

An aerial view of the Great Belt Bridge, showing the suspension cables and the roadway below. Two workers in orange safety gear are visible on a cable, performing maintenance. The bridge spans a large body of water.

# THE AGE OF DIGITAL ENABLED ASSET MANAGEMENT

## FROM THE GREAT BELT BRIDGE TO BRØNDBY STADIUM...AND BEYOND...

Sund&Belt / Ramboll joint presentation

November 20th 2020

**RAMBOLL**

Bright ideas. Sustainable change.

Sund&Belt  
*Sund&Belt*

## BJARNE JØRGENSEN



>Executive Director  
Operations & Asset Management  
Sund og Bælt Holding

M +45 2944 7240  
[bjg@sbfdk](mailto:bjg@sbfdk)

## TORBEN BANGSGAARD



>Chief consultant  
Monitoring and Analyses of Existing Structures  
Ramboll Denmark

M +45 5161 6790  
[tchr@ramboll.dk](mailto:tchr@ramboll.dk)



Kommercielle selskaber

**Partner**  
*Sund ≈ Bælt*

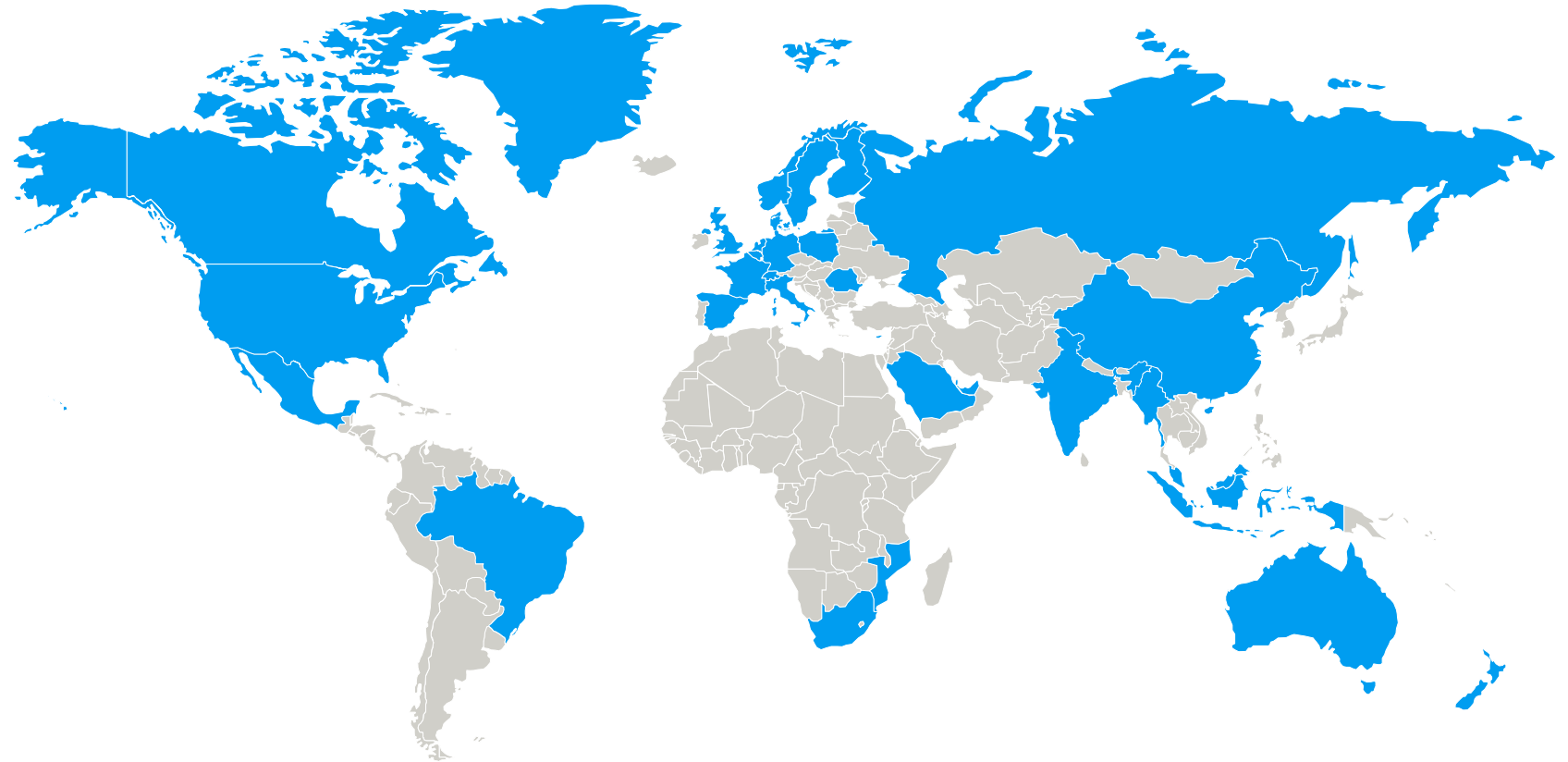


**BroBizz**  
**Operator**  
*Sund ≈ Bælt*

*Sund ≈ Bælt*  
*Sund ≈ Bælt*

## RAMBOLL IN BRIEF

- > Independent engineering, design and management consultancy
- > Strongholds Europe, North America, Middle East and Asia Pacific
- > Founded 1945 in Denmark
- > 15,000 experts
- > 35 countries – 300 offices
- > EUR 1.6 billion revenue

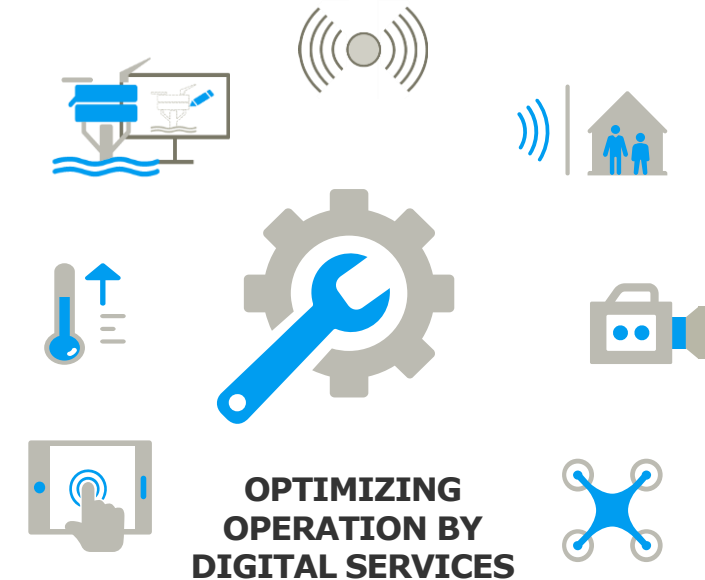
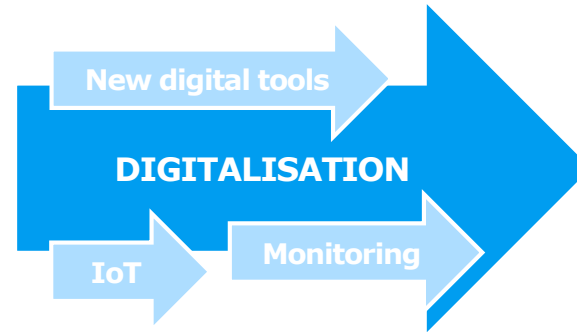


# AGENDA

- > **WHY DIGITAL ENABLED ASSET MANAGEMENT?**
- > **DIGITAL TWINS, SHMS & AI - LARGE SCALE MONITORING**
- > **THE GREAT BELT BRIDGE – SHMS, AI AND DIGITAL TWINS**
- > **BRØNDBY STADIUM – REHABILITATION OF SYDSIDEN  
USING SMARTPHONES, GOPRO CAMERAS (AND STEEL)**

# > WHY DIGITAL ENABLED ASSET MANAGEMENT

# DRIVERS FOR DIGITAL ENABLED ASSET MANAGEMENT: ASSET OWNERS ARE FACING MANY CHALLENGES



**Asset owners** are facing a number of challenges and external pressures that **require them to change the way they manage their assets**. Focus is not only on optimization of operations (OPEX), but also on sustainability, safety, performance and reliability.

A **key enabler** for managing those increasing challenges and expectations are through **utilization of new digital opportunities**. For example, digital monitoring of assets current performance and condition of assets can be used to gain insights on

# DIGITAL ENABLED ASSET MANAGEMENT (DEAM) DIFFERENTIATES BY COMBINING SERVICES ACROSS STRATEGIC AM ADVISORY, DIGITAL AND DOMAIN KNOWLEDGE

## TRADITIONAL ASSET MANAGEMENT SERVICES

*Challenge: Lack of insights from Digital Solutions leads to missing the opportunities on speedy response, reducing downtime etc.*

## ASSET MANAGEMENT (AM) ADVISORY



# DEAM

## THE TECH COMPANIES' SERVICES

*Challenge: Tech solutions that are weak on Domain Knowledge, thus lack physical insight and design knowledge*

## DOMAIN EXPERTISE



## DIGITAL\*



## CURRENT EXAMPLES OF DIGITAL TWINS AND DIGITAL DATA COLLECTION

*Challenge: Even if a digital twin is set-up with deep domain knowledge, it can only be a game changer if the digital twin is having impact on the overall AM strategy.*

\*) A big portion of digital solutions need to undergo a business case development, where domain knowledge and strategy need to be added for value generation

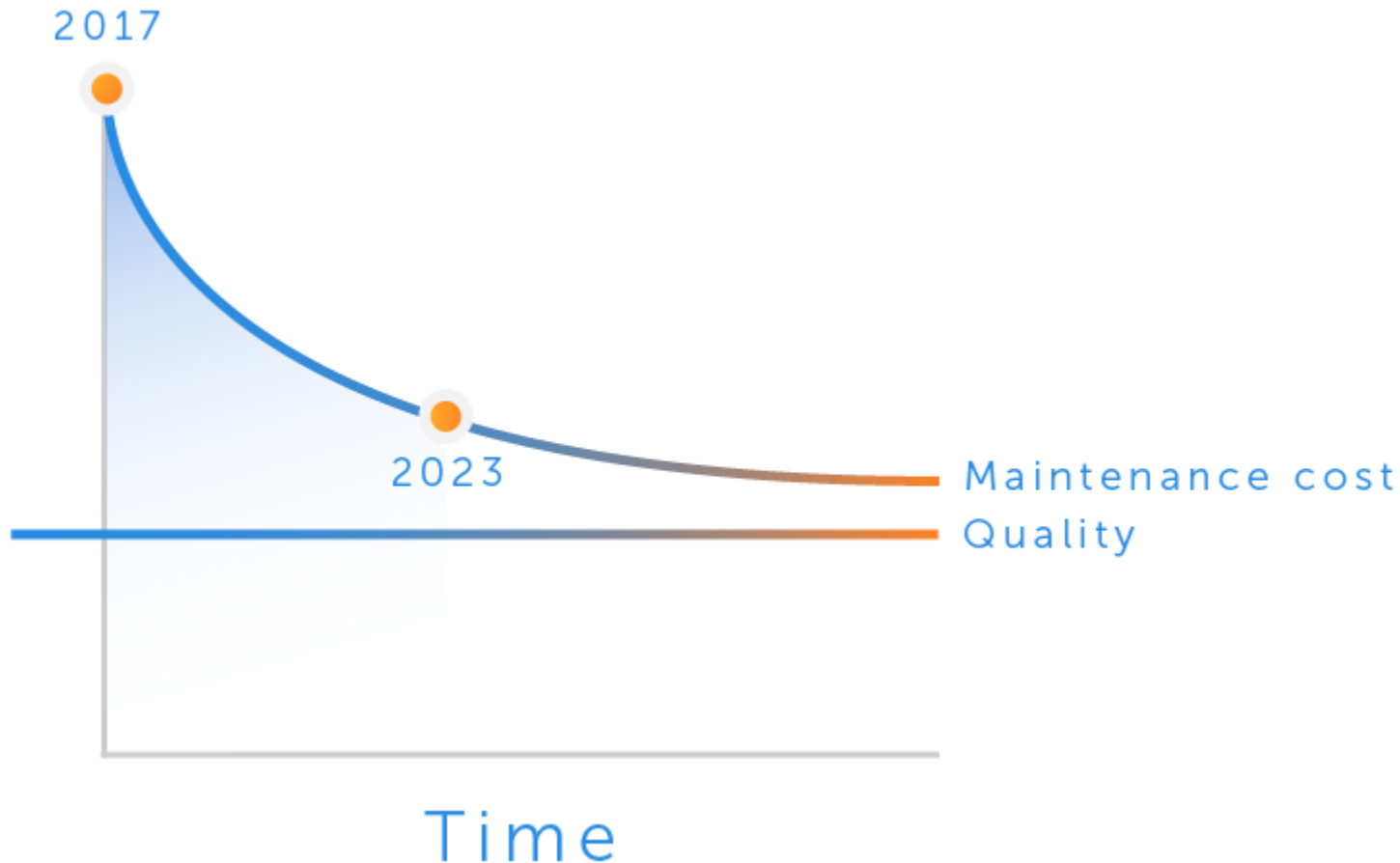




“We have become highly aware that value is not as much associated with the technology at hand, but rather lies in the data. Technology is volatile, while data is perpetual.

Mikkel Hemmingsen, CEO, Sund & Bælt A/S

# AMBITION FOR ASSET MANAGEMENT

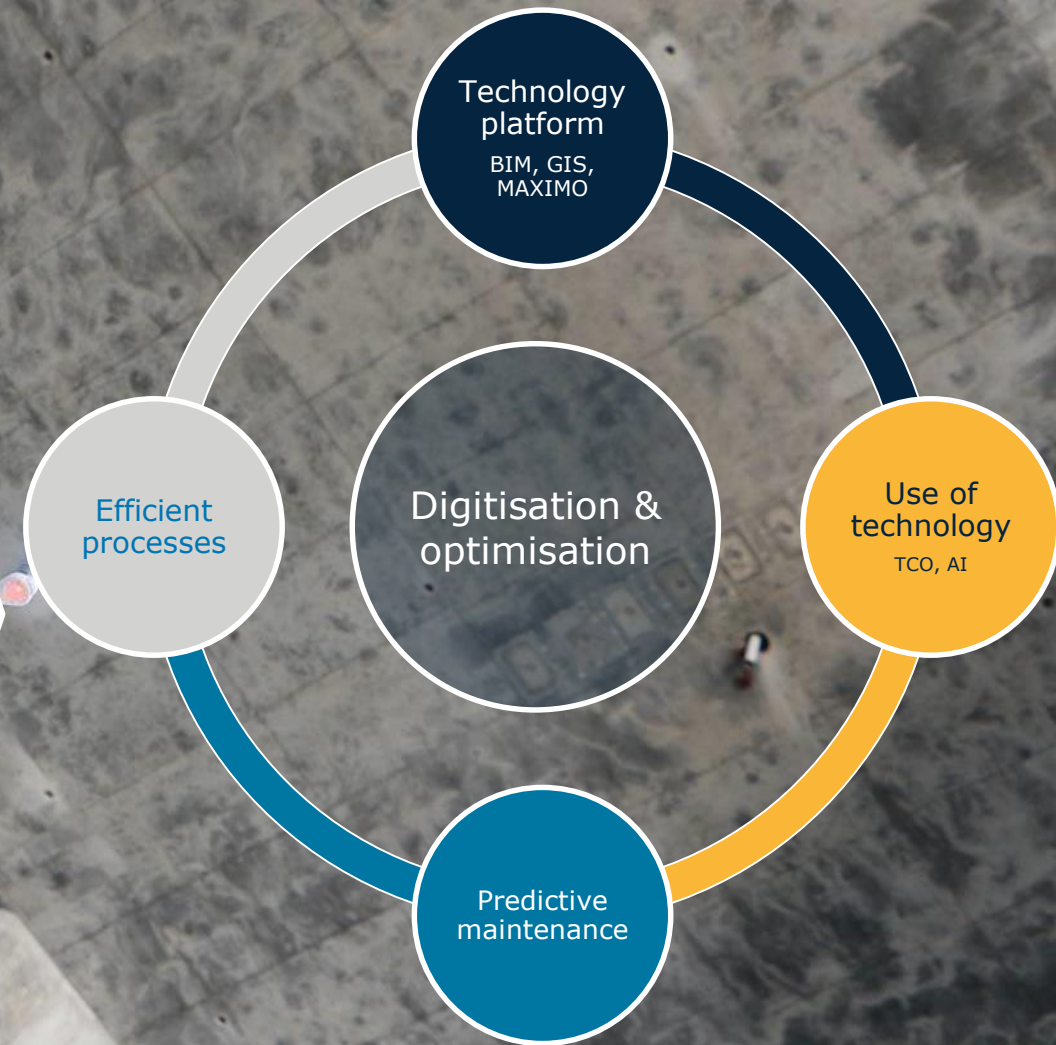


- Reduce operational cost 2% per year until 2023
- Keep constant cost level after 2023 despite aging assets
- Maintain quality and accessibility

# DIGITAL STRATEGY

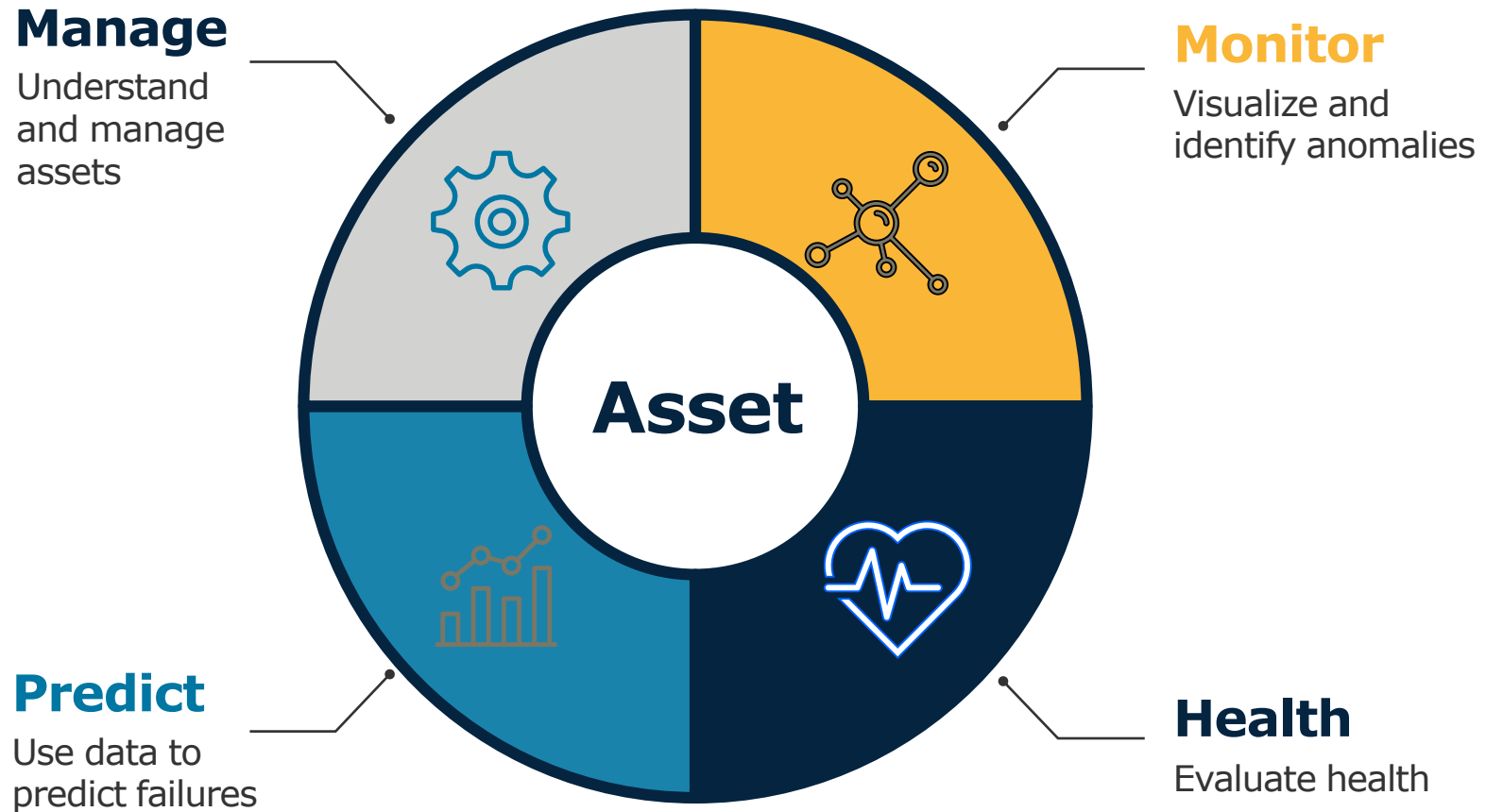
Data from drones, sensors and robots enables ...

- Increased Digitisation of our maintenance
- Big Data & Analytics, AI (Artificial Intelligence)
- New data sources; robots/drones/sensors
- Digital models: GIS, BIM, AR
- highend EAM approaches...



# THE JOURNEY TO ENTERPRISE MANAGEMENT

A digital transformation of the management of civil infrastructure forcing changes to the operating models including use of data



April-June 2020

August-October 2020

October-December 2020

January-March 2021

April-June 2021

Release 1:

Maximo R1

Release 2:

Mobile & GIS

Release 3:

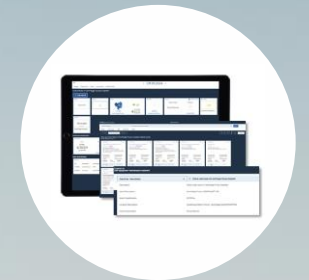
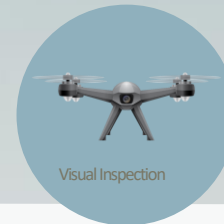
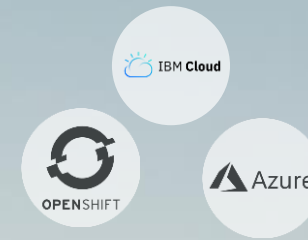
Defect Management

Release 4:

Move to Cloud &  
Visual Inspection

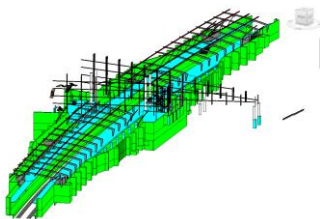
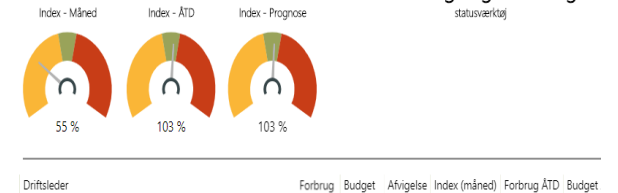
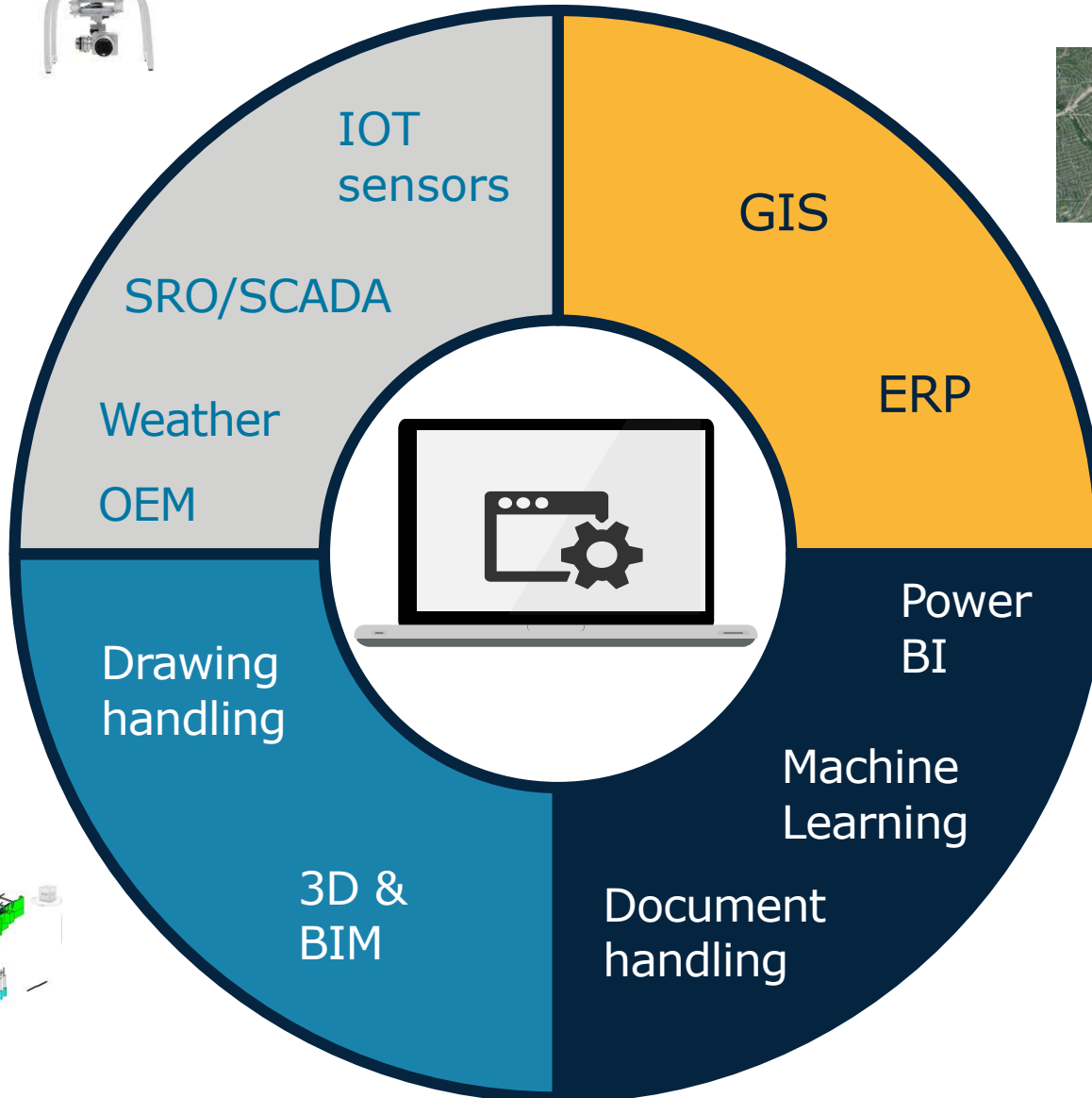
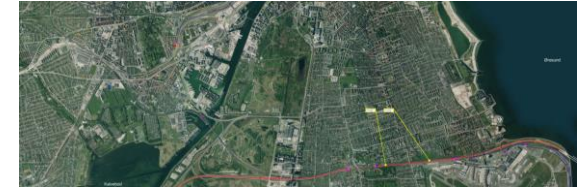
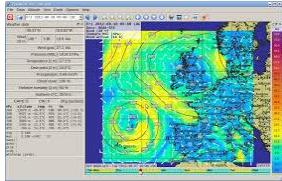
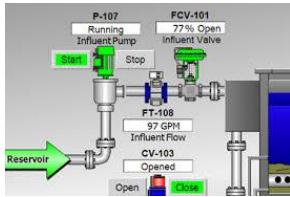
Release 5:

Predictions & Closures



Maximo for Civil Infrastructure

# MAXIMO FOR CIVIL INFRASTRUCTURE



# > DIGITAL TWINS, SHMS & AI - LARGE SCALE MONITORING

# SMART AIR MONITORING



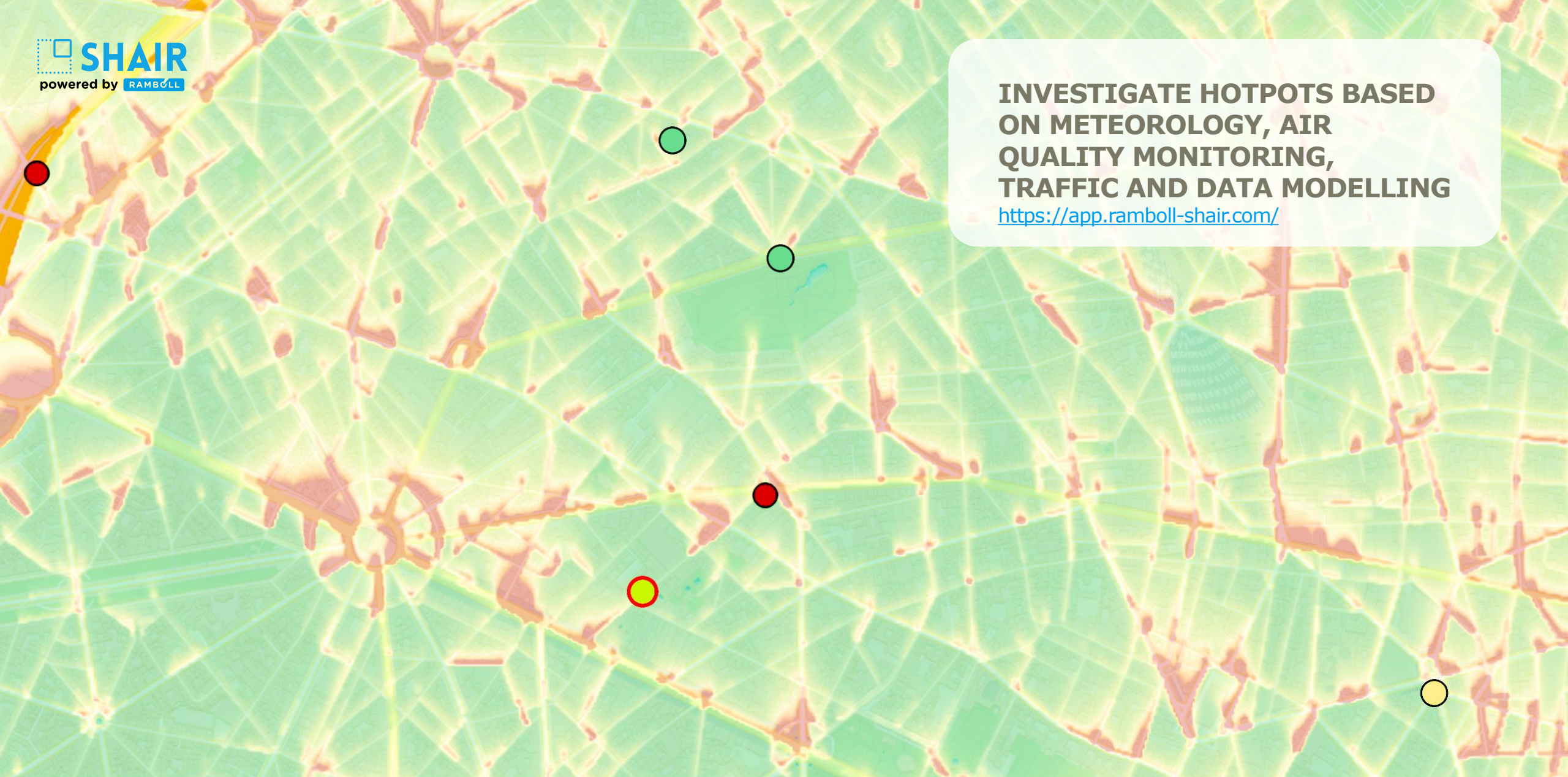
**SHAIR**

powered by **RAMBOLL**

Seeing **Hyperlocal** Air quality **In Real-time**



**INVESTIGATE HOTSPOTS BASED  
ON METEOROLOGY, AIR  
QUALITY MONITORING,  
TRAFFIC AND DATA MODELLING**  
<https://app.ramboll-shair.com/>



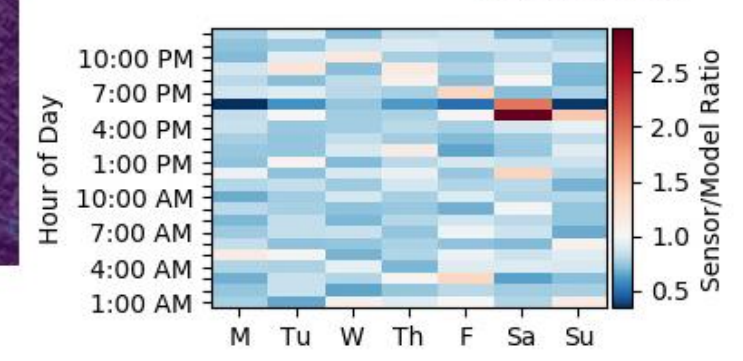
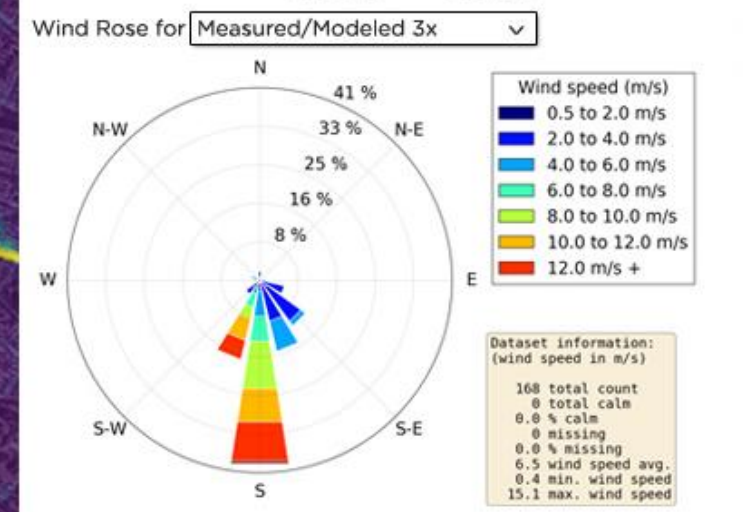
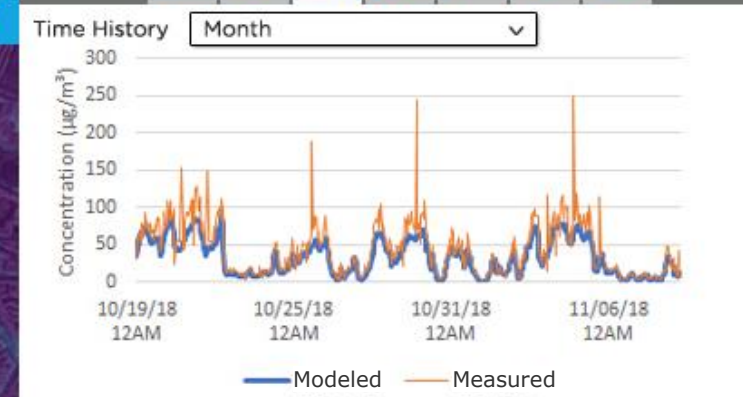
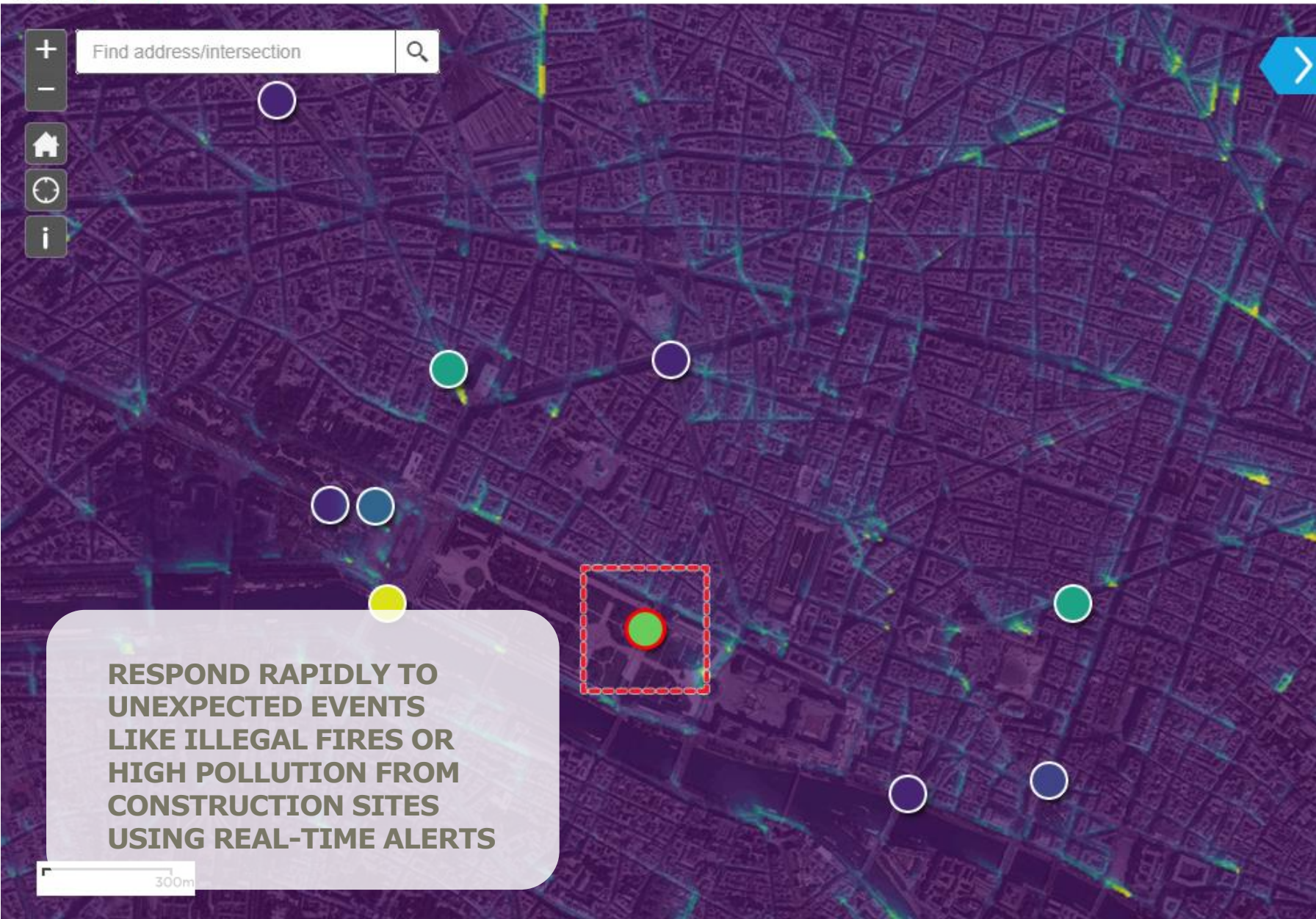
**PM<sub>2.5</sub>**  
SPECIES

**1-HOUR**  
AVERAGING PERIOD

0



15.0 ug/m<sup>3</sup>



# OFFSHORE



# TRUE DIGITAL TWIN



**Automatic load/model updating**

**Structural Reliability Assessments**

**Reliability Based Inspection Planning**

**Predictive Maintenance**

**Lifetime extension**

**Root cause analysis**

**Future Design Optimization**

**TRUE DIGITAL TWIN  
CALIBRATED TO  
MATCH PHYSICAL  
ASSET BASED ON  
MEASUREMENTS**

<https://ramboll.com/ingenuity/digital-twin-based-asset-management>





“Lifetime extension is not always about adding more steel to existing structures, but it is much more about utilizing what is already there. The True Digital Twin can help us unlock many more years of operation than the original design lifetime would suggest.”

Morten Nielsen, Integrity Advisor, Hess



# MAJOR CROSSINGS

# QUEENSFERRY CROSSING



**Automatic data analysis**

**Flexible UI for data examination**

**SHMS integrated with inspections/alarms**

**AM integration (alarms, reports, inspection, maintenance)**

**Intelligent Traffic Flow Control**

**TRAFFIC SCOTLAND**

**2.7 km TOTAL LENGTH**

**650 m MAIN SPANS**

**+1500 SENSORS SHMS**



# BOGIBEEL BRIDGE

**Automatic data analysis**

**UI for data  
examination/analysis**

**Damage accumulation  
models**

**AM integration  
(alarms,reports)**

**RAILWAY INDIA  
4.9km TOTAL LENGTH  
40x 125m SPANS  
+950 SENSORS SHMS**

# >THE GREAT BELT BRIDGE – SHMS, AI, DIGITAL TWINS

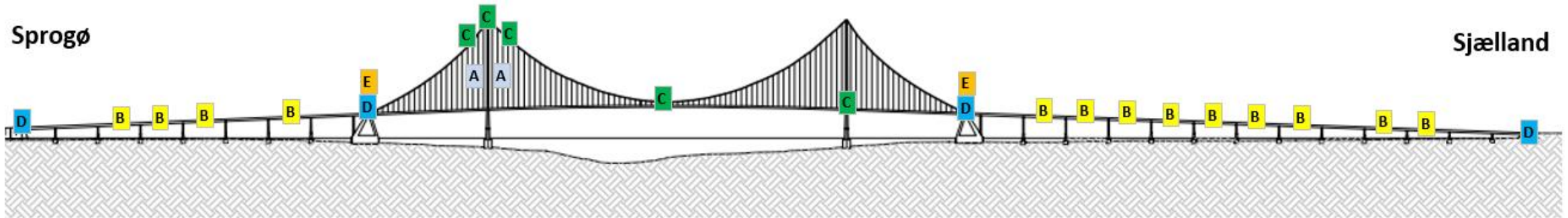
# THE GREAT BELT BRIDGE

KONMOS – STRUCTURAL MONITORING

**16.4 km TOTAL LENGTH**  
**1624 m MAIN SPAN**  
**+400 SENSORS SHMS**

# EAST BRIDGE SENSORS

## STRUCTURAL MONITORING SYSTEM



---

### Description

---

- A** Hanger accelerometers
  - B** Tuned Mass Dampers (TMD)
  - C** GPS
  - D** Horizontal displacement, bearings
  - E** Sensors at hydraulic buffers
- Weather station

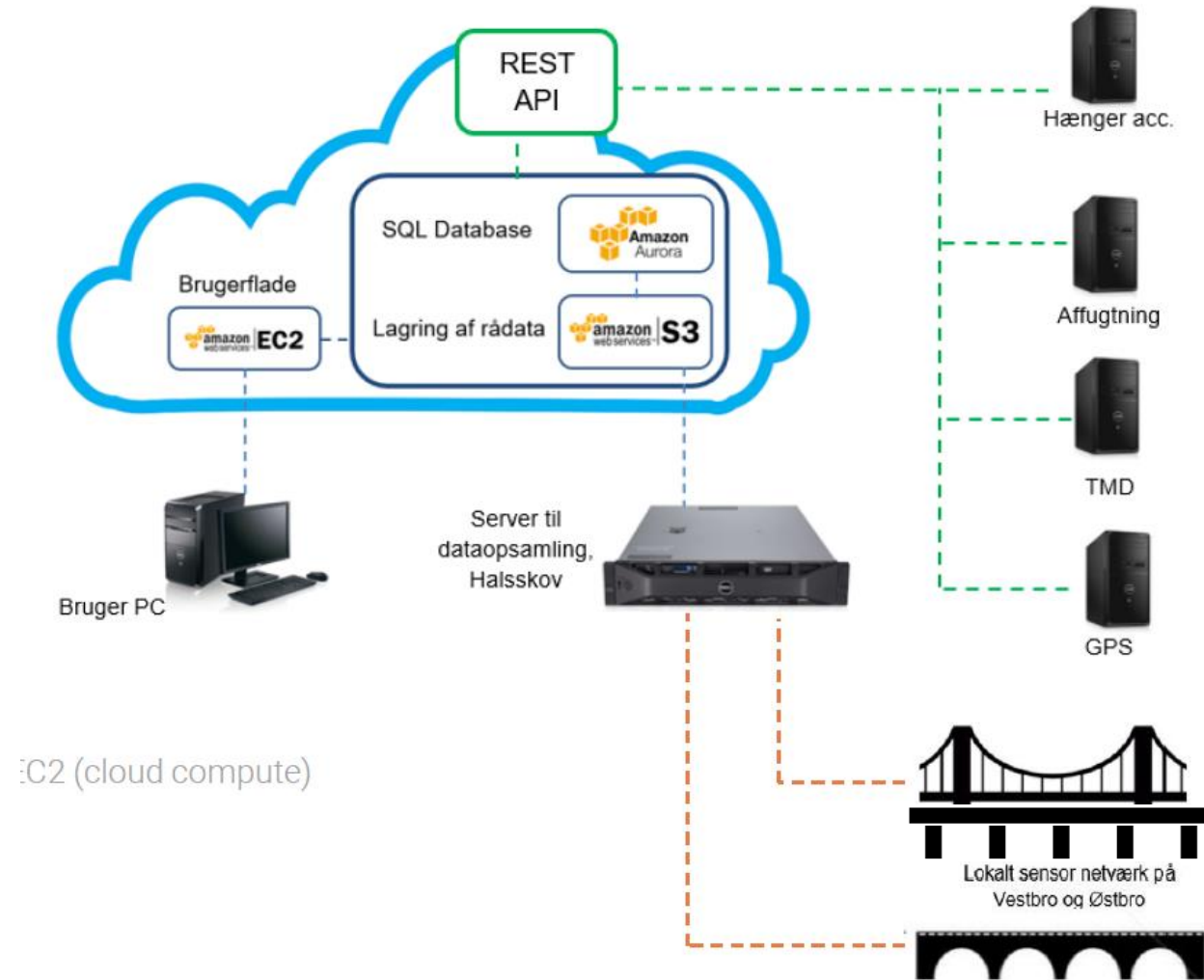
---

Total

---

# KONMOS CLOUD PLATFORM

## STRUCTURAL MONITORING SYSTEM



# KONMOS UI

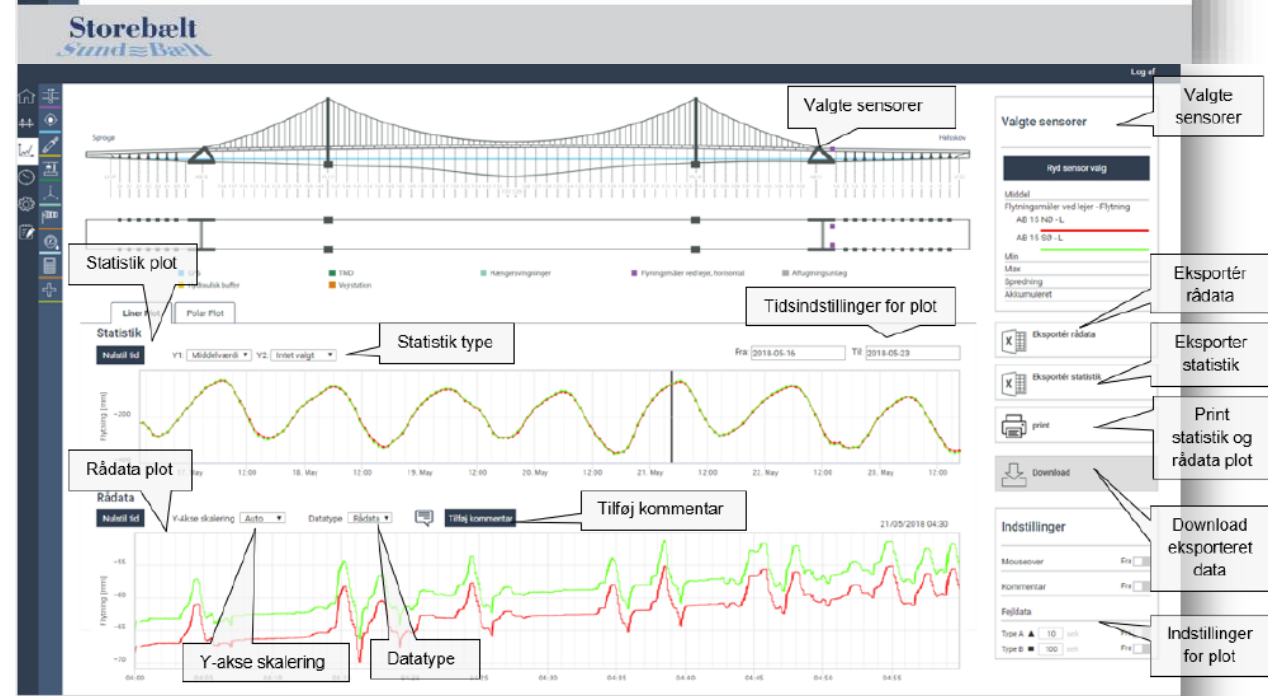
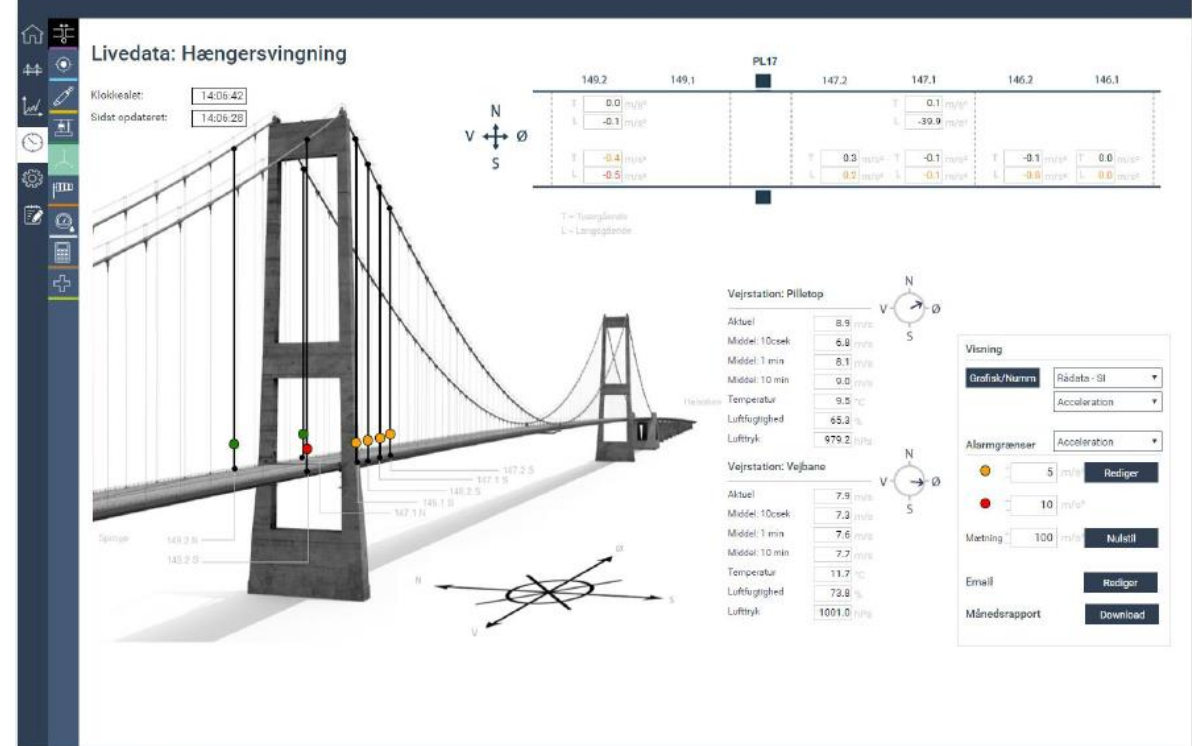
## Structural monitoring for maintenance

### Included sensors

- Approx. 250 channels on the West Bridge
- Approx. 450 channels on the East Bridge

### Main features

- Plot of 1 hour values from SQL database
- Plot of raw data from 1 hour files
- Online data
- Export to Excel



# HOTSPOT DIGITAL TWIN PROJECT 2020-22

**STRATEGY** FOR INTEGRATION OF  
DIGITAL TWINS IN AM/O&M

ESTABLISH DIGITAL TWINS FOR  
CRITICAL HOTSPOTS ON  
**HANGERS** AND **BRIDGE GIRDER**

BASED ON RAMBOLL'S **TRUE  
DIGITAL TWIN** TECHNOLOGY

UPGRADED **MONITORING SYSTEM**  
AND **CLOUD PLATFORM**

PARTNERING WITH **SACERTIS**  
(IT) FOR INTEGRATED VIBRATION  
MEASUREMENTS AND ANALYSIS

**RAMBOLL**

Bright ideas. Sustainable change.

Sund≅Bælt  
Sund≅Bælt

# DIGITAL TRANSFORMATIONS IN OPERATION & MAINTENANCE



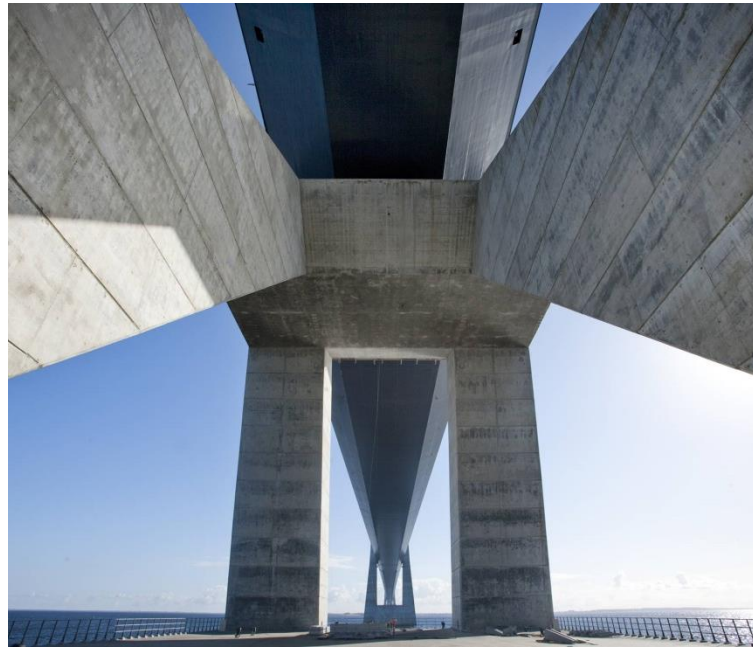


# CONCRETE INSPECTION ON STOREBÆLT LARGESCALE CONSTRUCTIONS

General inspection of concrete structures on the East Bridge is challenging on the following constructions:



Pylons



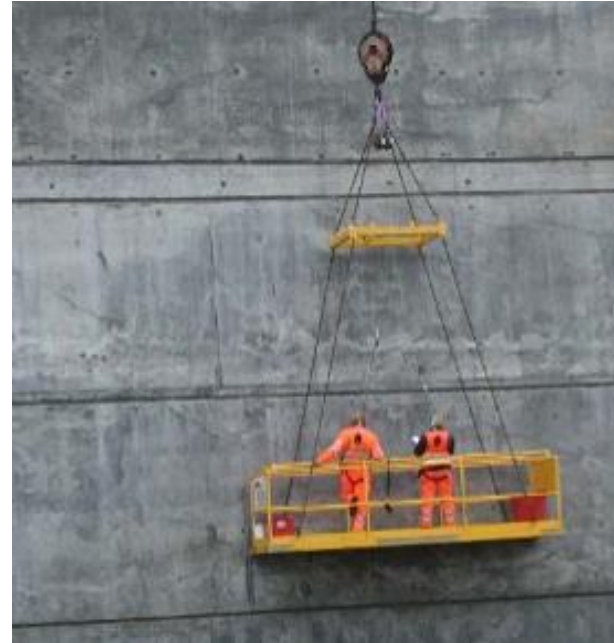
Anchor blocks



Piers

Steel/Main cable/Catenary  
hanger

# WHAT WE DID BEFORE



## Manual inspections

- From the floor/ground
- Lifts/platforms
- Access facilities
- Rope

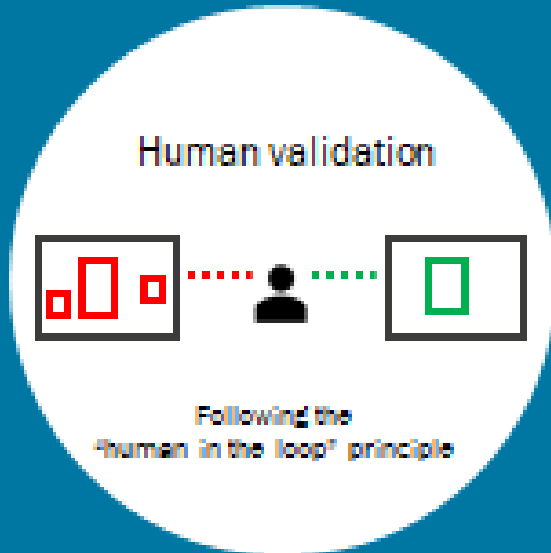
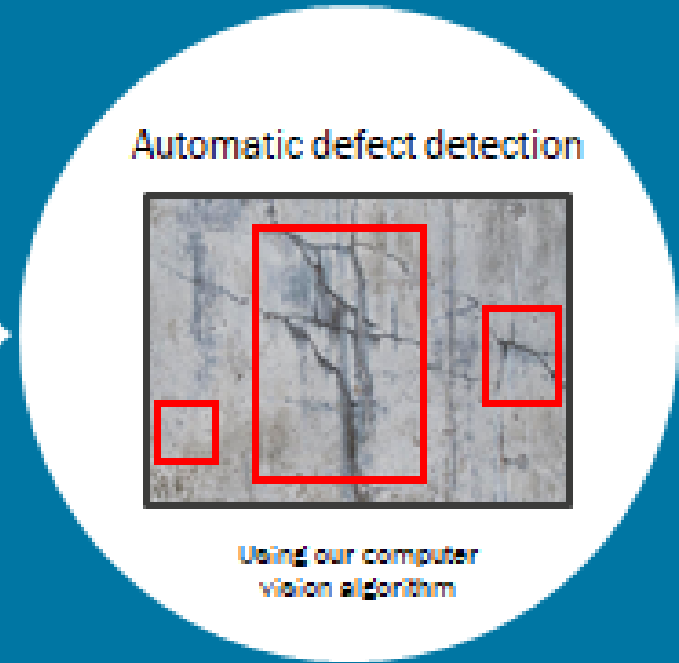
## Registrations

- Paper
- Digital (DB / APP)

## Challenges

- Traffic
- High costs
- The weather
- Slow soluble
- Hard to document

# PHOTOGRAPHIC ASSET INSPECTION



- Easily store thousands of images
- Reduce manual review time with automatic damage detection
- Spot trends in your growing dataset
- Export your data to your own systems

# THE COMPUTER VISION ALGORITHMS ARE TRAINED BY S&B AND RAMBOLL CONCRETE EXPERTS

- Photos of damages are used to train the algorithm
- Training material is selected and validated by Sund & Bælt employees
- Multiple categories are used for the training:
  - Crack
  - Crack with precipitation
  - Spalling
  - Spalling with visible corroded rebar
  - Algae
  - Rust



## REVIEW THE AUTOMATIC ANALYSIS AND ADD YOUR OWN ANNOTATIONS

- You can add cause, description and assign a condition rating
- Correcting errors will help the algorithm improve
- Track the damages over time by creating links between them
- See your assets in 3D to help locate damages

SBAppUWP

Analysis Image View AP Analysis - 1647

Map View ↗

Image View

Image Informations

Image Description  
DCIM\100MEDIA\DJI\_0068.JPG

Image Date: 5/9/2018  
Latitude: 55.339  
Longitude: 11.0147  
Altitude: 30.459  
Area: Great Belt Link, East Bridge, Anchor Block 18, Syd

Condition Rating  
Minor deterioration. Damage with

Tag Name \*  
Crack

Cause \*  
Frost/thawing

Description \*  
Small crack

Save

Test User

Settings

# > BRØNDBY STADIUM

## REHABILITATION OF SYDSIDEN STANDING TERRACE



Arbejdernes Landsbank

Arbejdernes Landsbank

Arbejdernes Landsbank

Arbejdernes Landsbank

Arbejdernes Landsbank

Arbejdernes Landsbank

# LOWER SOUTH SIDE STANDING TERRACE [NEDRE SYDSIDEN STÅTRIBUNE]

> DESIGNED-AND-BUILT IN 1990

> PREFABRICATED/PRESTRESSED CONCRETE ELEMENTS

> SIMPLY SUPPORTED TERRACE TT-ELEMENTS

[HIGH SLENDERNES - LENGTH 14 M - 1ST NATURAL FREQUENCY 5,4 HZ]



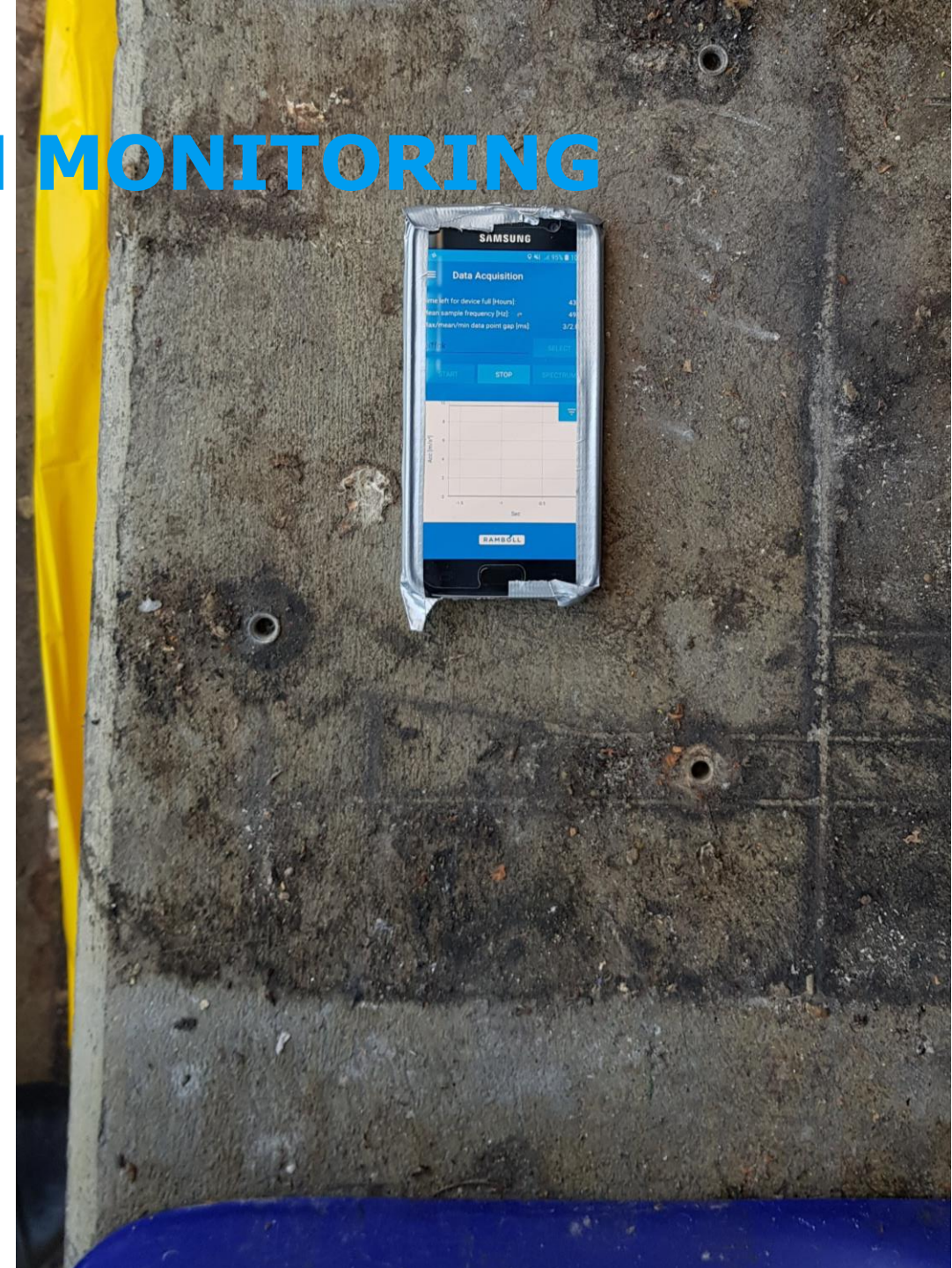
# SMART PHONE VIBRATION MONITORING

[COST EFFECTIVE MEASUREMENTS]



**RAMBOLL**

\*) iphone release to App Store scheduled for Q4/2020





# SUCCESSFUL REHABILITATION BY FALL 2020

[PROTOTYPE CROSS BRACING]



Bright ideas. Sustainable change.

