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Vicenza Pilot Action report & lesson learned

Province of Vicenza

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A. Executive Summary

The Province of Vicenza manages a wide and varied road network, including mountain roads where winter conditions can quickly become dangerous. Winter salting is an important issue in road management. Too little salting can affect road safety, while too much salting increases costs and has negative effects on roads and the environment. For this reason, deciding when, how much and where to salt is an important decision in terms of road network maintenance. However, deciding when and where salting is really needed is not always simple. The Province and its road management company, Vi.abilità, have traditionally relied on broad weather information and the judgements of local subcontractors, though this can make it difficult to verify whether interventions are timely, sufficient or excessive.

The Vicenza Pilot Action addressed this practical governance challenge by introducing more precise local data to verify if and how much this can contribute to better winter road maintenance decisions. The idea was to move from general weather assumptions towards evidence collected directly along the mountain roads where the problem occurs. Four meteorological stations, including 15 environmental sensors, were installed in selected locations along provincial roads in the mountain area. These locations were chosen by combining the knowledge of the Province, Iuav University of Venice (PP2 IUAV), Vi.abilità and ARPAV, the regional environmental agency, considering accident records, existing weather stations, road characteristics and local maintenance needs.

The sensors collect information such as air temperature, road surface temperature, humidity, rainfall and snowfall. This data is made available through online tools and Open Data channels, allowing both public authorities and other users to consult and reuse it. PP2IUAV is using the collected information, together with existing ARPAV data, to develop an algorithm that estimates when road conditions actually require salting. In this way, the pilot provides the Province of Vicenza with a reference framework to compare the estimated need for intervention with the work carried out by subcontractors.

The pilot produced several important results. First, it helped the Province, PP02IUAV and Vi.abilità build practical know-how on how to choose, locate and manage sensors in complex mountain areas. Second, it introduced a more scientific approach to deciding where sensors should be placed, making sure that new data adds value to existing sources rather than duplicating them. The pilot confirms that public authorities should be involved from the beginning, so that data collection responds to concrete governance needs, and it confirmed the importance of integrating data from different sources: not only the sensors specifically installed for the project, but also existing data made available by ARPAV and Vi.abilità. It also shows the importance of clear procurement standards, especially where the market for sensors and "data as a service" is still developing.

Preliminary applications of the model to the SP46, SP350 and SP349 road sections have already produced relevant findings. While the estimated salting needs were broadly consistent with actual maintenance practices on two of the three roads, more significant discrepancies emerged for the SP349, highlighting how sensor location and the morphological and microclimatic complexity of mountain roads can influence the accuracy of the results. These preliminary findings confirm the importance of integrating existing ARPAV data with the more localised Open Data collected by the EnCLOD stations, which will support the final calibration and validation of the model using data from winter 2025/2026.

More generally, the tool under development creates a common quantitative reference for winter road maintenance, which can be progressively improved through calibration, additional data sources and field validation. This can be used not only to take better decisions, but also as an ex-post assessment and evaluation instrument. It may also help to better plan and contract winter road salting services in the future.

In conclusion, the Vicenza Pilot Action offers a transferable model for provinces, mountain areas and road authorities wishing to improve winter maintenance, public procurement and environmental management through better data.

B. Introduction

EnCLOD pilot action in the Province of Vicenza is providing environmental data to support the informed decisions of its territorial government officers. The pilot action was designed by Province of Vicenza (LP) with IUAV University of Venice (PP2) and the support of Vi.abilità srl, the company charged with management of the network of roads under the responsibility of the Province (a total of 1.070 km). Objective of the pilot is to assess the efficiency of the activities carried out in winter to prevent ice formation on the roads (i.e. salt spreading): these activities are outsourced to local companies, therefore both the Province and Vi.abilità are interested in assessing the works done by sub-contractors. The pilot was aimed at estimating the number of days effectively requiring salt spreading during winter to compare the results with the registered working days.

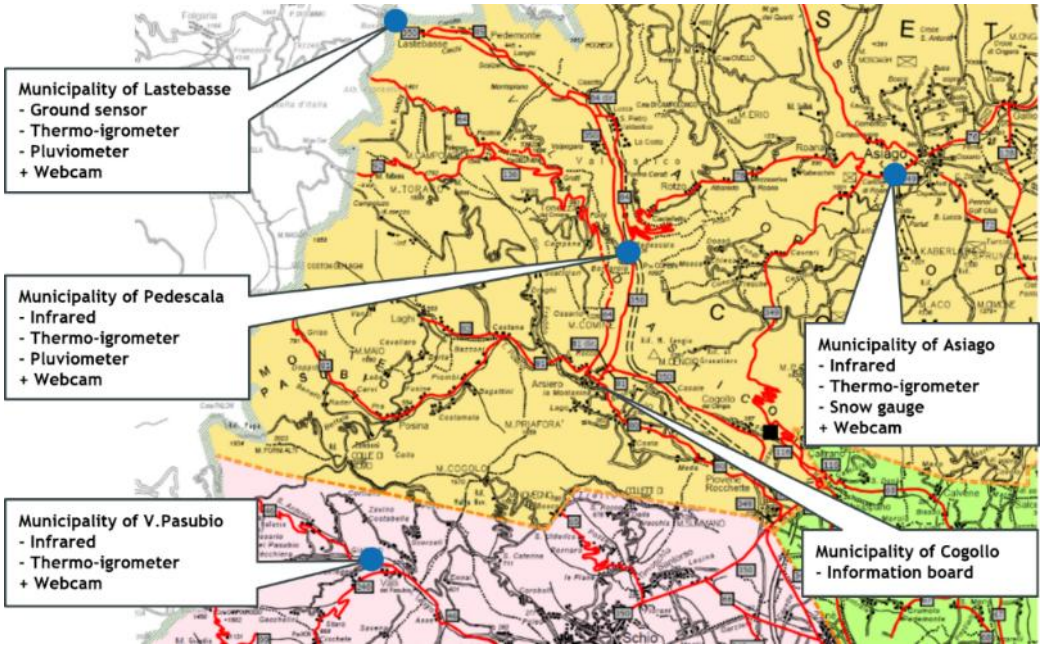
To this end, a network of 4 meteorological stations (for a total of 15 IoT sensors) was deployed by Project EnCLOD in key sites along the roads of the mountain part of Province of Vicenza (LP), providing environmental data to assess the road surface status. The results of the sensor deployment is a continuous flow of environmental data (air and road temperature, humidity, rain and snow falling, etc.) elaborated by the researchers of IUAV University of Venice (PP2) through an algorithm to estimate the number of days requiring interventions for road ice prevention. Furthermore, the datasets provided by the weather stations are published online and made available to the public, opening up to a wider range of usages by the local inhabitants, for example to plan their journeys in the mountain areas, or to develop further online tools.

During all the course of the project activities the implementation of the pilot action granted the officers of Province of Vicenza (LP) a number of lessons to be learned on the subject of data supported decisions, along with the awareness of the hindrances that can impede this process. Both on the governance level (with such topics as public procurement and data policy design) and on the technical level (with topics as data transmission in mountain areas) an important experience has been acquired, which will be useful for the future to Province of Vicenza (LP) and can be transmitted to other public authorities for a better use of open territorial data.

C. Key info on the Pilot Action

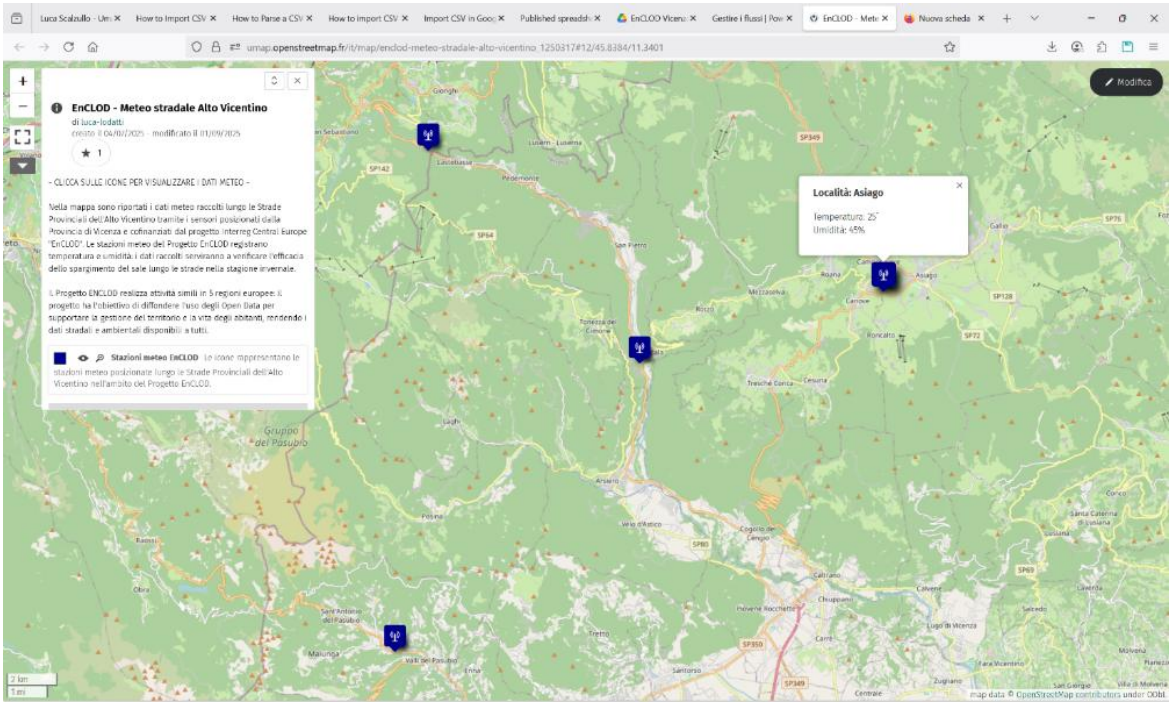
The pilot action of Province of Vicenza (LP) aims at assessing the status of the road surface during winter in the mountain part of the transport network for which the Province is responsible. The "Provincial Roads" amount to a total length of 1,070 kilometres: the formation of ice on the road surface in mountain areas during the winter season represents a relevant danger that yearly causes hundreds of accidents. To prevent it, an activity of salt spreading is implemented, managed by the Province through its controlled company Vi.abilità srl and effectively carried out by different local sub-contractors. The decision of intervening with salt spreading on the roads is based more on large scale meteorological data and on the evaluation of the single operators, than on specific micro-climatic data for each mountain road in the territory in charge of the Province. To assess and improve this management system, the pilot action deployed a network of weather stations that allows, through an algorithm developed by IUAV University of Venice (PP2), to estimate daily the status of the road surface, the presence of ice and therefore the need of intervening with salt spreading, thus offering an improved framework and reference benchmark for managing the works carried out by sub-contractors (through public procurement, tenders, etc.)

The Vicenza pilot action deployed a total of 15 environmental sensors grouped in 4 weather stations: these include 4 thermo-hygrometers, 3 infrared sensors, 1 road status ground sensors, 2 pluviometers, 1 snow gauge, along with 4 web cams. The meteorological stations were installed along 3 roads managed by the Province of Vicenza, strategically selected together with IUAV University of Venice (PP2), ARPAV (the Regional Environmental agency), and Vi.abilità (the road management company) in the mountain part of the territory in charge of the Province: the sites where chosen considering recent statistic on road accidents, the existing weather data from ARPAV, which also owns a sensor network although not focused on the road system, and the experience of road managers. The sensors' position overlooking the roads has been designed to effectively measure the surface temperature as well as pursuing other goals concerning their status, maintenance, and safety. Environmental data are generated in real time and aggregated in 15-minute intervals, gathered and transmitted by a datalogger. A connectivity model based on the mobile phone network is used: NarrowBand-IoT SIM Cards transmit the collected data of the 4 stations. Data is stored and published through a dedicated web platform (MINA), with traffic data accessible remotely on the platform and also transmitted via Ftp in CSV format. The MINA platform contains a dashboard and map for data visualizations and a set of base analytic instruments (table, graphs).



Map of sensor network with the 4 weather stations

The datasets from the weather stations of the pilot have been made available publicly through a dashboard for consultation and download (including metadata); data are updated every 15 minutes, with near real-time transmission. Moreover, the data are published on Open Data Veneto, the institutional web portal of the Veneto Region which collects OD of public administrations (at the moment encompassing 6,581 datasets from regional government, municipalities, etc.). Here on this platform, the datasets are published statically (with metadata, under open licence) within a 6 month period, since the web platform itself is static. Finally, the data is presented on the website of the Province of Vicenza in a page dedicated to the project EnCLOD (with a banner in the home page): here a selection of data (air humidity, temperature) is published within 15 min. update period. In the first days of the dataset publication, diffusion through social media and a local newspaper article brought them to the attention of the citizens.



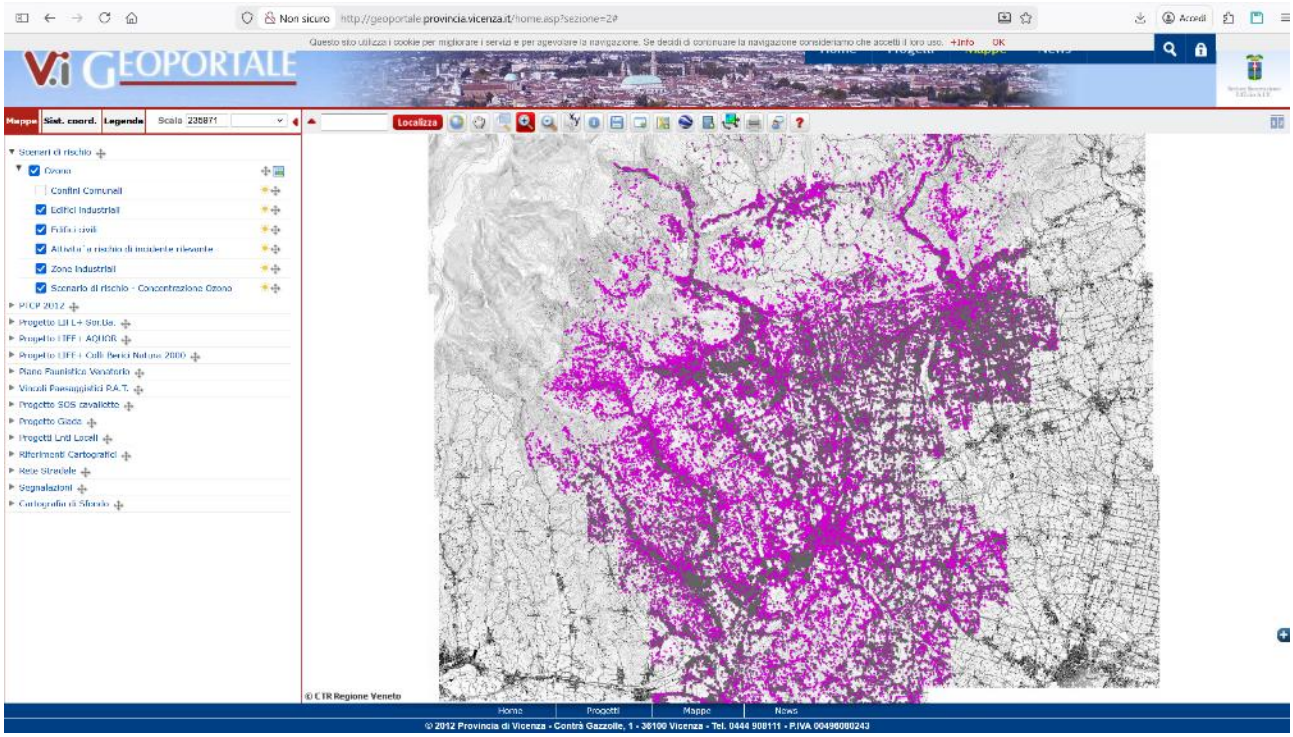
The online map used to display publicly the data from the weather stations, based on Open Street Map.

The algorithm developed by IUAV University of Venice (PP2) will assess, through the elaboration of the datasets coming from the 4 weather stations along with data from the Environmental Agency, the status of the road surface: a set of thresholds checked against the different meteorological values estimate the formation of ice on a daily period. The thresholds have been defined from literature for the first winter season and will then be refined on the basis of collected data. The number of days registering ice presence on the road surface, along with the total amount of salt, is a key value for management of ice prevention interventions. The road management, Vi.abilità srl, expressed during technical meetings for the project their interest: first, the application can be used for verifying the efficiency of the sub-contractor work, considering also the financial and environmental impact of the salt spreading on the asphalt of the roads. Further developments for the weather stations data collection could be their integration in a "control room" in course of implementation by Vi.abilità (along with traffic data) and potentially, in the future, the deployment of a larger sensor network that, through an AI-based prediction system, can forecast with greater precision when the salt spreading is needed.

D. City Open Data strategy inputs - governance level

1.1.1. Open data agenda in the pilot area

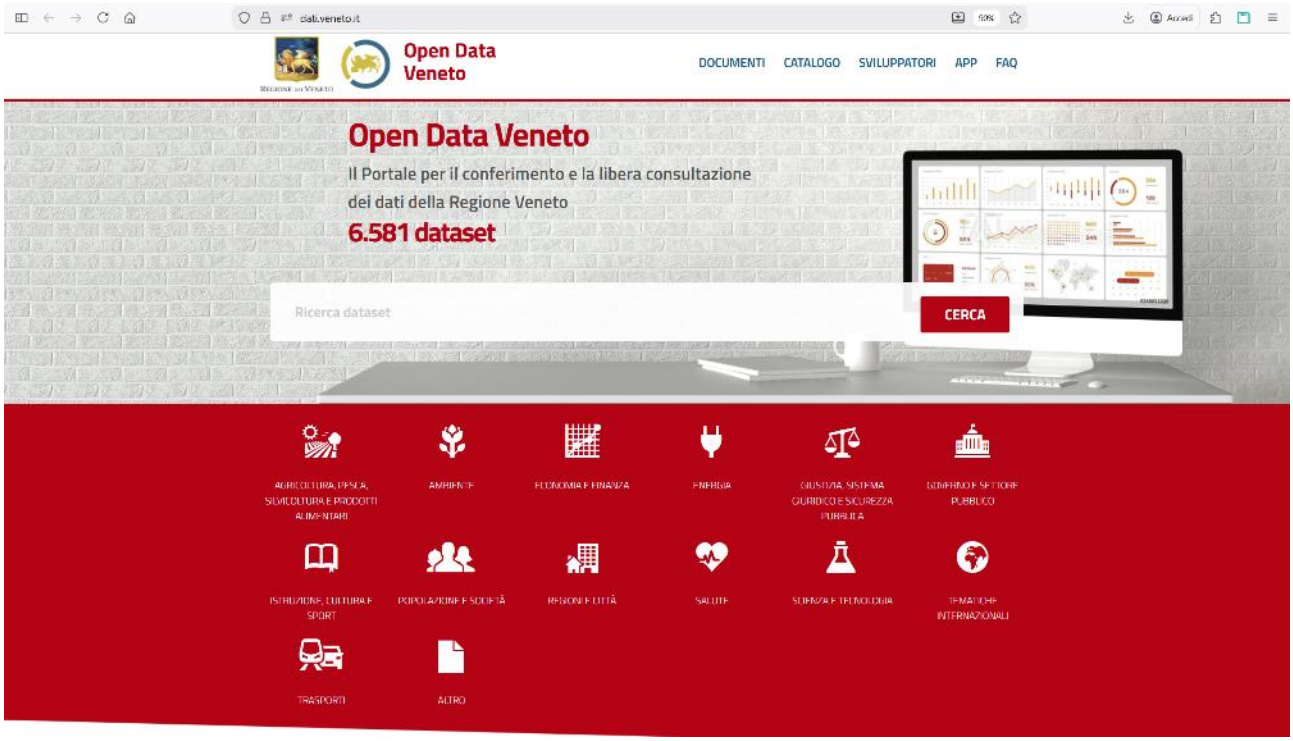
The policy framework of Open Data of the Province of Vicenza (LP) is not advanced as the ones of other EnCLOD project partners, yet through the years the Province committed to publishing owned territorial data with the available technologies at the time: the Geoportal created in 2010 hosts updated urban planning documents (tables, technical reports) with GIS functions, along with statistical, environmental and territorial data published with regular update or by specific survey projects. The web infrastructure is statical, updated periodically (generally within 6 months period) or through the work of targeted projects (i.e. on pollution in specific areas, etc.). There is a department of the Province dedicated to the management of web infrastructures, called “Information Systems and Services”, which consists of 3 officers and a director, responsible for updating and upgrading the website of the Province along with the Geoportal and the related data. A new website is in course of construction, expected within 2026, while a renovation of the Geoportal is planned in the longer term.



The Geoportal of the Province of Vicenza showing a survey on industrial plants and ozone pollution

Province of Vicenza (LP) thanks to EnCLOD Pilot Action entered the Open Data framework of the Veneto Region, which complies with the national regulations for Open Data usage. The Italian “Code of the digital administration” was approved by the national government in 2005, then the “Regulation on pluralism of information" was approved by the regional government in 2008 and brought in 2011 to the establishment of the web portal “Open Data Veneto” (see dati.veneto.it). This web infrastructure is presently the most comprehensive repository for the collection and consultation of OD coming from public authorities in the Venetian Region, even if solely in static form: it collects currently 6,581 datasets (1,589 for the territory of the Province of Vicenza), provided mainly from the municipalities, the environmental agency (ARPAV) and the Regional government.

One of the activities of Project EnCLOD for Open Data of the Province of Vicenza was entering the Open Data Veneto repository and uploading the first datasets: an official act was required (Decree of the President of the Province) and then an account provided by the department of the Regional Government responsible for managing the portal (ICT and Digital Agenda Department). The data collected from the weather stations of the pilot action have been uploaded in the OD repository, to be updated within a 6 months period. The department of the Province responsible for the management the Geoportal (Information Systems and Services Department) committed to update a selection of statistical data in the Open Data Veneto portal in the future.



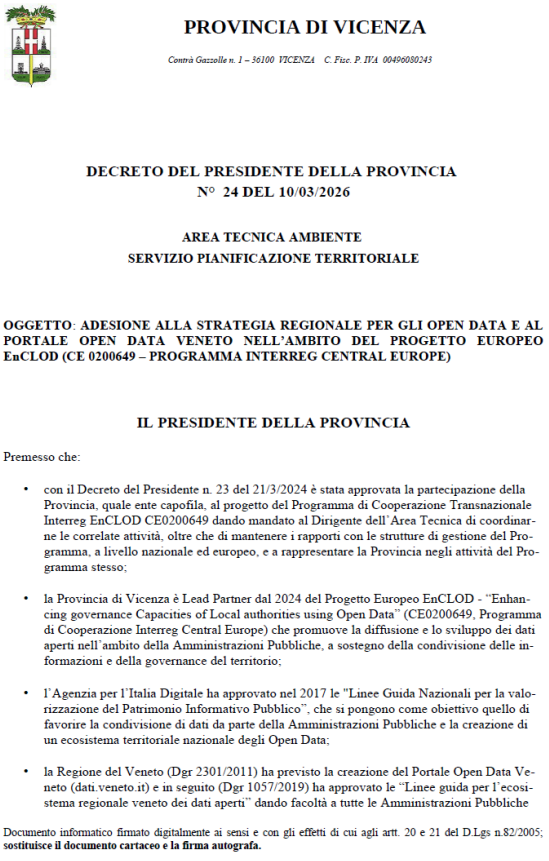
The Open Data Veneto web portal, collecting datasets from public authorities in the Veneto Region

In another domain, the public procurement activities of Province of Vicenza (LP), for supply and installation of the weather stations, showed how the governance framework for standards and tendering of sensors networks is a field still in course of development: the public procurement procedure, with a "Data as service" approach, incurred in a delay that made necessary about a year to deploy the weather stations, using all the time planned in the Application Form. A first opening of the tender went unanswered, because the high number of sensors were not considered acceptable by contractors for the proposed budget. Nonetheless, after devising a new proposal for the sensor network, co-designing it with a provider, the public procurement procedure could choose the provider offering the more favourable economic and technical offer (MTX srl). The "Data as service" has proved eventually an effective approach, but the supply and design of environmental sensors is still an underdeveloped topic in Italy and this condition, beside budget and administrative constraints, weighted on the implementation of the activities.

1.1.2. Future goals after the Pilot Action

All in all, Project EnCLOD Pilot Action has put the Province of Vicenza on a path for expanding the usage of Open Data and IoT sensors to support governance decisions, involving a larger number of stakeholders to build a local data ecosystem and the citizens to expand the creative use of data. A series of measures have been adopted during the activities of Project EnCLOD to define the future developments of Open Data by Province of Vicenza (LP), that shall find implementation in the future years.

In March 2026 a Decree of the President of the Province of Vicenza (Decree n.24, 10/03/2026) acknowledged the work carried out by EnCLOD for promoting the use of Open Data and the *Action Plans for OD and IoT usage for territorial governance* draft by the project. This official act shows the support to the Open Data principle promoted by the project in treating data gathered during the institutional activities, and the commitment to make a larger number of datasets available to both the public and the decision makers. With this act the Province has also entered the Open Data Veneto regional portal and will from now on upload datasets to the public platform regularly (beside EnCLOD data). The goal in this sense is to publish a wider range of information, through the work of the Department dedicated to Information Systems and Services, coming from such activities of the Province as demographic statistics, road management and environmental monitoring, improving the quantity and quality of data offered by the public administration.



PROVINCIA DI VICENZA

Contrà Gazzolle n. 1 – 36100 VICENZA C. Fisc. P. IVA 00496080243

DECRETO DEL PRESIDENTE DELLA PROVINCIA
N° 24 DEL 10/03/2026

AREA TECNICA AMBIENTE
SERVIZIO PIANIFICAZIONE TERRITORIALE

OGGETTO: ADESIONE ALLA STRATEGIA REGIONALE PER GLI OPEN DATA E AL PORTALE OPEN DATA VENETO NELL'AMBITO DEL PROGETTO EUROPEO EnCLOD (CE 0200649 – PROGRAMMA INTERREG CENTRAL EUROPE)

IL PRESIDENTE DELLA PROVINCIA

Premesso che:

- con il Decreto del Presidente n. 23 del 21/3/2024 è stata approvata la partecipazione della Provincia, quale ente capofila, al progetto del Programma di Cooperazione Transnazionale Interreg EnCLOD CE0200649 dando mandato al Dirigente dell'Area Tecnica di coordinarne le correlate attività, oltre che di mantenere i rapporti con le strutture di gestione del Programma, a livello nazionale ed europeo, e a rappresentare la Provincia negli attività del Programma stesso;
- la Provincia di Vicenza è Lead Partner dal 2024 del Progetto Europeo EnCLOD - "Enhancing governance Capacities of Local authorities using Open Data" (CE0200649, Programma di Cooperazione Interreg Central Europe) che promuove la diffusione e lo sviluppo dei dati aperti nell'ambito della Amministrazioni Pubbliche, a sostegno della condivisione delle informazioni e della governance del territorio;
- l'Agenzia per l'Italia Digitale ha approvato nel 2017 le "Linee Guida Nazionali per la valorizzazione del Patrimonio Informativo Pubblico", che si pongono come obiettivo quello di favorire la condivisione di dati da parte della Amministrazioni Pubbliche e la creazione di un ecosistema territoriale nazionale degli Open Data;
- la Regione del Veneto (Dgr 2301/2011) ha previsto la creazione del Portale Open Data Veneto (dati.veneto.it) e in seguito (Dgr 1057/2019) ha approvato le "Linee guida per l'ecosistema regionale veneto dei dati aperti" dando facoltà a tutte le Amministrazioni Pubbliche

Documento informatico firmato digitalmente ai sensi e con gli effetti di cui agli artt. 20 e 21 del D.Lgs n.82/2005; **sostituisce il documento cartaceo e la firma autografa.**

The Pilot Action, moreover, has opened the way to an active use of territorial sensors to support informed governance decisions, providing an example within the Province of how the holistic use of data (coming from both existing sources and newly deployed networks) can offer key information to support such administration activities as road management. The regular involvement of important stakeholders as the road management company (Vi.abilità srl) and the regional environmental agency (ARPAV) has shown the potentiality for building a data ecosystem which brings together datasets from different sources to help the decision makers and, through the Open Data approach, provides wider range of information to the SMEs and the public audience.

In the same direction goes the hackathon to be realised during June 2026, which is promoting the involvement of the local SMEs of the IT sector and of the university students. The event will be organized in a venue of the University of Vicenza with the support of the "Digital Innovation Hub Vicenza", a private company which is part of the local Confederation of Arts and Crafts. The objective is to reach the local IT ecosystem, first to build a local network of stakeholders interested in the use of Open data, and second to develop new concepts for the use of the Open Data collected and analysed by Project EnCLOD to support in new forms territorial governance and public awareness.

Potential developments for the Open Data approach by Province of Vicenza (LP) include the renovation of its institutional website and in the future of the Geoportal providing data from the planning, statistics and other departments to the public. The Geoportal provides at the moment only static data, adopting the technology in use when it was created: an upgrade to dynamic data and the expansion to present data coming from other territorial sources (Vi.abilità, ARPAV) can reach the goal of creating a territorial repository, based on the OD principle, to offer a knowledge framework both for the productive ecosystem and the public, potentially positioning itself as data hub for the territory administered by the Province.

Although the diffusion of Open Data in the area overseen by the Province of Vicenza is still limited, the Project EnCLOD pilot action has given a boost to its development in the next years, providing an example of what can be achieved through its use for territorial governance and bringing it to the attention of public managers and the decision makers. Further advancements will be necessary, both in the technologies used for managing datasets and in the range of public reached by open data, to achieve the next level of Open Data development in this territory, following the impulse that Project EnCLOd has given.

1.1.3. Key stakeholders

During its activities, Project EnCLOD has clearly identified and successfully engaged with the pilot action a set of key stakeholders, essential for the development of Open Data in the territory managed by Province of Vicenza (LP). These stakeholders, mentioned above, can be described and expanded as follows.

- *The Regional Environmental Agency (ARPAV*) regularly collects a relevant data pool with regard to climate, environment (waste, etc.) and pollution (air, water, etc.), carrying out its mandate efficiently. Yet these data are made available to the public through a number of different channels, web portals and geographic systems, that not always are clearly organized and use the latest technologies, reducing their impact.

- *The road management company of the Province of Vicenza (Vi.abilità srl)* oversees a complex mobility network that amounts to more than 1,000 kilometres and provides the transport framework for this territory. The collection of data regarding traffic, weather and road conditions is in their interest but presently only partially developed: the project of a 'control room' and an extended sensing network are being developed.

- *The Universities (IUAV University of Venice (PP2) and Vicenza University)* can offer an important scientific and technical support for the diffusion and use of Open Data, which has been tapped by Project EncLOD. This potential is presently only partially exploited, both in terms of scientific competencies and of the students' involvement, and offers room for further improvement in the future.

- The *Digital Innovation Hub Vicenza* is a small private company, part of the local Confederation of Arts and Crafts, which promotes the diffusion of IT tools at the service of SMEs. Their experience in organizing hackathons in this territory (5 events from 2018 and 2023) represent and an important resource for the enhancement of Open Data in this territory.

Overall, these key stakeholders provide the basis for giving origin to an efficient open data ecosystem in the territory administered by Province of Vicenza (LP), publishing and managing datasets of public interest in different fields. Project EnCLOD has given an example through its Pilot Action of how they can interact with each other, bringing to fruition this potential which can in the future reach important achievements.



E. City Open Data strategy inputs - technical level

1.1.4. Sensor placement/deployment

Sensor choice (type and performance), aligned with the available pilot action budget, has been a major first challenge in EnCLOD's pilot action for the Province of Vicenza. IUAV University of Venice (PP2) has been committed from the start, in tight cooperation with Province of Vicenza (LP), to effectively choose the best available option for the pilot action's purposes. The choice has been carried out through a process involving on the one side desk-based research on the available products; on the other side through ad-hoc, multiple consultations rounds with potential providers, with the road network manager (*Vi.Abilità)* and with ARPAV (the Environmental Agency of the Veneto Region) as a key stakeholder with major expertise in sensor network deployment, management, and data transmission and publication.

Once the sensor availability had been settled out, IUAV University of Venice (PP2) and Province of Vicenza (LP) put effort into the task of sensor placement. This has been determined through intersecting several aspects:

- Project (Pilot Action) requirements: the pilot action's objectives guided sensor placement, as data needed to be collected in iciness-risk areas, without environmental disturbances such as stronger winds or more solar exposure than average, to avoid over/underestimation of risk conditions;
- Road network characteristics: the roads on which sensor had to be located needed to be under Provincial administration (rather than municipal, national, or private), to be located within the planned area for winter services (i.e., road salting and snow prevention), and to be connected to the electric grid, crucial to power the sensor, as well as to the mobile phone network, crucial for sensor data transmission; finally, physical assets to safely install the sensors, such as traffic sign poles, public walls, etc., had to be present;
- Non-redundancy with ARPAV sensor networks: given the budget constraints, an effort was made through GIS-based analysis based on altitudes, terrain characteristics, and other factors to ensure that the EnCLOD sensors would provide additional relevant data compared to nearby weather sensors already in operation through ARPAV; the EnCLOD network should provide comparable while distinctive data;
- Relevance of the specific location: in order to maximise data relevance, a granular analysis (GIS-based, supported by manual elaboration through satellite views, Google Street View tools, and others) was conducted to identify the specific location among the selected provincial roads.

Combined, the process led to identifying three provincial roads which (SP 349, SP 350, SP46), thanks to their characteristics, were suitable for sensor installation. These share the fact that they start in the Padana Plain and climb towards the hills and pre-Alps of the Vicenza Province, thus crossing peri-urban, suburban, countryside, hill and mountain landscapes. All three are fully within the road salting area and have high number of salting interventions reported, at least in their mountainous sections. These roads have been the object of granular analysis, aimed at finding the best specific location for the sensors. The analysis encompassed all constraints highlighted above and included, moreover:

- Road accident analysis, filtered by accident reason (icy road, wet road, …), affected users (cars, HDVs, motorbikes, bikes, pedestrians), and injuries/fatalities;
- Contour lines;
- Shading analysis at the most accurate possible level (Corine Land Cover, 10x10 m.), including solar and vegetational factors;
- Climate/weather data analysis.

Overall, sensors have been placed following project and technical requirements as well as a scientific approach to ensure high-quality data collection, mutual benefit and validation of ARPAV data, and incremental benefits overall from the subsequent collection and sharing of data.

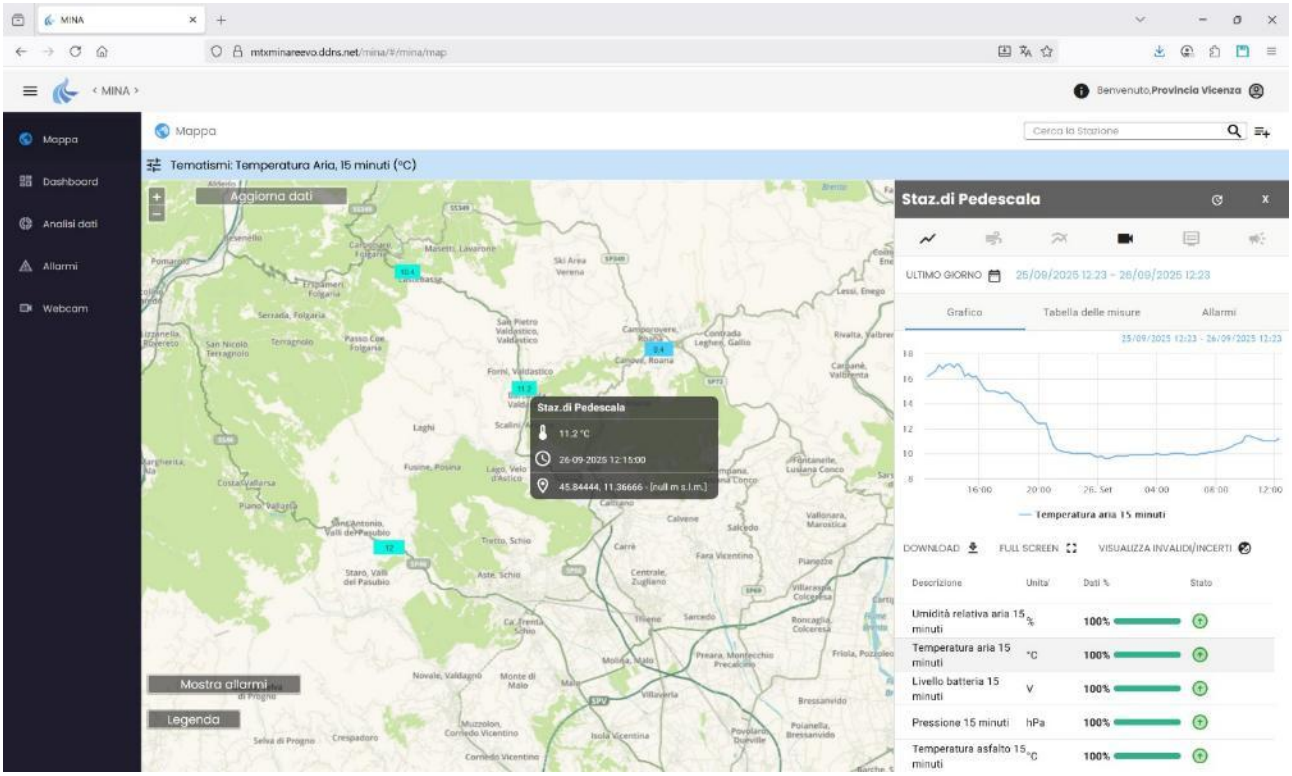
IUAV University of Venice (PP2) and Province of Vicenza (LP), including its road management subsidiary, have learned interesting and useful lessons from the sensor choice and placement processes. First, a solid know-how on sensor requirements, specifications, and deployment needs has been developed and consolidated, the importance of which goes beyond the pilot action and the project as a whole. Then, a scientific approach to estimate the validity of sensor placement choice, in an incremental perspective that values the existing resources, has been initiated and forms the basis for the tool development, a major output of EnCLOD's contribution in LP's area. Finally, to the extent of our knowledge, this is the first time in the Province of Vicenza that different authorities dealing with territorial data at various institutional levels (municipal, provincial regional; road data, weather and climate data, traffic and public transport data, etc), a regional University, and the Public Administration work together to maximize data availability and potentiality building synergies among different domains: this is an important governance-related and policy output that will last long as indirect inheritance of project EnCLOD.

The process of deploying and connecting the weather stations network, after the public procurement procedure, was carried out without encountering technical or administrative problems during the month of September 2025: both the authorization process and the connection to the data transmission network went smoothly, thanks to the cooperation of the supervising authorities and the choice of the right technology. The involvement of the road managing company (Vi.abilità srl) in the development of the pilot action from the start allowed to obtain easily the necessary authorizations for the sensor deployment works, and no further permissions were required because Province of Vicenza (LP) is the responsible body for the road network. The cooperation between public authorities proved efficient in this case, with the managing company supporting the whole process, and showed concretely the benefits of a supportive ecosystem.

The localization of the sensor network in a mountain territory posed at first some concerns regarding connectivity and data transmission for the meteorological stations. On advice of the data provider (MTX srl) the NarrowBand-IoT connectivity model was chosen, a low-power wide-area network (LPWAN) suitable for extended coverage of areas with high-density mobile connection. After a survey on the ground preliminary to the deployment, data transmission was designed and implemented through NarrowBand-IoT SIM Cards linked to the datalogger of the 4 weather stations. This technological solution resulted effective and the data transmission, with a 15-minute period, has never met any interruption. This shows that sensor deployment in a mountain or otherwise remote area can be achieved effectively by correctly evaluating the connectivity networks existing in the involved area.

1.1.5. Sensor data

For storing, managing and analysing the data collected from the weather stations, the sensor subcontractor (MTX srl) provided with a "Data as service" approach an online application, called MINA, developed with open-source technologies, which is made available through the cloud to ensure availability, accessibility and security of all data. The MINA database stores the measurements sent by the monitoring stations: air and road surface temperature, relative air humidity, air pressure, rainfall and snowfall, plus a webcam picture, with a 15 min period. All data is accessible through the web interface: the system offers a dashboard (see image below) with different functionalities for consulting and downloading the data at any time, analysing meteorological data (graphs, thresholds, etc.), as well as monitoring the activities of the sensor networks (operating status, etc.).



The dashboard in the web application MINA for viewing and downloading the data of the weather stations

The data management and publication process adopting the "Data as service" approach was a positive experience, relieving Province of Vicenza (LP) of technical and logistic activities as well as of the acquisition of equipment or infrastructures, while providing a reliable data flow. The data have been collected regularly since September 2025, no interruptions were registered, even under conditions of snowfall or very low temperature, and they are being used during the hackathon and for the tool developed by IUAV University of Venice (PP2). If an issue can be observed, it regards the integration of other features in the "Data as service" contracting, for publishing and conveying the data to the public, and was limited by the budget constraint and the tendering procedure. The final outcome was overall an effective data provision and Pilot Action implementation.

An important aspect, concerning the efficiency of datasets gathered in the Pilot Action, is their integration with existing sources, specifically the Regional Environmental Agency (ARPAV) with its network of meteorological stations. The "holistic" approach to territorial data for supporting the Pilot Action was adopted from the design phase, when the sites for the new weather stations were identified with the aim of integrating with the existing ones of ARPAV along the road network. The use of existing meteorological data together with new ones from EnCLOD sensors has been fundamental for developing the tool supporting the territorial governance of Province of Vicenza (LP). The importance of joining all the sources for territorial datasets is a lesson well represented by the Pilot Action of Vicenza, particularly in consideration of the budget constraints and its wide territory.

A similar direction was followed in gathering the datasets for the hackathon of June 2026. The topics identified while planning the event were transport, climate and environment, along with the background offered by territorial governance. Therefore a wide range of sources have been included in the data repository offered to the participant to the hackathon, including the Environmental Agency and the road management company (Vi.abilità srl) directly involved in the project, but also Copernicus EU initiative and OpenStreetMap for wide-range territorial information. During the technical meetings with expert stakeholders emerged the interest of cross-referencing datasets from different sources and on different

topics for developing new tools able to offer stimulating data to the citizens (for example matching environmental and meteorological data, or transport networks). The "holistic approach" to build a digital image of the territory proved once again an effective approach.

The final objective of data collection and processing by Pilot Action is a tool that is developed by IUAV University of Venice (PP2). This tool enables comparing the efficiency of the in-place road salting system with a *quasi*-optimal solution provided by the algorithm. More in detail, by elaborating the continuous data flow from the EnCLOD and ARPAV weather stations through a dedicated algorithm, the tool estimates for each winter day the actual need for salting interventions, the number of required treatments, and the corresponding quantities of salt, thus providing an operational benchmark for planning and ex post verification of winter road maintenance activities in the provincial network. Beyond supporting the efficiency and transparency of public procurement and subcontractor performance, the tool also creates a shared quantitative reference framework that can be progressively refined through threshold calibration, integration of additional data sources, and validation against observed field conditions. This experience has brought also methodological recommendations for designing and deploying sensor networks in complex territorial contexts, for integrating newly collected data with existing institutional datasets, and for structuring a collaborative workflow among road managers, environmental agencies, universities and IT providers, so that technical choices (sensor typology, siting, connectivity, data model) and governance choices (data-as-a-service contracts, open data publication, internal procedures) are co-developed from the outset and can be reused as a replicable approach in other territories.

1.1.6. Microzoning

Due to the different conditions compared to other Pilot Areas, no microzoning and related data processing was implemented by Province of Vicenza (LP): this occurred first because of the different territorial scale of the area tackled by the Pilot Action, which is a region-wide area rather than a city-wide one, and also because of inconsistencies emerging in the possible zoning solutions examined during the activities.

In fact, being the pilot area of Province of Vicenza (LP) wider (about 2.700 Km^2), a possible microzoning of this region would be based on the Municipalities in which the territory is institutionally divided: yet the Municipalities in the area are a total of 112, a high number, which could reduce the benefit of the zoning system for data grouping or for communication to the public. Other solutions were considered during the technical meetings, based on the zoning identified by territorial planning or by policy documents, but these other approaches would be in any case in conflict with the division between Municipalities that involve most of the existing datasets from public authorities and private subjects. All the existing statistics (demographics, etc.) as well as environmental and traffic datasets are related to the municipal areas, and the merging of such quantities of data (considering also dynamic ones) would require a massive amount of work, for what could be an overall arbitrary result.



The zoning of the territory overseen by Province of Vicenza LP considering the existing 112 Municipalities

Taking in consideration these difficulties and the substantial differences between the pilot area of Province of Vicenza (LP) and other ones, after conferring with the partners, microzoning was not implemented for the Pilot Action. The conclusion that microzoning is less effective for region-wide areas compared to cities is in any case a lesson that should be taken with caution, to be confirmed by other experiences.

F. Data-driven governance: Pilot first findings

The first application of the model developed by Iuav University of Venice has provided initial evidence of how meteorological and road-condition data can support more transparent and informed governance of winter road maintenance. At the current stage, the findings must be considered preliminary, as the model has not yet completed its final calibration and validation using the specific Open Data collected by the EnCLOD sensor network during winter 2025/2026. Nevertheless, the analyses already carried out provide relevant indications regarding both the potential of the tool and the factors that influence the reliability of its results.

The model analyses meteorological conditions through a sequence of thresholds relating to air temperature, road-surface temperature, relative humidity and precipitation. It then estimates, for each monitoring location and road section, the days on which salting may have been required, the potential number of interventions and the indicative quantity of salt to be used. The model was initially tested on data from winter 2023/2024 and subsequently recalibrated and refined using the winter 2024/2025 dataset.

The preliminary comparison between the interventions estimated by the model and the salting activities actually recorded produced different results across the three provincial road sections examined: SP46 del Pasubio, SP350 Valdastico and SP349 del Costo. For two of the three roads, the estimated range of necessary interventions was broadly consistent with the maintenance practices implemented. This initial correspondence suggests that the model can already provide a reasonably reliable overview of the existing operational approach and can contribute to defining a common quantitative reference for assessing winter maintenance activities. However, more significant discrepancies emerged for the SP349, indicating that the model's performance is not uniform across all territorial contexts.

These differences represent an important finding from a governance perspective. They suggest that the availability of meteorological data alone is not sufficient unless the monitoring stations are adequately located and their measurements are representative of the specific road sections under assessment. The Province of Vicenza's mountain road network is characterised by considerable variations in altitude, exposure, slope, shading and local microclimatic conditions, which can change significantly over short distances. The preliminary results therefore indicate that the model's accuracy tends to decrease as the morphological and infrastructural complexity of the road corridor increases. In particular, data from a station located at some distance from the road, or under different environmental conditions, may not fully reflect the actual state of the road surface.

This evidence confirms the added value of the EnCLOD sensor network, which was specifically designed to collect localised data along selected mountain roads. The next development phase will therefore test and refine the model using the Open Data collected by the EnCLOD stations during winter 2025/2026 and compare its estimates with the records of the interventions effectively performed by Vi.abilità and its subcontractors.

Although the final results are still being elaborated, the work carried out demonstrates the potential of a data-driven approach to support the Province of Vicenza and Vi.abilità in the ex-post assessment of winter road maintenance. Rather than replacing the technical experience of road managers and local operators, the model can provide a common evidence base against which interventions can be reviewed and discussed.

It may help identify cases in which the number of treatments appears consistent with meteorological conditions, as well as situations requiring further investigation due to possible under-treatment, over-treatment or insufficiently representative monitoring data.

Another potential application of the Open Data generated during the Pilot Action, together with the model developed by Iuav University of Venice, concerns the management of disputes, compensation claims and insurance litigation related to winter road conditions. During the Pilot implementation, Vi.abilità highlighted that such cases are not uncommon. In these situations, the availability of historical data describing the actual conditions of the specific road section involved—either through locally installed sensors or through a high-resolution model capable of reconstructing local meteorological conditions with greater spatial detail than conventional weather forecasting systems—could provide valuable objective evidence to clarify circumstances that might otherwise remain difficult to assess.

More generally, both representatives of the Province of Vicenza and managers of Vi.abilità agreed that the ex-post use of the model appears more valuable and operationally sustainable than its direct predictive use as a decision-support tool for determining whether salting operations should be carried out. This is primarily due to issues of legal responsibility, as well as to the way multi-year winter-maintenance contracts are currently structured with service providers. Winter road maintenance has a direct impact on public safety, making it essential that decision-making procedures and responsibilities remain clear and unambiguous, so as to avoid misunderstandings or liability issues that could ultimately increase risks for road users.

At the same time, the availability of a model that can be used to verify decisions after they have been taken represents a valuable resource for continuous organisational learning (also for externa providers), for quality assurance and for the evaluation of contractors' performance. In the future, the model could also support the review of operational procedures - for example, suggesting a different prioritisation of road sections for salting under ice-risk conditions, or for refining the subdivision of road networks into shorter segments characterised by more homogeneous climatic conditions - as well as the preparation of future winter-maintenance contracts. From a predictive and operational decision-support perspective, the Pilot Action suggests that a tool of this kind could usefully complement the information sources already employed by operators when deciding whether to undertake salting interventions. However, any direct operational use would require careful assessment and appropriate governance, given the important legal and ethical implications that such decision-support systems may introduce.

G. Summary of lessons learned and recommendations

ID	Typology	Brief description	Final recommendation	For whom
VI1	G	Developing open datasets in response to the specific requests coming from the public authorities responsible for territorial governance can promote the diffusion and adoption of data-driven solutions and of OD. Further uses for the open datasets will always be found by other actors.	Involving public authorities from the start in developing IoT networks and open data, responding to their specific requests, aiming at engaging the public sector	R/C
VI2	G	Public procurement in a market that in some countries is still not mature, (as the one of IoT sensors and data-as-service in Italy), can incur in delays and obstacles for the implementation of the activities. The definition of references for public procurement in this field can offer a support for further contracting,	Defining standards for tendering and procurement procedures (including references for data-as-service, time planning, etc.) can be a key element to support OD diffusion for public authorities	N/R
VI3	G	Co-design of the sensor network with an established tech company can be an important support to public administrations in the development of sensor networks and open datasets, to overcome the problems posed by public procurement, can be a key factor for its development by public bodies involved in territorial governance.	Adopting the support of an established tech company (or a scientific advisor) in the design and deployment of sensor networks, to integrate the competencies of public authorities	R/C
VI4	G	Beside the identification of best practices for Open Data development, the definition of a "reference scale" (as the "5 star scheme") can be useful to assess the state of OD diffusion in a city/region, positioning the area in the big picture of the global OD development, measuring its efforts and appraising its advancements.	Identifying a 'reference scale' for OD advancement in a city (either the "5-star" or another one") can be important to position it in the global picture	N/R
VI5	G	The creation of an "Open Data ecosystem" and the adoption of a "holistic approach" require the active involvement of many stakeholders of the public and private sector in an area, to promote data interoperability, exchange and common usage: these are all important steps for the OD diffusion	Engaging actively local and regional stakeholders in the data provision and usage field, to create a Open Data ecosystem, is important for the OD development	R/C

VI6	T	The placement of IoT sensor networks and their deployment in challenging areas require the analysis of data from different fields, examining the context (morphology, climate/weather, traffic, etc), the sensor management (power connection, budget constraints, etc.) as well as the required output, to achieve the best data sensing results.	Adopting a multi-disciplinary approach in designing the IoT sensor network placement, taking in consideration data referring to context/ environment, to sensor management, along with the expected output	R/C
VI7	T	The "Data as service" approach confirmed its efficacy to support public authorities in deploying IoT networks and collecting Open Data, providing a "full package" to the Province. The inclusion of additional services in the sub-contacting (for OD diffusion, assistance, data interoperability, etc.) could extend further its benefits.	Adopting the "Data as service" approach by public authorities, including when possible additional support (for data interoperability, technical assistance, etc.)	N/R/C
VI8	T	Deploying a sensor network in a mountain or otherwise remote area can be achieved effectively through the sensible evaluation of existing data transmission networks and feasible options: for example, considering the current diffusion of mobile coverage, or the low costs of integrating existing gates, to provide a solid data broadcast.	Not getting scared by deployment of sensor networks in remote areas, considering all available data transmission solutions (as mobile coverage, or gates integration) for a solid communication	R/C
VI9	T	The integration of data from different sources is a key step toward providing decision makers in their strategic choices for territorial governance. Solving problems concerning data interoperability, holistic data management, etc., is a fundamental preliminary stage to build a "digital twin" able to support data-driven decisions.	Integrating different data sources from the design phase of sensor networks and Open Data usage, to provide a multi-disciplinary image of the territorial system	
VI10	T	A cost-benefit analysis should be done while designing an IoT sensor network, assessing the use of high-profile sensors for providing high-resolution data, alongside low-profile ones to allow a greater number of sensing stations: the objective should be finding the right balance in response to the request for data coming from public authorities.	Evaluating carefully the choice of high-quality sensors and/or cheaper ones (within the budget constraints) to provide the expected data for their final purpose	R/C
VI11	T	The usage of IoT sensor networks and integrated data analysis can provide a substantial support to decision-making for territorial governance, offering operational benchmarks and verification to such programming activities as road management, climate change adaptation, etc. Such tools can create a shared territorial data ecosystem able to support the efficiency and transparency of public authorities.	Developing sensor networks and IT tools to promote data-driven decisions in territorial governance, encompassing data from different sources for the best results.	R/C