MONITORING SYSTEMS FOR CIVIL STRUCTURES

move
SOLUTIONS

We Love Measuring Our World

Business presentation
Move Solutions

MOVE SOLUTIONS

Business presentation

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"We love Measuring our World."

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IDENTITY

1.

WE LOVE MEASURING OUR WORLD

Move Solutions is a leading company in Smart Structural Health Monitoring thanks to our world-class service in both dynamic and static structural analysis. We offer unique wireless SHM systems and patented sensors for all civil infrastructures.

Our sensors are wireless, cost-effective, non-destructive, robust and small. Easy to install and to configure, they are also perfect for structures with difficult access, where wired systems would involve complex and expensive installations, or for historic buildings that require special attention and non-invasive technology.

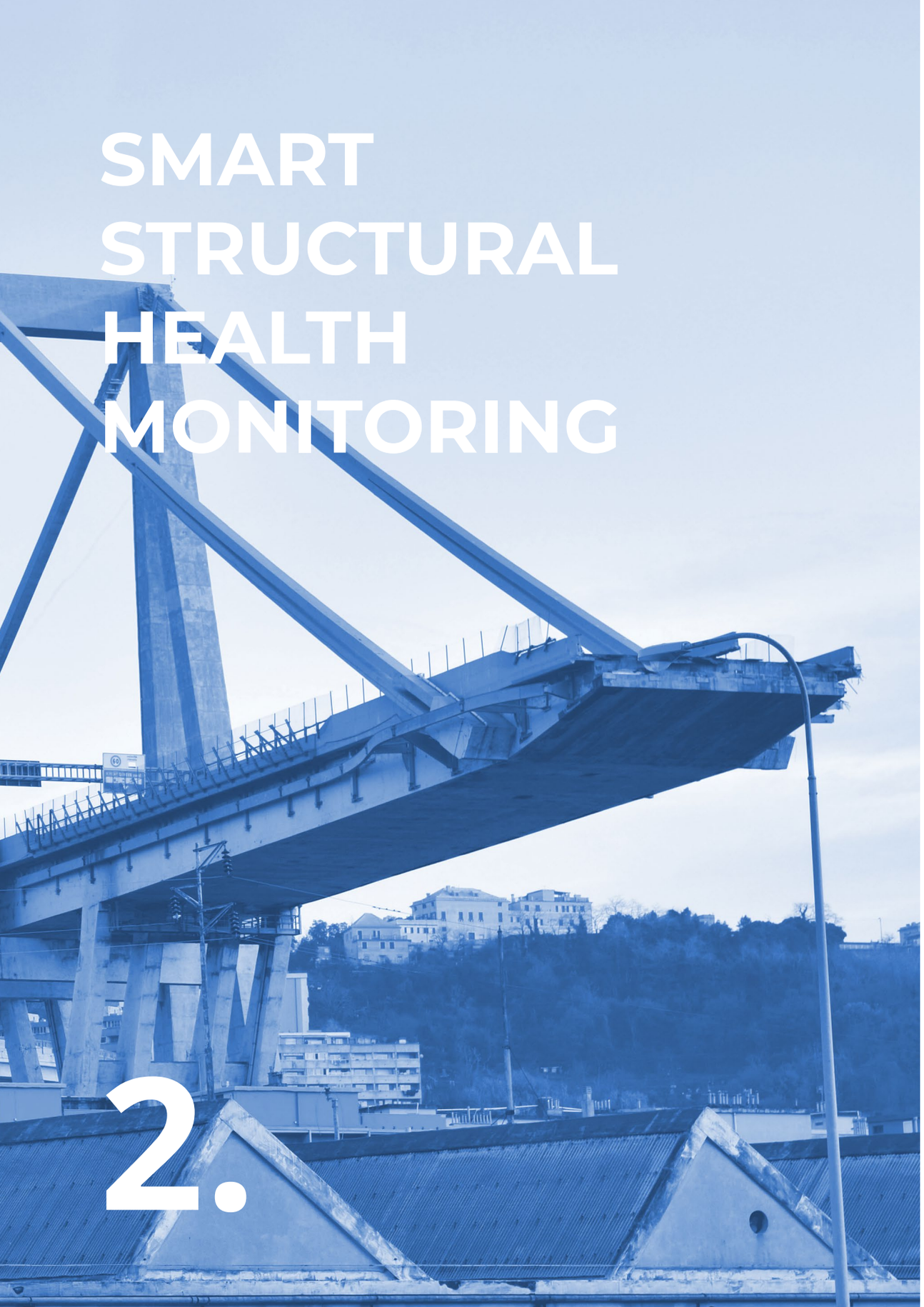
By combining the latest IoT technology with deep industry knowledge, Move Solutions is disrupting the world on Structural Health Monitoring.

Move Solutions wireless monitoring solutions combines three key elements: a network of innovative wireless sensors, a LoRaWAN communication gateway and an online data visualization platform. Wireless monitoring plays an invaluable role in the construction, maintenance and security of infrastructures, increasing the level of quality, reliability and safety of the SHM system.

From the R&D department of Move Solutions, Move-X was recently born: a division focused on supporting organisations worldwide in designing low-power powerful devices for more data-driven approaches to process and resource management.

We design remote and wireless monitoring technologies to access information on the behavior of any structure before, during and after construction. Our products and services offer safety and reliability, supporting civil and structural engineers in their projects and challenges.

SMART STRUCTURAL HEALTH MONITORING



2.

THE NEW DISRUPTIVE INNOVATION

A new era is coming — one that uses technology to embrace resilience, innovation and adaptability like never before.

Introducing IoT technology to the world of infrastructures is creating a new frontier for modern Structural Health Monitoring, allowing a level of control that was impossible before.

The problem of determining the structural safety level of civil infrastructures and buildings has raised growing concern all over the world. An example is reinforced concrete constructions: early 20th-century engineers believed they would last up to 1,000 years. We now know that their life span is around 50-100 years, sometimes less, with deterioration that can begin only after 10 years. That is why today it is critically important to face the problem of assessing their level of safety and structural integrity.

Thanks to IoT technology, we are able to provide wireless, small, non-destructive, low-cost devices that can be easily installed anywhere, with already integrated data-management software. That means that users and authorities can significantly reduce costs related to sensors, installation and monitoring process; preserve the integrity and the harmony of their structure (particularly important for historical buildings); better understand their data thanks to graphs and algorithms that make them more comprehensible; receive alerts in case of anomalies; have their structural health under control at all times, from anywhere they are.
Last, but not least, the use of IoT sensors is a more sustainable approach to SHM. In fact, it reduces commuting, as the structure health does not need to be checked on site; it cuts pollution generated by complex installations; thanks to continuous and precise monitoring, it also helps detecting problems in time, facilitating restoration instead of demolition (with its consequent need for waste disposal).

Using IoT devices for Structural Health Monitoring helps towards a more efficient use of the resources with positive implications both for the environment and the business operational costs.

FOCUS ON BRIDGES

Worldwide, there have been over 115 major bridge collapses since 2000, with more than 22 of them occurring over the past 2 years.

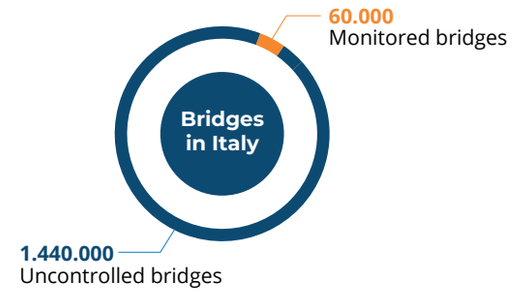
When a bridge collapses, there are usually a few contributing factors. However, the most worrying aspect of bridge failures is the fact that most of them are preventable. In fact, with proper inspection routine and maintenance bridges lifespan could be drastically improved.

In general, **the deterioration of a bridge can proceed very rapidly,** and postponing maintenance works will only create the need for major repairs later in time, which are generally less safe and also less preferable both from an environmental and economical point of view. Appropriate repair, strengthening, or replacement work should be done on every aging bridge to ensure their good performance in service condition.

That is also why regular monitoring is important: it helps identify what parts of the structure are deteriorating and what maintenance strategy is the most appropriate.

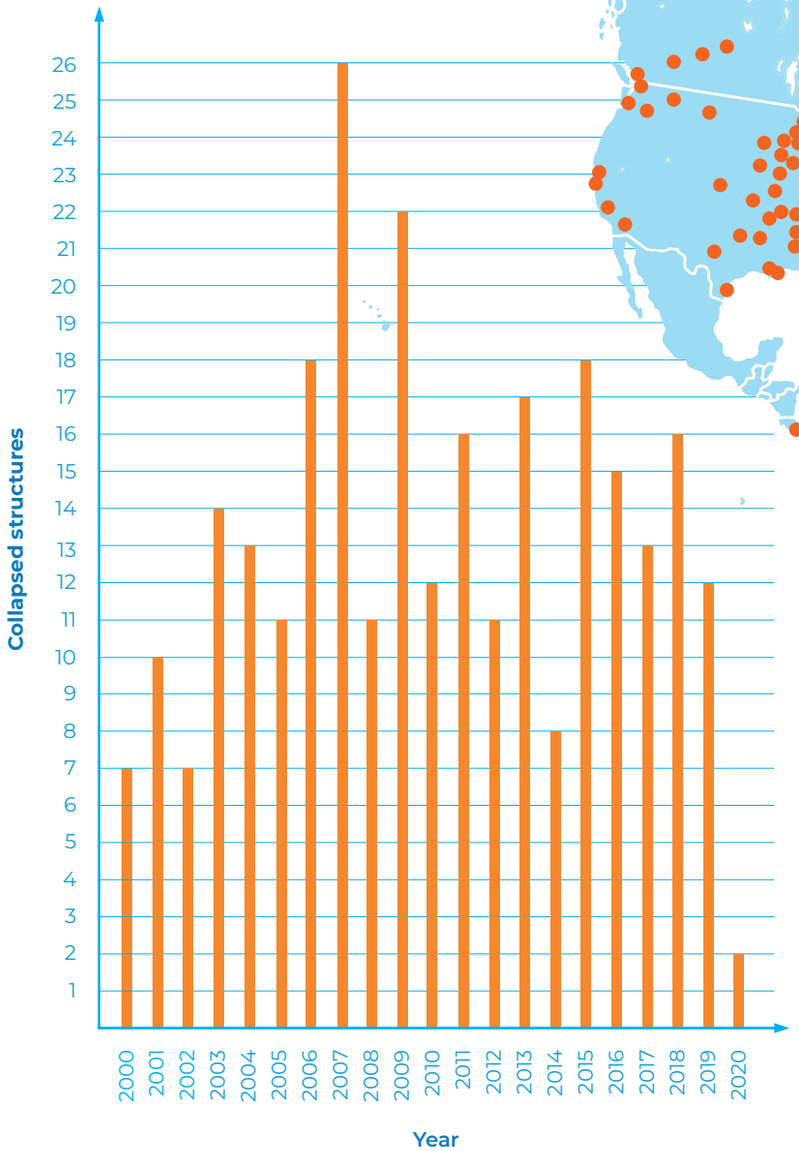
Since traditional onsite evaluation can do little when issues become critical or start between two inspections, there is increasing interest in wireless and remote structural health monitoring. This innovative way of doing SHM not only can be implemented through much easier and cost-effective installations but allows you to have a network of sensors that monitor the bridge 24/7 in order to identify, locate, and quantify damages as they happen. **By detecting damages at the earliest possible stage, smart SHM systems facilitate maintenance and rehabilitation processes and better ensure the safety of the whole structure.**

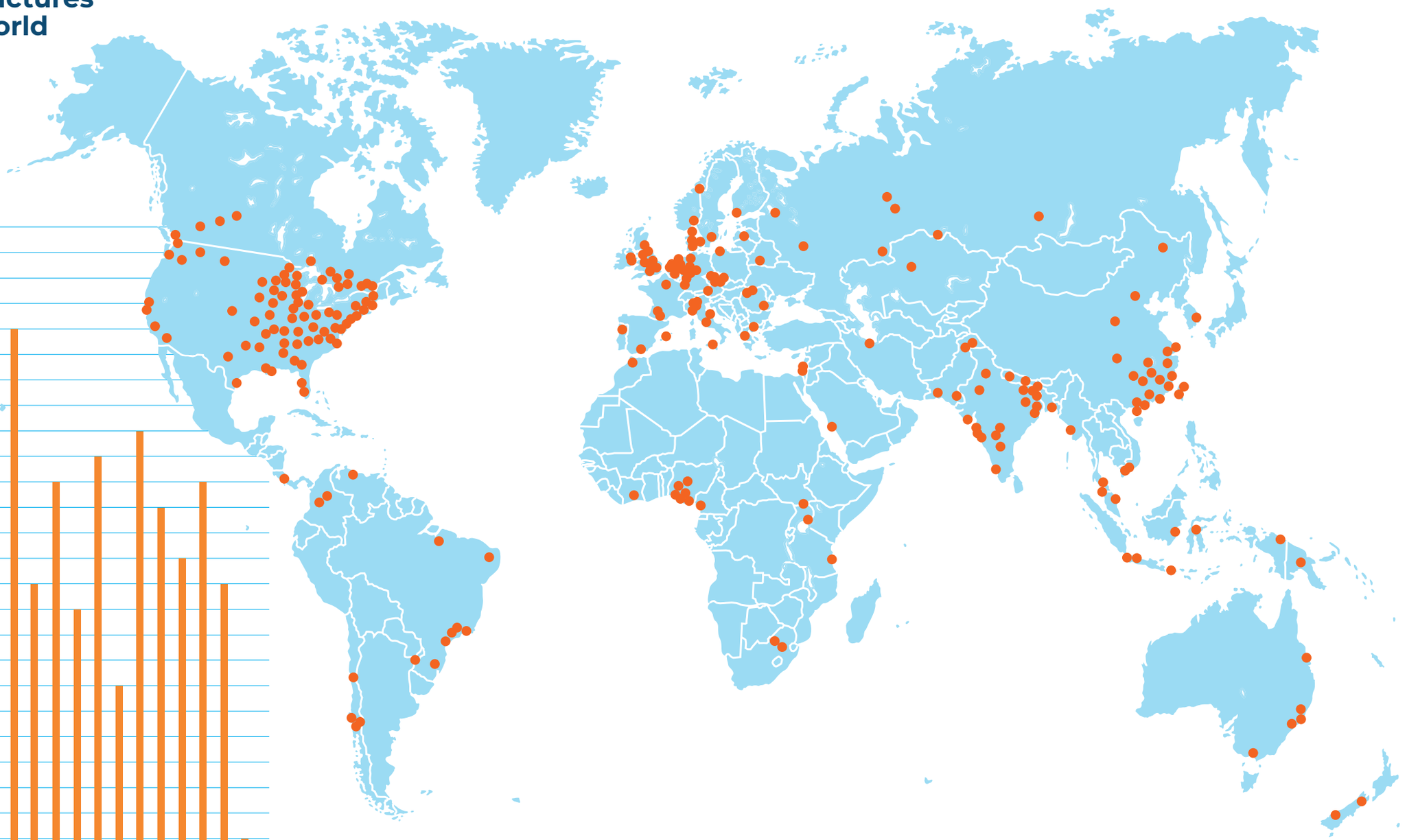
In Italy, more than 300 bridges are at risk of failure.



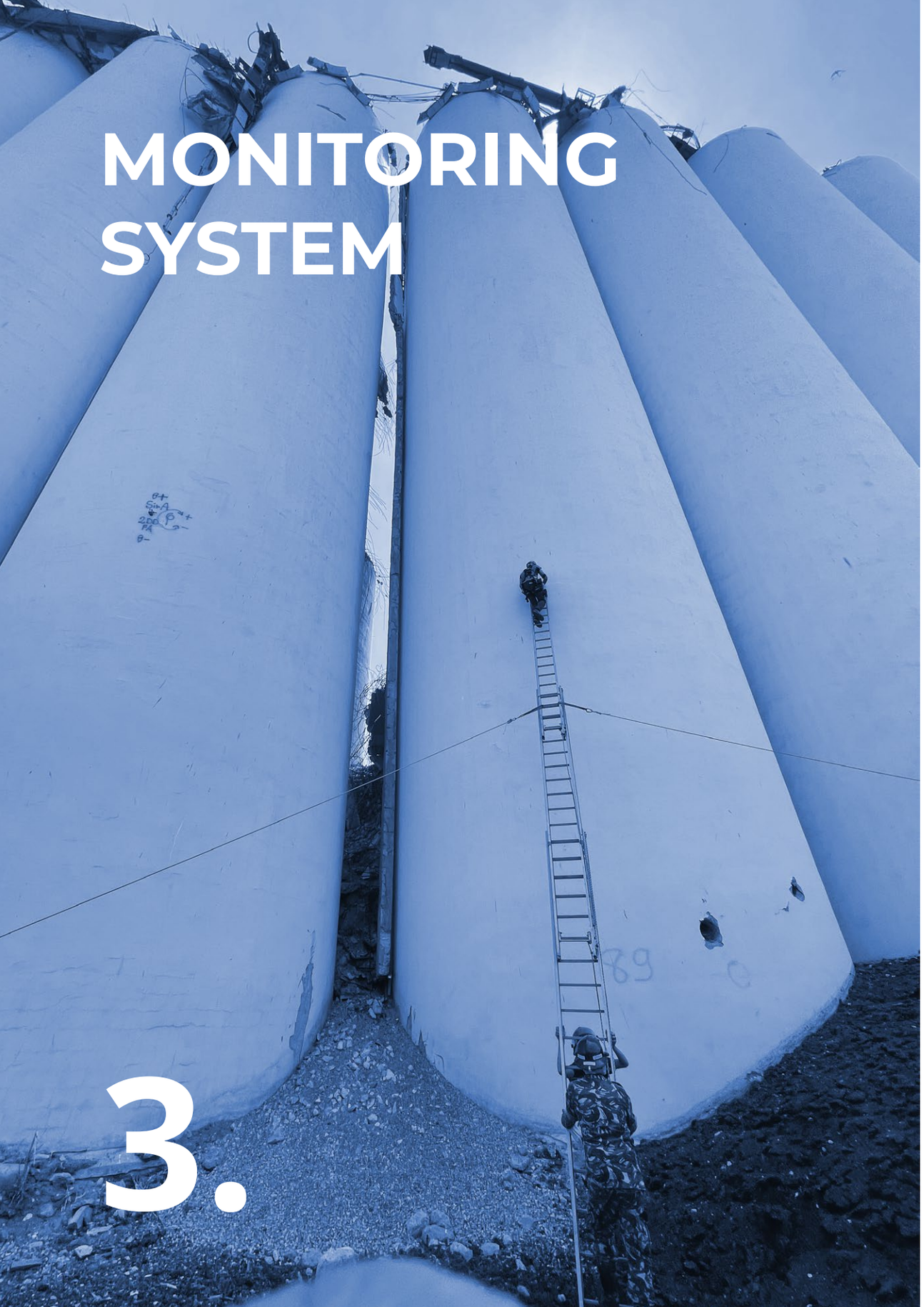
In the U.S., 1 in 9 bridges are considered to be structurally deficient.

Collapsed structures around the world





The graph on the left shows the main collapses worldwide per year, due to the inevitable degradation of the structures that were built about 50 years ago.



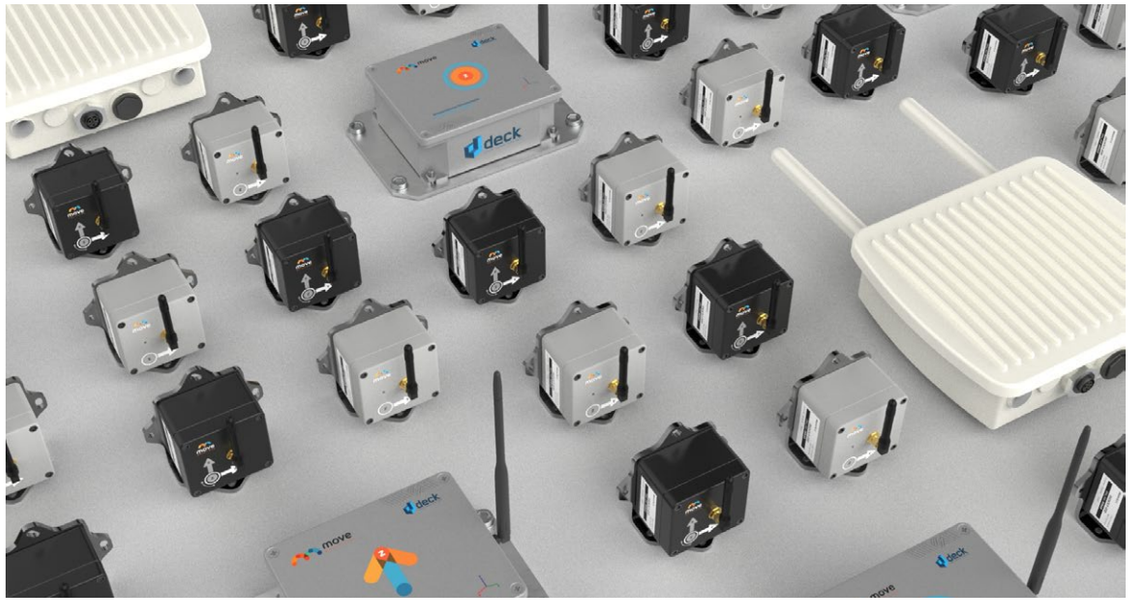
MONITORING SYSTEM

3.

STRUCTURAL HEALTH MONITORING

The **Move Solutions** monitoring system is composed of multiple types of sensors and wireless communication devices, capable of carrying out structural monitoring in both dynamic and static conditions. In addition, this system can integrate a wide range of geotechnical probes and sensors to provide data including:

- **Accelerations;**
- **Displacement;**
- **Angle variations;**
- **Vibrations;**
- **Static Deformation;**
- **Crack and joint movement;**
- **Lateral or vertical ground movement;**
- **Ground pore water pressure;**
- **Strain.**



WIRELESS SENSORS SYSTEM

The installation of the wireless sensor system on site is quick and easy: mount each device with at least two screws on the structure you want to monitor and power the LoRaWAN Gateway. The system can be configured remotely, before, during or after installation, using a laptop or a tablet. After the installation and the setup, the Move Wireless Monitoring System will start measuring and you can start monitoring from your desk. The wireless sensor system automatically communicates measurement data via the LoRaWAN communication protocol (hundreds, thousands of meters away) with the on-site gateway. The Gateway sends the data received via 4G or LTE to the online servers

Changing Needs

Adapt the monitoring system as your project progresses.

Protect People & Infrastructure

Early warning of distress and defects without leaving your desk. Automated alarms when trigger levels are breached.

Stay on Budget

Save money through reduced site visits and long life performance.

CLOUD PLATFORM

The Cloud Platform is a cloud-based web tool that allows you to access, view and export measurement data and configure the settings of the entire sensor system. You can access the Move Cloud platform 24/7 from any location or device around the world. One of the main advantages of the Move Cloud platform is that it offers remote access to measurement data and allows remote configuration of all installed sensors. This saves time, effort and money. Measurement data is analyzed thanks to advanced algorithms that show the information received in an easily understandable way, with graphs and a user-friendly platform.

Smart Monitoring

Change settings without leaving your desk and process data using automatic algorithms.

Efficient Wireless System

Data transmission between sensors takes place via long-range, low-power LoRaWAN communication.

24/7 Monitoring

Real-time data collection ensures efficient and predictive monitoring.

DECK Displacement Sensor

The Deck sensor is a wireless device that allows measuring the dynamic amplitude of the displacement with an accuracy of 0.01 mm and the vibration frequency (through an FFT algorithm) of any structure on which it is applied. On each sensor, a threshold can be set remotely via the Move Cloud Platform. Each sensor continuously samples the oscillation amplitude and, if this threshold is exceeded, then the sensor records and transmits the 10 seconds before and the 20 seconds after the event. It is full wireless, and the battery can last for years. It also mounts a temperature sensor.

The Deck sensor transmits accurate readings from the site via the LoRaWAN wireless communication protocol via a Gateway. You can view and interact with your data online using the Move Cloud Platform. There are multiple data processing and correlation algorithms developed by Move. Ideal for dynamic monitoring of large structures like bridges and overpasses.

Wireless Tiltmeter

The Triaxial Tilt Monitoring sensor is a highly accurate and exceptionally stable three-axis wireless Tiltmeter. Variable and remotely configurable sampling rates, a rugged design and a battery life of up to 8 years make this wireless Tiltmeter suitable for many environments and solutions. The wireless Tiltmeters transmit accurate readings from the site via the LoRaWAN wireless communication protocol via a Gateway.

You can view and interact with your data online using the Move Cloud Platform. There are multiple data processing and correlation algorithms developed by Move. It is possible to calculate the deflection of the structure with respect to a baseline. It also mounts a temperature sensor to relate thermal excursion and static deformation. Ideal for static monitoring of large structures and static load tests.

Accelerometer SHM

This device is the next and updated version of the Triaxial Acceleration Monitoring sensor. It's the Accelerometer SHM, an extremely precise three-axis wireless sensor, capable of synchronizing data samples with all the other Accelerometers SHM in the system. Wireless synchronized sampling is a very important feature that gives many benefits during structural monitoring. Thanks to this feature it is possible to carry out the Modal and Vibrational Analysis of any type of structure. Sample rates are variable and remotely configurable. The Accelerometer SHM also maintains the classic activation threshold operation. The battery-powered device has an operating autonomy of up to 8 years and it also has a temperature sensor.

The wireless Accelerometers SHM transmit accurate readings from the site via the LoRaWAN wireless communication protocol via a gateway. You can view and interact with your data online using the Move Cloud Platform.

Triaxial Vibrometer

This vibrometer is a wireless sensor used for three-axis vibration measurement. It detects movement speed, providing a full analysis of frequency and amplitude of vibrations.
Thanks to our Cloud Platform you can access Vibration Analysis of your structure remotely and in real time. Our technology allows you to also send an alert if the vibrations exceed the maximum level according to current legislation.
All sensors can measure temperature, they are battery-powered and they use LoRaWan communication.

Wireless Tilt Beam

The Tilt Beam device consists of a triaxial tilt monitoring sensor installed in the center of a steel tubular support. This stand can be 1, 2 or 3 meters long. Typically they are installed in series so that the end of one bar coincides with the start of the next until the required distance is covered. The differential movements of the structure cause a different rotation of the bars and this shows the differential movements or settlements of the structure to be monitored. Installation is quick and easy without the use of cables.

Gateway SHM

The Gateway SHM is a data reception and transmission unit with which, thanks to the LoRaWAN wide-range communication protocol, it is possible to manage and communicate simultaneously with dozens of devices and sensors. The Gateway SHM features LoRaWAN high gain antennas and LTE diversity to achieve greater cellular coverage. It also implements a Wifi Hotspot, an integrated GPS for very precise time synchronization and for the geolocalization of the device. It is very easy to configure given the automatic APN and POE input with injector included.

Gateway Pro NEW

This device receives the information transmitted by the multiple sensors installed via LoRaWAN, then, using cellular connectivity, it forwards this data to online servers. The internal antennas make the setup process even simpler, and the external status LEDs allow the user to quickly check the functionality of the device.
The device also implements a Wi-Fi hotspot and a built-in GPS for very precise synchronization and geolocation of the product. It is very easy to set up thanks to the automatic APN and the included PoE adapter.

Single Channel Node NEW

The Single Channel Node is a wireless datalogger that enables geotechnical probes for LoRaWAN wireless communication. Each node supports one geotechnical probe and can accommodate an extra NTC thermistor. The acquired data is wirelessly sent to the Gateway and forwarded to the Move Cloud Platform. On the Platform, the Single Channel Node can be remotely configured, and information about the structure can be accessed in real-time. This new Node comes with increased battery life, a wider range of supported probes and a new accelerometer-triggered acquisition mode!

Digital Communication Node

The Digital Communication Node is a device that enables all connected sensors (originally wired) for wireless LoRaWAN communication. The Digital Node is compatible with all geotechnical sensors that use the Modbus RTU communication protocol. Once the sensors are connected to this wireless device and the Gateways are correctly installed on-site, they are ready to receive, store and send data. You can freely configure the Digital Node and all the sensors connected remotely using the Move Cloud Platform. Perfect for implementing any monitoring system and meeting all project requirements.

Analog Communication Node

The Analog Communication Node is a wireless device that enables all connected sensors (originally wired) for wireless LoRaWAN communication. The Analog Node has a maximum of 4 channels supported and it is compatible with most of the analogue interfaces used for geotechnical sensors.
The Analog Communication Node transmits accurate readings from all sensors connected via the LoRaWAN wireless communication protocol to the Gateway.

The future IoT World.

High-computational power

Wireless LoRaWAN communication

Large power autonomy

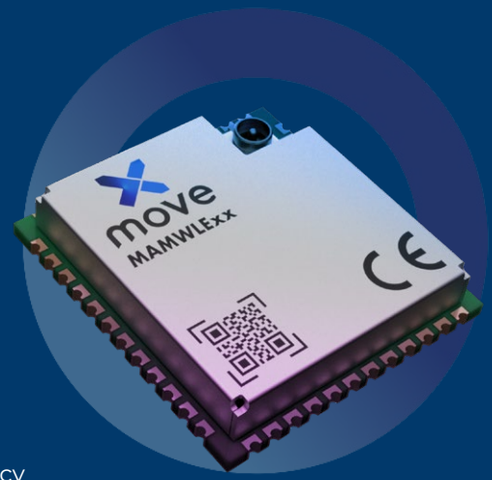
Move-X Electronics

Move-X was born as a **R&D division** of Move Solutions, which is a company focused on developing wireless and smart Structural Health Monitoring systems for civil infrastructures. It is now supporting organisations worldwide in designing low-power intelligent Internet of Things systems, unlocking a data-driven approach in process and resource management, which results in more efficient operations and better productivity.

We create innovative technology with one aim: encouraging companies to leverage the opportunities that come with Digital Transformation. We help our clients optimize production processes, supply chains, services and infrastructures; we support them in designing intelligent environmental monitoring systems, in detecting air and water quality, in implementing smart agriculture technology, and much more. Many applications, one result: helping businesses use their resources more efficiently

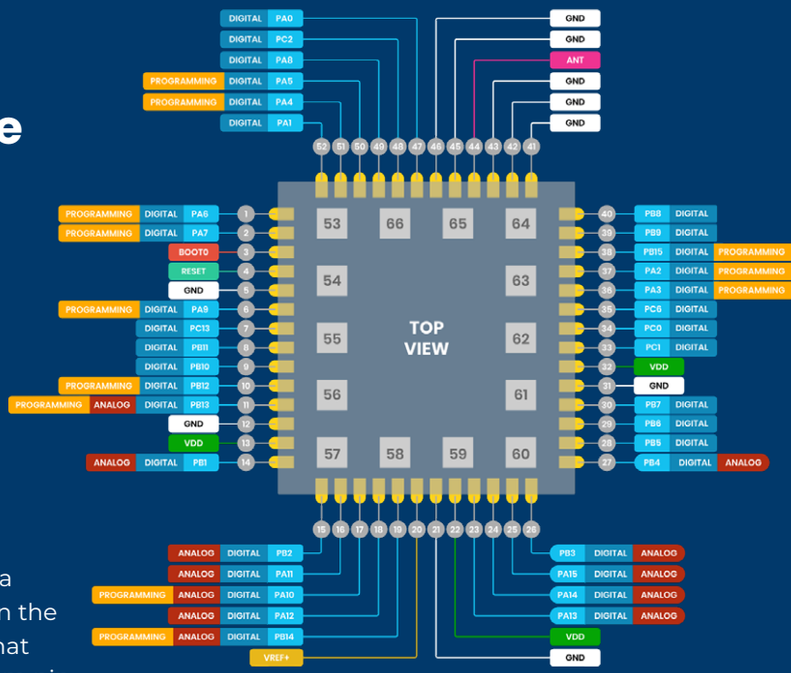
MAMWLE

Ultra low-power radio module for high-performance devices



The Move-X MAMWLE is a low-power, LoRaWAN-compliant radio module based on ST's STM32WLEx microcontroller by STMicroelectronics. Powered by a powerful 32-bit ARM Cortex-M4 with clock frequency up to 48MHz and paired with up to 64kB SRAM and 256kB Flash, it is suitable for the most demanding tasks. Its high computational capabilities make the MAMWLE the perfect core for devices in any kind of applications, from smart metering to automation control systems.

Easily integrable within any IoT application



The MAMWLE module is designed to be easily integrated into any PCB offering two assembly variants. One with a U.FI coaxial connector on the top of the package that can be directly plugged into the antenna through a pigtail, saving space on the mainboard. The other variants, that outputs the RF signal on a 50 Ohm pin, fits you if you wish to create your own antenna design.

move-x CICERONE

MKR Main Board
LoRaWAN + GNSS

Your **guide**
by your **side**

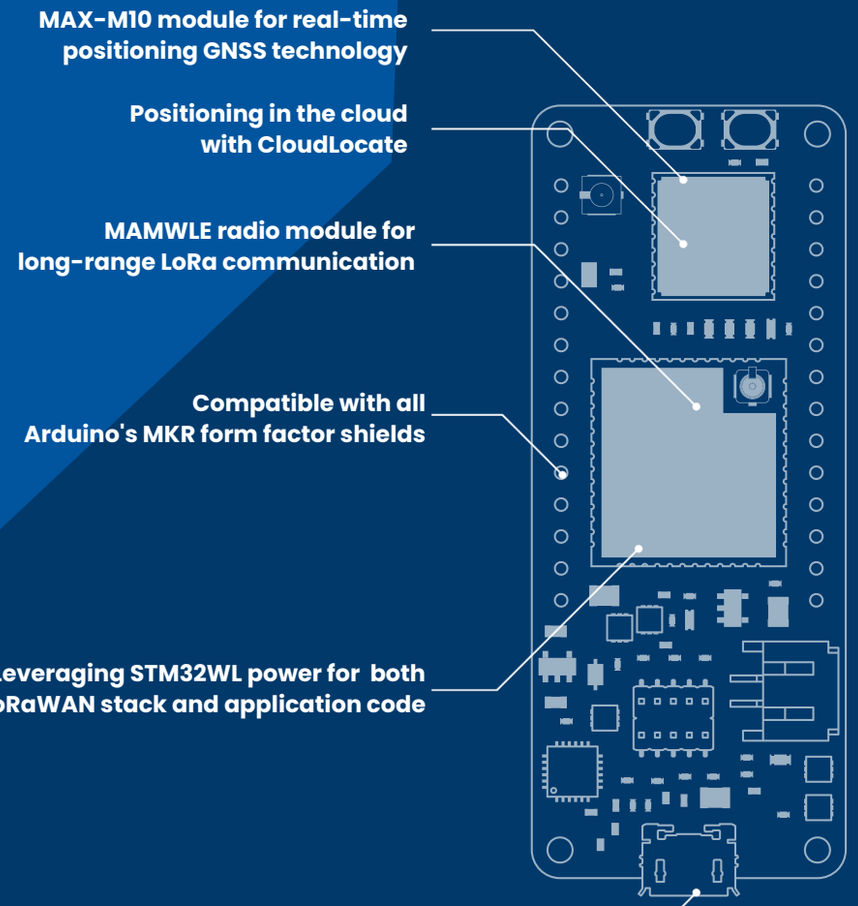
Cicerone is perfect for tracking applications that need meter-level accuracy and long-range low-power LoRaWAN connectivity.
It is based on **u-blox MAXM10S GNSS** and **Move-X MAMWLE** modules. This combination allows for best-in-class synergy between GNSS technology and long-range wireless connectivity for power-constrained applications.
The board is designed to extend the battery life of IoT asset tracking applications thanks to an on-board LiPo charging circuit and u-blox CloudLocate positioning.

For makers and engineers

- Quickly build complex IoT solutions in a small form factor thanks to the compatibility with Arduino IDE
- Expand the hardware with MKR shields

Applications

- Asset tracking
- Supply chain and logistics management
- Smart agriculture
- Smart cities
- Environment monitoring
- Infrastructure monitoring



Form Factor	Main board compatible with Arduino MKR
Modules	Move-X MAMWLE u-blox MAX-M10S
Chip	STM32WLE5
Clock	48 MHz
Memory	48kB SRAM, 128kB Flash
Wireless Connectivity	LoRaWAN, LoRa, FSK BeiDou, Galileo, GLONASS, GPS/QZSS
Radio Frequency	868-915 MHz
Pinout	22 digital, 16 PWM, 7 analog
Voltage	3.3V (operating)
Power Inpunts	USB, VIN pin, battery
Dimensions	63 x 25 mm

Go to website and
download the Datasheet:
www.move-x.it

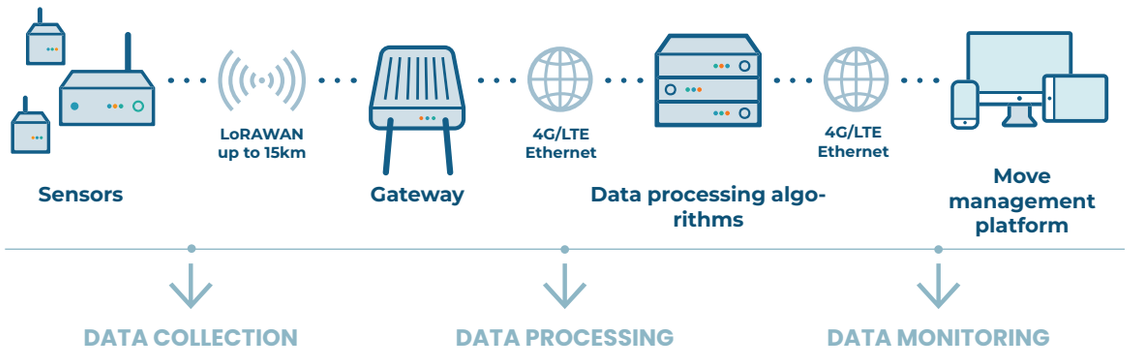
WIRELESS SHM SYSTEM

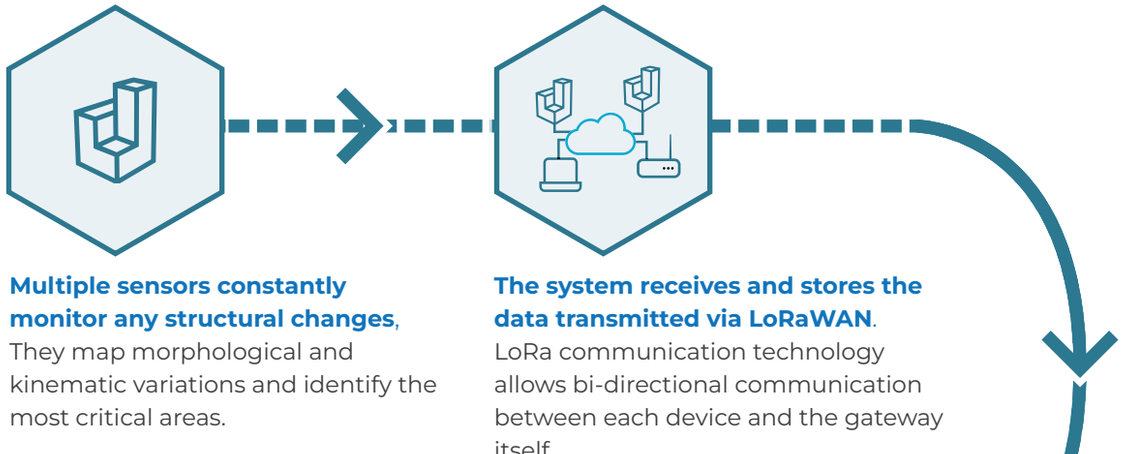
4.

THE SYSTEM: HOW IT WORKS

Move wireless monitoring solutions combines three key elements: a network of wireless sensors, a LoRaWAN communication Gateway and the Move Cloud Platform. The wireless sensor system automatically sends the measurement data, via LoRaWAN, to the on-site Gateway which in turn forwards the information via 4G or LTE to the online servers. The Move Cloud Platform is the cloud-based web tool that allows you to access, view and export your measurement data and configure the settings of the entire sensor system. You can access the Move Cloud Platform 24/7 from any location or device around the world. One of the main advantages of the Move Cloud Platform is that it offers remote access to measurement data and allows for remote configuration of all installed sensors. This saves time, effort and money. You will be able to analyze the measurement data thanks processing algorithms that, by performing complex calculations and correlations, will show easily understandable information about the structure, through the use of graphs and pictures. You can also easily configure alerts to multiple recipients who will receive threshold cross notifications via email. With just a click, you can then export all the measurement data in CSV format.

Several sensors detect any type of stress and any structural change in the structure, and then make them accessible and viewable via the Web Platform.





Multiple sensors constantly monitor any structural changes, They map morphological and kinematic variations and identify the most critical areas.

The system receives and stores the data transmitted via LoRaWAN. LoRa communication technology allows bi-directional communication between each device and the gateway itself.

The data is processed thanks to statistical analysis algorithms that generate reports and create a history of the structural behaviour. This database is available at any time for checks or revisions.

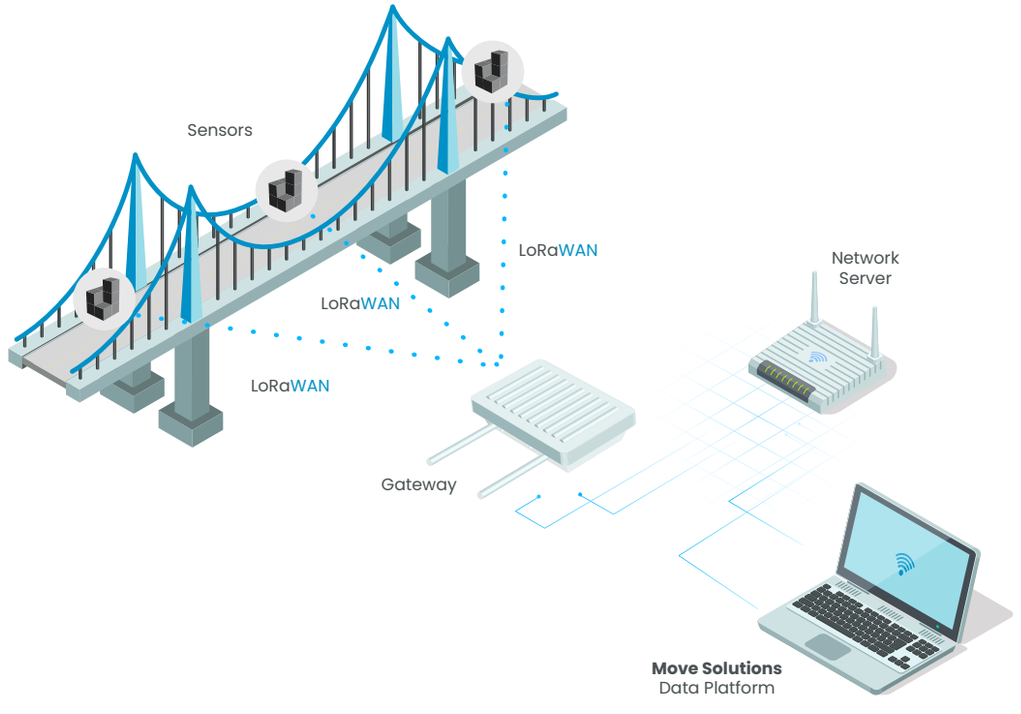
Data management, graphs, and structural analysis on the online platform.
nce received from the gateway, the data is forwarded to the Move Cloud Platform, a tool that helps engineers to better have the structure under control.

Timely maintenance interventions.
Thanks to continuous and real-time monitoring, it is possible to plan a more effective maintenance strategy, saving money and increasing safety.≤

LORAWAN COMMUNICATION

Using the LoRaWAN communication protocol, for wireless data transmission, it is possible to communicate across extended areas (over 10 km in optimal situations). This protocol operates with low transmission power and low energy consumption, making it perfect for transmitting raw data with devices that do not have large energy reserves. It is perfect for LoW Power Wide Area Networks. LoRaWAN uses free sub-gigahertz radio frequency bands such as 433 MHz, 868 MHz (Europe) and 915 MHz (North America).

Thanks to these features, wireless communication with LoRaWAN is perfect for the Internet of Things, where many devices are spread over large areas, often without electricity, and their function is usually to transmit very light data for long periods. as in the case of structural health monitoring. Several types of sensors can be installed in the same area: if the transmission takes place via LoRaWAN, all data can be collected by a single LoRa Gateway, which will forward them to the Cloud.



APPLICATIONS

5.

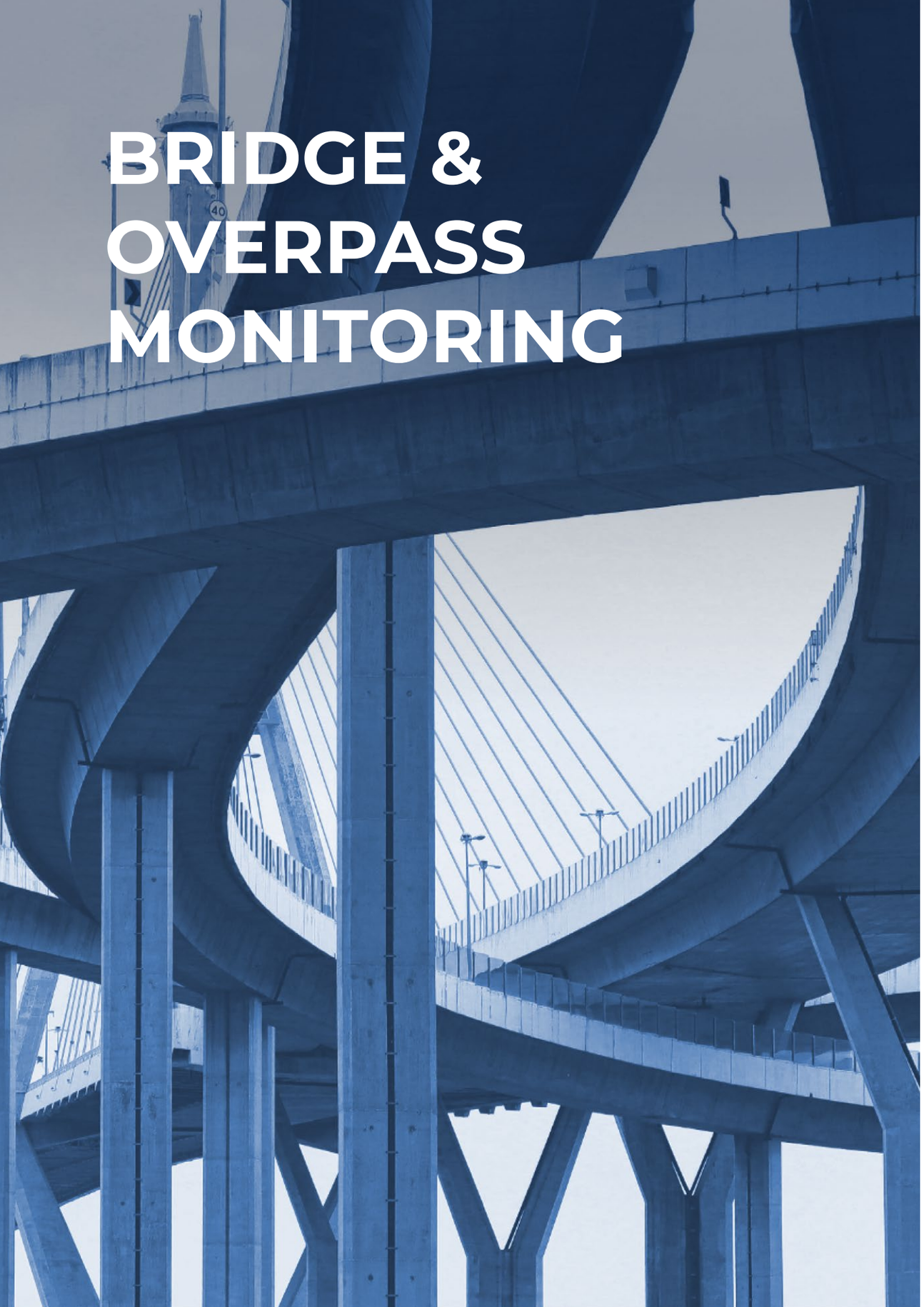
MONITORING SOLUTIONS

We are driving change with a unique wireless system for both dynamic and static structural monitoring. We offer innovative solutions for:

- **Bridges and overpasses**
- **Railways**
- **Vertical structures**
- **Tunnels**
- **Construction sites**
- **Geotechnical analysis**

Our sensors are smart, wireless, non-destructive and easy to install, allowing you to conduct remote, easy and cost-effective monitoring. Innovation to us means not doing things the way we always have but thinking outside the box to deliver faster and smarter solutions to your problems.

As a leading company in Smart Structural Health Monitoring, we offer world-class monitoring services in both dynamic and static structural analysis, providing unique wireless SHM systems for all civil infrastructures.



BRIDGE & OVERPASS MONITORING

MONITORING CHALLENGES

STATIC MONITORING
Analyzing the static deformation of the spans to understand the current state of the structure, especially during load tests.

DYNAMIC MONITORING
Monitoring dynamic parameters like oscillations and accelerations to understand the behaviour of the structure.

COST OF THE SYSTEM
Big structures are very costly to monitor with cabled installations: wireless sensors are the optimal solution.

ENSHURING STABILITY
Analyzing the deterioration over time of the crucial structural parts of the bridge or overpass requires high-quality technology.

KEY PARAMETERS

By using **Deck Dynamic Displacement Sensors** and **SHM Accelerometers** it is possible to obtain a complete dynamic characterization of the bridge or overpass: parameters as accelerations, dynamic displacements, modal frequencies and temperatures are constantly monitored. Tiltmeters allow for the analysis of the static of the structure: these sensors monitor the angular variations caused by the subsidence of the ground and/or structural parts. With the use of more tiltmeters in line it is also possible to obtain the static deformation of a span. Finally, Single Channel Nodes give the opportunity to expand our monitoring system to other non-native wireless instruments of geotechnical type.

Anomalies
You can analyse parameters like oscillations and accelerations caused by earthquakes or other anomaly events.

Modal analysis
You can monitor frequencies and natural modes of vibration of the structure.

Static monitoring
You can monitor the static parameters like inclination and the deformation of the deck, settlements, stress, expansion or contraction of cracks and joint displacements.

Vibrations trends
You can view all the trends of the parameters detected by the sensors such as displacement and acceleration.

RAILWAY MONITORING

MONITORING CHALLENGES

LONG RANGE MONITORING
You need to monitor long rail tracks covering remote distances.

DYNAMIC & STATIC MONITORING
It's necessary to monitor for a long period of time both the dynamic and static part.

TRACK STABILITY & GEOMETRY
It's necessary to keep the rails in line just as they were designed and positioned on site.

SURROUNDING STABILITY
Monitor slow subsidence of the ground due to work near the railway bed or to weather agents.

KEY PARAMETERS

Using a series of Tiltmeters or Tilt-beams, mounted on the sleepers, it is possible to obtain their rotations and longitudinal deformation, that represents the ground deformations.
The dynamic part of the monitoring is carried out with Deck sensors that allow you to monitor the dynamic displacement of the sleepers when the train passes.
With the use of Analog and Digital communication nodes, it is possible to complete the monitoring system with all non-native wireless geotechnical sensors.

Cant of the tracks
You can monitor the cant or the measurement of the difference in elevation between the outer rail and the inner rail.

Twist of the tracks
You can display the longitudinal deformation and the transversal deformation in percent between two crosspieces.

Vertical deflection
You can monitor the vertical displacement of the track and reconstruct the broken line of longitudinal deformation.

Ballast void
You can monitor the ground displacement (settlement or lateral movement) and correlates the amplitude of oscillation of the sleepers with the variation of the ballast.

BUILDING MONITORING

MONITORING CHALLENGES

STRUCTURAL DETERIORATION

Analyze the deterioration over time of the crucial structural parts of the building like floors and beams.

DYNAMIC MONITORING

It's necessary to monitor for a long period the dynamic conditions like the vibrations of the structure.

ENVIRONMENTAL PHENOMENA

Buildings are stressed by agents such as subsidence of the ground or vibrations caused by traffic or wind.

STATIC MONITORING

Monitor the static parameters of the structure like the slow subsidence of the ground due to works or to weather agents.

KEY PARAMETERS

Using Decks and Accelerometers to obtain a complete dynamic characterization of any type of building. You can monitor the modal frequencies and other parameters such as accelerations, dynamic displacements and temperature caused by road traffic or environmental and climate conditions.
With the use of Tiltmeters it is possible to monitor the static angular variation of the structural parts. Moreover, it is possible to obtain the deflection of floors, walls and beams through the use of more tilt meters in line.
With the use of Analog and Digital communication nodes it is possible to complete the monitoring system with other non-native wireless instruments of geotechnical type.

- **Modal analysis**

  You can monitor frequencies and natural modes of vibration of the structure.

- **Soil stability**

  You can evaluate both the pressures exerted by the ground, the load distribution on the foundations and its deformation (settlement or lateral movement).

- **Tilt variation**

  You can monitor the angular variation of the longitudinal and transverse axis of the structure.

- **Vibrations trends**

  You can view all the trends of the parameters detected by the sensors such as displacement, acceleration and speed.

TUNNEL MONITORING

MONITORING CHALLENGES

COST MAINTENANCE
Huge structures are very costly to monitor with cabled installations: wireless sensors are the optimal solution.

STATIC MONITORING
Control terrain deformation, tensions, stresses, and subsidence.

SOIL STABILITY
During the construction and the life of the tunnels it is important to understand the soil type and the deformation state.

STRUCTURAL DETERIORATION
It's necessary to analyze the degradation of the structure and of the ground over time.

KEY PARAMETERS

Using a series of Tiltmeters or Tilt-beams, positioned in series on a section of the tunnel, it is possible to obtain convergence measurements of the coating and to establish if and how it is deforming.
With the use of the Analog and Digital communication nodes, it was possible to expand this monitoring system to other non-native wireless instruments of geotechnical type, such as load cells, crackmeters, vibrating wire and more.

- **Soil stability**

  You can evaluate both the pressures exerted by the ground, the load distribution on the foundations and its deformation.
- **Geotechnical parameters**

  You can monitor the ground displacement (settlement or lateral movement) and groundwater levels.
- **Tilt variation**

  You can measure the Pitch angle and the Roll angle with high precision. These measurements allow obtaining fundamental parameters for the static monitoring of the tracks.
- **Environmental monitoring**

  Control of all external atmospheric agents such as wind direction and speed, rain, humidity and temperature.

CONSTRUCTION SITE MONITORING

MONITORING CHALLENGES

STATIC MONITORING
Analyzing the inclination and the displacement of piles and construction site elements.

DYNAMIC MONITORING
Monitoring dynamic parameters of surrounding infrastructures to make sure they are not negatevly affected by the vibrations generated from the construction site.

CHANGING NEEDS
Adapting the monitoring system as the project progresses.

SOIL STABILITY
Monitoring the soil type and the deformation state during the construction works.

KEY PARAMETERS

By installing Vibrometers and **SHM Accelerometers** it is possible to monitor how the vibration generated by the construction works affect the surrounding structures. **Tiltmeters** allow for the analysis of the static parameters of the construction site: these sensors monitor the rotational trend of the shoring piles or other elements during all phases of work. With the use of **Tilt beams**, it is also possible to understand the displacement of a certain point.

Anomalies
You can analyse parameters like oscillations and accelerations caused by excessive vibrations or other unusual events.

Modal analysis
You can monitor frequencies and natural modes of vibration of the structure.

Static monitoring
You can monitor the static parameters like inclination and deformation, settlements, stress, expansion or contraction.

Vibrations trends
You can view all the trends of the parameters detected by the sensors such as displacement and acceleration.

GEOTECHNICAL MONITORING

MONITORING CHALLENGES

SOIL MONITORING

Monitoring the behaviour of rocks, foundations, embankments, slopes, etc.

WATER MONITORING

Monitoring waters to understand whether they can have an impact soil stability and structures.

WEATHER MONITORING

Measuring whether-related parameters to make sure they do not exceed certain parameters that could negatively affect infrastructures.

KEY PARAMETERS

All structures, from the skyscraper to the bridge of a stream, must be in balance with the surrounding environment. It is therefore essential to monitor not only the structure but also the entire context in which it is immersed.

By using **Tiltmeters** it is possible to monitor the inclination of key elements, while with more Tiltmeters in line it can be analysed the deflection of floors, walls and others. **Single Channel Nodes** enable to expand the monitoring system with other non-native wireless instruments of geotechnical type, such as strain gauge tubes, radar level sensors, barometers, etc.

CLOUD PLATFORM

6.

DATA MANAGEMENT INTERFACE

The Move Cloud Platform is a remotely accessible online portal where it is possible to view the data detected by the sensors, manage and configure the entire monitoring system and process the results using specially designed algorithms. It is possible to understand the ageing of the structure and estimate the intensity of the stresses, optimizing preventive and predictive maintenance interventions through multiple tools. This portal is a service that Move Solutions offers to all its customers with the aim of facilitating and speeding up their work of analyzing and studying monitoring data. In this way, civil and structural engineers who start a monitoring project also get free access to all the operating parameters of each individual sensor installed. You can also access the historical data database to quickly retrieve all the desired data and compare or correlate them with each other.

To monitor and check safely, remotely and constantly any structure, receiving information in real time.

Analyze

Monitor 24/24h displaying, comparing and downloading all the data and trends you want.

Manage

Set the alarm threshold, the sampling frequency and many other parameters for any device.

Understand

By viewing the trends and statistics you get a complete sensitivity on the health and behavior of the structure.

DATA PROCESSING ALGORITHMS

The Move Cloud Platform offers multiple types of raw data visualization, but above all, it offers specific tools designed specifically in response to the most frequent requests. There are tools for every type of monitored structure, from bridges and viaducts to railways to static load tests. These data processing algorithms are essential to automate those long, repetitive and complex processes that the customer would usually have to do externally with other software.

Data cleaning

Advanced analysis tools are available to ease deep understanding and data processing.

Advanced analysis algorithms

Receive only clean and validated data. Unwanted noise and interference are automatically blocked and removed.

Access to all historical data

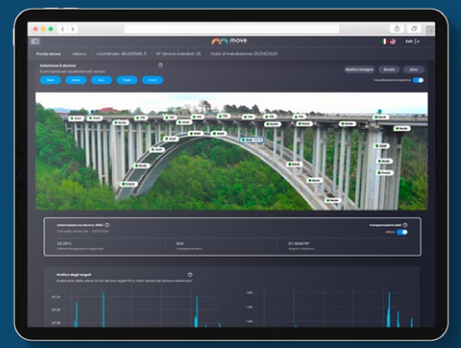
You can quickly access and recover all your data by selecting any time interval to view whenever you want.

Freely configure all sensors

Simply manage each sensor by setting the alarm and activation thresholds, the sampling frequency and the resolution.

Technical support

We guarantee reliable and constant end-to-end support.
Custom development available.

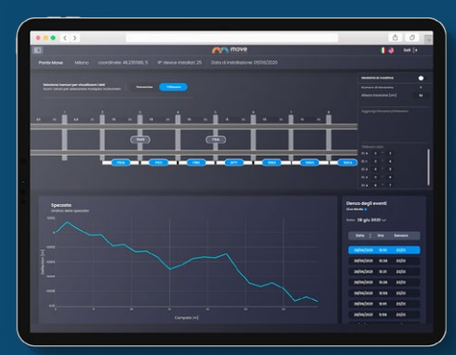


Dashboard

User experience is essential in complex management portals like Move Cloud Platform. This is why it has been specially designed to help understand the data and to be simple and intuitive. It is possible to customize and manage the display of the installed sensors, uploading photographs or technical drawings of the structure in which to apply the installed sensors, and much more.

Raw data

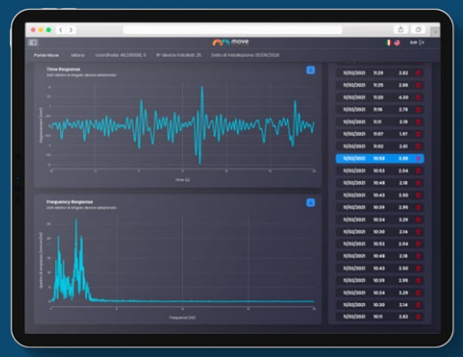
It is possible to access and analyze all the historic data detected by the sensors, compare and correlate them with each other. Through the analysis of raw data, it is possible to understand the trend of the state of health over time of the monitored structure.



Tools for every type of structure

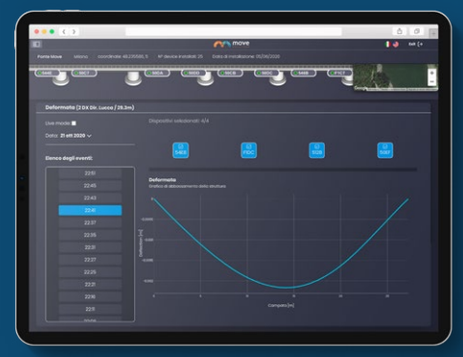
Specific tools have been developed for each type of civil structure to respond to all monitoring needs. Some structures respond differently to failure or ageing and require monitoring of very different parameters.

Algorithms



FFT (Frequency Response)

Algorithm for the fast and optimized calculation of the DFT (Discrete Fourier Transform) which allows to highlight the spectral contents of the signals coming from the sensors. It provides the frequency response of the oscillations thanks to which it is possible to obtain characteristics and information of the signal, not perceptible in the time domain.

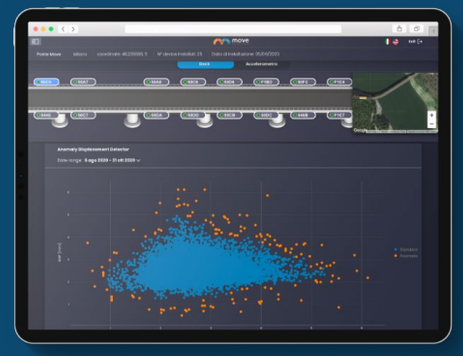


Static Deflection

This algorithm allows to visualisation of the deformation of the structure. In the case of bridge monitoring, it's perfect for the deformation of a span during a load test in a static regime. By providing multiple angular values, it is possible to reconstruct the sag using a least-squares estimation algorithm.

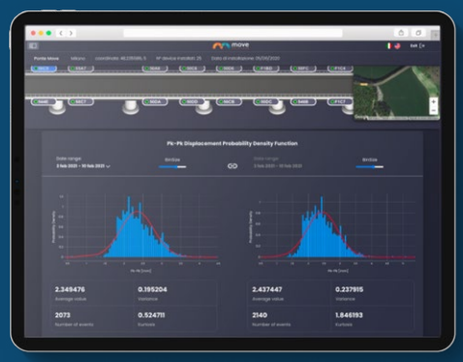
FDD - Frequency Domain Decomposition

Algorithm that performs a statistical processing starting from all the oscillations. It is used to estimate the frequency response of the structure, through which it is possible to extrapolate useful modal information. It allows you to make an active and prolonged monitoring of even a very complex structure.



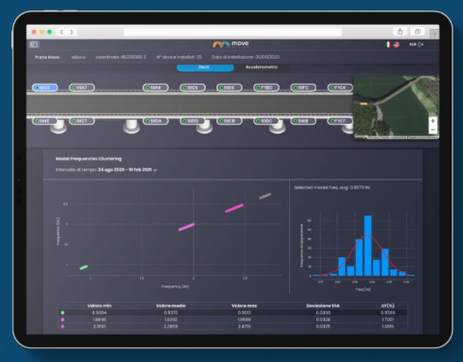
Anomaly Displacement Detector

Graph that highlights the displacement events defined as anomalous compared to those defined as standard, recorded in a determinate time interval. It is possible to analyze the movements of a single sensor or to correlate those of two different sensors.



Pk-Pk Displacement Probability Density Function

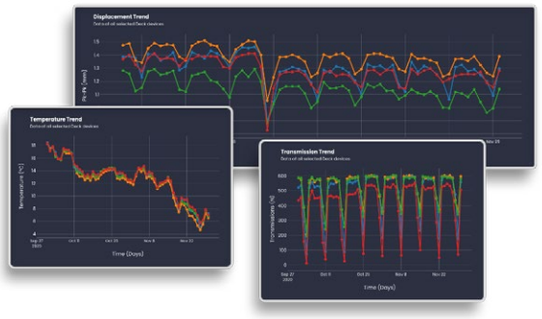
The histogram highlights the intensity of the frequency of appearance of each peak to peak displacement value recorded. In this way, it is possible to understand which is the average displacement of the structure and which is the anomalous one.



Modal Frequency Clustering

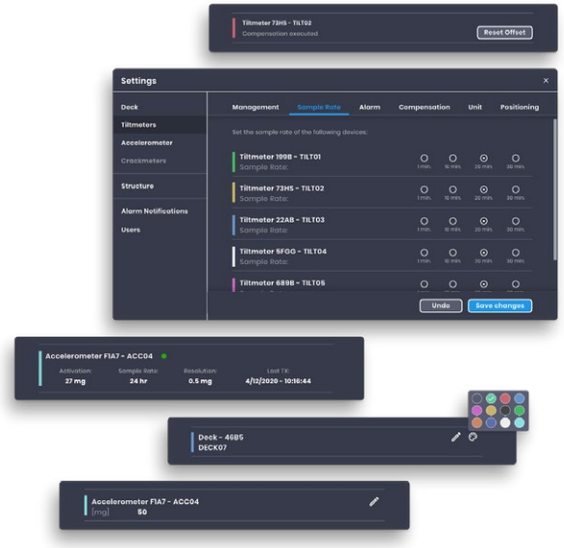
This algorithm allows the identification of modal frequencies in a given time period. The table below the graph also summarizes the statistical indices of interest of the various frequencies of which it is also possible to observe the histograms.

Check and manage your sensors easily thanks to our Web platform.



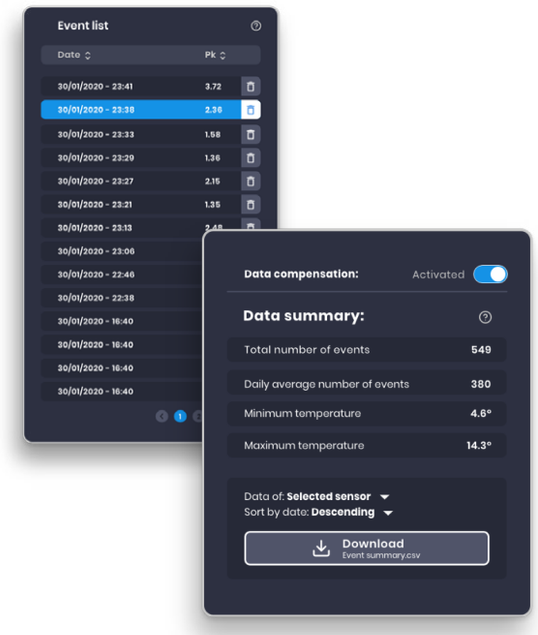
Acquire and analyze data in real time.

Make decisions with confidence. Multiple visualization and analysis tools help you make sense of complex data. Get complete sensitivity on state and structural behavior through our data processing and statistics algorithms.



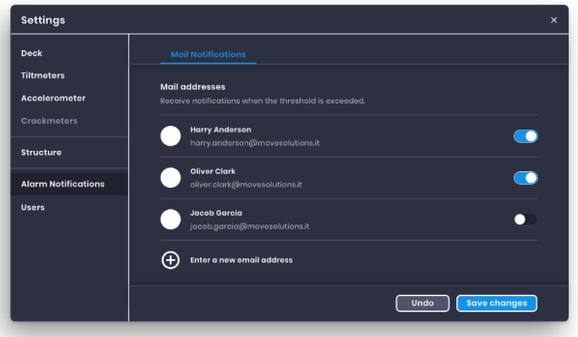
Manage and configure your devices remotely.

Modify the operating and display parameters of each specific sensor. Set the alarm and activation threshold, resolution, sampling frequency and much more.



Access the database of all the events ever detected.

View, compare and fully understand all raw data. Convert them into actionable results. Download all events, even individually, in .csv format, or all graphs in .png.



Alarms to notify you immediately.

In case anything goes wrong, count on the alarms to notify you immediately. Scheduled custom reporting keeps stakeholders updated.

CASE STUDIES

7.

Vespucci Bridge - Engr. Morandi

Subject: Bridge over the Arno river, built in 1957 Structure: 3 spans, 2 stacks
Location: Florence, Italy
Start of monitoring: November 2018
Installation: DECK devices; Accelerometers; Gateway

The Vespucci bridge is one of the central bridges of Florence that allows you to join the San Frediano district to the rest of the city, separated by the Arno river. It is a structure in c.a.p. arch divided into 3 spans, with an overall length of 162m. Designed by Eng. Morandi and built between 1954-1957, suffers from deterioration of the concrete, like many works of the time. This deterioration has affected the two piers even more markedly, especially the one on the left (San Frediano side) due to the erosion of the riverbed by the currents of the Arno river. This structural deterioration required continuous monitoring and safety works.
The monitoring system, designed for the bridge in question, provided for the use of a dynamic sensor package:
Vertical Deck sensors positioned at the centerline of each span, as shown in the figure, allow the measurement of the maximum oscillation amplitude, frequencies and temperature;
Triaxial Accelerometers, positioned on the 2 stacks, allow, with a high resolution and reliability, to measure the acceleration in the 3 axes caused by external events such as traffic and works.
The objective of the monitoring is to constantly analyze the fundamental parameters to establish the state of health of the bridge as a whole both in the construction phase and in that of daily traffic. During the monitoring period, a comparison test with radar interferometry was carried out with Prof. Pieraccini of the University of Florence, from whom the article "Bridge Monitoring using geophones: test and comparison with interferometric radar" which was published at DAMAS2019 (Damage Assessment of Structures) in Porto, Portugal.

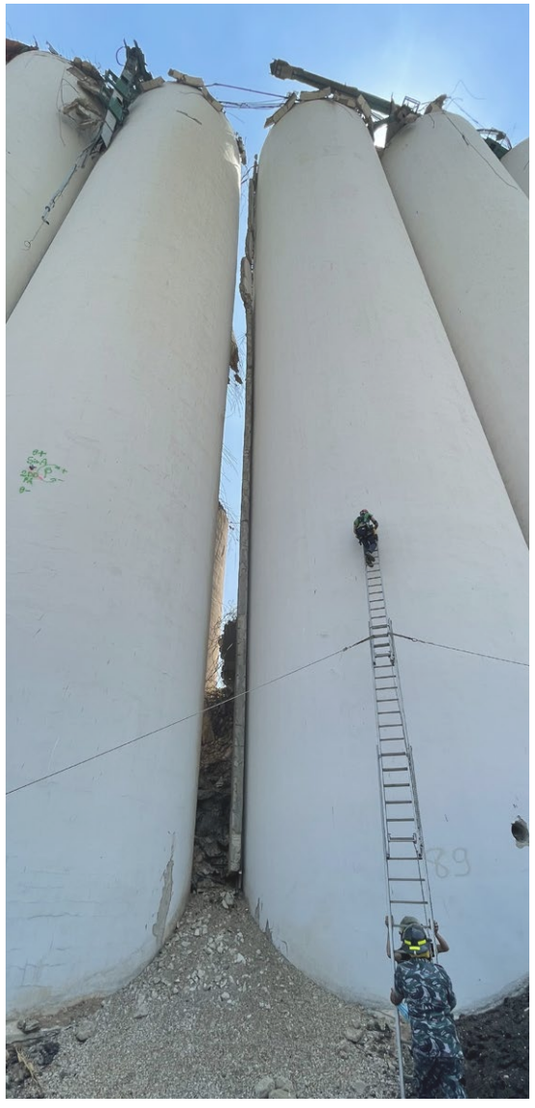
Colosseum - Archaeological Park

Company: IMG
Organizations: Ministry of Cultural Heritage and Activities and Tourism Colosseum Archaeological Park
Country: Italy
Location: Rome (RO)
Start of monitoring: 2021
Installation: Triaxial Accelerometer; Triaxial Tiltmeter; Analog Communication Nodes

The Colosseum is a historical structure of inestimable cultural value both for Italy and for the whole world.
It is, therefore, necessary to preserve and protect the structural integrity of the historic structures that are incorporated into a constantly developing urban context such as that of the Italian capital.
A tender has been announced by the “Ministry of Cultural Heritage” and the contracting authority for the project is the “Parco Archeologico del Colosseo“.
The aim of this monitoring project is to be the pilot project for processing the monitoring of the Colosseum and verifying the satellite data already acquired and being studied on the ground.
Move Solutions was therefore involved as a specialized partner by IMG, an Italian company that won the tender, providing a complete structural and environmental monitoring system.
The monitoring system consists of Triaxial Accelerometer, Triaxial Tiltmeter and multiple probes connected to Analog Communication Nodes. All sensors supplied by Move Solutions are completely wireless and easily managed remotely thanks to the Move Cloud Platform.
For the entire installation on the Colosseum, which is absolutely non-invasive, it took only 2 days. In addition, to reduce the visual impact and to better incorporate these IoT devices in the historical context of the Colosseum, the sensors were painted by a restorer appointed by the “Belle Arti di Roma” with the aim of camouflaging them.

Beirut Silos

Company: Smartec SA-Amann Engineering GmbH
Structure: Grain Silos
Country: Lebanon
Location: Beirut
Start of monitoring: 2021
Installation: Gateway; Triaxial Tiltmeters



The Beirut Grain Silos, 42 cylindrical reinforced concrete structures 48 meters high containing 85% of Lebanon's grain reserves, were built in the port of the capital in the late 1960s. On August 4, 2020, the tremendous explosion that occurred in the warehouse of storage just 85m away from the Silos caused enormous damage, impacting the city along a 600m radius. The part of the structure facing east collapsed completely, while the one facing west resisted without collapsing, preventing the shock wave of the explosion from reaching the western part of the city with all its original strength. The Beirut grain silos therefore partially protected the city of Beirut from destruction, despite being only a few tens of meters away from the heart of the detonation. Thanks to this huge contribution to the city, this structure has become a symbol for the whole of Lebanon.

A few months after the catastrophic event, after the 3D laser measurements of the end of 2020 and the spring of 2021, inclinations that were not visible without adequate instrumentation were highlighted. For this reason, the Swiss company Smartec was able to deliver to its customer, Amann Engineering GmbH (Geneva CH), a wireless sensor system from Move Solutions for the permanent monitoring of the Beirut silos.
The monitoring system consists of multiple Triaxial Tiltmeter sensors, installed tens of meters high to monitor any angular variation of the inclination of the structure. These wireless devices are very easy to install and therefore are perfect for a dangerous and difficult to access facility like this one. The entire monitoring system uses LoRaWAN radio communication to send the detected data to the Gateway installed on site. These Triaxial Tilmeter by Move Solutions, installed on the walls of the Silos, allow monitoring these rotations imperceptible to the naked eye with high resolution and precision correlating it to a temperature measurement.
The collected data can be viewed in real-time thanks to the Move Solutions ™ Move Cloud Platform, which allows the customer to remotely monitor the site of interest and, through the many tools available, facilitates its analysis. With the Move Cloud Platform, the customer was able to set different operating parameters for each sensor, including sampling rates, alarm thresholds and much more. The system guarantees constant monitoring of the health of the structure and the creation of historical records of the collected data which can be accessed at any time.

Casella Bridge

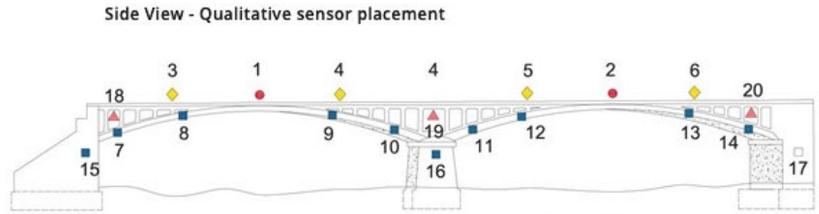
Company: Metropolitan city of Genoa
Structure: Arch bridge
Country: Italy
Place: Casella (GE)
Start of monitoring: 2020
Installation: DECK devices; Triaxial Tiltmeters

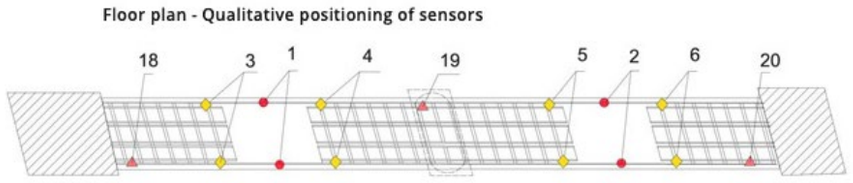
The bridge located on the Scrivia river, one of the arteries of the homonymous valley, is a structure all about 160 meters long and is divided into 7 spans with lowered arches, in reinforced concrete. Built-in the early 1900s, it served as a road and rail bridge for years. In 1980 the extension of the bridge over the Scrivia (structure in reinforced concrete with slab and beams) was carried out and also a shift of the railway network to its own site, thus splitting the two uses.

To monitor the health of the bridge, a wireless sensor network was installed consisting of DECK to monitor displacement and Triaxial Tiltmeter to monitor the inclination of the structure. DECK sensors were installed on the intrados of the arch and also on the piles, to record all the dynamic events caused by the passage of the train at high speeds. The Triaxial Tiltmeters were installed in strategic points of the structure to monitor the presence or absence of inclinations. Effects due to temperature such as seasonality were excluded from this analysis of static movements.

Zambeccari Bridge

Company: Vega
Country: Italy
Place: Pontremoli (MS)
Start of monitoring: 2020
Installation: DECK devices; Triaxial Accelerometers; Triaxial Tiltmeters





	Amount
Pair of Dynamic Displacement Sensor (1-2)	4
Pair of Triaxial Accelerometers (3-4-5-6)	8
Triaxial Tiltmeters (7-8-9-10-11-12-13-14-15-16-17)	11
Temperature Sensors (18-19-20)	3
Total devices :	26

The Zambeccari bridge in Pontremoli was built in the early 1900s on the Verde stream. It is a reinforced concrete bridge developed on two spans of the same length. In May 2020, the closure to both vehicular and pedestrian traffic is ordered for structural checks. The objective of the temporary closure of the structure is to clarify the state of health of the bridge and its structural degradation. After verifying the state of the Zambeccari bridge by the Vega Engineering company, the structure was reopened with a reduced carriageway. Vega has prepared, with the approval of the municipality, the insertion of a continuous and remote structural monitoring system.
This wireless monitoring system involves the use of a package of sensors for both dynamic and static monitoring. Sensors have been installed for detecting the displacement Deck, Triaxial Accelerometers and Triaxial Tiltmeters to measure the quantities of interest such as dynamic oscillations, accelerations and static deformations.
The Move Cloud Platform is the portal for accessing the data detected by the sensors that allow them to be examined and consulted at any time. This web platform also allows data processing through specially designed algorithms to analyze the modal dynamic characterization of the bridge with the FFT and FDD tools.

Temporary bridge for a construction site in San Lorenzo di Sebato

Subject: Modular metal bridge over a river
Structure: 1 span
Location: San Lorenzo di Sebato, Bolzano, Italy
Start of monitoring: June 2019 (Single test)
Installation: DECK devices; Gateway

This temporary metal bridge was installed at the end of June 2019 in San Lorenzo di Sebato, Trentino Alto Adige, to allow the passage of operating vehicles necessary for the development of a construction site, and it will remain operational for a few years. After the first installation, a static deformation test was done by loading in the center of the bridge some trucks, waiting for the lowering of the structure. Then two central deck sensors were mounted (one on each side) and dynamic oscillation tests were done with the passage of the trucks.

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