ADVANCED ICT TECHNOLOGIES FOR COSTS OPTIMIZATION AND INNOVATION OF WINTER MAINTENANCE PROCESSES IN THE PERSPECTIVE OF SMART-CITY

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ABSTRACT

Recent worldwide events show that winter is becoming a critical seasons for the citizens. It is in fact quite common that sub-zero temperatures as well as heavy snow create major impact on mobility and road/highway management. In this framework, after the last AIPCR in Quebec, the European commission funded the GOLDEN-ICE project that has represented a successful story of cooperation between research and industries with significant results which started an innovation of process, products and defined a roadmap to enable new enhanced services.
Anyway the necessity to maintain the roads open and safe is still a continuously growing concern and cost for the smart-cities of the future. Nowadays the most common solutions to guarantee such conditions during winter time are still salt spreaders and snow ploughs. However, massive and extended use of salt can have remarkable consequences on the environment itself and furthermore, from an economic point of view, salt spreading is a critical problem. In order to keep up with these needs and to assure an adequate security level for citizens, it becomes increasingly important to improve technology applied to winter maintenance process. The goal of innovation consists in the reduction of costs and environmental impact, preserving a high level of services quality and roads safety. From the economic side, an optimized spreading allows significant costs reductions deriving from a precise and reduced usage of salt.
The roadmap presented in this paper aims to go beyond the state of the art, leveraging on advanced technology paradigms such as Cloud-Computing and IoT. On top of these pillars, the idea is to develop an innovative platform with new On Board Units able to control the equipment in connection with a centralized Decision Support System, which optimize the spreading and the whole winter maintenance process, according to the analysis of aggregated data coming from multiple sources like sensors and precise maps.
This scenario includes the definition of innovative sensors able to monitor the road surface conditions. Measures will be aggregated at centralized level with additional open data such as weather forecasting and thermal maps obtained relying on sensors' information history.

Moreover the spreading algorithm is based on road morphology obtained by means of ADAS maps and advanced GPS/Galileo/GLONASS satellite receivers.
The paper will detail the innovation roadmap describing the results obtained by the field test campaigns in terms of salt usage optimization and related saving of costs and impact on pollution.

1. INTRODUCTION

As every city mayor knows, timely salt-spreading and snow removal can be a critical factor of success (or failure) for her political career. Despite this obvious consideration, the challenge of road-maintenance through long winter seasons can be very tough, especially in times of shrinking municipal budgets. On one hand, keeping a redundant apparatus of workers and equipment, including thousand tons of road salt, in winter maintenance stand-by mode can be very expensive. On the other hand, snowfalls often come with short notice, and if a community finds itself unprepared it can be very hard to find last-minute remedies. When the streets get covered by snow, a city that hasn't enough salt stocks will learn how hard, and expensive, can be to obtain new ones from its neighbours. This city is surely not a Smart City.
But what is then a "Smart City"? The term is not new, and not an easy one to characterize. There is no universally accepted definition, but an authentic multitude of definitions, not always consistent, which highlight different aspects of a problem with many facets[*]. Despite this proliferation of interpretations, the essence of the Smart City issue is for us relatively simple: since we are in the presence of a strong concentration of the human population in urban areas (a growing phenomenon in Europe and even more so in emerging areas of the world)[†], cities are the place of the world where the bulk of the consumption of energy and non-renewable resources is concentrated. This implies that the product- and process- innovations which must guide us towards a new model of sustainable development should be experimented first of all within cities, where they may cause more benefits. A Smart City will be therefore a city that is able to activate an integrated and interdisciplinary approach to its planning and management, with the aim of reaching, over time, the target of triple sustainability, i.e. social, economic and environmental sustainability at the same time.
The pursuit of the sustainable development[‡] model has prompted the European Commission to dedicate to Smart Cities one of the most important initiatives of The European Strategic Energy Technology Plan, better known as SET-Plan [1], and subsequently to announce the creation of a European Innovation Partnership dedicated to Smart Cities and Communities (SCC) [2]. The latter is designed to accelerate the creation and widespread adoption of innovative solutions that are at the crossroads of three strategic pillars of urban evolution: Energy, Information and Communication Technologies (ICT) and Mobility. The EU had in fact already in 2011 developed a shared vision of the role of cities in sustainable urban and territorial development, indicating that "European cities should be places of advanced social progress and environmental regeneration, as well as places of attraction and engines of economic growth based on a holistic integrated

[*] For a critical review of the many different shades of the Smart City concept, and of the analogs Digital City, Connected City, Intelligent City, etc. see for example [5]

[†] 68% of the EU population now lives in urban areas, and this percentage is growing, albeit slower than some years ago [6]. According to the UN [7] by 2030 the urban population worldwide will grow from 3.3 billion to almost 5 billion.

[‡] Meaning one that should be able to combine greater energy efficiency and lower consumption of non-renewable resources with greater satisfaction of the people.

approach in which all aspects of sustainability are taken into account." The SCC should make a key contribution to this broader European political agenda.
The GOLDEN-ICE and GOLDEN-INFRA projects here described fit very well in this framework and are therefore by all means Smart City Projects. They feature an holistic integrated approach at the crossroads of Energy, ICT and Mobility, that helps to reach all three sides of the triple sustainability triangle. In social terms, the projects provide safer roads and a better level of service for the community. In economic terms, they allow direct savings due to a significant reduction (up to 20%) of the quantity of salt to stock and use, and of the personnel on board the street plows, and indirect savings in terms of less fuel used thanks to the optimization of the routes and less accidents to deal with. Last but not least, in environmental terms, the projects have a significant positive impact, because it is well known that road salts enter the environment through losses at salt storage and snow disposal sites and through runoff and splash from roadways. Research has revealed that high releases of road salts are having an adverse effect on freshwater ecosystems, soil, vegetation and wildlife [3] and that road salt used throughout the winter is making lakes and rivers saltier, which could affect aquatic life and drinking water [4].

2. ROADMAP

As well known, until few years ago the winter maintenance service was generally carried on with trucks equipped with heavy mechanical tools manually managed by drivers, without any kind of remote feedback. Therefore the efficiency and the quality of the interventions were strictly dependent on human decisions and professionalism. It was clear that the winter maintenance service should be improved through the integration of ICT and navigation technologies. With this intention, an ad-hoc Consortium was created, composed by an international leader in the winter maintenance service distribution, an electronic system integrator and a Research centre on Information and Communication Technologies (ICT) to pool their know-how in order to enhance the technology platform.

The evolution process of the winter maintenance service as set up by the Consortium followed a pre-established road map, that foresees a number of intermediate steps from the state of the art to the best technology solution.

Figure 1 sketches the entire innovation roadmap, from the analysis of the state of the art to the final solution.

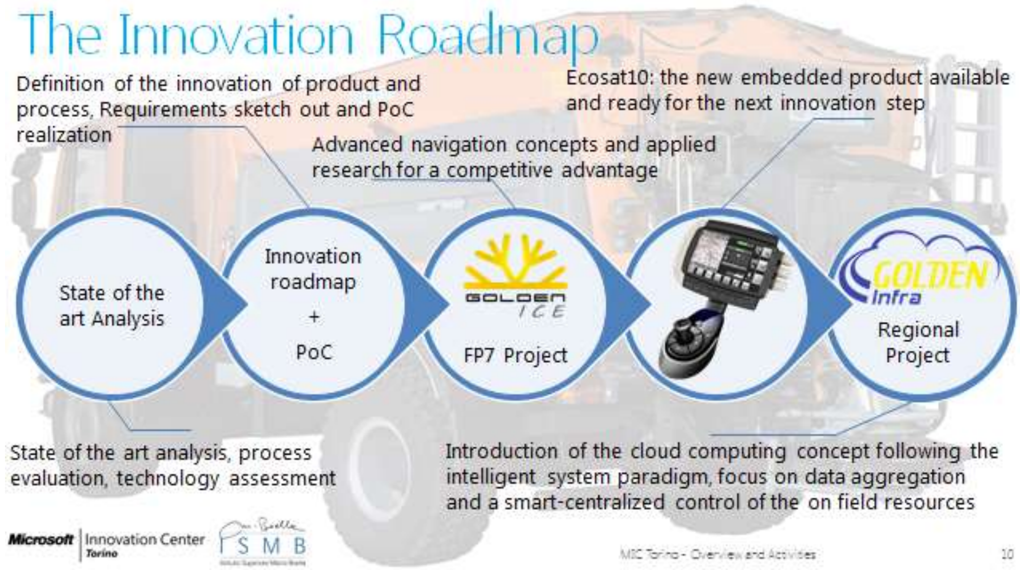

Figure 1 – Innovation roadmap foreseen for the winter maintenance service

The first step aimed at giving intelligence to the truck equipment. It was necessary to realize an internet-enabled telematic device capable of controlling the spreading actions. Such activity was successfully carried on within the GOLDEN-ICE project described in Section 2.1. At the end of the project, the salt spreader was transformed from a simple mechanic instrument into a logical node of the winter maintenance service. The ICT equipment called On Board Unit (OBU) permits to automate the procedures of the interventions. Such approach provides important benefits for both the service provider and the community:

- Service optimization;
- Simpler service procedures;
- Cost reduction;
- Pollution reduction;
- Improved safety for spreader drivers.

The following step was focused on migration of the centralized system toward cloud computing technology, relying on the OBU communication facilities. in order to power up the high level services within the GOLDEN-INFRA framework. Such project aims at harmonizing a fleet of isolated OBUs into a more complex system exploiting the powerful features offered by cloud computing platforms and potentiality offered by OBUs data aggregation, in line with the Intelligent System (IS) paradigm. The GOLDEN-INFRA cloud platform leverages the introduction of new added value functionalities thanks to its own flexibility. It will deliver a Decision Support System (DSS) for the decision maker that permits to overlap advanced and innovative services relying on smart centralized control of the on-field resources.

2.1. GOLDEN-ICE

GOLDEN-ICE [8] was a European Framework Program 7 (FP7) project that represented the first concrete and successful step on the innovation process illustrated in the evolution roadmap.
Such project, that received Europe wide media attention, aimed at exploiting innovations in the field of winter services equipment, joining the most advanced ICT technologies with the modern mechanical equipment for salt spreading. The most relevant achievement of this activity was the On Board Unit (OBU), that is a Nav-COM smart device able to control via

CAN bus the spreading functions and to perform advanced functionalities. Figure 2 shows the hardware architecture (left) and final prototype (right) of the OBU device.

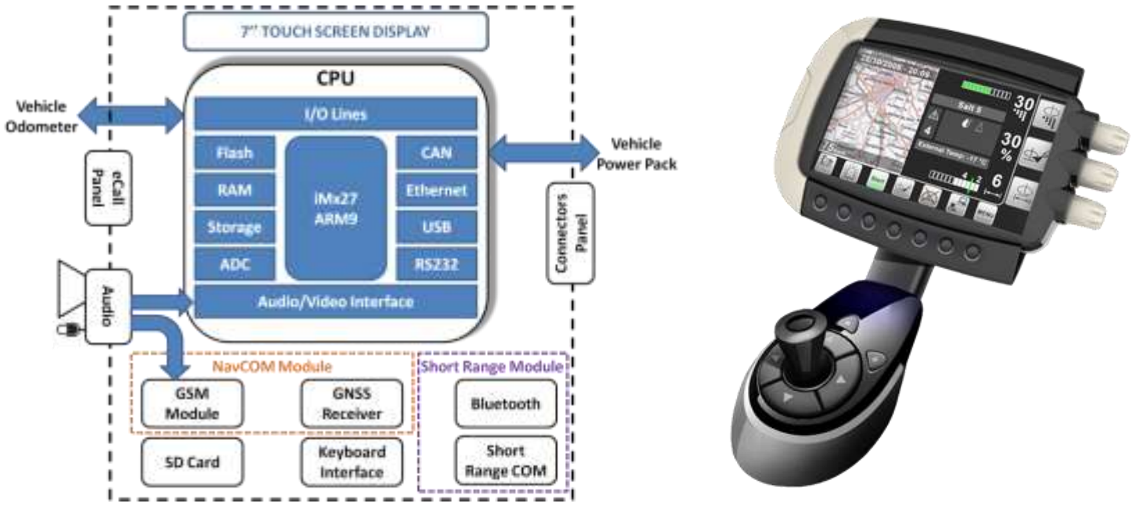

Figure 2 - GOLDEN-ICE OBU

The OBU software package, that is based on Microsoft Windows Compact Edition (Windows CE) [22] Operating System, provides an enhanced assistance to the driver, thanks to the user friendly Graphical User Interface (GUI) with integrated digital maps.
Such device is able to regulate the spreading parameters (e.g. amount of salt or solution, spreading width, etc.) and to give immediate feedback about the real truck behaviour and position.

The most relevant feature of the GOLDEN-ICE OBU is the automatic control of the salt spreading process. The OBU self-management capability goes in the direction of providing an intelligent platform capable to optimize the salt used according to the real safety requirements (road morphology, weather conditions, etc.). In this phase, this functionality is obtained with the reproduction of recorded sessions and is called Route Replay. The Route Replay represents the basis for the integration of advanced and completely automatic decision algorithms that will be investigated in the follow up activities.
The automatic salt spreader control relies on precise, available and trustable GNSS positioning; therefore GOLDEN-ICE devoted a huge effort in the navigation field. Particularly interesting is the adoption of the Protection Level, that provides an upper bound to the positioning error. In the GOLDEN-ICE framework, an Augmentation Module was developed in order to easily integrate EGNOS facilities, including Protection Level, as explained in Section 3.3.

Thanks to its own GSM communication capabilities, the OBU is enabled to establish a logical link with the Operational Control Centre (OCC). Within the GOLDEN-ICE project, such connection was exploited to perform remote tracking and telemetry of the salt spreader activity. The OBU communication facilities represent the basis of the evolution toward the Intelligent System paradigm, that is the key point for the next step of the roadmap: GOLDEN-INFRA.

2.2. GOLDEN-INFRA

The evolution of the GOLDEN-ICE project is GOLDEN-INFRA. This project focuses on the high level winter maintenance service based on the combination of the OBU internet capabilities with a cloud computing platform, that permits real time information exchange for the provisioning of innovative winter maintenance services, in line with the Intelligent

System paradigm. The GOLDEN-INFRA cloud based system will provide a flexible and scalable platform enabling the remote control of the involved truck during missions, transforming the OBU into an enhanced remote actuator of the system service.

The core of the GOLDEN-ICE project is the cloud based Management Center (MC), that provides added value information (e.g. weather forecasts) to the fleet of the OBUs acting on the field. Through this data, the MC modifies in real time the spreading activity effectively performed, allowing to further optimize salt consumption by means of a coordination of multiple trucks.

The GOLDEN-INFRA platform adopts the most relevant cloud computing paradigms, like Intelligent Device Management (IDM), and gives the possibility to integrate new services without changing the hardware equipment. Furthermore, the GOLDEN-INFRA system allows interaction with third party technology (e.g. weather forecast), via the cloud platform, in order to further improve the quality of the final service.

Further technical details about the GOLDEN-INFRA project are reported in Section 3.1.

2.3. Future Roadmap

The MC architecture proposed within the GOLDEN-INFRA project can be considered as a starting point for all future innovations of the platform in the winter maintenance services domain. Following current ICT trends, the system will be extended in several different directions in order to offer additional different features that will build up to create a highly automated Control Center and an extensive Decision Support System (DSS) for the winter maintenance operators.

The points of intervention will cover almost all the entities that form the current architecture. The OBUs operability will be enhanced by the introduction of a multi-constellation GNSS receiver and by the integration of IMUs (Inertial Measurement Units), which, in association with the adoption of the EDAS augmentation service, will increase the positioning precision. Furthermore, the data collected by the OBUs will be extended to provide additional information, e.g. road conditions, vehicle history for maintenance purposes and other significant information for the decision support process in the Big Data domain. At the OCC, the usage of additional and more precise geo-located data (e.g. Earth Observations) can be introduced into the existing DSS as the new primary source of complementary information, such as weather forecasts, snow information and road weather information. Secondary data sources will come from third party services, i.e. traffic information, road databases, Road Weather Information System (RWIS) and geo information. The GOLDEN-INFRA cloud infrastructure will also be extended to provide a better integration of the winter maintenance operations and new functionalities both for daily operations and for integration and analysis procedures.

All these fields of innovations will trace the roadmap for a continuous improvement of winter maintenance services and all the related operations and procedures.

3. TECHNOLOGY INNOVATION

3.1. Cloud IOT Paradigm: Intelligent System

As explained in Section 2.2, the GOLDEN-INFRA project fits into the innovation roadmap of the winter maintenance process and relies on the communication between the OBU deriving from the GOLDEN-ICE project and a Management Center (MC). Within the project, the OBUs are transformed in recognizable elements and acquire intelligence and the possibility to communicate. This feature allows to send data about the object itself and to access other aggregate information generated by other systems, in line with the Internet of Things (IoT) paradigm.

The IoT paradigm is part of the wider Intelligent System (IS) [9] concept, that is the Microsoft IoT declination including the notion of “Big Data”. An Intelligent System is composed by peripheral devices with network capabilities that can access to remote resources, establishing a bidirectional data channel. In this way, the system is able to provide information to the devices and to process data coming from them.

In the GOLDEN-INFRA project, the IS paradigm is implemented by many connected devices placed on the salt spreaders and a MC that is responsible for implementing decision-making strategies to provide commands and to manage the vehicles. The MC is able to integrate heterogeneous information coming from different sources, like historical salt spreading data and weather forecasts, in order to optimize the decision-making process.

The overall system architecture, depicted in Figure 3, is composed by the following elements:

- The salt spreader vehicles equipped with OBUs that implement the spreading features and the innovative services coordinated with the MC.
- The salt spreader MC, that manages the registered devices and processes the information coming from the devices and from additional services.
- The additional services, like the Augmentation Module, the Weather Forecast service and the eCall service.
- The highway services that give traffic information.

The MC is the core of the system and is developed as an enterprise software architecture in a cloud computing environment using the Platform as a Service (PaaS) facilities provided by Microsoft’s Windows Azure [21] technology, taking advantage of its flexible and scalable features.

Winter maintenance is a typical application where one can appreciate the advantages of using a flexible and elastic platform, where IT resources are used more intensively during a limited period of the year.

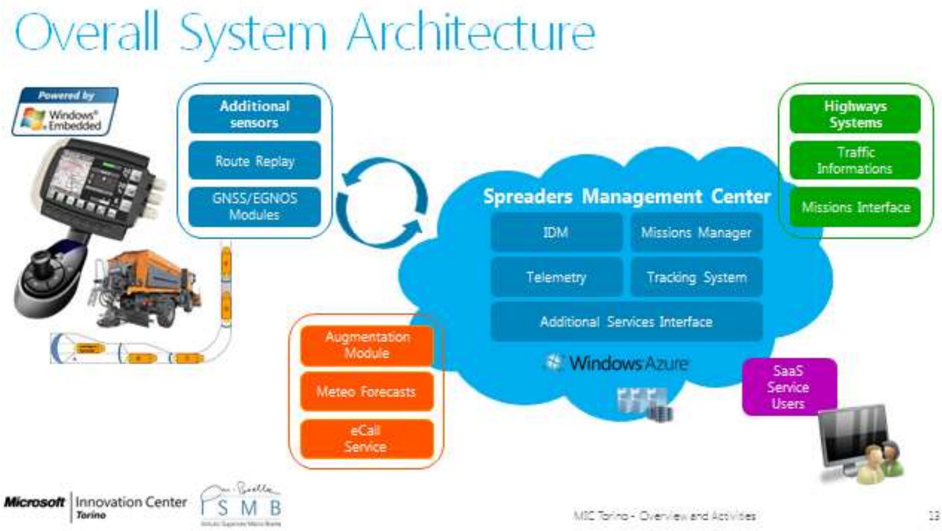

Figure 3 – GOLDEN-INFRA overall system architecture

The MC modules are listed in the following:

- **Intelligent Device Management (IDM)**: this module is responsible for managing OBUs diagnostic, that is the basis to provide an efficient remote assistance; moreover, it is in charge of providing software package upgrades in order to allow the OBUs to update themselves.
- **Telemetry**: this module controls the spreader parameters (e.g. speed, spreading width, etc.). The module collects and stores data about device operation, spread parameters and position of the vehicles, to create statistics and reports.
- **Mission Manager**: this module sends data to the OBU about the missions. These data are processed by the MC and cross-correlated with data coming from the additional services.
- **Tracking**: this module tracks the position of every vehicle of the fleet.
- **Additional Service Layer**: this module is dedicated to the communication with external services, that improve the quality of the winter maintenance service.

The GOLDEN-INFRA architecture integrates and communicates with additional services to get useful information for planning the missions:

- **Augmentation Module**: a service able to improve the positioning performance;
- **Weather Forecast**: a service that gathers information about current and expected weather conditions;
- **eCall**: an assistance service for the salt spreader vehicles.

The locally available highway services provide information to the MC about traffic flows, scheduled maintenance and unforeseen events.

3.2. Open Data and Big Data

As discussed in paragraph 3.1, the GOLDEN-INFRA project is compliant with the IS paradigm. An IS adds the capability to manage large amounts of data to an IoT infrastructure, where each element can communicate with others. Moreover, an IS can gain knowledge from this data and can manage the peripheral devices depending on the results of data mining. This pattern gives the possibility to adapt the working mode of a system to the boundary conditions. These large amounts of data are commonly called Big Data [10] and represent both a challenge and an opportunity. A challenge from the management point of view because traditional databases and software tools are not

equipped to handle these large datasets. An opportunity from the business point of view as companies can mine this flood of data to gain valuable insights to enhance business results and improve the services quality.
In the GOLDEN-INFRA project, data come from multiple sources, like movable sensors on board the salt spreader vehicles and fixed sensors positioned along the roads. The OBU is the gateway between the sensors and the actuators of the salt spreader and the MC, i.e. the DSS, able to define the spreading policy on the basis of data mining. The GOLDEN-INFRA system makes use of innovative sensors able to monitor the road surface. The DSS, that analyses this information, can decide to change the amount of salt that it is needed. This loop of information between the vehicles and the MC allows to optimize the consumption of salt, reducing costs and environmental damages at the same time.
The GOLDEN-INFRA project makes also use of third party services, such as the weather forecasting or highway services. These services provide additional data that everyone can freely use and aggregate with the ones generated by the system itself. These data are defined as Open data when they are made freely available by public administrations, as is usually the case. Open data are normally reusable and redistributable because they are not covered by copyright or other restriction mechanisms.
The data collected by sensors and web services can open new business perspectives, not strictly limited to the winter maintenance field. For example, an evaluation of the road surface condition can derive from the analysis of data coming from sensors mounted on the salt spreader. The results of this evaluation, or even the raw data alone, could then be sold to motorway concessionaires or public administrations. This knowledge can be useful to increase the efficiency of road maintenance according to the innovation roadmap defined in the framework of the smart city concept.
The OBUs network can also be exploited as a sensors infrastructure placed on the road system able to gather information not concerned with winter maintenance. As a meaningful example, traffic flows could be induced by analysing the salt spreader speed during different periods of the day. This analysis can subsequently be used to refine data initially coming from the highway services. This loop creates a positive feedback of updated data that can be sold or freely redistributed to the traffic information services available to the end users.

3.3. GNSS

Satellite navigation [12] represents a fundamental building block for the winter maintenance technology presented in this article and for any possible future innovation on this field. The possibility to rely on accurate, reliable and always available positioning is the basis of the automatic control of the salt spreader activity and plays a key role in Location Based Services (LBS).

The GOLDEN- ICE and INFRA framework relies on the strengths ensured by Wide Area Differential GPS (WADGPS) systems, that support the navigation systems providing differential corrections that improve the accuracy of the position [19]. In particular the European Geostationary Navigation Overlay System (EGNOS) [17] is the WADGPS infrastructure for Europe. Furthermore, WADGPS permits to calculate the so called Protection Level, that is a sort of upper bound of the positioning error based on integrity information. The possibility to estimate the error of the position represents an added value within the winter maintenance service; therefore, during the GOLDEN-ICE project development phase, an independent module was created, called Augmentation module. Such module acts as a middleware toward the EGNOS\EDAS system, providing advanced WADGPS functionalities (including Protection Level computation) via a web interface.

The Augmentation Module service [16] was conceived as part of the cloud computing paradigm and represents a sort of independent achievement of the GOLDEN-ICE project that can be easily integrated in other systems.

The next envisageable steps in the navigation sector in order to further enhance the quality of the positioning system are listed in the following:

- **Multi constellation GPS [13], Galileo [14] and GLONASS receiver integrated within the OBU**: Multi constellation receivers will improve the positioning service availability and accuracy, thanks to the increasing number of satellites in view. Moreover, the availability of additional constellations enables the GNSS receiver and the overall OBU to exploit the advantages of GLONASS and Galileo. GLONASS allows to improve the quality of the service in Northern latitudes in Europe while Galileo, with respect to GPS, provides additional services that can ensure added value to winter maintenance such as drastically reducing the probability of jamming and spoofing thanks to both the robustness of the signal and the advanced cryptographic technique.
- **Adoption of Inertial Navigation Sensor (INS) [15]:** It will permit to perform dead reckoning procedures (useful when GNSS is not available, e.g. in tunnels or urban canyons).
- **Local Area Differential GPS (LADGPS):** Such strategy should be investigated in order to further improve the accuracy.

The increasing accuracy and reliability of the positions will allow to enlarge the number of applications and features connected to the presented system. It has to be remarked that precise localization associated to the salt spreading operations can be exploited in two directions:

- **Service enhancement**: Precise positions can be combined with other technologies to foster a completely automatic intervention. In this sense, the consortium will investigate the adoption of advanced cartographic technology (like Advanced Driver Assistance Systems (ADAS) maps [20]);
- **Information provision**: The accurate localization collected during operations could be used to provide valuable information not only for salt spreading, but also for third party systems and applications. An important example is the possibility to perform an accurate mapping of the road surface in order to define the road morphology.

4. RESULTS AND POTENTIAL IMPACTS

It is not easy to certify all the benefits provided by the advanced winter maintenance platform. The main tangible achievement is the salt saving and the consequent cost (and environmental damage) reduction; however there are many other added values deriving from the adoption of such technology, such as:

- Improvement of the road safety;
- Costs reduction in terms of infrastructure;
- Possibility to interact with other services;
- Exploitation of salt spreading truck as added value data source and potential future opportunities connected to them;
- Generation of new economic opportunities.

The following sections present the results of the GOLDEN-ICE project and the expected future achievements deriving from GOLDEN-INFRA and its technological evolutions.

4.1. GOLDEN-ICE Results

This section will highlight the results from the on-field tests included within the GOLDEN-ICE final reports. Such tests highlight the quantifiable advantages that come from the GOLDEN-ICE concept (the amount of salt saved during missions without reducing the quality of service).

In order to evaluate the salt saving obtained thanks to the GOLDEN-ICE system it was necessary to perform several comparison tests with different operating strategies:

- **Using GOLDEN-ICE OBU equipment in traditional salt spreading mode**: the truck was equipped with OBU in order to perform salt spreading in traditional mode, i.e. selecting constant parameters to apply along the path;
- **Use GOLDEN-ICE OBU equipment in GOLDEN-ICE salt saving mode**: the truck was equipped with a GOLDEN-ICE OBU controlled by Route-Replay pre-configured parameters pattern based on road morphology. This means that user parameters were changed along the path, in order to optimize the amount of salt spread without changes in safety levels.

Among the tests performed on the field, this paragraph reports the results associated to two interesting paths, in which the road width varied. Such condition permits to underline the contribution offered by the GOLDEN-ICE system. In order to obtain a reliable analysis and simplify tests procedures, the strategy during comparison tests was that of maintaining a constant dosage of salt on both tests, varying just the spreading width according to effective road width in GOLDEN-ICE salt saving mode. During the spreading tests in traditional mode, a medium spreading width was selected. Generally speaking, the road width can range from 2m (the narrower urban street where a salt spreader can pass) to 12m (highway with 3 lanes plus an emergency lane).
The value selected for traditional tests was 6m, that corresponds approximately to a standard European extra-urban route with 2 lanes or to a bidirectional city street, suitable for overall testing scenarios.
This means that a conservative strategy was selected; therefore the results obtained during tests can be considered as a benchmark that might be significantly improved with a customization in dosage (according to road morphology).

Table 1 and Table 2 report the main details of the above mentioned tests. In both cases, the GOLDEN-ICE strategy reduces the amount of salt by more than 18%.

DETAILS	TRADITIONAL STRATEGY	GOLDEN-ICE STRATEGY
Distance	10 Km	10 Km
Dosage (g/m2)	15	15
Spreading Width	6 m	Variable (according to the effective road width)
Total Salt Spreading	**1420 g**	**1160 g**

Table 1 - Comparison between traditional strategy and GOLDEN-ICE strategy (1st scenario)

DETAILS	TRADITIONAL STRATEGY	GOLDEN-ICE STRATEGY
Distance	24.2 Km	24.2 Km
Dosage (g/m2)	15	15
Spreading Width	6 m	Variable (according to the effective road width)
Total Salt Spreading	**3500 g**	**2860 g**

Table 2 - Comparison between traditional strategy and GOLDEN-ICE strategy (2nd scenario)

This 18% salt reduction can be easily translated in 18% of salt saved and 18% of cost reduction on the material employed and 18% of polluting substance that is not thrown on the terrain (soul, rivers and so on), mitigating the environmental impact of road salting.

Considering that only one spreading parameter was variated, this result can be considered a realistic good lower bound achievement for the project. Such result confirms the potential cost reduction that may be reached exploiting the GOLDEN-ICE strategy with respect to state of the art technology.

4.2. Future Expected Results

GOLDEN-ICE represented the first evolutionary step toward the enhanced winter maintenance system proposed in the roadmap, as explained in Section 2.1. The positive results obtained during the project test phase invites us to investigate other opportunities that can be achieved thanks to this technology.

The GOLDEN-ICE OBUs can be seen not only as service consumers, but also as data providers. The salt-spreading trucks can be seen as additional telematic boxes spread over the territory that continuously observe the real road condition and other relevant information (weather, traffic status, etc.) that can be collected from a cloud platform in order to generate added value information within the Big Data domain, as described in Section 3.2. Such data can be exploited not only to improve the winter maintenance service, but also to provide information to third party applications and services, creating a fruitful link with third party platforms.
In this sense, during the follow up of the current activities, it will be possible to operate in two different directions:

- **OBU sensors extension**: The OBU hardware-software architecture was defined to be scalable and flexible; therefore, it will be possible to integrate and manage additional sensors and devices (e.g. video cameras, weather stations) in order to provide new information to the cloud platform (e.g. traffic information).
- **Data exploitation strategy**: Different strategies will be applied to the exploitation of the potential massive information coming from OBUs:

- **Open Data [11]**: information deriving from OBUs could be made public, i.e. available (freely) for everyone who wants to get and use it. In this case, the benefit would be for the community at large.
- **Proprietary Data**: The aggregated and/or manipulated data could be purchased by interested third parties, creating new revenue sources for the service providers.

It is expected that the winter maintenance service will take further advantage of the additional information provided by both GOLDEN-INFRA innovations (e.g. weather forecast services) and potential OBU feedbacks. First of all, the strategy followed to spread the salt would be further automatized and optimized. The spreading process would be controlled by an algorithm that may benefit from the knowledge of additional parameters (e.g. punctual road morphology, instantaneous temperature, humidity, etc.). This means that the GOLDEN-ICE initial route recording phase would no more be necessary, improving the overall process efficiency.

The presented scenario goes in the direction of an enhanced and completely self-assisted and scalable service. It would permit to drastically reduce the time of the intervention and potentially even the overall number of trucks involved. Road safety and the environment would benefit from this evolution, with positive spillovers for the territory, in line with Microsoft's green campaign [23] and the smart city concept.

Cloud-based winter maintenance will foster the creation of innovative third party services thanks to its flexibility and scalability, creating new interesting opportunities for the involved territory, also in business terms. This aspect, even if it is more difficult to quantify, will represent a further important achievement for the presented systems.

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