How a 10 engineers startup

CAN SAVE THE ITALIAN INFRASTRUCTURES

sensoworks

Index

sensoworks
SENSING THE FUTURE

How a 10 engineers startup can save the Italian infrastructures

1. Acknowledgements

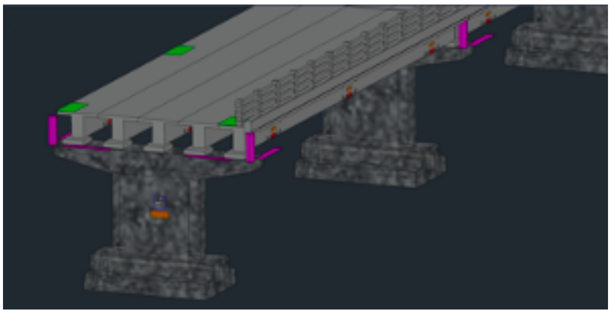
Lorem ipsum dolor sit amet, consectetur adipiscing elit. In pretium sed enim nec efficitur. Proin cursus pellentesque sodales. Mauris at mi lacus. Morbi tempor ullamcorper nisl, ac mattis diam gravida sit amet. Aenean quam mi, maximus ac bibendum sit amet, sollicitudin eu sem. Nullam eget dui felis. Maecenas pulvinar lectus eu nulla convallis pretium. Nam vitae tellus diam. In venenatis eu dui nec tempor. Praesent in orci eget libero porttitor iaculis vitae at dolor.

Nam bibendum neque vitae libero auctor, vitae tristique elit auctor. Morbi quis pharetra diam, et aliquam leo. Mauris condimentum, risus vel convallis fermentum, ante turpis volutpat elit, id tristique neque ipsum eu purus. Donec non efficitur massa. Fusce accumsan congue finibus. Sed aliquam malesuada leo vehicula convallis. Phasellus porta tincidunt luctus. Sed facilisis varius ornare. Suspendisse a dolor hendrerit, ultricies libero non, volutpat magna. Integer consectetur, dolor vel dictum elementum, purus dui consectetur nunc, eu mattis nisi dui imperdiet sem. Curabitur vitae bibendum lacus, sit amet pellentesque libero. Donec sagittis sagittis arcu sit amet blandit. Curabitur convallis tellus urna, in venenatis ligula vulputate quis.

Curabitur ac nisi bibendum, elementum magna venenatis, malesuada lacus. Vestibulum purus libero, aliquam in leo nec, consequat porta est. Quisque sit amet.

2. Who is Sensoworks

Sensoworks is the IoT platform that integrates IoT devices with company systems and cloud infrastructures. It's a ready-to-use "made in Italy" platform for the remote management and control of complex infrastructure systems.



Sensoworks gathers, monitors and interprets the data collected from sensors connected to machinery or infrastructure. It allows the customers to develop and manage their own IoT ecosystem simplifying the flow of data, communication among items, device management and, in general, enabling advanced application functionalities.

3. Our vision, methods and tools

One of Sensoworks's most important missions is **to have things speak**, with a strong focus on infrastructure management - such as bridges, tunnels, construction sites, buildings, windmills - simplifying all the pieces of infrastructure in need of maintenance or monitoring.

What we do is to understand - and help our customers understand - the health status of these "objects", starting from the huge amount of data they communicate. This way, we can easily prevent breakdowns or issues.

For this reason, we cooperate with companies that chose a solid foundation in infrastructure monitoring, with those that manufacture advanced sensors and with experts in the field of monitored "things".

The cooperation with physics, geologists, construction engineers is what makes the difference in delivering real results in these kinds of projects. We firmly believe that **combining two skills yields more than just their algebraic sum**. Only facing a problem from different angles and with different professional backgrounds allows us to solve whatever issue better and faster.

4. From theory ...

a) Industry Problems

Infrastructure monitoring has been a hot topic in recent years: several cases reported in the news let us know that there's a clear necessity - both at the institutional and the industrial level - for a faster and more efficient solution to the main infrastructural problems.

These can be divided into three main categories:

- Infrastructure-age related issues;
- Overemployment-related issues;
- Lesser statistical issues (extraordinary events, design issues, etc.).

In the first place, we have one of the most critical issues for our country. The majority of our infrastructure (highways, entire neighborhoods of our largest cities, bridges, dams, etc.) were built in about 20-30 years, mainly between the '50s and the '70s.

What follows is that infrastructure, today, is almost 50 years old, sometimes even older, and presents issues related to stability. However, we should stress that the age of infrastructure is a common issue across all European countries (where they developed their infrastructure in the same years Italy did), but it is perhaps more critical in the USA, where they started the construction of infrastructure before the war but did not need to renovate it due to its effects.

In the second place, we have an issue related to the overemployment of infrastructure, especially for mobility purposes (i.e. roads, highways, bridges, etc.). In the years these were designed - that is from the '50s onward - no one could imagine the exponential growth in the number of vehicles travelling on our streets. Here too, we have to stress that: in this case, maybe, the issue is more critical to Italy rather than for other countries such as Germany. Their logistics are mainly based on rubber rather than iron (they prefer trucks rather than trains for the transfer of consumer goods).

In the third place, we find a set of lesser statistical cases regarding potential anomalies, likewise critical in their consequences. We can trace this third set of issues back to the increasingly frequent natural disasters - due to the growing anthropization of territories and, more generally, to climate changing phenomena on a global scale. The hard predictability of these phenomena puts all kinds of infrastructures at risk. To natural disasters, we also add lesser cases due to potential human mistakes in the construction, whether they are related to the infrastructure design, making or the materials' quality.

The whole of these issues (not an exhaustive list, but rather a hint of what the industry is in constant need of) should clarify the reasons why in the last years the research of new technological solutions is becoming increasingly hectic and relevant, in such a way to involve governments and multinational companies alike.

b) Traditional Solutions

A traditional solution usually relies on visual/manual periodic monitoring by human resources, remotely or on-site. However, these are very expensive and inefficient operations, for several reasons.

First off, from a chronological perspective, we cannot say for sure that periodic inspections can correctly foresee potential harmful events. A periodic monitoring every few months could ignore events starting and ending within the time between the periodic checks.

Moreover, human mistakes due to distractions, wrong measurements or even the tiniest errors might take no notice of imminent danger. Speaking of effort in terms of time, then, it's clear that cost of a resource and its deployment in a given place to carry out monitoring activities has a tangible impact on any project.

c) New Solutions

The great tech developments at the IT (new software programs for data processing, incredible speed for internet data transfer) and technical levels (data storage, manufacturing of miniaturized sensors to be installed in the most peculiar contexts) allows for the development of technological solutions we could not even imagine just 10 years ago.

To the traditional manual and visual solutions, today, we can add (and often we can utterly replace) an innovative and completely automated solution based on, for instance, on the platform we developed and named after our company. Sensoworks.

In line with the industry's technological developments, Sensoworks and similar infrastructure monitoring platforms, allow for the constant gathering of information from the infrastructure it is installed on. They also allow the immediate processing of the gathered data (through advanced algorithms increasingly reliant on machine learning to improve autonomously). Thanks to such a pervasive solution, even the answer can be as immediate. Not only, the platform can give us an extremely precise answer, aimed only at the exact point of the infrastructure that needs maintenance.

The speed of gathering and processing the information it's not important only to cut the maintenance costs (which are important nonetheless), but also for the safety of the piece of infrastructure's users (residents of a building, passersby on a road, vehicles on a highway) who can have a timely notification in case of potential issues.

d) New technologies

New technological solutions are based on many little innovative pieces. Base technologies, or components, unavoidable for the construction of a successful monitoring solution are:

Sensors

Sensors are the foundation of our platform, the long antennas we gather relevant information with. Information which we then translate in real value for companies that have complex infrastructures to monitor. Accelerometers, extension gauges, clinometers, pressure sensors, and various kinds of hardware allow us an extremely precise, timely, constant and reliable monitoring. For example, we built our architecture to simplify the process of "adding" and "change" of sensors in the whole monitoring activity, whenever you want, whenever you need, with the least impact on your IT infrastructure.

IoT

Internet of Things is not just a trendy word for us. It is also the pillar upon which all the data collection, storing and alert activities are based. New broadband technologies, mobile communications, these are all components that make information available in real time and infrastructure monitoring possible.

Cloud/On-Premise

Every company is different, with different needs and specific, internal safety guidelines, sometimes with different national or international laws to follow according to the installation location.

A new monitoring solution must foresee what kind of technology will be necessary to integrate the customer digital infrastructure while maintaining the right flexibility to choose where and how to install and use our whole product, besides the degree of dependency on external servers.

New platforms such as Sensoworks are usually as flexible as it gets to allow their customers to modify their infrastructure according to the evolving market needs.

5. … to practice: A real monitoring project

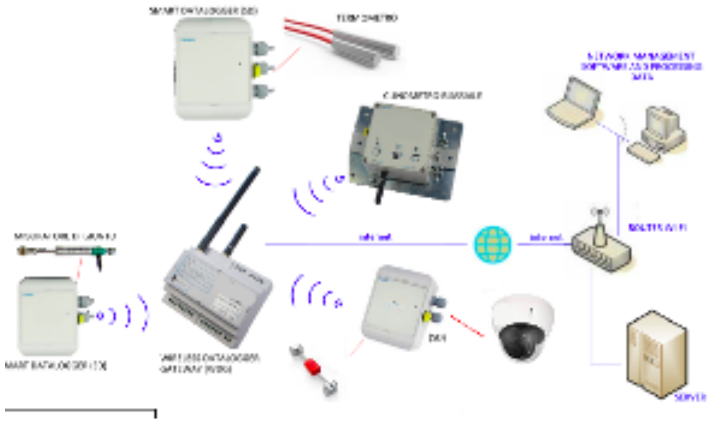
a) Essential elements of a monitoring project

Here are the fundamental elements to monitor a Sensoworks project. As we'll see, the monitoring platform is only a piece of a larger puzzle, although fundamental to prepare and then implement an efficient monitoring solution:

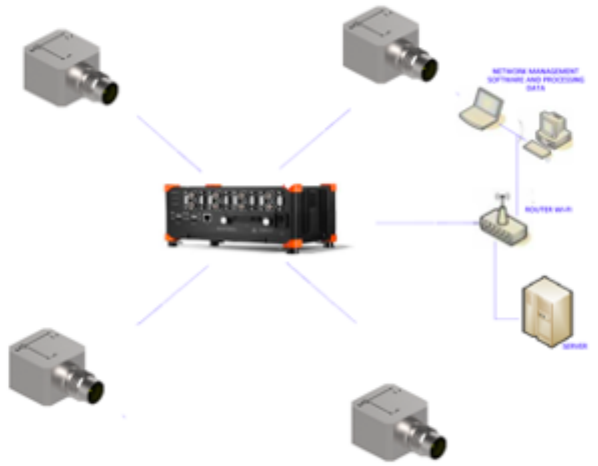
- An initial brief with the customer to verify the monitoring requests and consequent delivery of the monitoring activity.
- Gathering of the specifications for the item to monitor.
- Structural analysis of the item and involvement of technical consultants for each aspect of the analysis.
- Design of the hardware monitoring system and set up of the necessary software to implement it on Sensoworks's platform.
- Installation of a web of sensors and specific tech devices for the monitoring activity.
- Provision of Sensoworks's platform, set up together with the customer.
- Continuous monitoring service with alerts and checks arranged with the customer.

The proposed monitoring system (as for the case study we'll see later) integrates different measurement kinds and technologies:

Static Monitoring: for pillars and supports, beams through joint gauges, clinometers, extension gauges. It allows for the evaluation of the static behavior of critical components of works to monitor their conditions while operating and highlighting the consequences of decay and/or deterioration.

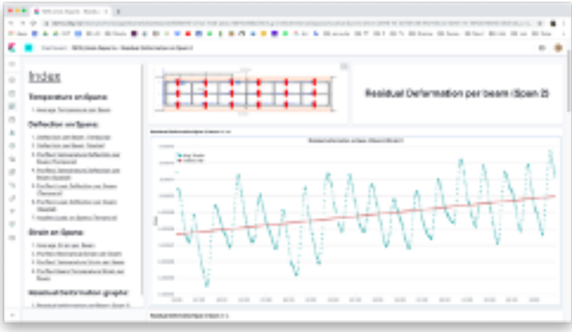


Dynamic Monitoring: through accelerometers, allows for the evaluation of the dynamic behavior of structures throughout their operation cycle via the verification of design hypotheses and to evaluate structural performance losses even following extraordinary phenomena such as earthquakes, floods, etc.



Visual Control Component: for critical supports and elements via directionable iP cameras. It allows for the direct visual evaluation of critical segments and/or elements to optimize the surveillance, inspection and maintenance activity of the team according to the maintenance plan.

The system aims at allowing the infrastructure manager to acquire relevant data to evaluate the infrastructure's behavior while operating, so as to define its conditions and predict potential issues due to decay and/or anomalies.



Moreover, we also proposed to use the equipment for the evaluation of the infrastructure's history. Data which will be consequently gathered to follow the evolution of the work's behavior (static and dynamic) and conditions in time, through:

- Identification of sudden or progressive damage of structures/materials while operating or extraordinary events, such as earthquakes
- Evaluation of critical variations in the typical parameters of the structure (static and dynamic parameters), starting from a nominal condition (baseline);
- Survey of potential anomalies in time, allowing for more efficient maintenance interventions and reparations, with minimum intervention effort by the maintenance team and a consequent reduction of operation costs.

Our proposed system is based on a solid architecture certified by its implementation in numerous similar projects. It allows for the optimization of the management and maintenance of the system and it minimizes the risks related to data loss and creating a web of external connection to transmit all the necessary information in whatever format and requirements. We deliver a full monitoring project to structures and users concerned with the phenomena affecting the piece of infrastructure and the information gathered in close and constant contact with the system management.

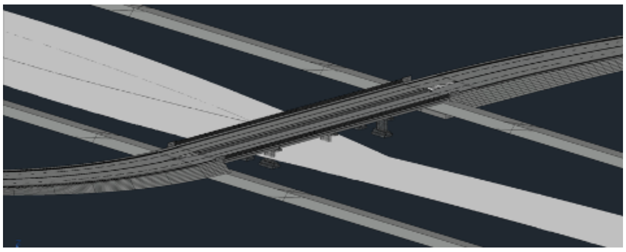
The opportunity to set up the thresholds, as well as to define the logic behind the analyses of the historical trends, allows the customer to understand what is going on and to intervene in time if necessary.

To evaluate the changes in the materials and to react before the emergence of serious harms, it is fundamental to implement a specific monitoring system made up of:

- A web of sensors, disposed along the structure;
- Systems for the acquisition of data and terminals to store and analyze the measurements;
- Systems to transmit the data with remote processing terminals and software procedures for the analysis and interpretation of data;
- Alarm systems;
- A platform to visualize historical or near real time-data.

b) Case Study - Proposal for the static and dynamic monitoring of a bridge

The following case study is that of an ANAS infrastructure, specifically a bridge with the following characteristics:



- 1 roadway
- 2 aisles
- 3 double-T, steel beams supporting each aisle.

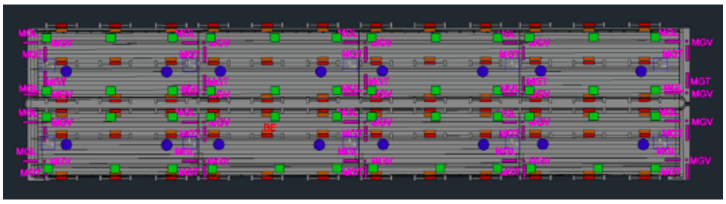
The solution we proposed - based on Sensoworks's integrated system - is characterized by the opportunity to optimize and maximize the value of data and information, allowing for a more reliable and less subject to external factors behavioral analysis

We consider the system's components as a whole rather than individual, disjointed elements. We valorize the global condition of the infrastructure through the union of its components' potentiality, which we can summarize in:

6. Sensoworks's way

Sensor Monitoring

Our platform connects to all the installed sensors to allow you to set up your infrastructure and to customize it straight on the platform. Once set up, all the sensors are immediately monitored in real time. All the data are gathered, registered and structured to be analysed by our powerful predictive algorithms.



Automatic Actions

Sensoworks can be easily programmed to set up utterly automatic actions, based on the stored information and configured algorithms according to the customer's specifications. Choose the action you want to trigger when something specific happens.

Customized Reports

Choose among already existing templates or log in the Sensowors's Report sections to set up engaging and simple reports.

Predictive Maintenance

We accurately choose the companies we work with to develop the right algorithms to efficiently and constantly monitor the health status of your machinery, buildings or infrastructure. Thousands of monitoring hours allows us to understand what is going on and to notify you immediately, with a straight connection to your company's departments.

Certified on Blockchain

We focus on the security of stored information. All the data we gather, share and analyze are not only protected but also certified through blockchain technology.

The result is an extra layer of security, information and precision.

7. SHM (Structure Health Monitoring): Static and dynamic monitoring

Structural Health Monitoring (SHM) has rapidly become one of the main interests in the civil, mechanical, and aerospace engineering field. Every structure is subject to various internal and external factors, which can cause damage due to usage or malfunction.

The triggering causes can be, for example, deterioration, a non-carried out construction process or lack of quality controls in extreme situations, such as accidents or environmental stress. SHM consists not only in identifying sudden or progressive damage but also in monitoring structural performance during operating conditions or exceptional events, for example in the case of an earthquake. Structural monitoring involves a large number of applications in civil engineering such as design, damage assessment, maintenance and structural control during extraordinary events such as earthquakes.

In order to evaluate these changes and to react correctly before serious damage occurs, it is essential to implement a specific monitoring system. Monitoring structural behavior can detect anomalies in time, allowing for more efficient maintenance and repair interventions, with a consequent reduction in the operating costs. Even for already-built structures, especially of monumental and historical nature, SHM can help in the acquisition of fundamental data.

SHM is carried out using a sensor net, appropriately arranged on the structure, data acquisition systems, units for storage and analysis of measurements, data transmission systems to remote processing units and software procedures for analysis and data interpretation.

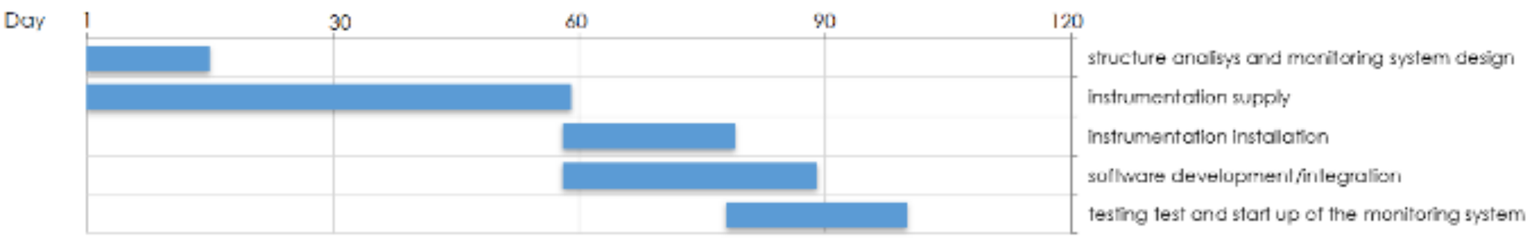
The state of the structures can be checked through the execution of:

- **Static measurements** that require the application of tools to measure absolute or relative displacements of structural elements such as piers, supports and beams, to allow the evaluation of the static behavior of critical elements.
- **Dynamic measurements** based on the analysis of signals coming from natural or induced vibrations and allow, in addition to the verification of the design hypotheses, the evaluation of the dynamic behavior of the structures during their operating life cycle, through the analysis of the variation of the parameters' modal frequencies (natural frequencies of vibration, modal deformations, damping, etc.).

8. Project timeline & The Importance of Constant Monitoring

The implementation of a monitoring system is generally completed by carrying out the following steps:

- structure **analysis** and monitoring system **design**: during this phase, which we carry out together with the customer, we analyze the characteristics and features of the structure, identifying the structural elements that need to be checked the most. Then, we proceed to choose the different types of sensors to install and their position on the structure according to the different variables to measure.
- **equipment supply**: supplying time depends on various parameters such as the type of sensor and data logger to use, the quantities needed, the supply capacity of the selected manufacturer, etc.
- **equipment installation**: the installation time depends on the type of equipment to be installed and the accessibility to the installation points of the sensors on the structure. In the specific case of a bridge, it is often necessary to use aerial platforms to reach the measurement points.
- **software development/integration**: the software development/integration phase involves the implementation of APIs for the integration of the acquisition systems. Sensoworks's IoT platform allows for the customization of the interface and data visualization.



- **testing** and launch of the monitoring system: the last step before the final delivery involves the execution of in-depth verification tests of the data acquisition and measurement equipment and the correct operation of the software.
- Once the tuning operations for the monitoring system are complete, the system is delivered to the customer or to the infrastructure manager. The duration of the monitoring may be limited in time if the objective is to check the structure during the execution of particular processes in correspondence with adjacent areas or extended to the entire life of the structures.

9. Timeline+100 parole

Lorem ipsum dolor sit amet, consectetur adipiscing elit. In pretium sed enim nec efficitur. Proin cursus pellentesque sodales. Mauris at mi lacus. Morbi tempor ullamcorper nisl, ac mattis diam gravida sit amet. Aenean quam mi, maximus ac bibendum sit amet, sollicitudin eu sem. Nullam eget dui felis. Maecenas pulvinar lectus eu nulla convallis pretium. Nam vitae tellus diam. In venenatis eu dui nec tempor. Praesent in orci eget libero porttitor iaculis vitae at dolor.

Nam bibendum neque vitae libero auctor, vitae tristique elit auctor. Morbi quis pharetra diam, et aliquam leo. Mauris condimentum, risus vel convallis fermentum, ante turpis volutpat elit, id tristique neque ipsum eu purus. Donec non efficitur massa. Fusce accumsan congue finibus. Sed aliquam malesuada leo vehicula convallis. Phasellus porta tincidunt luctus. Sed facilisis varius ornare. Suspendisse a dolor hendrerit, ultricies libero non, volutpat magna.

a) Typical Project Costs 150 parole

The monitoring systems consist of structural monitoring, geomatic monitoring and geotechnical monitoring systems, with different instrumentation.

Monitoring systems are to be installed in advance (well before the beginning of works) in order to acquire the necessary reference basis with regard to the variations produced by seasonal and daily thermal cycles and to keep under control the damage already present and the possible unfavorable evolutions of the mechanisms activated or to be activated.

Due to the duration of the construction of the .... and, consequently, the duration of the monitoring systems, it has been considered that the initial choices could have been adapted to technological developments and to the availability of new instruments introduced by the Manufacturers.

Moreover the experience gained during the construction has been used to improve the system reliability by using more appropriate components/instruments.

Type of Instrumentation

The monitoring instrumentation can be divided in two main families:

- Instrumentation for Building & Monuments / Structural monitoring
- Instrumentation for Soil / Geotechnical Monitoring Monuments monitoring included both static and dynamic systems with automatic data acquisition and transmission systems to measure the following parameters:
    - Overall movements (by means of Automatic Total Stations –ATS -with geodetic prisms) and manual leveling devices with leveling pins;
    - Local movements / deformations (by means of joint meters, crackmeters, pendulums, tiltmeters, el-beams,)
    - Load / Forces (by means of Load Cells and Strain Gauges)-Environmental conditions (by means of temperature gauges, wind gauges, rain gauges, humidity sensors)
    - Dynamic / Seismic actions (by means of Seismometers, accelerometers) Soil monitoring included both manual measurements and automatic data acquisition and transmission systems to measure the following parameters:
    - Vertical movements(Settlement) (by means of Rod Extensometers, Incremental Extensometers, ATS)
    - Horizontal movements (by means of Manual Inclinometers, In Place Inclinometers, Estenso-Inclinometers)
    - Pore pressure and Water Levels (by means of Electric Piezometers, Casagrande Piezometers, Pressure Transducers)

b) Measuring Principles

The monitoring instrumentation has been selected in order to provide for high reliability and robustness to reduce the maintenance activity which could be very critical in urban area and especially o the historical building where access is limited and controlled by archeological authority which has to release special permission for each intervention.

According to these assumptions, the following measuring principles have been selected:

- Joint MetersPotentiometer13CrackmetersVibrating WireStrain GaugesVibrating WireWall Clinometers / Tilt BeamsMEMSInclinometersMEMSRod ExtensometersVibrating WireElectric PiezometersVibrating WireLoad CellsResistive Strain GaugeEstenso-InclinometersPotentiometer-MEMSPendulumsMagnetic/ OpticTriaxial AccelerometersMEMS

Some costs are relatively simple to quantify and can be measured on the basis of the data available on the market or on site.

Others are not so easily measurable, (eg.. final labor costs associated with inspections and data processing time). For these, an in-depth analysis of the specific case is indispensable to estimate the market costs of the necessary technologies. A final cost database is, thus, strictly depending on the specific project and the data about hypothetical costs in the field, interviews with suppliers and further research.In general, the cost elements can be listed as follows:

- Capital costs
- Operating costs
- External and service costs.

Conclusions

The pressure to improve the economic performance of the infrastructural Italian environment, and the safety of citizens and operators, has sparked the necessity of data-driven projects and stimulated the creation of new and advanced infrastructure Management Systems (i.e. Sensoworks's IoT platform).

These necessities, together with technological progress, are leading to improved structure management actions (i.e. preventive or predictive **maintenance**, **preservation**, **rehabilitation**, **replacement decisions**). The use of remote sensing technologies presents a potential alternative to improve current practices by providing both qualitative and quantitative measures of a bridge's condition.

The benefits and costs of deployed remote sensing technologies and procedures largely depend on specific locations, types and number of bridges, traffic and other aspects. While the cost effectiveness of remote sensing technologies is highly dependent on the success of the integration with existing bridge inspections (both regular and bridge scoping) and with the standardization of data collection techniques, simplification of data processing steps, and development of reporting procedures to increase the overall benefits of structure monitoring and to diminish the impact of potentially high initial fixed costs.

10. Glossary 10-15 lemmi

- **Accelerometers** (sensor), used for dynamic monitoring and usually provided by internal algorithms, they are a key component in modern electronic equipment. Available with analogue and digital outputs.
- **Beams** are the simplest structural forms for bridge spans supported by an abutment or pier at each end. No moments are transferred throughout the support, hence their structural type is known as simply supported.
- **Clinometers** (sensor), an instrument used for measuring angles of slope (or tilt), elevation, or depression of an object with respect to gravity's direction. It is also known as a tilt indicator, tilt sensor, tiltmeter, slope alert, slope gauge, gradient meter, gradiometer, level gauge, level meter, declinometer, and pitch & roll indicator. Clinometers measure both inclines (positive slopes, as seen by an observer looking upwards) and declines (negative slopes, as seen by an observer looking downward) using three different units of measure: degrees, percent, and topo (see Grade (slope) for details)
- **Strain gauges** (sensor) measures the length of flexible electrical cord, the larger the diameter of the conductors need be to minimise voltage drop (wire gauge numbers are smaller for larger diameter wire).
- **Infrastructure Monitoring** is defined as the deployment of a built-in knowledge base to automatically diagnose performance and availability problems across the technology stack before productivity compromised
- **IoT devices** piece of hardware with a sensor that transmits data from one place to another over the Internet. Types of IoT devices include wireless sensors, software, actuators, and computer devices. They can be embedded into mobile devices, industrial equipment, environmental sensors, medical devices, and more.
- **Monitoring (static and dynamic)** infrastructure behaviour can be recorded dynamically (changing his status in the space) or statically (maintaining fixed the space data). Usually this data is recorded incrementally at fixed time steps. This does not give a complete picture of the actual performance of the structure since there may be a significant structural response between fixed time steps which would be missed by other technology. Sensoworks records both dynamic and static structure behaviour at the same time continuously, at a frequency of 100 hertz (100 times per second).
- **Pressure (sensor)** is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed (i.e. electrical signal).
- **Remote Management** Remote management ensures that your IoT devices are connected, and monitors that connection 24/7 to enable reliable, secure and cost-efficient delivery of your IoT services anywhere in the world


sensoworks