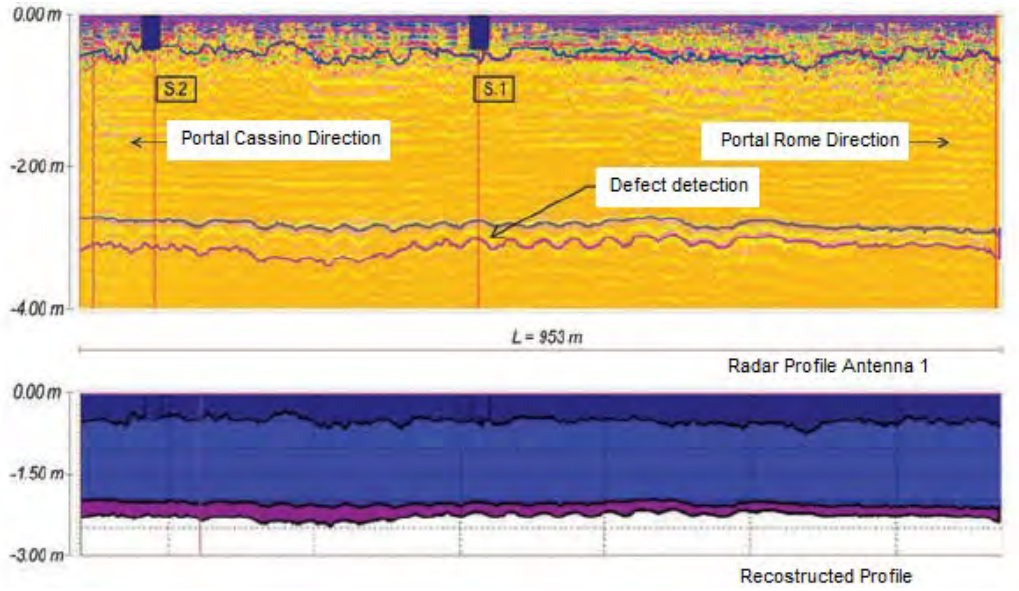




Survey & Inspection: ARCHITA







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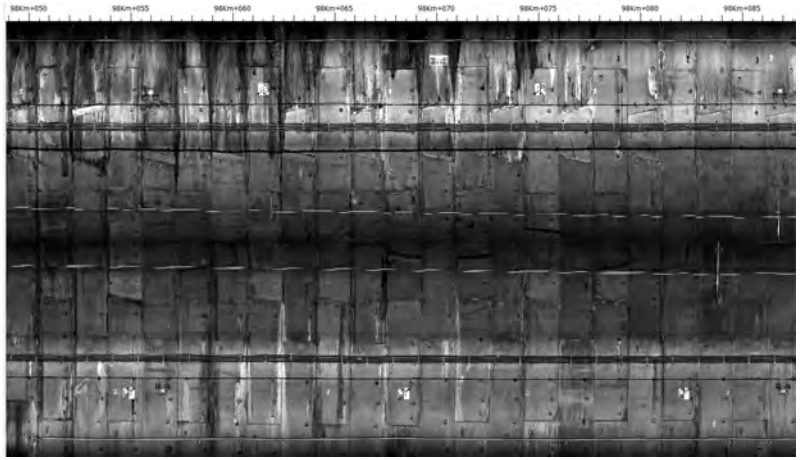
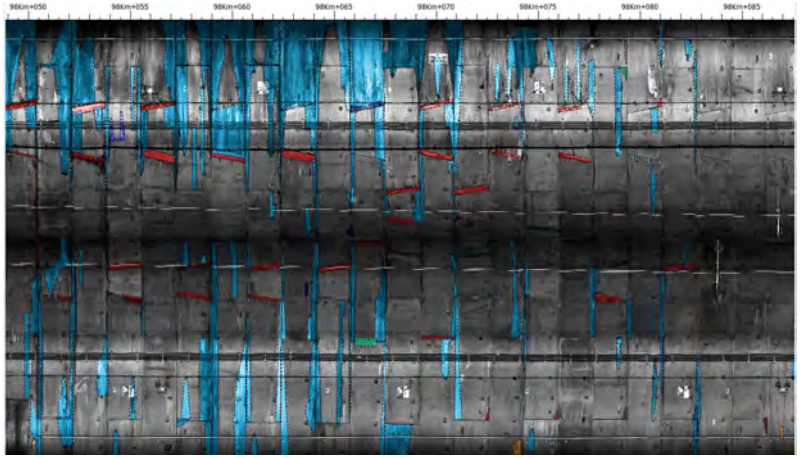
Defects Analysis: Manual detection workflow



From HD photo, thermal imagine and GPR

Defects due to the presence of water					
C6	**Percolation from the joints**				
Definition: Infiltration of water through joints (longitudinal, transversal, mortar injection holes, segment connectors). Presence of humidity or water in the concrete as a result of infiltration. The phenomenon occurs in the presence of imperfect, if not absent, waterproofing at the construction joints.					
Unità of measure: m^2					
Intensity assessment	*0.25*	Surface stains of salt and chloride deposits	**Extension evaluation**	*0.25*	% (Tot Area / Sector Area)
	0.5	Deep stains of salt and chloride deposits		*0.5*	% (Tot Area / Sector Area)
	0.75	Wet surface		*0.75*	% (Tot Area / Sector Area)
	1	Dripping surface		*1*	% (Tot Area / Sector Area)

Defects Catalogue



Defects from manual detection

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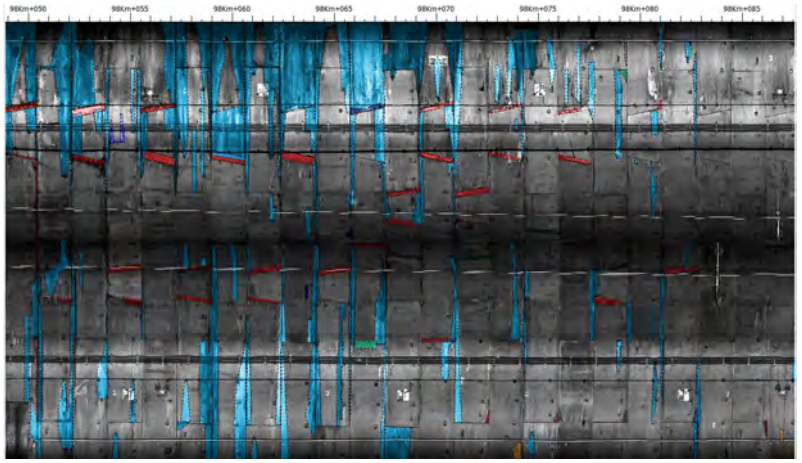
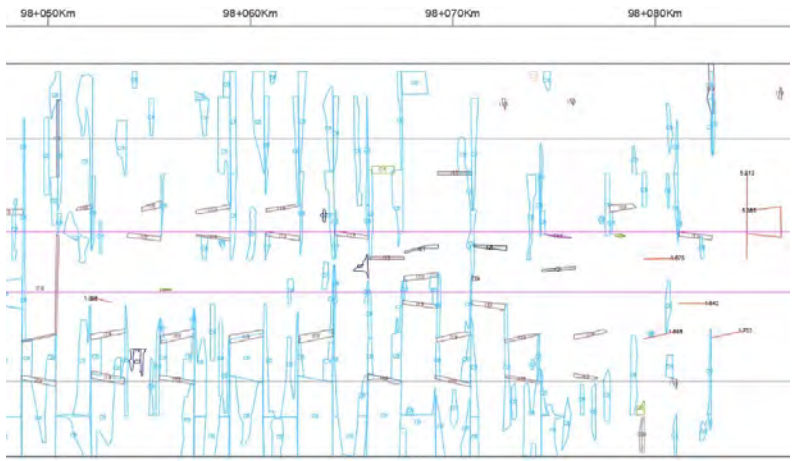
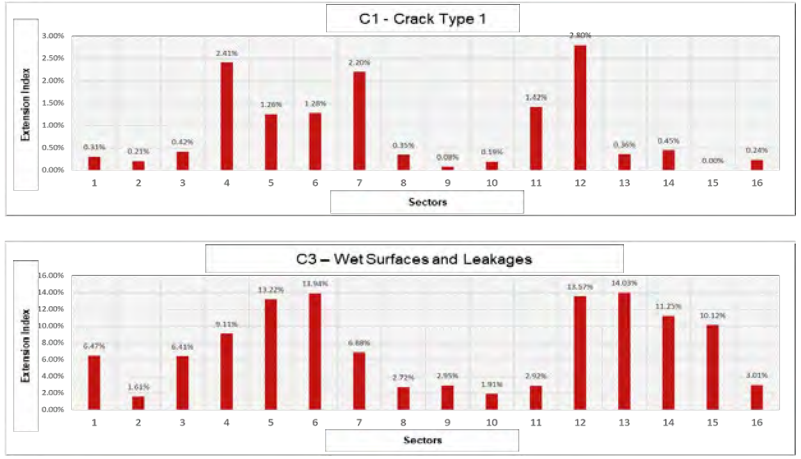
Defects Analysis: Manual detection, output and indexes



Defects from manual detection



Output CAD



Extension Indexes

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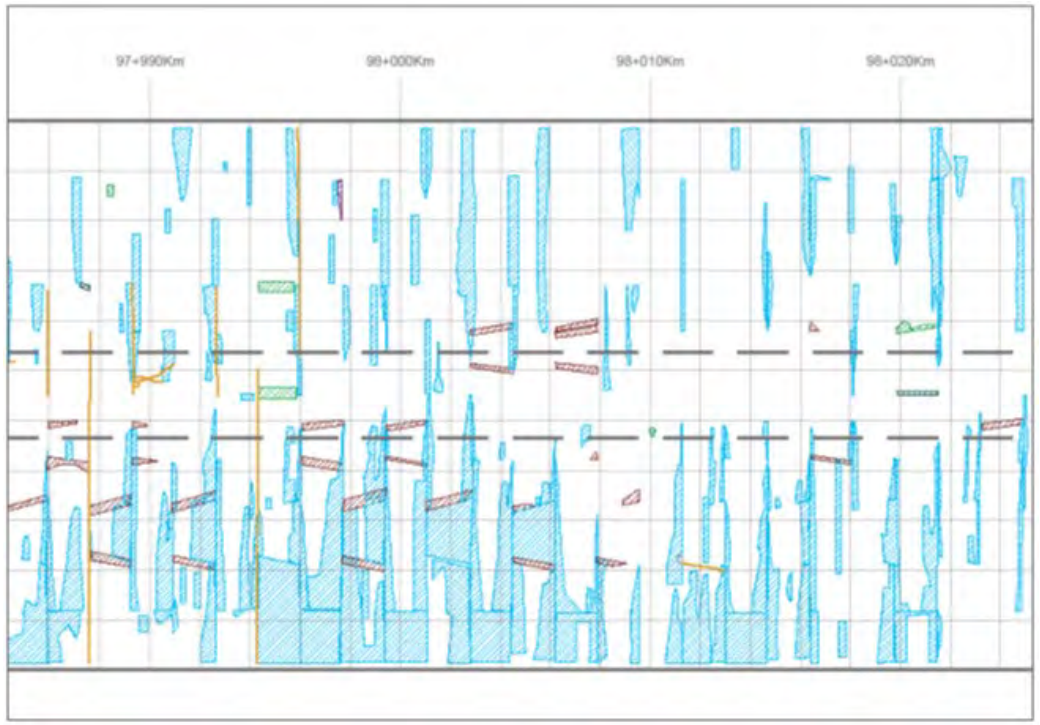
Manual detection, output and indexes



Defects information modeling
and Vulnerability analysis

Priority and Risk analysis

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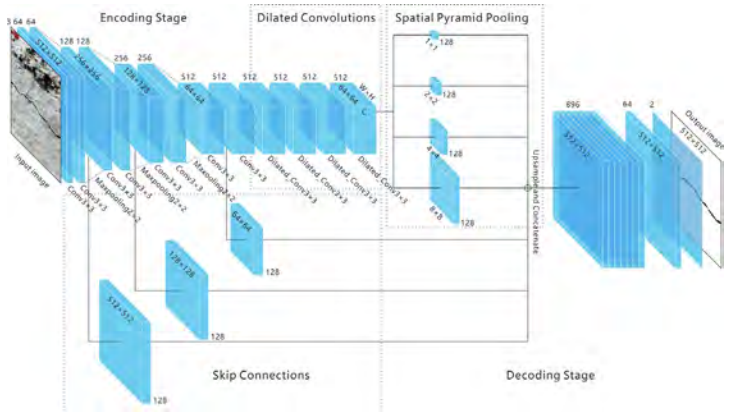
Defects Analysis: Automatic detection

ROCSCIENCE INTERNATIONAL CONFERENCE

THE EVOLUTION OF GEOTECH: 25 YEARS OF INNOVATION

ETSH

Artificial intelligence and image processing in the MIRET approach for the water detection and integrated geotechnical management of existing mechanized tunnels: methodology, algorithm and case study



New Civil Engineer TechFest.

FESTIVAL OF INNOVATION AND TECHNOLOGY 2021

FINALIST

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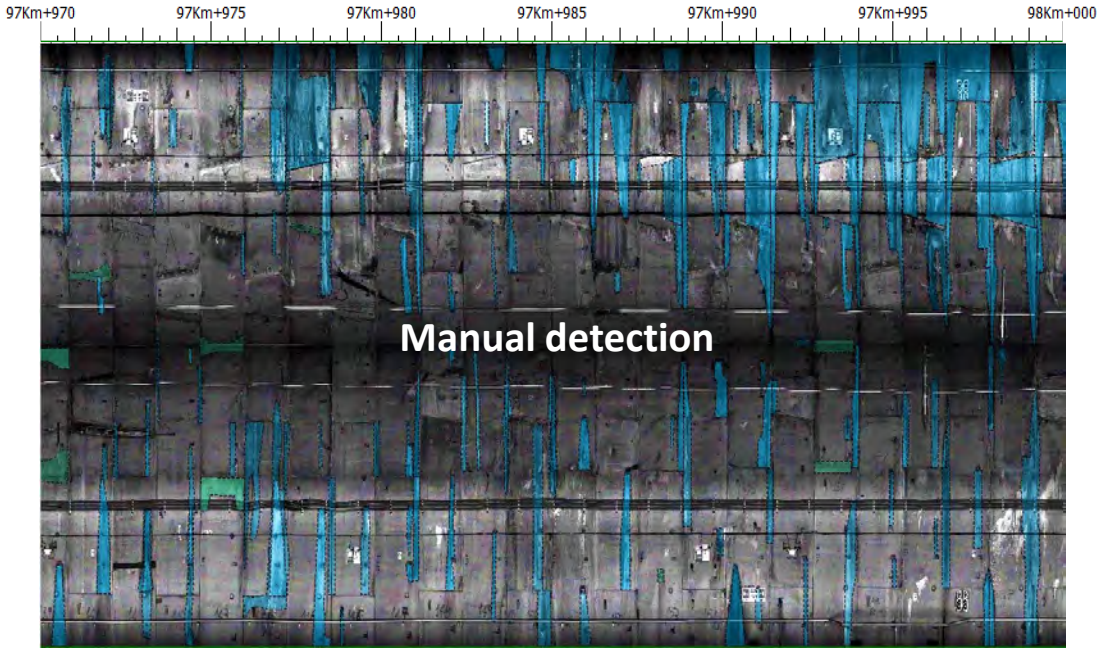
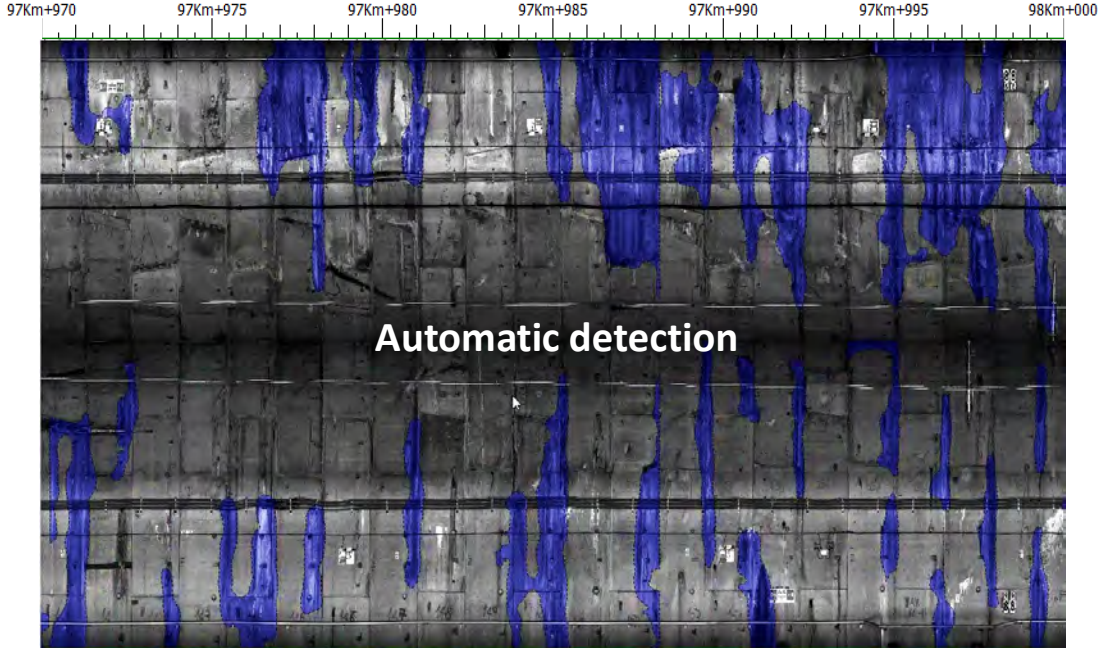
Defects Analysis: Water defects, results and comparison



Total water defects (C5+C6+C7) = 142.42 m^2

Detection time: about 5 days/km



Total water defects = 161.71 m^2

Detection time: about 10 min/km

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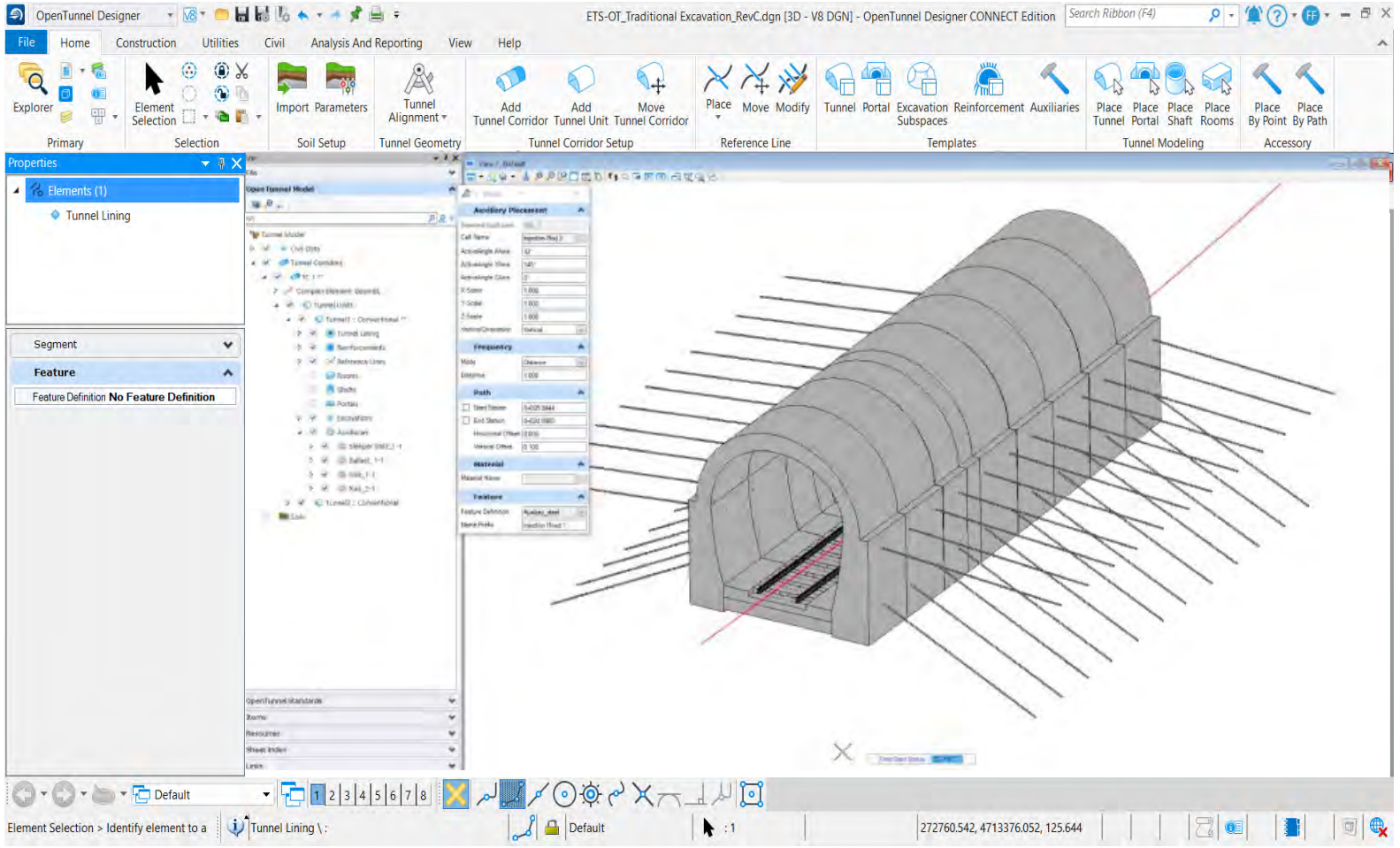
Tunnel Digitalization: Integrated tunnel design solution

OpenTunnel Designer

Bentley
Advancing Infrastructure



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Tunnel Digitalization: User experience

Project description

We tested OpenTunnel Designer on two case studies of railway **existing tunnels**, one for **rehabilitation** of *Heritage tunnel* **(***1886, masonry lining***)** and one for **maintenance** of *Modern tunnel* (2016, *precast concrete segmental lining)*. In both cases, the software made it possible to generate the geometries and process the information quickly and with a tolerable accuracy margin for the design.

For the first one, the design takes place by importing the geometry derived from the survey with ARCHITA and assigning the discretized sections along the alignment.
Starting from the actual state of the tunnel, it is possible to step to modelling the maintenance works, which are created within the OpenTunnel families and positioned according to the design indications.

For the second one, the actual setup is created starting from the as-built layout of the construction. Thanks to the capability of OpenTunnel Designer to create customized sections, we can obtain quickly the 3D geometries of the tunnel.

Tunnel Digitalization: User experience

Adopted workflow

The following workflow has been adopted in the process of modeling the existing tunnel using OpenTunnel:

- Starting from the point cloud file that represent the as build geometry tunnel, tunnel cross sections has been extracted at every point of interest;
- The cross sections then have been imported in OpenTunnel for further customization and modeling;
- Using the OpenTunnel cross sections the tunnel solid, reinforcement and auxiliary elements have been modeled using the automated parametric tools from OpenTunnel;
- Using automated drawing generation tools, plan, profile and cross sections drawings have been created and then compared with design drawings created by ETS team.

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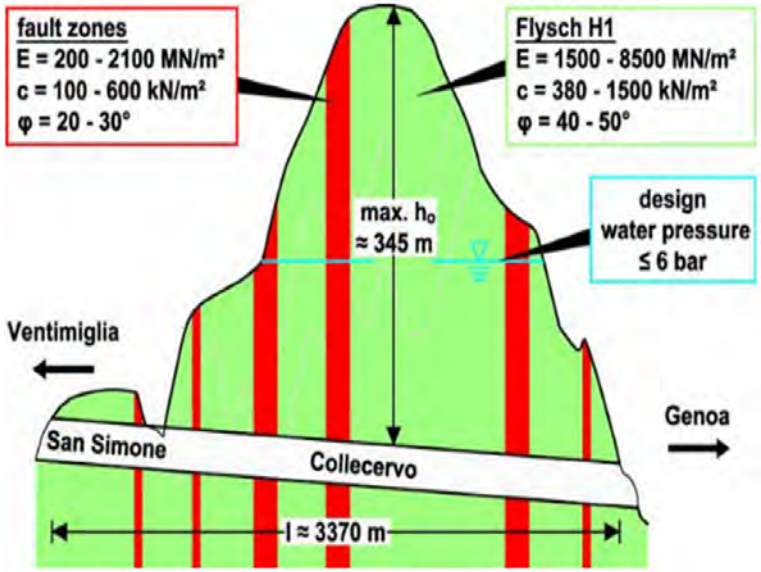
Existing tunnels: Maintenance of Modern tunnel

Key plan

Galleria Collecervo	
Method of escavation	Mechanized
Type of TBM	Single shield
Segment configuration	4 rectangular + 3 trapeziodal
Segmentation	4 regular stone + 2 boundary stone + key
Size of key	two rams position
Internal diameter	10.8 m
Segment thickness	0.4 m
Ring lenght	1.7 m
Concrete strenght	45 Mpa
Reinforcement tipe	Rebar
Connectors in circumferential joint	Dowel
Connectors in radial joint	Dowel
Type of gaskets	Elastomer material
Type of backfill grout	Mortar

Segmental lining characteristics



Geomechanical profile

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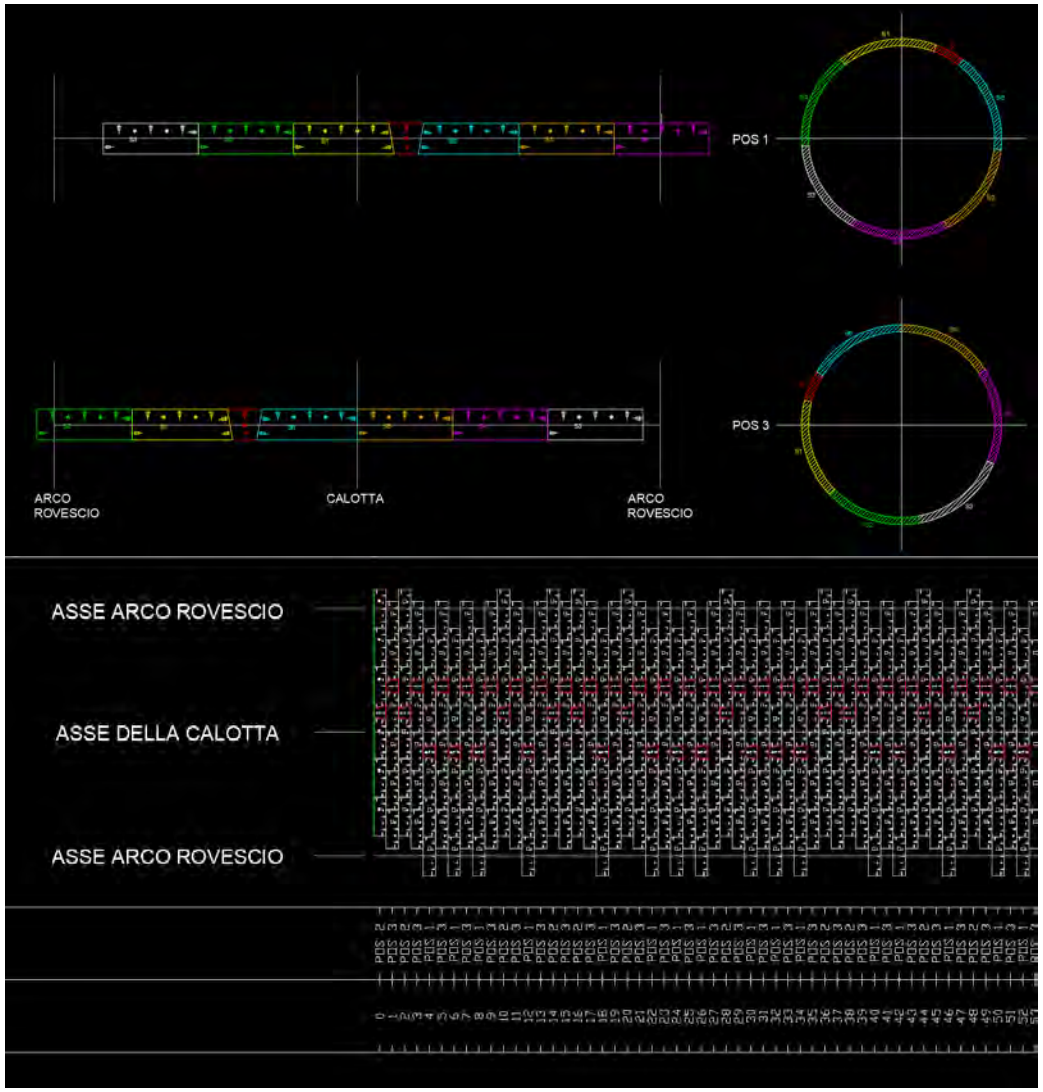
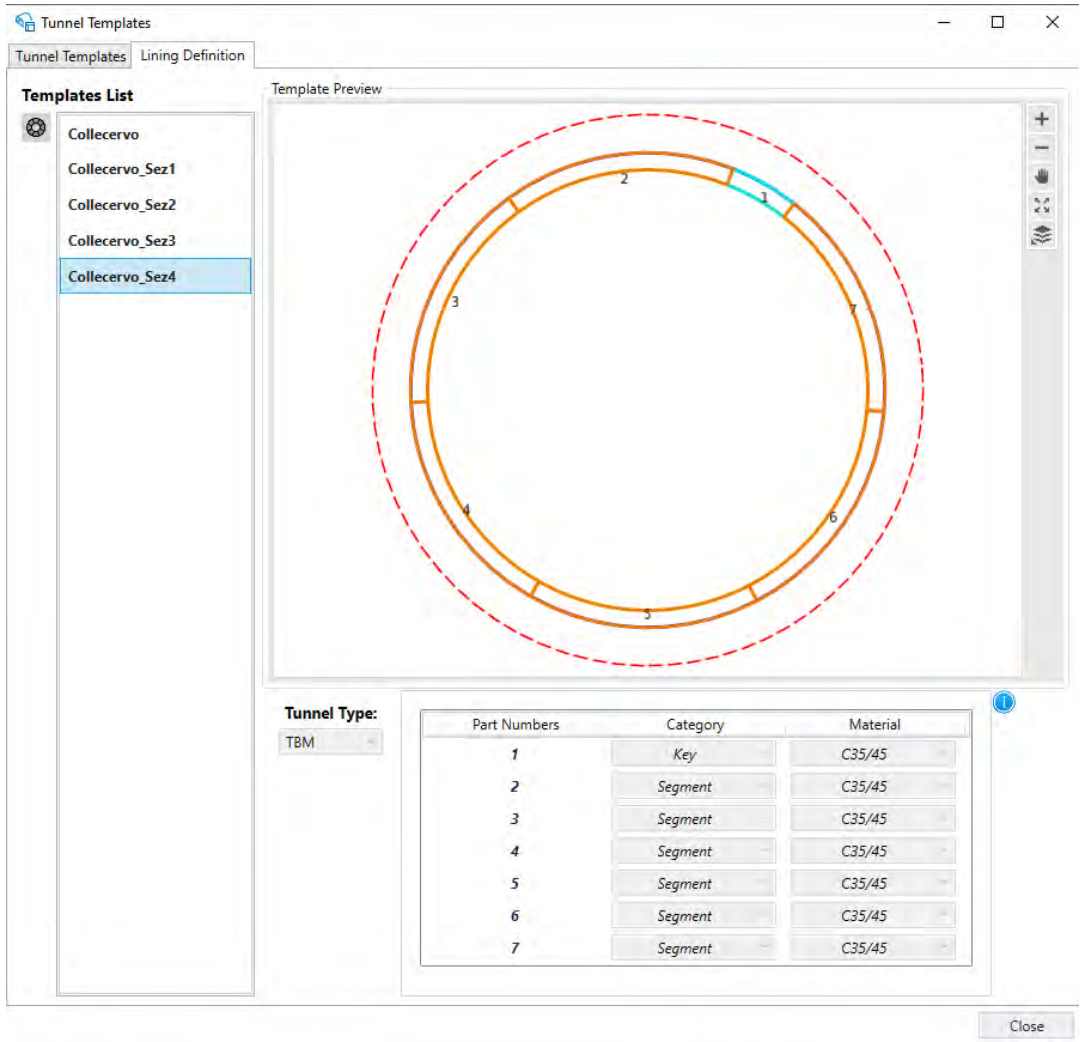
OpenTunnel Designer: From As-built layout to construction





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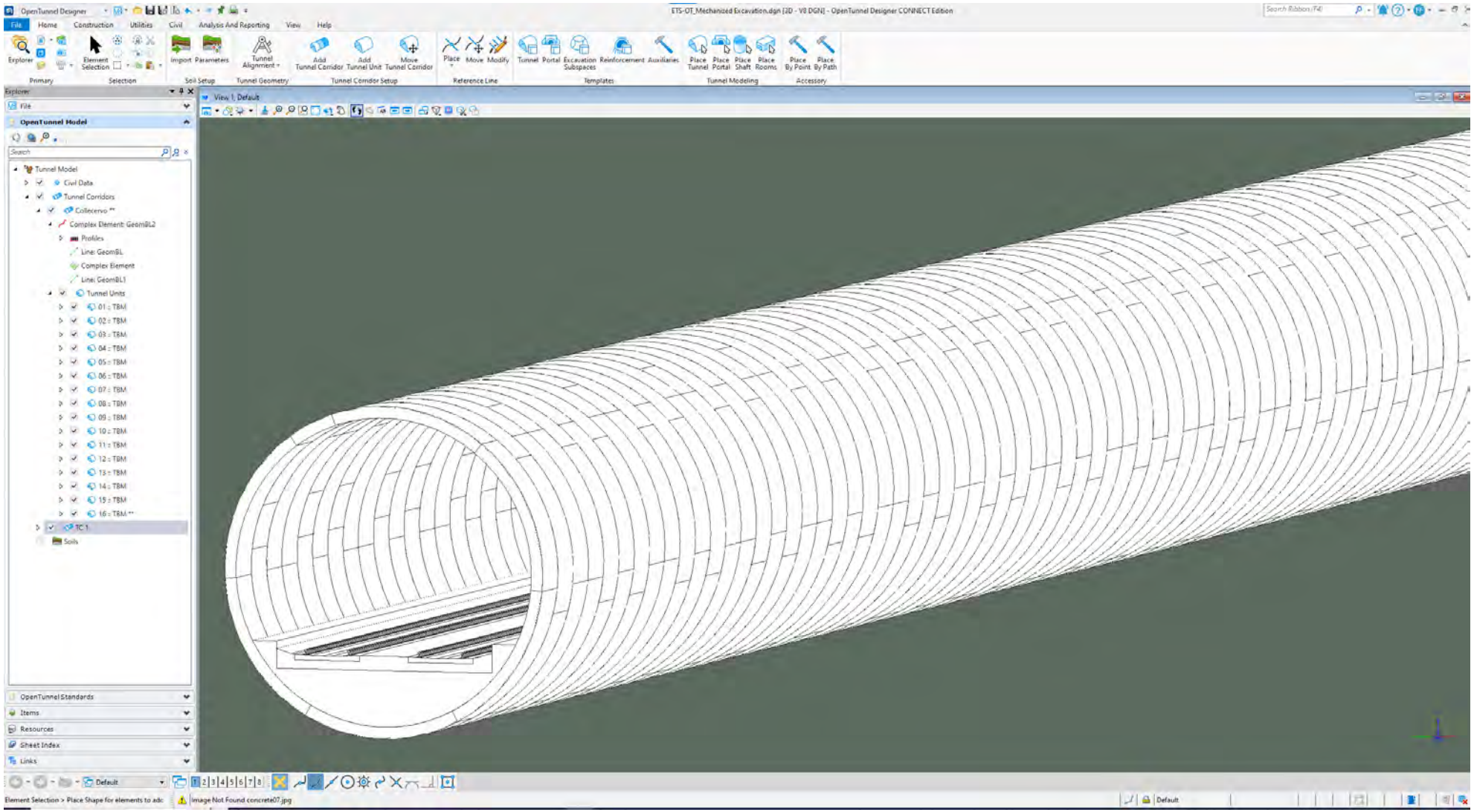
OpenTunnel Designer: From As-built layout to construction



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Existing tunnels: Rehabilitation of Heritage tunnel

Key plan

Preliminary survey

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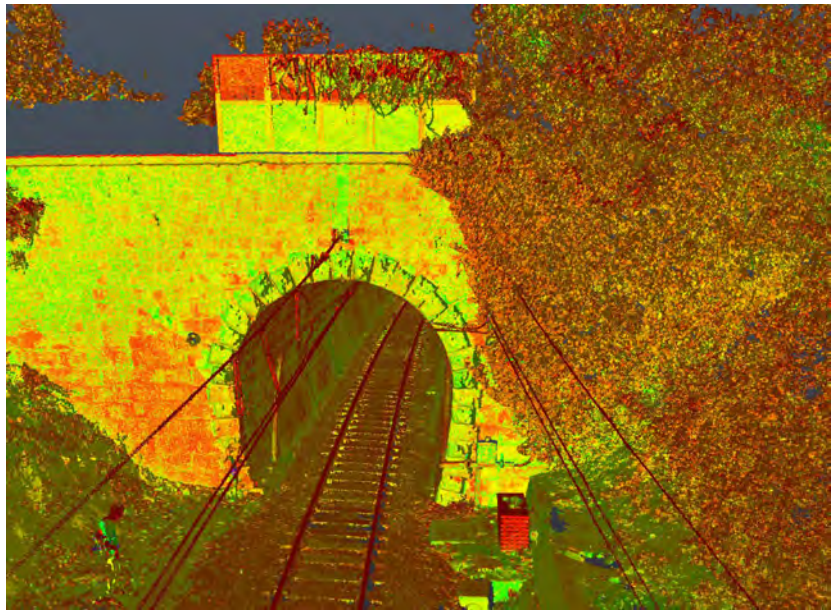
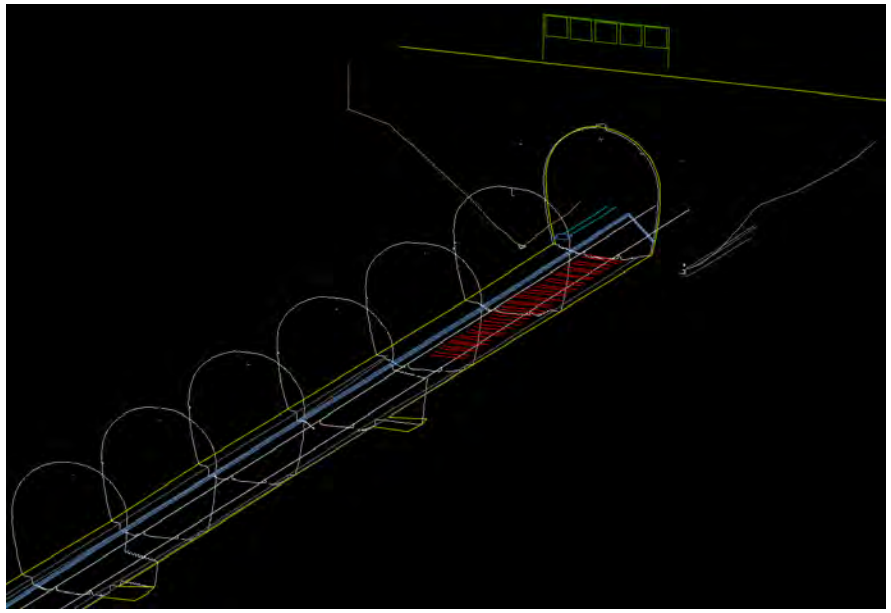
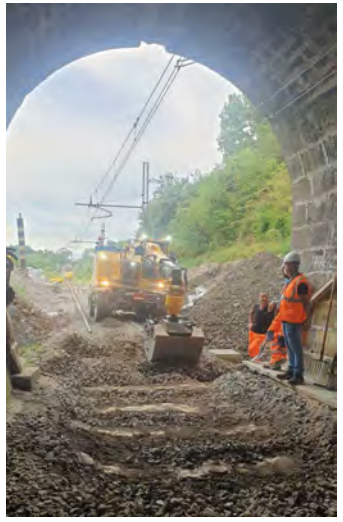
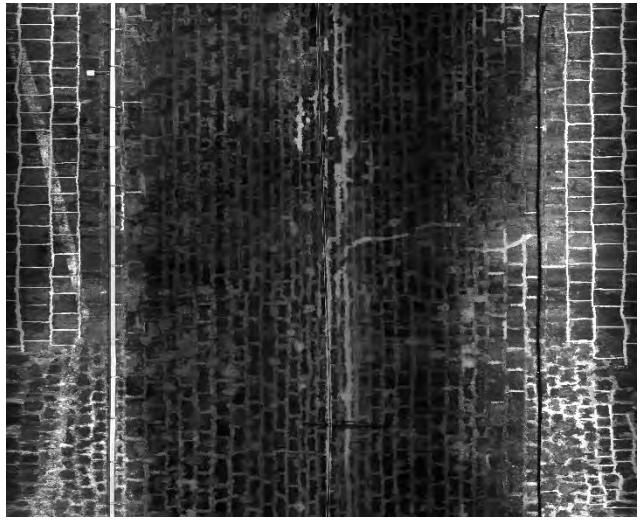
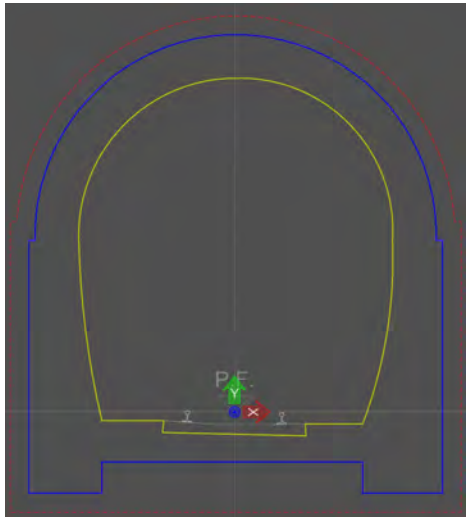
OpenTunnel Designer: Tunnel Rehabilitation project











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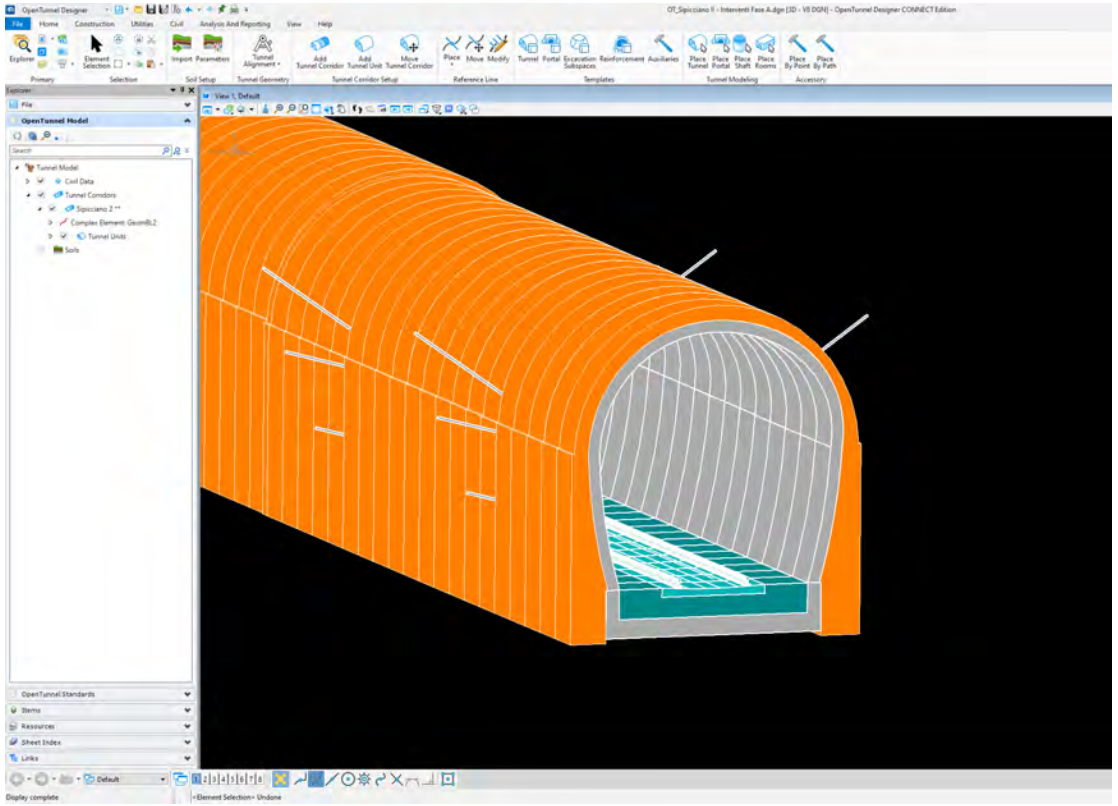
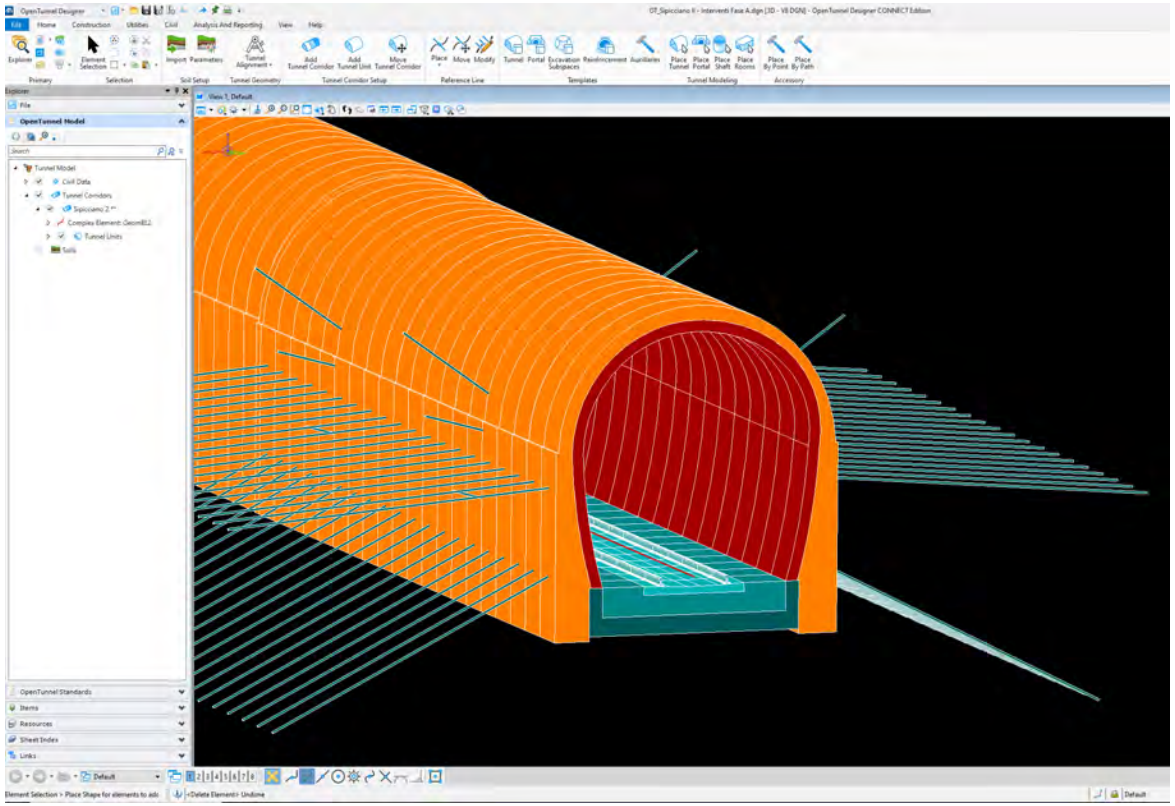
OpenTunnel Designer: Tunnel Rehabilitation project

2013



State-of-art: Drainage

2022



Rehabilitation: Anchors

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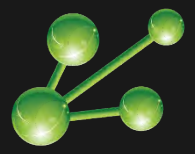
Bentley Tunnel Design Solution: Description

Integrated tunnel design solution optimized to reduce risk and meet deliverable requirements of today and the future.

Increased Productivity and Collaboration

Integrated BIM design spanning ground interpretation, physical modeling and geotechnical design

Complete workflow from initial planning to final deliverables



Leapfrog Works

OpenTunnel Designer

PLAXIS

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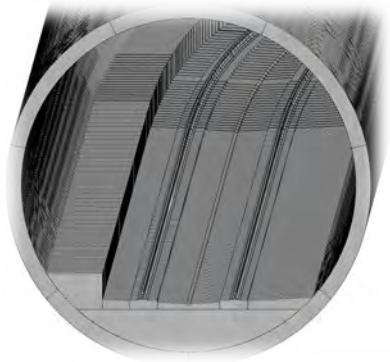
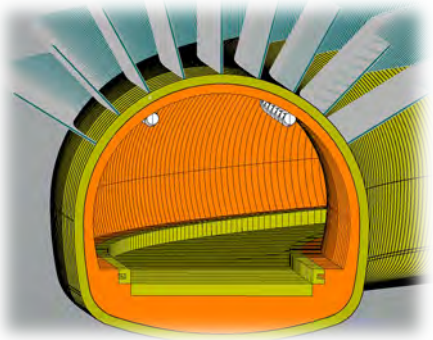
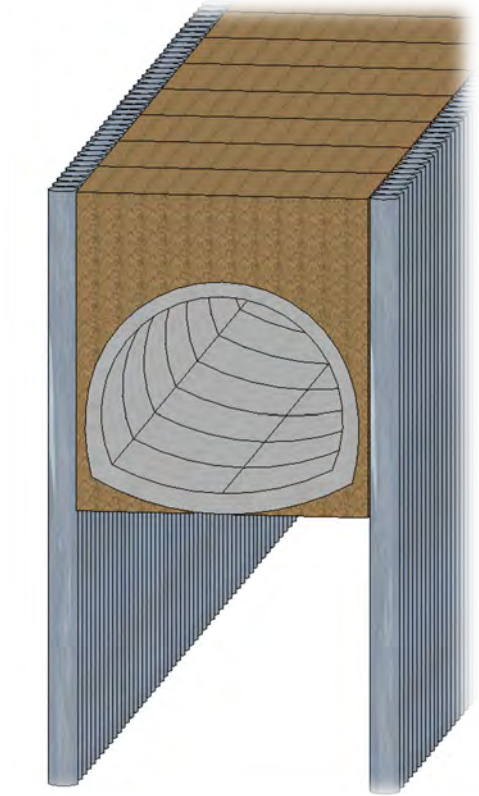
OpenTunnel Designer: Why?

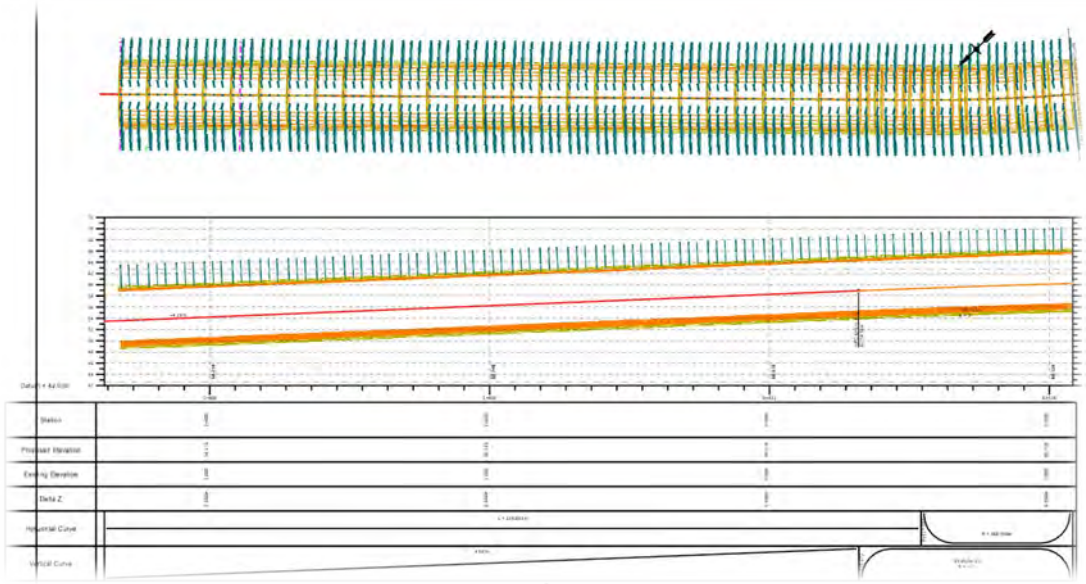
GET THE RIGHT TOOLS FOR THE JOB

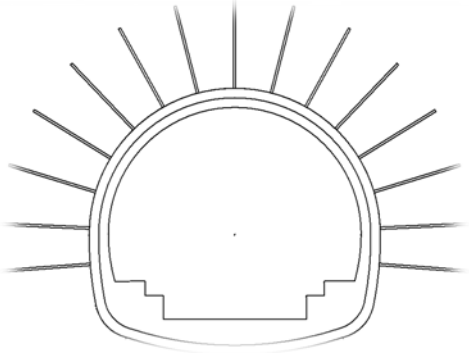
OpenTunnel Designer produces intelligent, parametric models that are rich in engineering content properties for various tunnel components. Model the full excavation shape, excavation tracks, the tunnel lining for conventional and mechanized tunnels alongside the tunnel reinforcements for conventional tunnels. Model, analyze and design as a true 3D solution, as well as perform clash detection with other structures, objects, and utilities to eliminate problems before they occur.











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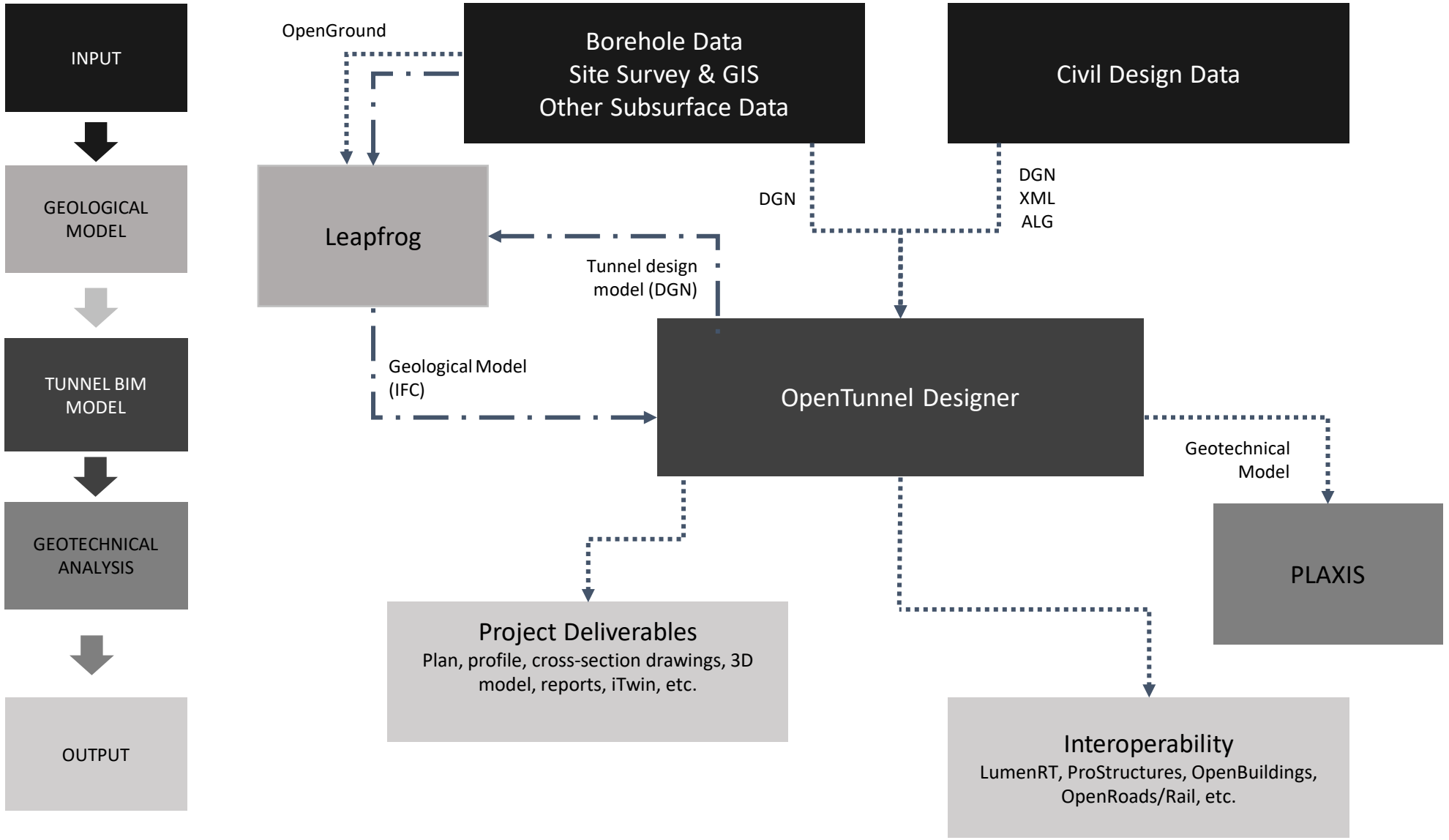
Bentley Tunnel Design Solution: Workflow



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OpenTunnel Designer: Tunnel Rehabilitation project

Cross section creation

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OpenTunnel Designer: Tunnel Rehabilitation project

Tunnel creation

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OpenTunnel Designer: Tunnel Rehabilitation project

Reinforcement and auxiliary placement

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OpenTunnel Designer: Tunnel Rehabilitation project

Automated drawing generation tools

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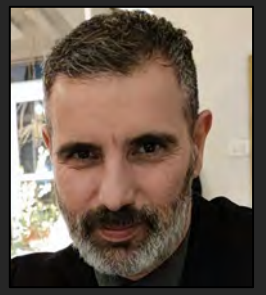
OpenTunnel Designer: Benefits

- Reduce modeling time up to 50% by using intelligent parametric constrained cross section geometry that parametrically updates the 3D solid on the fly.
- Reduce the drafting time up to 70% by automatically generating the plan, profile and cross section drawings that are always in sync with the 3D model.
- Automatically create the geotechnical models for PLAXIS 2D/3D. Depending on the complexity of the physical model a time reduction up to 80% can be achieved on more complex tunnels, especially in the case of PLAXIS 3D.
- Easily identify and mitigate risk from the early stages of design by using a best practice engineering geology approach and clash detection technology.
- Easy collaboration between different disciplines (geology, road, bridge, geotechnical, drafters, etc.) that are working with one single source of truth.
- Matched with dynamic change management you'll mitigate rework and reduce time delays with all team members now working in one application

Questions and Answers with:

Federico Foria
Manager, Geotechnics, Geology and Hydraulics Department; and Research & Development Department
ETS



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