LIFE11 ENV/IT/000002

Final Report

Covering the project activities from 01/09/2012 to 01/06/2016

Reporting Date

01/09/2016

LIFE+ PROJECT NAME

CLEAN-ROADS

Data Project

Project location	Province of Trento
Project start date:	01/09/2012
Project end date:	01/06/2016
Total budget	€ 1.474.750
EC contribution:	€ 687.150
(%) of eligible costs	50.00%

Data Beneficiary

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1. List of Contents

Acronyms

CAN: Controller Area Network

CRR: Correct Rejection Ratio

DBMS: Data Base Management System

DTM: Digital Terrain Model

EC: European Commission

ECMWF: European Centre for Medium-Range Weather Forecasts

FAR: False Alarm Ratio

FDO: Financial Desk Officer

GIS: Geographical Information System

GUI: Graphical User Interface

HMI: Human Machine Interface

HR: Hit Ratio

ITS: Intelligent Transportation System

MAR: Missed Alarm Ratio

MDSS: Maintenance Decision Support System

NWP: Numerical Weather Prediction

PAT: Provincia Autonoma di Trento (Autonomous Province of Trento) – Coordinating Beneficiary

PM: Particulate Matter

PMF: Positive Matrix Factorization

RST: Road Surface Temperature

RWIS: Road Weather Information System

TDO: Technical Desk Officer

VKT: Vehicles Kilometers Travelled

VMS: Variable Message Sign

XML: eXtensible Markup Language

2. Executive Summary

2.1 Project objectives

The CLEAN-ROADS project aimed to address the environmental problem which is caused by a wide use of de-/anti icing chemicals (in particular, salt) during the winter road maintenance operations in the Autonomous Province of Trento. Several studies have already demonstrated that road salt has a negative impact on the surrounding environment, with short- and long-term damages to the aquatic systems, to the vegetation, to the air quality, to the wildlife, to the human health, but also on the road infrastructure and the vehicles. Before CLEAN-ROADS, local winter road treatments were carried out on the base of subjective criteria only and didn't rely on quantitative data, with the natural consequence of overestimating the amount of required salt and thus of resources waste.

The objectives of the CLEAN-ROADS have been to:

- deepen and quantify at a local level the environmental impact produced by salt in the environmental ecosystem near the road infrastructure;
- put the basis for a more efficient use of salt during winter road maintenance operations through the introduction of a Maintenance Decision Support System (MDSS) supported by a Road Weather Information System (RWIS).

Thanks to this novel MDSS, road operators can have at disposal not only real-time information about the conditions of the roads and the weather, but also short-term forecasts about their evolution and real-time alarms in case a road treatment is needed. In this way, the Road Management Service of the Autonomous Province of Trento can be in the condition to enhance its procedures of interventions, in particular transforming reactive treatments in more efficient proactive ones, which could be carried out with a reduced amount of salt.

The project's benefits were observed during the final pilot phase, in which the demonstrative system was experimentally applied on a significant test route. During the three years of the project a gradual, positive impact on the environment has been achieved thanks to a strong and continuous activity of involvement and training of road operators. The early activation of a specific monitoring site during the preparatory actions gave the opportunity to collect a baseline dataset and to investigate the ex-ante / ex-post environmental impacts generated by the project's actions.

One of the aims of the CLEAN-ROADS project was also to target road safety during the winter seasons by:

- properly and timely informing local travellers and drivers, distributing relevant road-weather information now at disposal through the available info-mobility channels;
- organizing dedicated awareness-raising actions that aimed to increase the level of responsibility of local travellers in trips organization and planning during the winter seasons and in the proper adaptation of their driving style as a function of the observed road conditions.

Being the topics and the environmental concern investigated by the CLEAN-ROADS project of global relevancy, the project aimed also to create active exchange activities with inter-regional, national and European stakeholders, organizations and networks, with the intention to learn and study alternative solutions that are applied in similar and/or different environments but also to share and exchange the lessons learnt in the project, thus creating the opportunities for the activation of similar practices in other realities.

2.2 Key deliverables and outputs

Project beneficiaries positively concluded all the activities foreseen in the CLEAN-ROADS project, and in particular they have succeeded in conducting to a positive end all the preparatory, implementation, integration, monitoring, communication and project management actions scheduled in the project proposal. The most relevant results obtained can be summarized as follows:

Project management:

- the conclusion of the **Partnership Agreements** and the creation and actuation of the **internal project management structure**, which was in charge of the overall coordination, management and organisation of all different project activities and initiatives, including the ones assigned to external assistance providers (**Action E1-E2-E3**);
- the systematic execution of the **internal procedures** for the periodical collection by the Coordinating Beneficiary of the costs statements and all the reference supporting documentation from each single Associated Beneficiary (**Action E1**).

Technical project implementation:

- the conclusion of the **two baseline data collection campaigns** during the winter seasons 2012/2013 and 2013/2014 (**Action A1**), <u>as indicated in the recovery plan presented through the Inception Report</u>;
- the conclusion of the **preparatory studies** related to the consolidation of the users' and system requirements (**Action A2**), which have availed in particular of the strong cooperation activated with the <u>road operators</u> staff in the scope of <u>Task D2.1</u>;
- the conclusion of the **system design and implementation activities** (**Action B1 – Action B2**), including the **integration** of all initial system prototypes (**Action B3**) in one single system that has been widely tested and validated on the field during the **winter season 2014/2015**;
- the conclusion of the **final pilot activities** during the **winter season 2015-2016** (**Action B4**), in which the system was finally validated and demonstrated as a whole, and its benefits specifically investigated (<u>according to the new planning agreed in the second amendment to the Grant Agreement</u>).

Target audience and environmental monitoring:

- the conclusion of the **initial impact evaluation analysis**, in which the monitoring indicators and methodology have been defined and consolidated (**Action C1-C2**);
- the conclusion of the **ex-ante, process and ex-post impact evaluations** on the target audience (**Action C1**), which have allowed to provide a first evidence of the social impacts that the project is producing;
- the conclusion of the ex-ante, process and ex-post environmental impact evaluations (**Action C2**), carried out during the winter seasons 2013/2014, 2014/2015 and 2015/2016 which have allowed to provide a detailed understanding of the local environmental problems as well as to appreciate the improvements that the MDSS has generated.

Dissemination and international networking:

- the continuous enrichment of the contents of the **project website** (**Action D1**), as well as the installation of the **LIFE+ notice boards** (**Action D4**);
- the organization of **two training courses for all road operators** of the Autonomous Province of Trento (Trento, 30/09-01/10-02/10 2014 and 06-08/10 2015) and the establishment of a specific internal working group with the road operators involved in the pilot demonstration of the RWIS (in the scope of **Action D2**, Task D2.1);
- the execution of several initial local involvement activities in the scope of **Action D2**, Tasks D2.2 and D2.3, namely the organization of **three project workshops** (Trento, 15/01/2015, 06/02/2015 and 26/05/2016 respectively), the preparation of several **dissemination products** (in particular a flyer, a video and video and the Layman's Report), the fulfilment of several initial **dissemination activities on the local media channels** destined to the local population and the participation to local **dissemination and awareness-raising initiatives** and the initial involvement of several **inter-regional stakeholders**;
- the presentation of the project at the several international conferences (**Action D3**), in particular **SIRWEC 2014** conference, the main international forum of discussion on road weather topics, **ITS World Congress 2015**, the main conference of intelligent transport systems in the world and **EGU 2016**, the European geophysics Union conference.

Key output deliverables related to the above mentioned activities and annexed to this Final Report are[1]:

- D.B3.1: *"Complete road condition control system demonstrator"*, D.B3.2: *"Validation tests description and results"*, which describe the different system components in their final configuration (i.e. static and mobile RWIS stations, the logics for the automatic generation of alarms and the forecasts of road weather conditions, as well as the applications destined to road operators local travellers) and the results of the final validation tests carried out during the winter season 2015/2016;
- D.B4.1: *"Results of the application of enhanced procedures"*, D.B4.2: *"Assessment of benefits on local road management"*, which present the achieved / achievable optimization margins and a cost/benefit analysis for determining the long-term economic sustainability of the system and the possible perspectives of replication on the entire Province of Trento;
- D.C1.4: *"Process evaluation"* and D.C1.5: *"Ex-post impact evaluation"*, which present the results of the process and ex-post monitoring activities on the target audience;
- D.C2.3: *"Process evaluation"* and D.C2.4: *"Ex-post impact evaluation"*, which illustrate the results of the environmental monitoring activities carried out during winter seasons 2014/2015 and 2015/16;
- D.D2.3: *"Documentation related to the first and second project workshop"*, D.D2.5: *"The realization of the 2nd training course"*, D.D2.7: *"Press articles related to the press release published by the Coordinating Beneficiary"*, D.D2.8: *"Documentation*

[1] Please note that the final outputs of Actions A1, A2, B1, B2 and D4 as well as the intermediate outputs of actions C1, C2, D2, D3, E1, E2 and E3 were already delivered to the EC in annex to the previous intermediate reports.

related to the meetings with the road maintenance operators". These reports present in detail what has been carried out for local disseminating the project and for the involving local stakeholders in the project.

- D.D3.1: *"Organization of networking activities"*, which describes the international networking activities carried out by the project;
- D.D5.1: *"Layman's report"*, i.e. the report destined to the general public;
- D.D6.1: *"After-LIFE communication plan"* which describes the dissemination activities that will be carried out after the project end.
- D.E1.4: *"Final financial report"*, D.E2.5: *"Preparation report for checkpoint 4"*, D.E2.6: *"Preparation report for final checkpoint"*, D.E3.3: *"Report CP3 – System integration"*, D.E3.3: *"Report CP4 – Final CheckPoint"*. These internal reports, produced in the scope of the project management activities, discuss the proper achievement of milestones and check points as well as the financial progress.
- D.E4.1: *"Audit verification certificate"* which is a report produced by the Independent Auditor and certifies the project expenditures.

The comparison between quantitative **expected and achieved results** can be summarized as follows:

- **Winter road treatment activities**. The introduction of the CLEAN-ROADS system determined a **reduction of 15-20%** in the number of road salting activities, with a potential of a further **15%** improvement that could be immediately reached already from the next winter season. Similar figures apply also for the usage of resources (salt, maintenance vehicles, operators' time). This result is absolutely in line with the expected results. What is however absolutely relevant, is that by properly enhancing some treatment techniques (e.g. use of pre-wetted salt instead of dry salt) the perspective of improvement are incredibly higher, estimated up to **80%** to current treatment activities.
- **Environment**. Environmental results must be interpreted differently from what originally expected, i.e. an average reduction of chloride concentrations in aquatic systems and air pollutant levels. They must be better intended in terms of **environmental damage avoided thanks to road salting treatments that were not carried out thanks to CLEAN-ROADS**. Environmental monitoring activities have clearly put in evidence the different modalities with which salt is dispersed in the environment, according to the meteorological conditions in correspondence and after a treatment. As far as contribution of road salting to **air pollution** is concerned, it has been quantified in the order of some $\mu g/m^3$ during the days following intense salt distribution, with **maxima exceeding 3 $\mu g/m^3$**. However, even if subtracting this quantity to mean daily PM_{10} concentration as stated in Directive 2008/50/CE, the number of days when the **PM_{10} limit value** was exceeded cannot be reduced. On the other side, the estimation is that probably due to CLEAN-ROADS there has been already a reduction of these exceeding days; in particular, in December 2015, characterized by a period favourable to high air pollution, older treatment habits could probably lead to one or two more exceedings than those effectively registered. As far as contribution of road salting to **aquatic systems** is concerned, the concentration of chloride in run-off waters has empirically demonstrated to **exceed the standards for freshwaters**, indicating a **potential impact on the aquatic life**. The environmental impact was particularly troubling during winter season 2013/2014 characterized by

frequent exceptional rainy precipitation, which had the effect to continuously wash out salt from the roads. The situation improved in the following winters, thanks to sensibly better favourable meteorological conditions but also to a more aware use of road salt. Maximum concentrations of chlorides in run-off waters decreased of more than 60% from winter season 2013/2014 to winter season 2015/2016. **Significant improvements are possible with the introduction of pre-wetted salt**, which may lead operators to treat roads not immediately after a precipitation event as they use to do (dry salt adheres better to road surface if it wet or humid), but only when effectively needed.

- **Local travellers' habits**. The evaluation of traffic-related externalities in correspondence of the case study road has confirmed that the introduction of **the CLEAN-ROADS system did not produce any negative impact on road safety**, with the number of road accidents always in the order of 4-8 accidents per winter season, and mostly of them not related to road conditions but to frequency of precipitation events. Driving behaviours and travelling patterns studies have confirmed a **relationship between precipitation events in winter and traffic**, with number of transits and averages speeds proportionally reducing as a function of the severity and intensity of the precipitation event. Despite improved end-users traveller information services, patterns did not significantly change during the project execution.

In order to properly capitalize project results and further investigate a possible business case for the large-scale implementation of CLEAN-ROADS, PAT finally agreed with the other associated partners, to **continue the pilot project activities during the next three winter seasons**.

2.3 Final Report structure

The report is structured as follows. Chapter 3 provides an overall introduction to the problem targeted by the project, and its expected longer term results. Chapter 4 illustrates in a detailed way the technical achievements, including dissemination activities as well. This chapter contains moreover an evaluation of the project implementation and an analysis of the long-term benefits.

3. Introduction

3.1 Background, problems and objectives

The **environmental problem** targeted by the CLEAN-ROADS project is related to the damages produced by an excessive use of chemical de-icers for winter road maintenance. Several literature studies have already investigated the negative impacts that common de-icers have on soil, vegetation, air and water, but also on highway structures and vehicles. Because of its hydroscopic nature and its extremely solubility in water, more than 50% of salt used for de-icing purposes is typically **dispersed through aqueous solutions**, which affect surface water, percolate through the soil, and reach the groundwater aquifers, with a potential damage that is detectable for several hundreds of meters from treated road. Salt can also be dispersed in **solid form**, remaining on the road surface or getting ploughed into the adjacent snowbank. Small fraction of salt solution and/or salt particles can also be launched as **aerosols** by traffic or wind, landing in snow banks or on nearby vegetation in a region up to 100 meters. The **hypothesis at the base of the project** is to demonstrate how this environmental impact can be addressed through a decision support system, which through detailed data and information about road weather conditions, combined with short-term forecasts about possible icing events, aims to put the local road network management personnel in the conditions to maximize the efficiency with which salt resources are today commonly used for winter road treatments. The **proposed solution** is both technical but also organizational: not only state-of-art ITS technologies are proposed to be jointly used in this demonstration, but also novel modalities and procedures for the management of winter road maintenance activities are going to be explored. The **expected environmental benefits** that the project aims to demonstrate in the test area where the system is going to be deployed can be quantified in terms of (i) an overall reduction of 30% of road salt resources; (ii) a reduction of 10-20% of the chloride concentrations in the local eco-system and specifically in the near aquatic systems; (iii) a reduction of 15-30% of the number of road salting treatments required for each route stretch; (iv) a reduction of 15-30% of the total number of VKT by winter maintenance vehicles; and (v) a reduction of air pollutant levels of 10-20%. Moreover, thanks to awareness-raising activities realized in the project targeting local travellers, it is possible to expect **significant additional benefits** such as (i) a reduction of 15-30% of the number of accidents caused by ice and/or snow on the roads; (ii) a reduction of 5-10% of traffic volumes during critical atmospheric conditions; and (iii) a reduction of 15-30% of the winter traffic congestion situations caused by meteorological factors.

3.2 Expected longer term results

De-icing activities are aspects considered in different EU directives, in particular the ones related to **air and water quality** (i.e. Directives 2008/50/EC and 2006/118/EC, respectively). The environmental monitoring activities carried out by CLEAN-ROADS cover specifically these two different matrixes. The project therefore is not only to be interpreted as a direct **attempt to fulfil the objectives set in these directives**, in particular a better understanding of the local environmental phenomena: the creation of integrated monitoring sites gives in fact the possibility to introduce **more advanced policies for the local combined management of air and water quality**. The empirical results obtained in the CLEAN-ROADS project could be used by the European Commission in order to further develop and improve the existing legislation and guidelines.

4. Technical part

4.1 Technical progress, per task

This section of the Final Report offers a detailed overview of the technical progress of the activities carried out in each technical project action, i.e.:

- **Action A1** “Experimental data collection campaign during a winter season”
- **Action B1** “System design”
- **Action B2** “System implementation”
- **Action B3** “System integration”
- **Action B4** “Pilot execution”
- **Action C1** “Monitoring the impact on the target audience and local welfare”
- **Action C2** “Monitoring the environmental impact of the project”

The progress of Action D (dissemination) is presented in paragraph 5.2. The effective Gantt diagram for the period **September 2012** (project start) **– June 2016** (project end) is presented in Figure 1, according to the following legend: original activities as indicated in the project proposal (grey), modifications already introduced with the Inception and Progress Reports (brown), and modifications introduced with the approved 2nd amendment to the Grant Agreement (yellow). It is important to underline that after the last temporal plan shared with the EC, no further adaptations have been necessary.

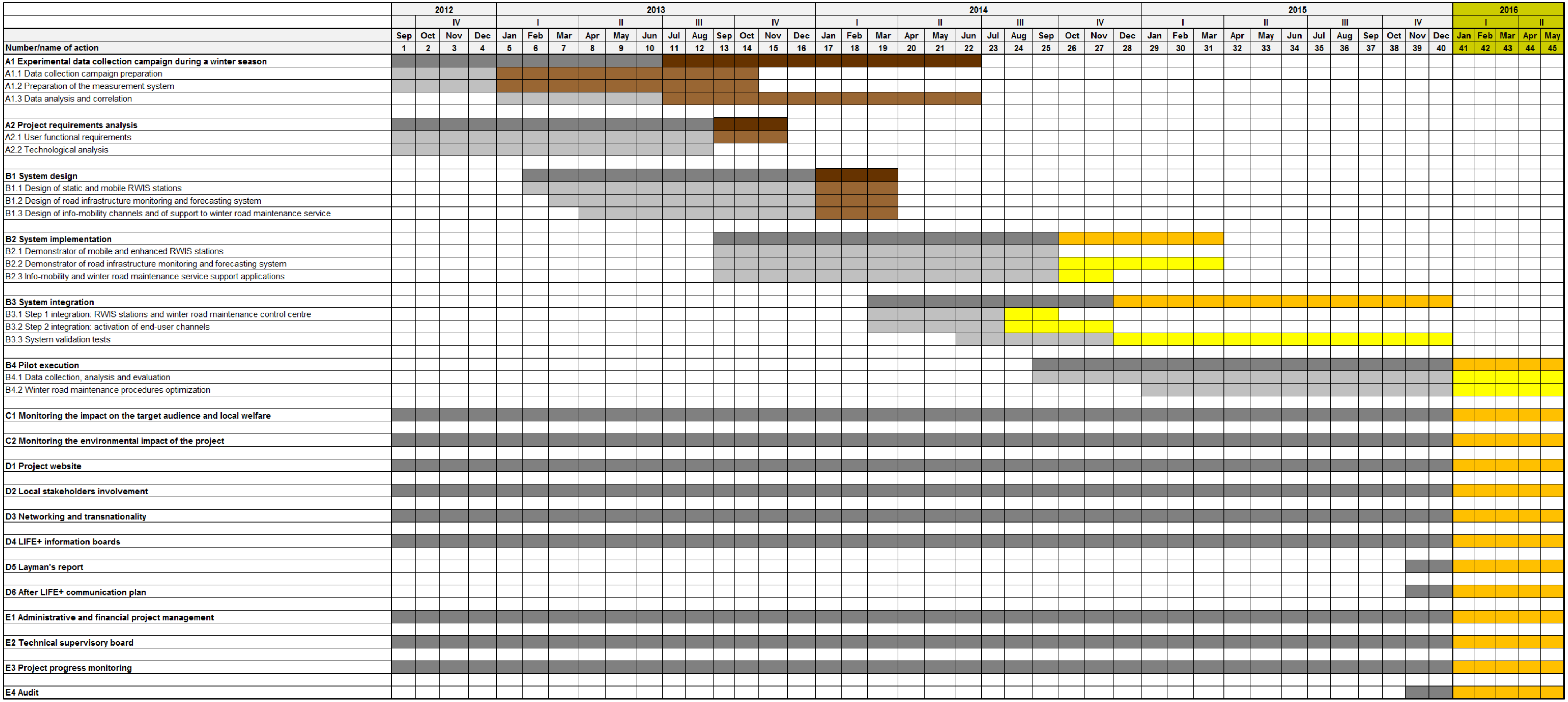


Figure 1: The overall effective Gantt diagram.

4.1.1 Action A1: Experimental data collection campaign during a winter season

Status of the action: the Action has been successfully completed in June 2014 (M22), completely in line with the revised schedule proposed in the Progress Report. The main activities and results of the different tasks of this action can be summarized as follows:

Task A1.1 "*Data collection campaign preparation*". The original plan intended to immediately identify the locations in which the five static monitoring stations should have been positioned. As explained in the Inception Report during the kick-off of the project it was taken the decision to **install only one road monitoring station during the first winter season** and to define the position of the remaining four stations at a following stage after a more detailed evaluation of the baseline data.

The **first monitoring site**, which represents the unique location for the monitoring of the environmental impacts as well, was decided to be placed in correspondence of the small village of **Cadino**, in the north part of the case study road (Figure 2). The selection of this location, coordinated by the Coordinating Beneficiary, was carried out on top of different opposite requirements, with the aim to maximize the compromise between the technical complexity in the installation of all necessary monitoring equipment and the relevancy of the environmental context for the collection of representative data during the winter seasons. The limited availability of power supply influenced in particular the choice of installing the monitoring site in correspondence of a VMS installation located in the target area.

Figure 2: The position of the monitoring site for the baseline data collection.

During the winter season 2013-2014, this preparation phase additionally covered the organization of specific field activities for the **collection of baseline data** to support the process of **identification of the most suitable location** for the **additional five road weather monitoring sites**, the most important being a **thermal mapping campaign** of the entire road infrastructure within the test area, which has been carried out by means of the first prototype of the mobile RWIS system installed on one of the maintenance vehicles (Figure 3). The 33 test sessions, organized even with the objective to initially validate the functioning of this measurement system developed by FAMAS, have revealed that on average the **spatial RST differences are quite limited in amplitude**. The relative measurement offsets detected have revealed to be, on average and during the coldest hours of the day, only in the order of 2-3°C.

Figure 3: Mobile RWIS station prototype used during first field session activities in winter season 2013/2014.

Task A1.2 "*Preparation of the measurement system*". The main activities that were carried in the scope of this task were the following:

- the **installation of the first complete monitoring site** in the location of Cadino before the winter season 2013/2014 (Figure 4), in strict cooperation between the Road Management Service and the Environmental Agency of PAT as well as FAMAS (responsible respectively for the overall coordination of the installation activities, the preparation of the environmental monitoring site and the installation of all road-weather-traffic sensors). The site is composed by:
    - a **road-weather** station, equipped with state-of-art meteorological sensors and detectors for measuring the conditions of the road;
    - a **traffic monitoring** station, characterized by non-invasive traffic detectors positioned on top of the VMS portal;
    - an **air quality monitoring** station, composed by air pollutants concentrations sensors installed over a container in which other useful connectors and instrumentation are located;
    - a **water quality monitoring station**, i.e. a system for collecting, sampling and analysing run-off waters from a qualitative and quantitative point of view.
- the **enhancement of the monitoring of road management operators activities**. In order to avoid errors due to the manual procedure for the recording of road treatment activities, road operators were furnished with a specific tracking solution called **trackoid**, developed by a local environmental engineering society, **HydroloGIS**. Trackoid is mainly an extremely simple application running on Android **mobile devices** for automatically tracking and geo-locating working operations, even on a real-time basis. In the scope of the project, trackoid was introduced by the Road Management Service of PAT in order to register in a very detailed way each winter road maintenance activity on the case study

road. Registered data can be easily checked through a web application, where all statistical information related to each recorded treatment can be analysed, even on a GIS support. Several meetings with road operators were organized in preparation of the winter season 2013/2014 in order to properly introduce this tool and explain the motivations beyond its usage. A complete how-to has been moreover prepared and put at their disposal.

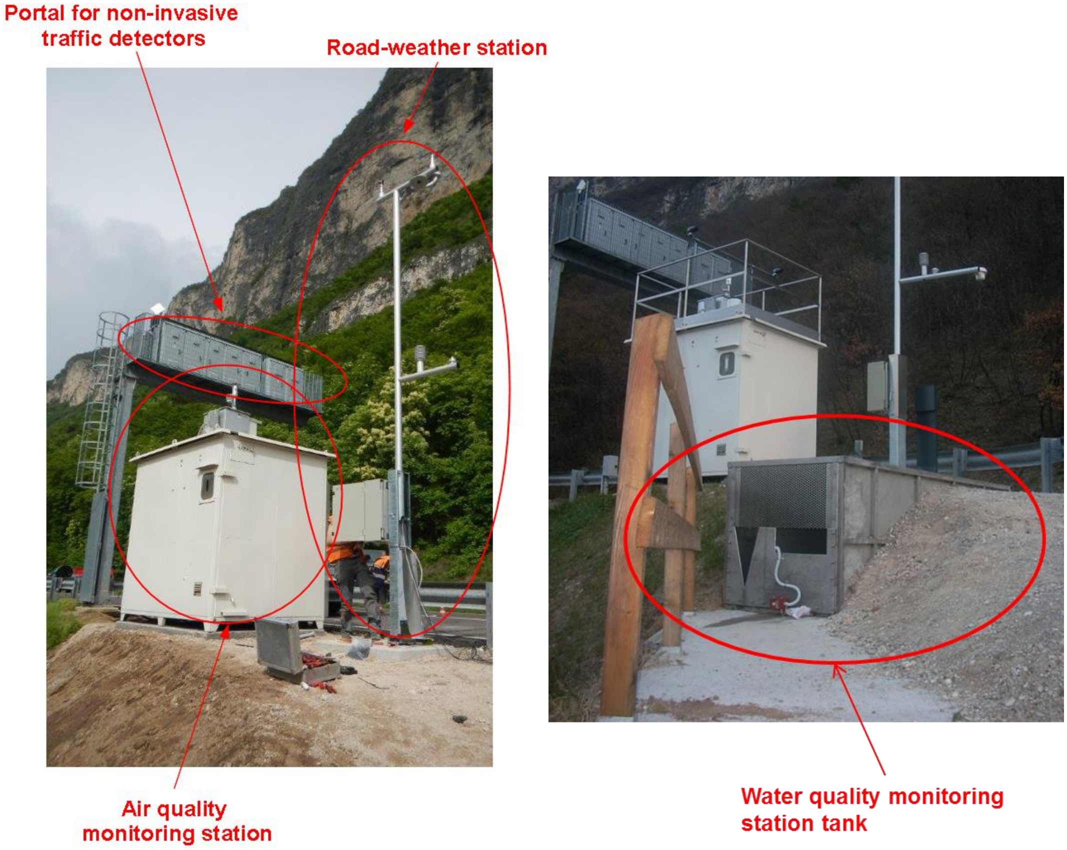


Figure 4: The first complete monitoring site in Cadino.

Task A1.3 "*Data analysis and correlation*". In the scope of this task, two baseline data analysis was completed, mainly by IDM and the Meteo Service of PAT:

- **Winter season 2012/2013 baseline data assessment**. A first evaluation of the reference road maintenance inefficiencies was carried out by considering the limited and disaggregated amount of information available at the project start, in particular traffic and meteorological data from existing meteorological stations and traffic detectors in correspondence of the case study road and data concerning winter road maintenance treatments in the test site area, which were manually recorded during this winter period. A simple and **rough evaluation model** was developed in order to estimate the effective necessity for road treatments based on the measured meteorological conditions.

  Initial results showed how the **potential of reduction of patrol trips and treatment' activities** is in the order of 30% and 50%, respectively, confirming the achievability of project results. Moreover, this analysis highlighted that the highest savings are located in correspondence of milder and uncertain conditions, when the boundary between deciding for an action of not is thinner. On the other side, the limited number of hits obtained through the model, i.e. the conditions of both observed and estimated treatments (about 50%) and the high number of missed alarms, i.e. the conditions of both estimated treatments without a correspondence in the road operators activities (about 45%) indicate how these results must be handled very carefully with the need for more detailed investigation analysis.

- **Winter season 2013/2014 baseline data assessment**. This second study was carried out by taking complete advantage of the measurements taken in the complete monitoring site activated in Cadino, as well as the accurate recordings of road operators' activities through the trackoid system. The winter season 2013-2014 was characterized by **exceptional meteorological conditions**, with extremely mild weather and prolonged absence of harsh winter patterns. Just to give an idea of this fact, RST measurements were lower than -1°C for just 5.5 hours. The preliminary **optimization margin estimation model** was significantly improved on top of this new available knowledge[2]. The obtained results are summarized in the confusion matrixes of Table 1. **The final estimation in terms of maximum number of treatments that can be avoided**, if one could have at disposal in advance a perfect knowledge of the road conditions, is quantified for the winter season **in the order of about 63%**. If one takes in consideration **patrol trips and anti-ice treatments only**, this optimization margin is even higher, and can be estimated **in the order of 79%.**

			Treatments observed					
			YES					NO
			Patrol trip	Anti-ice	Prev.snow	S. Remov.	TOTAL	
Treatments estimated	YES	Patrol trip	4				4	
		Anti-ice		4			4	
		Prev.snow			2		2	3
		S. Remov.			1	7	8	
		TOTAL					**18**	**3**
	NO		14	17	0	0	**31**	**230**

		Treatments observed	
		YES	NO
Treatments estimated	YES	HR = 36.7%	FAR = 14.3%
	NO	MAR = 63.2%	CRR = 98.7%

Table 1: Results of the optimization margins' analysis with the winter season 2013-2014 dataset.

These **results** are consistent with what has obtained for the winter season 2012-2013, and are significantly **amplified by the exceptional mild conditions observed**, since the central winter months have presented climatological patterns similar to the queues of the winter. All this has therefore confirmed the hypothesis for which the **most relevant inefficiencies are probably to be associated to minimum temperatures falling in the proximity of 0°C**.

Expected vs. achieved outputs: the expected outputs of Action A1 are a prototype system (D.A1.1, describing the first prototype of all RWIS stations) and two reports (D.A1.2 and D.A1.3) presenting the preparation activities of the monitoring sites and the first assessment of the baseline data and the potential optimization margins in the today's winter road maintenance activities, respectively. Action A1 has managed to achieve all these outputs – but with the important modification related to the choice to install just one monitoring site during this preparatory action, and shift the installation of the remaining ones to the implementation phase (more specifically to Action B2). The second and final version of Action A1

[2] For more details on this, please refer to Action A1 section in the Mid-Term Report, pp.17-18.

deliverables, covering in particular the preparatory activities carried out during the winter season 2013-2014, were annexed the Mid-Term Report.

Indicators of progress: not applicable for Action A1.

Comparison with the time schedule and problems encountered: the Action has been completed in June 2014 (M22), whether the original timing was to finalize this preparatory action by June 2013 (M10), i.e. exactly one year before. This significant delay has been caused by the **impossibility to complete all expected preparatory activities during the winter season 2012-2013** due to bureaucratic delays in the approval of the budget allocated for the infrastructure works which were required in order to properly install all road-weather and environmental sensors in correspondence of the identified monitoring points completely in line with the time schedule. For this reason, a **recovery plan** was immediately defined and presented in the Inception Report, obtaining the approval by the EC. In this plan, this set of preparatory tasks was extended for exactly one year and the activity set for the following winter seasons was completely updated. The execution of this recovery plan was successfully carried out, demonstrating the validity and the feasibility of the identified countermeasures.

Objectives achievability: all the objectives of this action have been properly fulfilled, in line with the recovery plans introduced from the project start.

Perspectives for continuing the action after the end of the project: the activities of this preparatory action were specifically needed for the collection of a detailed road weather baseline dataset and for the investigation of the environmental impacts associated to local winter road treatments. Similar activities could be exploited even after the project's end: in particular, similar environmental monitoring sites could be installed in other critical points of the local network, based on the experience and the results obtained in Action C2. On the other side, it is important to properly maintain this first installation, in order to ensure the accurate and continuous monitoring of the controlled parameters. This work is confirmed to continue under the direct supervision of the different departments of PAT involved in the project, with the active collaboration of beneficiary FAMAS, as stated in a proper agreement finalized at the project's end. Last but not least, the promising results related to the initial optimization margin assessment studies have been the basis for the final optimization margins' analysis of Action B4, that have demonstrated their potential to replicate similar investigations not only to future extensions of the CLEAN-ROADS system, but also to other neighbouring regions, in which similar installations have started to be introduced.

4.1.2 Action A2: Project Requirement Analysis

Status of the action: the Action was successfully completed in November 2013 (M15). The activities of this Action were mainly managed by IDM in strict cooperation with all beneficiaries for their parts of competence (i.e.: FAMAS for the technological evaluation of the RWIS components; Road Management Service of PAT for the whole process of users' requirements process; and the Meteo Service of PAT for the analysis of the literature in the field of road weather forecast modeling). The main activities and results of the different tasks of this action can be summarized as follows:

Task A2.1 "*User functional requirements*". In the scope of this task the following activities have been carried out.

- The **evaluation of the user needs**, in direct relationship with the target audience (in particular road operators, in strict cooperation with Task D2.1). The assessment of the needs of local travellers, which are here summarized in the customer satisfaction analysis results (Figure 5), was assessed by combining the results of the first public survey organized in the scope of Action C1 with reference state-of-art studies. Drivers' awareness has in particular resulted to be one of the major topics to be addressed by the entire CLEAN-ROADS initiative.

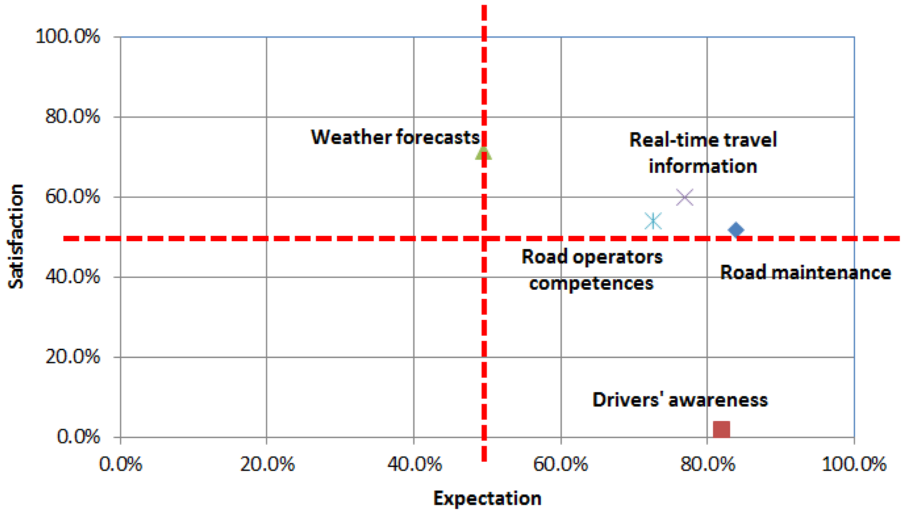


Figure 5: User requirements – customer satisfaction analysis results.

- The **analysis of the observed inefficiencies**, based on the initial results given by the winter season 2012/2013 baseline data assessment and a wider evaluation of the entire management of winter road maintenance process and organization within the PAT. The different inefficiencies covering both all planning, execution and evaluation of the road maintenance activities, as well the trip decisions of travellers during the winter season are illustrated in Figure 6. The inefficiencies with the lowest optimization margins are associated to the management of snowfalls and road safety levels, which already present a very appreciable starting point.

- The **identification of the use cases**, i.e. the development of reference scenarios to be deployed on top of the CLEAN-ROADS system and specifically targeting one or more reference inefficiencies.

- The **definition of the system concept**, developed by taking also in active consideration the results of the technological analysis of Task A2.2.

- The **consolidation of a list of high-level requirements**, to be used as an operative input for the following design and implementation actions (Actions B1 and B2).

Task A2.2 "*Technological analysis*". In the scope of this task several literatures studies were completed. The studies were very important for the initial definition of the system concept, in order to ensure that is consistent with what has been already tested and experimented elsewhere, but also easily scalable when new technologies currently under research will be mature for deployment. Studies mainly covered:

- a comprehensive overview of the different **physical phenomena that influence the conditions of the road network**, in particular during the winter season, including a wide investigation of the current **state-of-art technologies for the monitoring of road weather conditions** through static and mobile probes;

- an analysis of the reference state-of-art in the field of **numerical prediction of weather forecasts** and **road weather modelling techniques**;

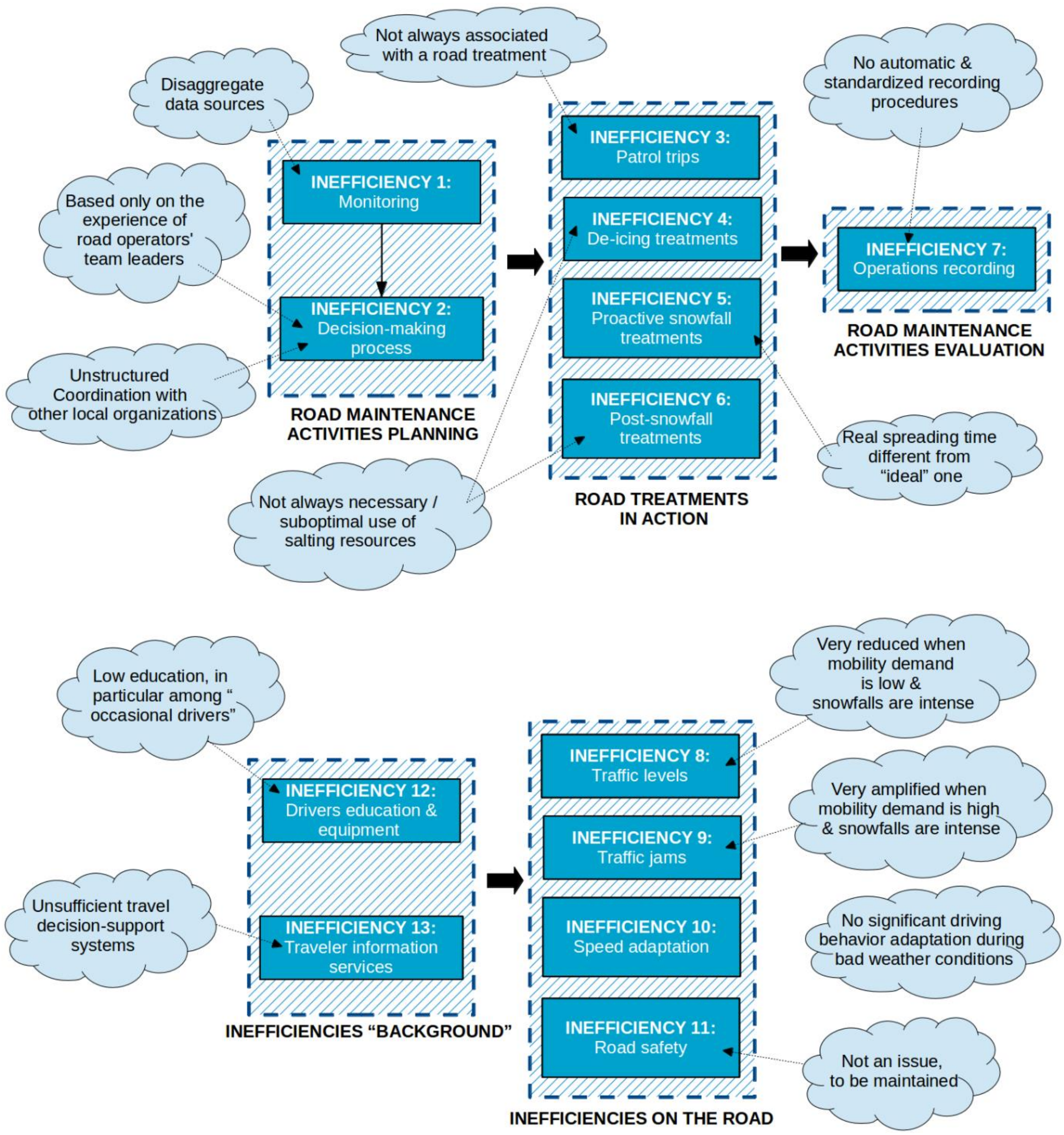


Figure 6: A graphical summary of identified inefficiencies targeted by CLEAN-ROADS.

- a comprehensive and detailed **study of the basic elements of a RWIS**, and in particular of the peculiarities of a **MDSS**, with a specific analysis of best-practices and activities carried out all around the world;
- a final investigation about the future evolution of RWIS in the perspective of **cooperative intelligent transportation systems** (C-ITS).

Expected vs. achieved outputs: the expected outputs of Action A2 are two reports presenting the results of these preparatory studies, one for each task. Action A2 has successfully managed to achieve all these outputs. The deliverables of Action A2 were annexed together with the Progress Report.

Comparison with the time schedule and problems encountered: the Action was completed in November 2013 (M15), whether the original timing was to finalize this preparatory action by August 2013 (M12). The duration of this action was extended for a couple of months in order to better assess the functional requirements of the local travellers through the results of the public survey organized in the scope of Action C1. No particular problems were encountered during the execution of this action.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 2.

Milestones	Means of verification	Comments	Reference report
M.A2.1 "Users' requirements analysis concluded"	• requirements' lists with functional and performance needs described and prioritized; • number of meetings with stakeholders / dimension of audience involved.	Requirements lists available as indicated. Frequent number of meeting with road operators and road management staff (see Task D2.1 for more details) completed. Public survey with more than 1.000 responses finalized	D.A2.1
M.A2.2 "Technological preliminary evaluation realized"	• presence of details and bibliography for each component / aspect of a RWIS	Each aspect of a RWIS was analysed with a proper level of investigation. A complete evaluation of the state-of-art initiatives was included as well.	D.A2.2

Table 2: Indicators of progress – Action A2.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: the results of this action have been very important to properly guide not only the implementation process of the CLEAN-ROADS system, but also the future technological exploitation of the system. In this scenario, beneficiaries will have only to need to simply update the contents of these studies as a function of the new technological solutions and initiatives launched at an international level. The inclusion of advanced functionalities in the system could be easily and quickly take place on top of this comprehensive background work.

4.1.3 Action B1: System Design

Status of the action: the Action was successfully completed in March 2014 (M19). The activities of this Action were mainly managed by FAMAS, with the cooperation of other beneficiaries for their parts of competence (Meteo Service of PAT for the forecasting components of the system, Road Management Service of PAT for the distribution of information to the target groups, IDM for the technological support in the specification of the central core of the system). In the scope of this Action, the system concept of the CLEAN-ROADS system developed in Action A2, graphically reported in Figure 7, was technically specified. The main activities and results of the different tasks of this action can be summarized as follows:
Task B1.1 "*Design of static and mobile RWIS stations*". This task specifically focused on the technical specification of the remote monitoring part of the CLEAN-ROADS system, i.e. the static and mobile probes for the measurement of the road weather conditions. More in particular, the following activities have been completed:

- **Design of the static RWIS stations**, divided in:
    - **early static RWIS station design**, which covered the design of the first road weather station installed in Cadino in the scope of Action A1;

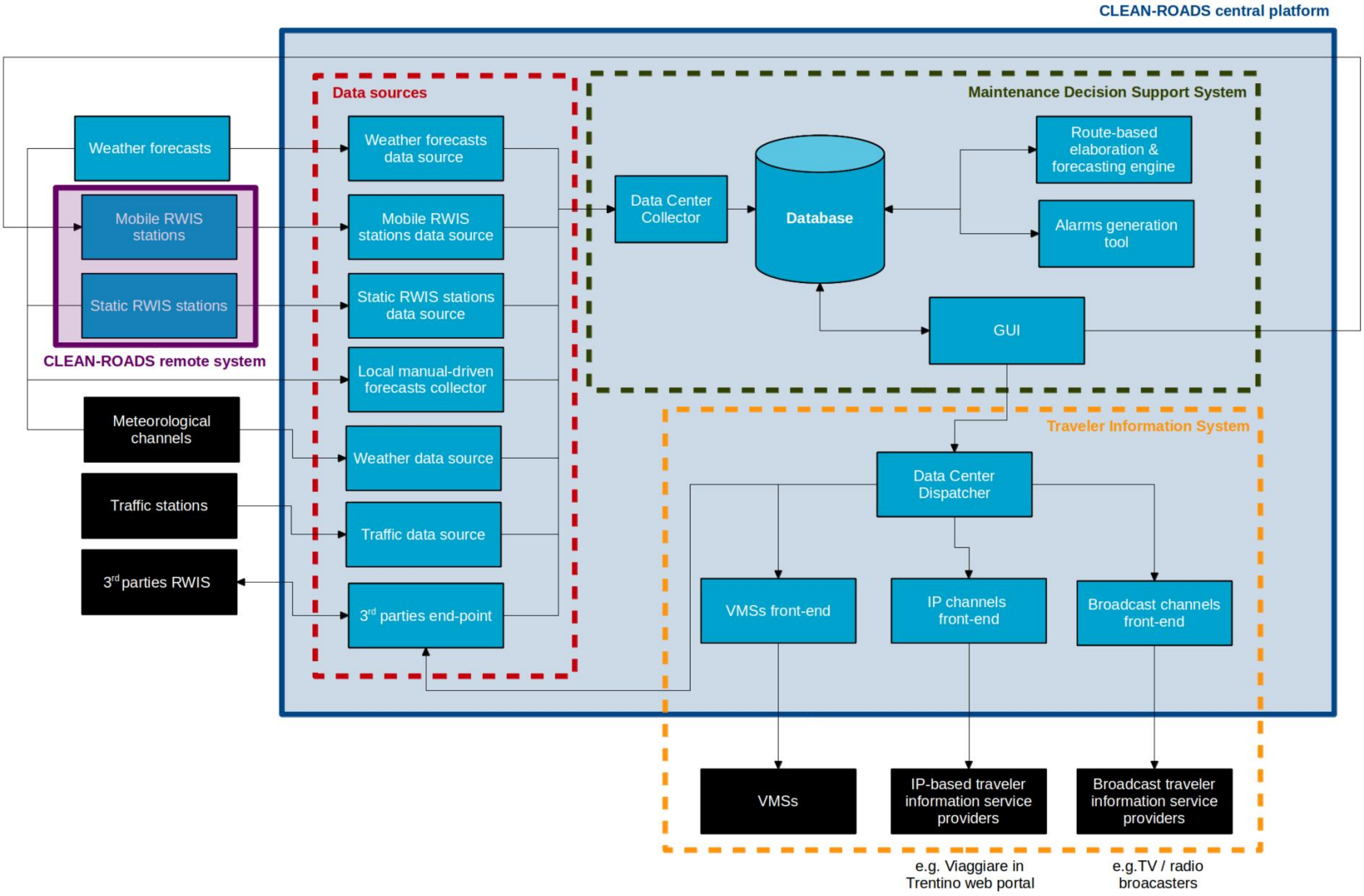


Figure 7: The concept of the CLEAN-ROADS system.

- **final static RWIS station design,** which covered the design of the additional five road weather stations installed in the scope of Action B2.

The static RWIS station is a fixed monitoring installation, to be installed on the side of a road, that is capable of monitoring **meteorological data**, data about the **road surface conditions**, and <u>optionally traffic and other environmental data</u> as well.

Several specifications aspects were handled, in particular **power supply methods** (230 Volt power supply or photovoltaic panels), **sensors selection**, dimensioning of the remote control unit, **data transmission to the control centre** (project choice: 3G/4G connection), **diagnostic data collection** (for the verification of the proper station's correct functioning), **connections, housing and placement** (designed as a function of the practical limitations which are present in the chosen monitoring sites). The final static RWIS station design choices were similar to the early ones. In the additional installations, it was decided to introduce <u>three of five stations powered with photovoltaic panels</u>, and to consider a reduced set of sensors.

- **Selection of the location of the additional static RWIS stations**, mainly influenced by the results of the preparatory activities of Action A1. The fairly flat and uniform temperature profile in the stretch of study suggested that it would have been completely useless to install all RWIS stations in the case study road. For this reason,

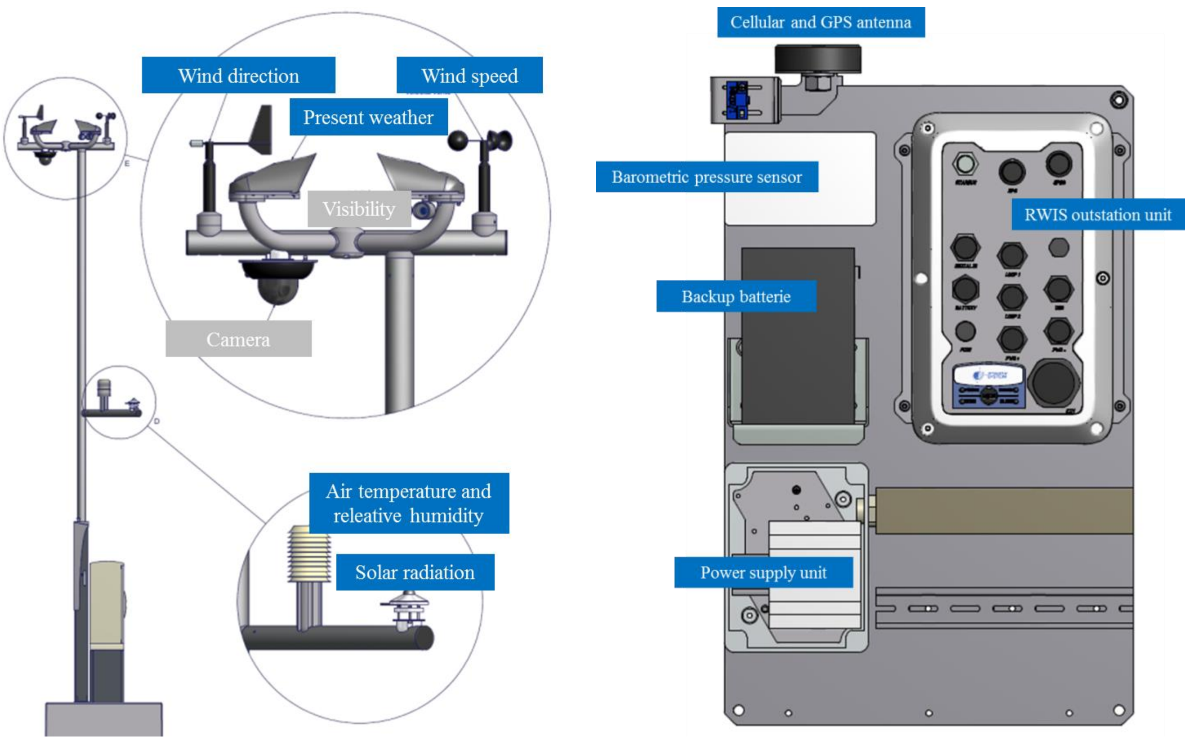


Figure 8: A couple of design schemes of the static RWIS station.

in accordance with the EC, in this phase it was taken the important decision to **install three monitoring stations outside the test route**, as illustrated in Figure 9 (where green coloured stations are those located in the case study road, and the orange coloured ones placed outside this test area). The advantages of such a decision are several, and can be summarized as follows:

- by placing a station on a **viaduct**, the project could have the chance to study the completely different cooling and heating processes which take place on suspended roads;
- in light of the extremely 2013-2014 winter season, by placing a station at **higher altitude**, the project could immediately have the chance to consider a broader range of meteorological conditions, and to use all this "extended" data in order to properly train the forecast models;
- by placing a station in a similar road environment, but quite **far from the case study road**, the project could immediately have the chance to evaluate the future scalability of this system at regional level and beyond.

- **Design of the mobile RWIS stations**, divided in:
  - **early mobile RWIS station design**, which covered the design of the first mobile system prototype used during the winter season 2013-2014;
  - **final mobile RWIS station design,** which covered the design of the final mobile system prototype introduced from winter season 2014-2015.

The mobile RWIS station is a completely new prototype to be developed from zero, which probably represents one the most advanced components of the entire CLEAN-ROADS system.

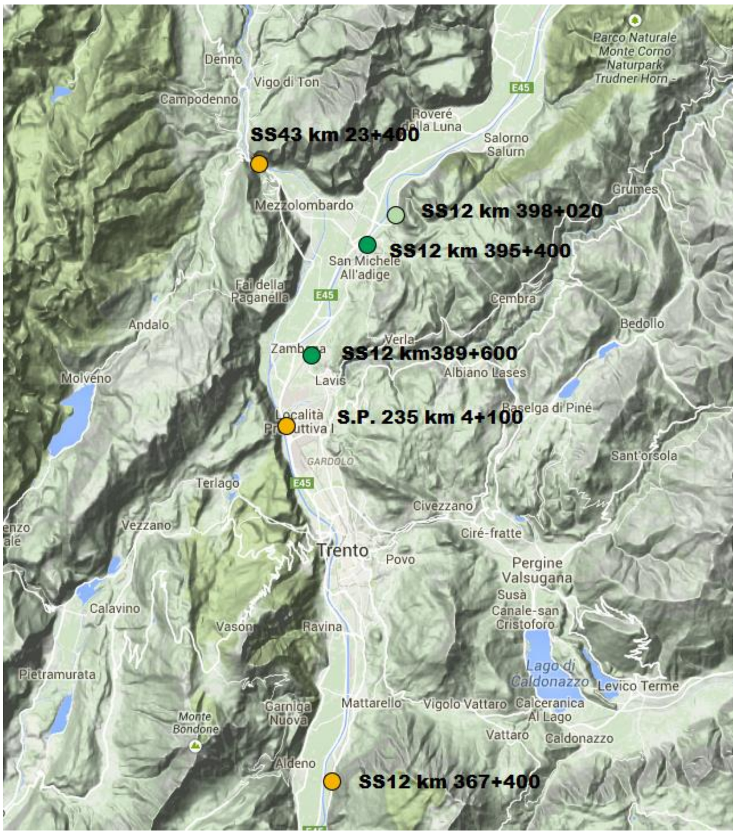


Figure 9: The choice of the locations of the static RWIS stations installations.

In the scope of this activity, the technical design of how properly introducing the **trackoid** system for the automatic recording of road operators' activities was included. Different specifications aspects were handled, in particular the **sensor and components selection** (selected sensor technology is a thermopile), the **on-board system integration** (installation issues and overall electric and hardware design), the **telematics and HMI components**. A specific support for the on-board installation was in particular specifically studied and designed. A reference thermal mapping sensor for the proper inter-calibration of the mobile measurements was considered in this system architecture as well. The experience gained during the winter season 2013/2014 allowed to verify the quality of the design choices identified for the construction of the prototype and to highlight possible initial improvements to the system, in particular (i) the choice to use **Bluetooth transmissions** for the transfer of the sensor measurements to the on-board control unit and (ii) the inclusion of an **air temperature sensor** in the system architecture, a parameter which has been decided to be read from the CAN bus network of the vehicle.

Task B1.2 "*Design of road infrastructure monitoring and forecasting system*". This task specifically focused on the technical specification of the server-side part of the CLEAN-ROADS system, covering in particular:

- the overall **data aggregation and storage** to be performed by the **DBMS.** A proper professional DBMS solution was selected and configured on the base of the technical specifications of the system. The data model and the database tables were designed, so to manage real-time and historical data with high performance.
- the automatic routines for the evaluation of the **presence of alarming situations** and the **prediction of road conditions**. A complex automatic "engine", fed by the data which are continuously gathered in the central system, was designed (Figure 10).

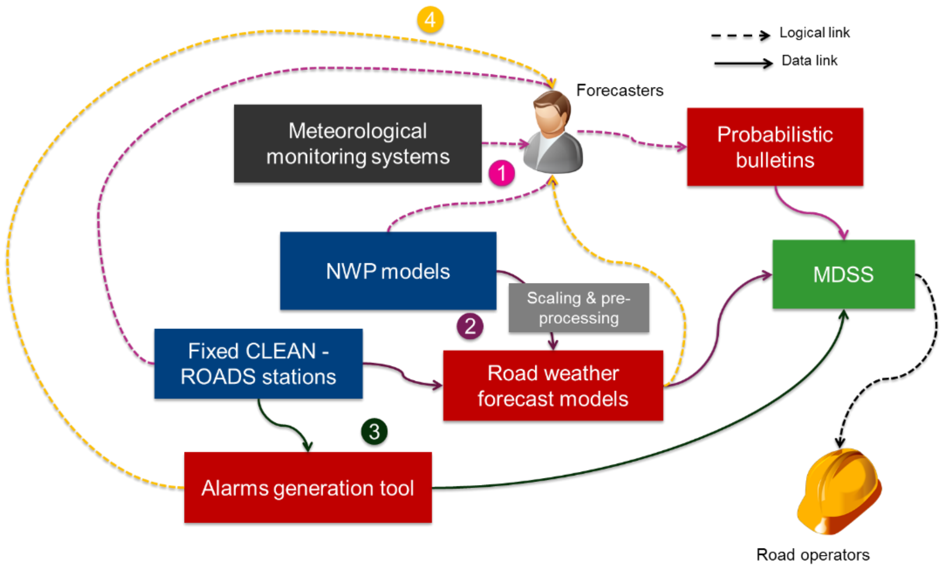


Figure 10: A graphical representation of the complete forecasting and elaboration "engine". Blocks in blue and black colour are components (included / not included in the system, respectively) providing data. Blocks in red colour are elaboration and forecasting components / outputs.

This engine integrates heterogeneous forecasting and elaboration components, in particular:

- <u>step 1</u>: **probabilistic bulletins**. These bulletins are intended to be produced on a daily basis by forecasters of the Weather Service of PAT. The bulletins have a probabilistic form, i.e. they indicate the likelihood of target events (in particular: snow event; snow event with more than five centimetres per hour; temperatures under 0°C; ice event) in terms of probability classes. Road operators avail of these bulletins at the **end of the morning**, and can have a first prediction about possible issues for the incoming night;
- <u>step 2</u>: **road weather forecast models**. A certain number of models capable of estimating in quantitative terms the road surface temperature at the locations in which the static RWIS stations are installed were explored, mainly:
  - **METRo**, which is the reference road weather model in the worldwide state-of-art, that forecasts RST and the conditions of the road as a function of the outputs of a NWP model and the raw measurements of static RWIS station. During this design process, it was identified how to <u>improve and adapt the model</u> as a function of the particular orographic environment in the PAT.
  - **Reuter**, which is one of the models used in weather science to calculate how the ground temperature at night decreases from its initial value at sunset. This model, which is particular suitable for certain meteorological conditions favourable for the ice formation, depends only the raw measurements of static RWIS station. In the scope of the project, this model was designed in order to be executed iteratively, by taking advantage of the continuous availability of field data.

  The outputs of these models are intended to be at disposal of the road operators during the **late afternoon / early evening**. The forecasted period is very short, i.e. <u>maximum 12 hours</u>. It is important to underline that in light of the exceptional winter conditions of season 2013-2014, and the consequent need to improve the efforts for properly calibrating the selected road weather forecast models during the following winter seasons, a specific **external assistance contract** with a local company with specific expertise in environmental modelling was defined.

- step 3: **alarm generation tool**. The last step of this complex "engine" is the automatic management of real-time conditions, which can properly guide road operators in their treatments' actions. A wide set of alarms was designed on top of what already defined for the optimization margin assessment tool developed in the scope of Action A1, with several additional physical constraints taken from previous similar literature works. The presence of alarms are automatically detected for each data record collected by each static RWIS station. Proper control logics were studied in order to avoid the over-production of single false alarms caused by isolated data errors. Thanks to this tool, road operators can be immediately alerted when a specific condition of risk is detected.

Task B1.3 "*Design of modalities of integration with info-mobility channels and of support to winter road maintenance service*". This task covered the technical design of the last part of the CLEAN-ROADS system, i.e. the interfaces with road operators and local travellers. Most of the effort has been placed on the specification of all necessary interfaces with the "core" of the CLEAN-ROADS system, covered in Task B1.2. A unique point of distribution of data and information managed in the knowledge base has been introduced and technically designed – the CLEAN-ROADS "Dispatcher". Four different **end-users application services** were moreover specified:

- the **MDSS GUI**;
- a set of **analytics clients** through which authorized personnel can visualize and download data managed within the CLEAN-ROADS system;
- additional informative layers in the web portal "**Viaggiare in Trentino**";
- an **additional web application**, through which the project has experimented the sharing of an extended set of information with local travellers, also in the direction of **increasing the awareness and responsibility of driving** under certain road weather conditions.

The work of continuous fine-tuning of the best usable graphical HMI of the end-users applications was covered by Actions B2 and B3, in cooperation with the target user groups.

Expected vs. achieved outputs: the expected results of Action B1 are two reports presenting the results of these design activities, one covering the results to be achieved in Tasks B1.1 and B1.2 (D.B1.1) and in Task B1.3 (D.B1.2). Action B1 has successfully managed to achieve all these outputs. The deliverables of Action B1 were already annexed together with the Mid-Term Report.

Comparison with the time schedule and problems encountered: the Action was completed in March 2014 (M19), whether the original timing was to finalize this action by December 2013 (M16). The duration of this action was extended for a couple of months in order to fine tune some technical decisions as a function of the empirical results obtained during the pilot activities of winter season 2013-2014 (e.g. the selection of the location for the static RWIS stations).

Objectives achievability: all the objectives of this action have been properly fulfilled.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 3.

Milestones	Means of verification	Comments	Reference report
M.B1.1 "Technical specifications for static and mobile RWIS stations available"	Specification document with components analysis, flow charts and numerical constraints.	All specification aspects for both system components were covered with the proper level of detail.	D.B1.1
M.B1.2 "Technical specifications for road infrastructure monitoring centre components available"		Forecasting and elaboration components selected and configured, with a proper integration plan for practical use by road operators.	D.B1.1
M.B1.3 "Technical specifications for road weather information distribution system components available"		Road weather information distribution architecture specified, end-users applications set defined.	D.B1.2

Table 3: Indicators of progress – Action B1.

Perspectives for continuing the action after the end of the project: thanks to this action, a first overall design for all CLEAN-ROADS components is now available. After the end of the project, it is possible to imagine to continue this action in two directions:

- <u>design of the extension of the functionalities of the system</u>, possibly with a review of the user functional requirements;
- <u>improvement of the design choices related to one or more system components</u>, e.g. when new available technological developments will be sufficiently mature for a large-scale deployment for such an application.

4.1.4 Action B2: System Implementation

Status of the action: the Action was completed in March 2015 (M31), completely in line with the time schedule indicated in the recovery plan presented in the official request of amendment accepted by the EC. The activities of this Action were mainly managed by FAMAS, with the cooperation of other beneficiaries for their parts of competence (Weather Service of PAT for the implementation of the probabilistic bulletin and the Reuter's forecast model, Road Management Service of PAT for the support in the development process of the end-users applications, IDM for the implementation of the automatic alarming logics, the calibration and enhancement of the METRo model, and the development of the project web application). The main activities and results of the different tasks of this action can be summarized as follows:

<u>Task B2.1 *"Demonstrator of mobile and enhanced static RWIS stations"*</u>. This task managed to implement and validate the remote monitoring part of the CLEAN-ROADS system, i.e. the static and mobile probes for the measurement of the road weather conditions. More in particular, the following activities were completed:

- the implementation of the **final mobile RWIS station prototype**, including the hardware support for the on-board installation of the RST sensors.

- The **installation of the remaining 5 RWIS stations** (with enhancement of the RWIS station installed during the preparatory phase), a process which has been successfully concluded before the kick-off of the winter 2014/2015 (Figure 11).

(a) San Michele – case study road.

(b) Cantoniera – case study road.

(c) Acquaviva – exploitation analysis.

(d) Viadotto A22 – viaduct analysis.

(e) Rocchetta – higher altitude analysis.

Figure 11: The additional static RWIS stations installed during the implementation phase of the project.

- The empirical **validation of mobile and static RWIS station prototypes** during the winter season 2014/2015. As far the **static RWIS stations** are concerned, measurements have demonstrated the reliability of the chosen technologies for detecting on a real-time basis the target road weather conditions. As far the **mobile RWIS station** is concerned, thermal mapping sessions were extended both from a geographical point of view, in order to collect useful datasets even at higher altitudes, and both in terms of number of repetitions, which have covered a broader range of different meteorological conditions. A **specific methodology** has been introduced in order to properly evaluate and classify all this huge amount of raw data. Sessions have been classified as a function of the meteorological conditions detected by the static

RWIS stations; reference classes have been taken from state-of-art recommendations. On the other site, each test route has been divided in elementary road stretches, so to simplify the comparison of the measurements taken in different test sessions. Thermal sessions have confirmed, even during “extreme weather conditions” (i.e. cold nights with clear sky and absence of wind), that RST variations are generally quite limited in amplitude, confirming the preliminary results obtained during the winter season 2013-2014. Milder areas are located, as expected, in correspondence of urbanized areas, with high density of buildings, and in areas with dense vegetation. The sessions covering the **mountain areas** revealed how RST differences are on average more emphasized, in the order of 4-5°C in the analysed road stretches.

Task B2.2 *“Demonstrator of road infrastructure monitoring and forecasting system”*. This task managed to **prepare the IT environment for the initial hosting of the server-side part of the CLEAN-ROADS system**, and to **develop the automatic routines** specified in Action B1 for the automatic detection of alarming situations and the prediction of the road conditions, namely:

- the **probabilistic bulletins** (Figure 12). The bulletins are manually compiled by the forecasters of the Weather Service of PAT and automatic delivered to the CLEAN-ROADS system;

Meteotrentino

Centro funzionale di Protezione Civile

Bollettino per Cadino

emesso martedì 25 marzo 2014 alle ore 10:30

Seleziona la stazione: Cadino

Tipo orario (solare =1, legale = 2): 1

	ore	neve	neve>5 cm/h	temp<0°	ghiaccio
25-mar-2014	2014-03-24 23:00	0	0	0	0
	2014-03-25 02:00	0	0	0	0
	2014-03-25 05:00	0	0	0	0
	2014-03-25 08:00	0	0	0	0
	2014-03-25 11:00	0	0	0	0
	2014-03-25 14:00	0	0	0	0
	2014-03-25 17:00	0	0	0	0
	2014-03-25 20:00	0	0	1	0
	ore	**neve**	**neve>5 cm/h**	**temp<0°**	**ghiaccio**
26-mar-2014	2014-03-25 23:00	0	0	1	0
	2014-03-26 02:00	0	0	1	0
	2014-03-26 05:00	0	0	0	0
	2014-03-26 08:00	0	0	0	0
	2014-03-26 11:00	0	0	0	0
	2014-03-26 14:00	0	0	0	0
	2014-03-26 17:00	0	0	0	0
	2014-03-26 20:00	0	0	0	0

legenda	probabilità	codice/colore
	<1%	0
	1-5%	1
	5-30%	2
	30-60%	3
	>60%	4

Figure 12: Example of probabilistic bulletin, as compiled by the forecasters of the Meteo Service of PAT.

- the **Reuter’s model**. The iterative logics for the estimation of the RST decay according to the available RST measurements was implemented. For each monitoring site, the orographic sunset time was calculated, and allowed to properly calibrate the execution of the model at all static monitored locations;
- the **METRo model**. During this phase, the model was specifically calibrated and extended for the intended use in the CLEAN-ROADS project. This activity availed of the external assistance consultancy of company CISMA. More specifically, the most relevant aspects covered during this implementation process were:

- **the pre-processing of the NWP data in input to the model**, by correcting air temperature forecasts with respect to the air temperature measurements collected by the static RWIS stations so to improve the overall accuracy of METRo in this particular application case;
- **the configuration of the coupling window**, finally set to eight hours, which is considered to be the optimal time interval for adapting NWP forecast data to static RWIS measurements;
- **the configuration of the visible horizon of each monitoring site**, derived from accurate DTM analysis, which is necessary to properly modelling the heating and cooling processes of the road during sunrise and sunset;
- **the execution of the calibrated METRo model in the "best" and "worst" forecast cases**, which is obtained by forcing the NWP cloud cover forecast to its minimum and maximum value, respectively. An **automatized procedure** was also developed in order to automatically generate the **three model outputs** (standard configuration as well as "best" and "worst" cases) at **three different times** (i.e. 8:00 PM, 10:00 PM and 12:00 PM).
- the **persistence method**. The logics for the estimation of the RST trend with best match between current RST measurements and historical RST patterns was implemented and made available for use;
- the **alarm generation tool**. The whole set of alarms designed in Action B1 was implemented, as well the intelligent logic for highlighting a potential dangerous situation to road operators.

The activities of this task were completed with an **initial validation of the implemented elaboration and forecast components** on the base of the data collected in **winter season 2014-2015**, on top of the measurements continuously collected by the static RWIS stations. The objective of this analysis was to verify the level of accuracy and reliability reached by the different components, and to get a first assessment of what could have been achieved if such components would have been at disposal of the road operators. For more detailed results of this initial validation process, please refer to section 5.1.4 of the Mid-Term Report.

Task B2.3 *"Info-mobility and winter road maintenance service support applications"*. This task managed to **implement the interfaces between the CLEAN-ROADS systems and the traveller information channels managed by the PAT**, as well as to **develop the prototype applications destined to road operators and local travellers**. A great attention was put on the definition of the graphical HMI of the end-users services, in particular on which data / information to be displayed and in which form. More specifically:

- **Road operators application (MDSS GUI)**. It is a web application that road operators can access at the following web site: mdss.clean-roads.eu. In the main view users can have an immediate understanding of the current road weather conditions detected by the static and mobile RWIS stations, in particular if a precipitation event is on-going and what are the conditions of the road. Probabilistic bulletins are also displayed. Through a proper menu, users can decide which informative layer they may want to visualize. By clicking on each static RWIS station, it is possible to get a more detailed overview of the most recent road weather measurements. The inclusion of visual information (made available through web-cams) further simplifies this activity of road conditions monitoring. The MDSS GUI is also an instrument for the project staff responsible of the maintenance of the entire CLEAN-ROADS system, since it allows to check the proper functioning of all field components.

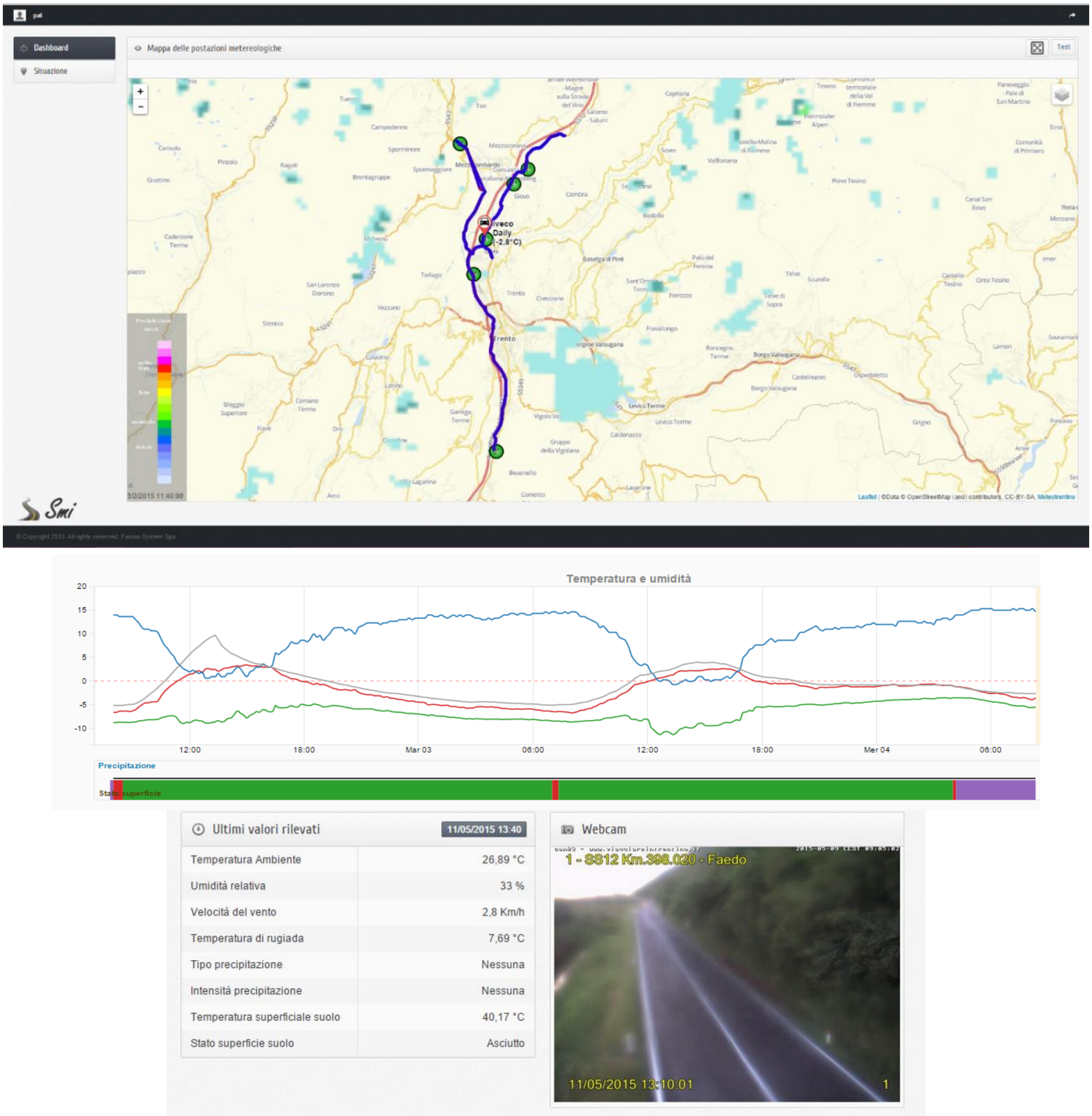


Figure 13: The MDSS GUI (road operators application) prototype.

- **Analytics clients**. They are desktop applications which can visualized privileged users to <u>visualize and download</u> data managed by the CLEAN-ROADS system, which are specifically useful for complex offline data analysis. Several clients were implemented, each of them managing the access to specific data types, i.e. static road weather data, thermal mapping data, NWP and road weather models forecasts and traffic data (available for the Cadino site only).

- **Integration of road weather information on “Viaggiare in Trentino” web portal**. Thanks to the interface between the CLEAN-ROADS Dispatcher and the dispatcher already in use by PAT for the distribution of real-time travel information in the region, it was possible to start integrating the “Viaggiare in Trentino” web portal (http://www.viaggiareintrentino.it/) with relevant road weather information. The first information which was integrated is related to the <u>publication of notifications to possible icy / snow events</u>. These notifications are automatically generated if the predicted associated risk in the probabilistic bulletin is sufficiently high.

- **Project web application**. Local travellers can have the chance to get much more detailed information about road conditions through an additional web application, accessible at http://map.clean-roads.eu/. The GUI is similar to the one developed for road operators, but with much more limited data and information displayed. One of the most interesting aspect of this application is the possibility to empirically test with the users the concept of "**level of service**" of a road, which is indicated by the current RST and the presence of precipitation in correspondence of the static RWIS stations

Expected vs. achieved outputs: the expected results of Action B2 are six prototypes and a report providing the results of the validation tests of specific system components. Action B2 has successfully managed to achieve all these outputs. The deliverables of Action B2 were annexed together with the Mid-Term Report.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 4.

Milestones	Means of verification	Comments	Reference report
M.B2.1 "First implementation phase is concluded and validation activities have been started"	Prototypes to be validated	All prototype components were successfully implemented: static and mobile RWIS stations; real-time road conditions monitoring software (i.e. the automatic alarms generation tool); road conditions forecasts software (i.e. all the forecasting models and methods); road operators application and local travellers application.	D.B2.1… D.B2.6
M.B2.2 "System components have been implemented and validated"	Prototypes validated	The prototype components of the CLEAN-ROADS system were successfully validated during the winter season 2014/2015.	D.B2.7

Table 4: Indicators of progress – Action B2.

Comparison with the time schedule and problems encountered: the Action was completed in March 2015 (M31), whether the original timing was to finalize this action by September 2014 (M25). The duration of this action was extended for the duration of the winter season 2014/2015 in light of the recovery plan accepted by the EC which led to a postponement of the project closure date. These additional months were necessary to properly **calibrate and verify** in particular **the road forecast models under real winter conditions**. This activity revealed to be impossible before, in light of the exceptional mild conditions encountered during the winter season 2013-2014.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: this Action has managed to reach the important result of implementing a first prototype of the CLEAN-ROADS system components. This implementation work has relevant potential to be further improved after the project's end, in particular as far as some of the most complex components is concerned, like for example the mobile RWIS station or the road weather forecast models. The improvement in the performance and in the capabilities of these components will further extend the potential for increasing the efficiency of road treatment activities and reducing their associated environmental impact.

4.1.5 Action B3: System integration

Status of the action: the Action was successfully completed in December 2015 (M40), as finally planned in the amended project proposal. Before the kick-off of the winter season 2014-2015, it was possible to arrive at a **first overall integration of the CLEAN-ROADS components**, which permitted to complete the first overall testing phase of Action B4. The activities of this Action were coordinated by IDM, but mainly technically covered by FAMAS, with the cooperation of Weather Service of PAT for the integration of the forecast components and the Road Management Service of PAT for the final tuning in the presentation of available data and information to road operators and drivers. The main activities and results of the different tasks of this action can be summarized as follows:

Task B3.1 "*Step 1 integration: RWIS stations and winter road maintenance control centre*". In the scope of this task, all components covering the monitoring and elaboration / forecasting part of the system were integrated together and fine-tuned in order to produce the complete system demonstrator. Activities covering the different system components were the following:

- **static RWIS stations**: basic equipment and installation modalities (also considering forecasting models' needs) were further consolidated and S.Michele RWIS station was repositioned in other monitoring point outside the case study road (**Civezzano**, Figure 14). This decision, previously discussed and agreed with the EC, was taken in the perspective of more specifically assessing the potential of **replicability and exploitability** of the system in other sensible areas of the road network of PAT. The location was chosen in light of its representativeness of what is intended a very critical spot in winter: very cold conditions due to poor sunlight and vicinity of a creek, significant traffic flows (SS47 – 2 roadways with 4 lanes, main road connection with Veneto region).
- **mobile RWIS station**: during the project a specific test vehicle was needed for performing thermal mapping operations, with the goal to understand spatial variations of road surface temperatures[3]. During this final integration process FAMAS managed to develop a more compact mobile RWIS station solution, that can be installed in other parts of the vehicle (i.e. in correspondence of the rearview mirror), with very limited hardware and installation effort (Figure 14). This is a very relevant result, since this technology can now be finally exploited on any existing vehicles, including common motor cars, salt trucks, or other interesting fleets (e.g. public transportation means);
- **real-time road conditions monitoring software**: the alarms generation logics was fine-tuned, leading to a final consolidated version of the set of alarms and of the modalities of delivery to road operators. Moreover, the automatic alarms generation tool was successfully integrated in the MDSS;
- **road conditions forecast software**: the engine was further developed and put into practice. The complete engine is characterized by the supervised issue of probabilistic bulletins and the automatic execution of METRo and Reuter's models in single and combined mode in correspondence of the static RWIS stations. A third component was added, i.e. the automatic spatial extension of **road weather forecasts** from the single station location to the **entire monitored road network**.

Task B3.2 "*Step 2 integration: activation of end-user informative channels*". The activities of this task cover the **final integration between the CLEAN-ROADS system and the end-users applications**, in particular:

[3] For more details on this, please refer to Annex 8.1, clarification point n.25.

Figure 14: The Civezzano RWIS station (left) and the enhanced mobile RWIS station demonstrator (right).

- **road operators MDSS application**: system components and functionalities were properly integrated, and the GUI significantly improved, also as a function of the inputs received by the road operators. An automatic notification service based on SMS / automatic calls was developed in order to properly delivery the hazards identified by the alarms generation chain.
- **local travellers application**: the need for further improving the preliminary modalities of presentation of the information (also in the perspective to start creating a culture of "road level of service" acceptance and therefore of higher responsibility in the local travellers while on the roads during the winter season), linked to a lack of usability of the prototype service led to a **significant improvement of the first web-application prototype**. A specific external consultancy was moreover activated with a local company (Madeincima) expert in the design and development of GUI of web-based and mobile applications, with the intention to take benefit of specific external knowledge and expertise in this domain. The new GUI (Figure 15) was also integrated in the main traveller information web-portal of PAT "**Viaggiare in Trentino**".

Task B3.3 "*System validation tests*". The activities of this task were organized as follows:

- **a preliminary validation of the first integrated version of the CLEAN-ROADS system**, carried out during winter season 2014/2015;
- **a final validation of the complete CLEAN-ROADS system**, carried out during the first months of winter season 2015/2016;

The results of the validation tests can be summarized as follows:

- **static RWIS stations**: performance analysis on the real-time availability of the stations and the installed sensors confirm the reached maturity of the system, also in the perspective of its exploitation, not only in the scope of CLEAN-ROADS but also for new pilot / commercial applications;

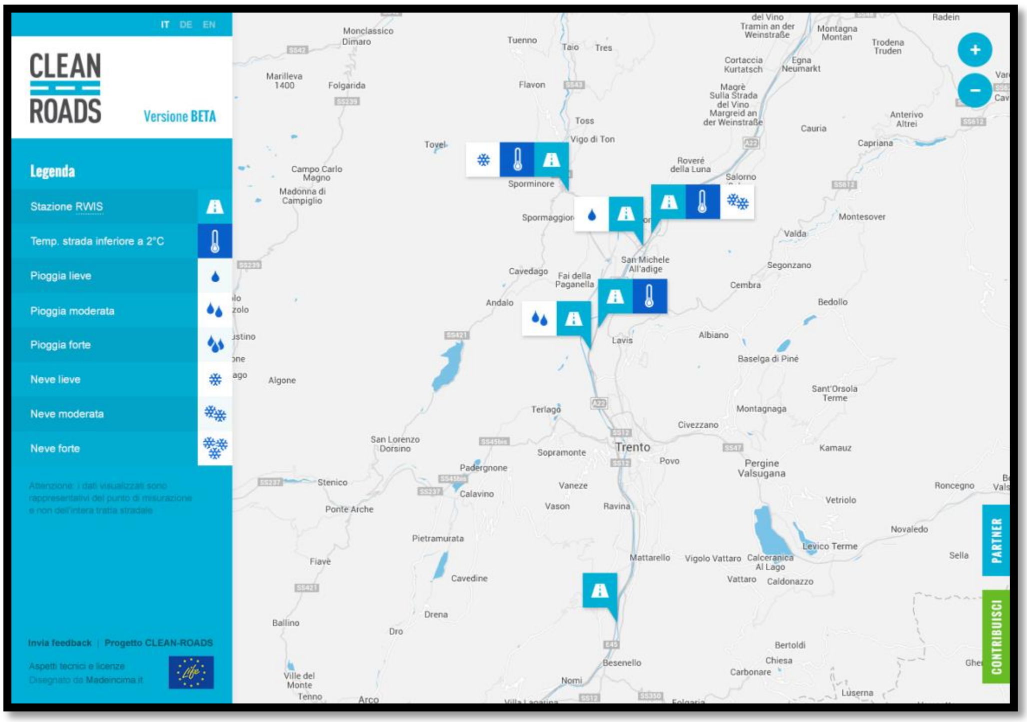


Figure 15: The final version of the end-users web application (web site: map.clean-roads.eu)

- **thermal mapping sessions**: several thermal mapping surveys were carried out during the winter seasons 2014/2015 and 2015/2016 (21 and 17 days of surveys, respectively) to finally validate not only the **mobile RWIS station prototype** but also the proposed methodology for the calculation of **route-based real-time and forecast maps** of road surface temperatures. Sessions covered not only the case study road, but also an additional road stretch in which the new RWIS station was installed in Civezzano, always in the aforementioned perspective of replicability and exploitability of the system. Results demonstrated the suitability of this novel approach, which can capitalize the spatial information provided by the mobile RWIS station. Real-time modelling and forecasting tools have shown to fit well with new acquired thermal fingerprints;

- **real-time road conditions monitoring software**: validation tests carried out during the first months of the winter season 2015/2016 put in evidence the necessity to **further improve some of the automatic logics**, in particular in relationship to two use case: **hoarfrost** – and **water cover freezing** events. For hoarfrost event, a probabilistic approach was introduced in order to better cope with the uncertainty related to the formation of this risk.

- **road conditions forecast software**: final validation tests demonstrated the potential of combining METRo and Reuter for further improving the overall accuracy performances of road weather forecasts. This is possible since the two models are intrinsically different in nature, and can better fit different sets of use cases. These results supported the choice to use in the CLEAN-ROADS system just the combination of these two forecasting models.

Expected vs. achieved outputs: the expected outputs of Action B3 are a prototype (i.e. the complete CLEAN-ROADS system prototype) and a report, presenting the results of the final validation tests. Action B3 has successfully managed to achieve all these outputs. The deliverables of Action B3 are annexed together with the Final Report.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 5.

Milestones	Means of verification	Comments	Reference report
M.B3.1 "First integration phase is successfully terminated"	Real-time conditions monitoring and forecasting demonstrator	Static and mobile RWIS stations have reached a mature and pre-commercial version. Site-specific and route-based real-time and forecasting components have been fine-tuned and integrated in the MDSS. The road operators GUI has been finalized in strict relationship with road operators.	D.B3.1
M.B3.2 "Second integration phase is successfully terminated"	Distribution of road weather information on traveller information channels activated	An enhanced GUI based on the perspective to start creating a culture of "road level of service" acceptance was developed and integrated in the current traveller information services: the pilot end-users application and "Viaggiare in Trentino".	D.B3.1
M.B3.3 "Validation tests are properly concluded"	• Number of demonstrator versions • Test procedures defined • Proof of validation tests • Validation test results	Two validation sessions carried out (winter seasons 2014/2015 and 2015/2016), with different fine-tuned versions of system components. Validation test procedures followed based on state-of-art methodologies.	D.B3.2

Table 5: Indicators of progress – Action B3.

Comparison with the time schedule and problems encountered: the Action was completed in December 2015 (M40), perfectly in line with the new temporal plan submitted and accepted by the EC through the amendment of the Grant Agreement. The execution of this action was carried out smoothly, without any significant technical inconvenient. The Action only suffered of the delays in the proper validation of all system components developed in Action B2, which have determined to complete this integration process only at the beginning of the winter season 2015/2016.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: thanks to this action, a first overall complete CLEAN-ROADS prototype system is now available. After the end of the project, it is possible to imagine to continue this action in two directions:

- improve the scale of the system, i.e. by adding new monitoring units in the system and extending the geographical scope of its application – a task partially already carried out due to the decision to extend the area monitored by the project;
- expanding the capabilities of the system, i.e. by enhancing the properties and the functionalities of each existing system component (e.g. mobile RWIS station with extended set of sensors, more advanced road weather forecast models) and/or by introducing new system components which at present do not exist (e.g. interface with similar RWIS managed by other organizations responsible for the management of neighbouring road infrastructure, automatic interface with automatic on-board salt spreader).

4.1.6 Action B4: Pilot realization

Status of the action: the Action was successfully completed in May 2016 (M45), as finally planned in the amended project proposal. The activities of this Action were coordinated by the Road Management Service of PAT, which mainly covered the definition of the optimized winter road maintenance procedures and the final economical cost / benefit analysis, assisted by IDM, FAMAS and the Weather Service of PAT for the quantification of the achieved / achievable improvements in the road maintenance activities. The methodology followed in this final assessment activity is summarized in Figure 16. Task B4.1 dealt mainly with economic benefits assessment for understanding the suitability for exploiting the system in other areas of interest in the PAT, with an identification of the reproducibility criteria to be followed. On the other side, task B4.2 covered the management of the pilot phase, with a very detailed investigation of occurred treatments in relationship to indications given by the MDSS and a quantification of the optimization margins that were already possible to achieve and the ones that are likely to be reached by further improving the procedures and techniques of interventions. Being the results of task B4.1 depending on those of task B4.2, the latter ones are presented first.

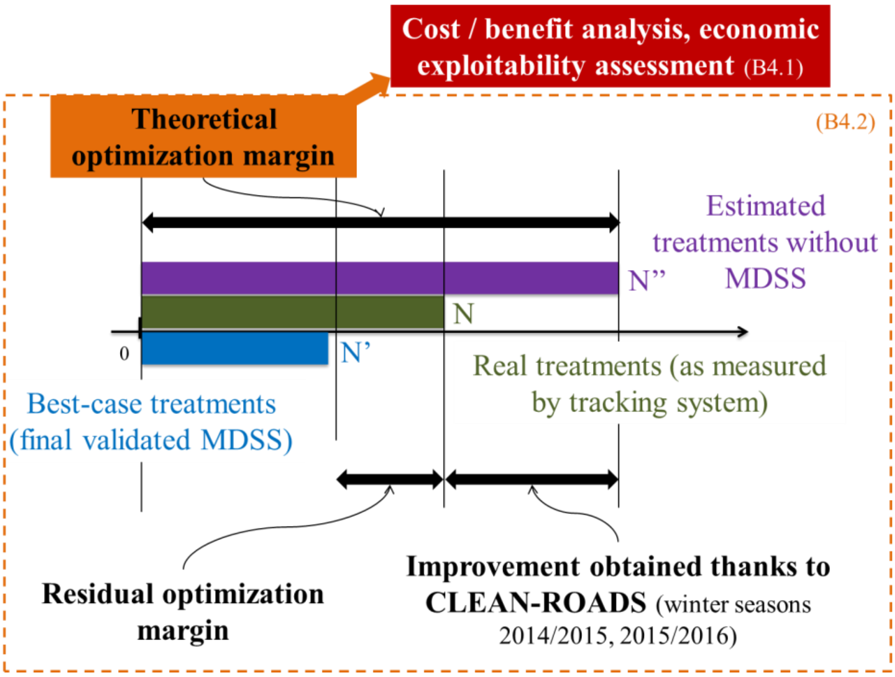


Figure 16: Methodology for the final assessment of CLEAN-ROADS benefits.

<u>Task B4.2 "*Winter road maintenance procedures optimization*"</u>. The **operational introduction of the CLEAN-ROADS system in the daily road maintenance activities** was one of the project milestones, which has put the <u>basis for new enhanced road maintenance procedures</u>. During winter seasons 2014/2015 and 2015/2016, road operators significantly changed their habits, in particular as far as the monitoring of the conditions of the road and of the weather is concerned. Now the main source of information is the new MDSS GUI, which is always checked before a decision of a treatment action. Moreover, this check is carried out systematically, in the early morning and in the every afternoon, even if the risk of ice on the roads is minimum. Thanks to the <u>automatic notification services of the MDSS</u>, it was also possible to complete a first crucial step in the **introduction of "objective" recommendations** for the salting activities, <u>based on the effective or estimated risk of road hazards on the road</u>. The main results of the optimization margins' analysis are summarized in Table 6.

Indicator	Worst-case	Best-case	Reasonable result
Improvement obtained (winter season 2014/2015)	23%	35%	29%
Improvement obtained (winter season 2015/2016)	3%	12%	7%
		Average improvement obtained	**18%**
Residual optimization margin (winter season 2014/2015)	0%	59%	26%
Residual optimization margin (winter season 2015/2016)	0%	70%	50%
		Average residual optimization margin	**38%**

Table 6: Summary of optimization margins' assessment results.

Improvements already obtained thanks to CLEAN-ROADS in terms of **avoided number of treatments** are estimated **in the order of 15%-20%**. This estimation was mainly performed by comparing the effective treatments registered with a simulation of what they would have carried out without the MDSS. This "equivalent road operator profile" was determined by correlating historical salting activities in the winter seasons immediately before the project with reference meteorological conditions and forecast, based on available historical datasets. As far as **residual optimization margins** are concerned, it is estimated that the application of the final validated MDSS, without any change in the current order of services or treatment techniques, can lead to a **further improvement, in the order of 25-50%**. This analysis has however put in evidence that by properly improving the road maintenance service the theoretical optimization margins can be much higher, **up to 70%** - more in line to what originally estimated in the previous preparatory and implementation actions. In particular, final pilot activities clearly revealed the **habits of road operators to treat the road immediately after a precipitation event**, even if ice formation risks are very unlikely: this is due to the fact that they have at disposal **dry salt**, which better sticks to the road surface if humid or wet. Indeed, when the road is dry, dry salt could be more easily dispersed in air and outside the roadway. This is very inefficient, and can lead to severe environmental damages: as empirically demonstrated in Action C2, if a subsequent precipitation event takes place, salt can be completely washed out on the road, and reach the nearby aquatic system without any benefit on road safety. In order to improve these habits, PAT has already decided to test the use of **pre-wetted salt**, which can properly apply to the road surface even if it is dry. In this way, it is possible to activate a road treatment only when strictly necessary (i.e. when notified by the MDSS), and as a consequence allow to determine a further significant reduction in the use of treatment resources.

Task B4.1 "*Data collection, analysis and evaluation*". In this task, technical considerations about the savings of the CLEAN-ROADS were translated in economic terms, with the purpose to understand the **economic sustainability** of the system, even if **expanded on larger scale** in the PAT. In particular, this analysis (summarized in Table 7) considered only the road infrastructure at the valley bottom, which is the area in which a similar system could be exploited, at least in a next future step. Investment and maintenance costs were estimated, and put in comparison with the "reasonable" economic savings obtainable with the CLEAN-ROADS system, estimated as a whole as 20% of the entire current expenditures (i.e. salting resources and maintenance vehicles' usage).

Parameter	Value
Road network PAT (valley bottom) - A	400 [km]
Total salting resources (valley bottom) – B	1.274 [tons]
Total winter road maintenance costs (valley bottom)	145.161 €
Proposed static RWIS stations density - C	1/20 [stations/km]

Nr. of necessary static RWIS stations – A*C	20
Initial MDSS investment costs	339.753 €
MDSS maintenance costs	83.639 €
Estimated reduction in salting resources (valley bottom) – D	20%
Estimated salting resources savings (valley bottom) – E = B*D	29.030 €
Estimated savings in maintenance vehicles usage – F	14.400 €
Estimated overall savings – E+F	43.430 €
Difference estimated overall savings vs. MDSS maintenance costs	**- 40.207 €**

Table 7: Summary of cost / benefit assessment results.

Under these conservative but realistic hypothesis, the analysis has put in evidence that **savings in the winter road maintenance activities are alone not able to cover necessary costs to implement and maintain the system**, since annual maintenance costs alone are estimated to be higher than cost savings: in this way, the break-even point can never be reached. The investigation of alternative scenarios confirmed these preliminary conclusions.

This result must however be properly evaluated: in fact, this analysis did not consider other potential savings, which are however much more difficult to estimate: **environmental costs** and **road users costs** (e.g. costs associated to accidents, congestions, increase vehicle usage and corrosion). On the other side, there are **other advantages that are not economically quantifiable**: just to make an example, in case of disputes with motorists, with the MDSS road operators can have a quantitative support for justifying their treatment decisions. These conflicting results, together with the perspectives of improvement of the treatment techniques put in evidence in task B4.2, are the main reasons why PAT, together with the other associated partners, has decided to **continue the pilot activities during the next three winter seasons**, and further **investigate a possible business case for the large-scale implementation of the CLEAN-ROADS system**.

This exploitation perspective was also supported by the definition of **reproducibility criteria**, In order to replicate / extend the system in other road networks, one should consider the following list of tasks:

1. **During winter season 1: carry out preliminary initial thermal mapping surveys** during “extreme” conditions (i.e. near sunrise, with cold, calm and clear-sky weather). Surveys must be able to collect spatial measurements related not only to road surface temperatures but also to **air temperatures** and **relative humidity**, in order to verify the presence of specific spots that are much prone than other to hoarfrost events. It is also recommended to **start recording the treatment activities of road operators** with an automatic tool, if not already existing.
2. **After winter season 1 and before winter season 2: identify possible monitoring points**, by considering not only stretches that have shown a higher risk of ice formation, but also additional criteria / constraints such as installation feasibility / costs, average amount of precipitation during winter (if available), historical information about traffic volumes and accidents. A quantitative ranking can be determined and the most “representative” location for the entire monitored route can be selected. Road forecast model **METRo** can be **configured** according to the orographic characteristics of the selected point. The static RWIS station can be installed so to guarantee the proper data input stream to forecasting models.
3. **During winter season 2:** road weather forecasts are tested and validated. Road operators can start use the **MDSS** and the **real-time road conditions monitoring software** and improve the efficiency of their work. Drivers and travellers can get additional information on the **information services** they have at disposal. It is

recommended to organize an **additional number of thermal mapping surveys** in order to increase the representativity of the statistical samples collected.

4. **After winter season 2 and before winter season 3:** system validation activities are completed, with fine-tuning of the calibration settings (if needed).
5. **From winter season 3:** complete CLEAN-ROADS system can be used in operational mode, including **road weather forecasts** and **route-based tools**.

Expected vs. achieved outputs: the expected outputs of Action B4 are two reports presenting the results of these empirical findings. The deliverables of Action B4 are annexed together with the Final Report.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 8.

Milestones	Means of verification	Comments	Reference report
M.B4.1 "Empirical cost-benefit evaluation of CLEAN-ROADS system completed"	• Evaluation methodology • Cost/benefit analysis • System exploitability considerations	The evaluation methodology has been consolidated. The cost / benefit analysis related to the winter seasons 2014/2015 and 2015/2016 are completed. Guidelines for the reproducibility of the system in other road networks have been refined.	D.B4.2
M.B4.2 "Novel winter road maintenance procedures successfully introduced"	• Evaluation of current winter maintenance organization situation • Proposed winter maintenance optimized procedures • Empirical application of novel procedures description	Current winter maintenance organization was already evaluated in the preparatory actions, and re-analysed in the scope of this action. First empirical investigation of enhanced procedures carried out during winter season 2014/2015. Improved winter maintenance procedures introduced during winter season 2015/2016. Novel winter road maintenance techniques for follow-up activities identified.	D.B4.1

Table 8: Indicators of progress – Action B4.

Comparison with the time schedule and problems encountered: the Action was completed in May 2016 (M45), at the end of the five months of project prolongation granted by the EC through the amendment of the Grant Agreement. In light of the countermeasures taken during the execution of the previous actions, the execution of this action was carried out smoothly, without any significant technical inconvenient.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: as already underlined, project partners have already agreed to **continue the pilot activities of Action B4 for other three winter seasons**, with the intention to better consolidate and capitalize the project's results. During this period, the residual optimization margin estimates are going to be verified, and a further work of **improvement of the road maintenance procedures** is going to take place, in particular as far as the **use of pre-wetted salt** instead of dry salt is concerned. The **assessment tools** that have been implemented are going to be used on a yearly basis in order to continuously monitor the savings obtained thanks to the CLEAN-ROADS system. In case of further **geographical extensions of the system**, the reproducibility criteria consolidated at the project's end are going to be applied and eventually refined on the base of this future empirical experience.

4.1.7 Action C1: Monitoring the impact on the target audience and local welfare

Status of the action: the Action was successfully completed in May 2016 (M45). The activities of this Action were mainly carried out by IDM, in strict cooperation with the Road Management Service of PAT, in particular as far as the organization of specific monitoring initiatives towards the target groups of the projects is concerned. The main activities and results of the different tasks of this action can be summarized as follows:

- **initial impact evaluation**. During this initial study, target groups and monitoring indicators were analysed and consolidated. This activity also covered the detailed planning of all monitoring activities during the whole project execution.
- **ex-ante impact evaluation**. During this first monitoring analysis, an initial quantification of the monitoring indicators was completed. Following "direct" monitoring initiatives were in particular completed:
    - organization of a **public online survey** for the initial "direct" monitoring assessment covering **local travellers**. This survey was completed in 2013 with the intention to collect useful indications for the requirements analysis covered by Action A2 as well. The survey got a great acknowledgment, with about 1.250 people providing their comments to the proposed questions;
    - organization of **an ex-ante survey** targeting **local stakeholders**, requesting some information related to the current practices in the road maintenance. Thanks to this monitoring activity, information provided by ten local stakeholders were collected.
- **first process evaluation of the project impacts**. This monitoring phase covered the initial update of the monitoring indicators and a first evaluation of the impacts of the project on the target audience. Following "direct" monitoring initiatives were in particular completed:
    - organization of a **second public online survey** destined to **local travellers**. This survey was completed in 2014, and was coupled with a collection of specific feedback related to the prototypes for the distribution of road weather information. The survey got a reduced acknowledgment, with only 125 people providing their comments to the proposed questions.
    - organization of a **first survey destined to road operators**. This survey, opened to the whole staff of the PAT (204 operators), was carried out in correspondence of the first training course held in 2014.
    - organization of a first **questionnaire destined to local stakeholders**, carried out during the first project workshop (January 2014), aiming at evaluating if this "seeding" event had concrete impacts in the improvement of current winter road maintenance practises. Thanks to this action, 37 feedbacks were received.
- **second process evaluation of the project impacts**. This monitoring phase covered the intermediate update of the monitoring indicators and a second evaluation checkpoint of the impacts of the project on the target audience. Following "direct" monitoring initiatives were in particular completed:

- organization of a **third public online survey** destined to **local travellers**. This survey was organized before the kick-off of the final pilot winter season 2015/2016, with the purpose to evaluate the ex-ante expectations of travellers regarding the use of the final version of the pilot end-users application. The survey got a reduced acknowledgment, with only 105 people providing their comments to the proposed questions;
- organization of a **second survey destined to road operators**. This survey, opened to the whole staff of the PAT (191 operators), was carried out in correspondence of the second training course held in 2015. A specific action of **feedback collection** was also organized with the **team of road operators** (6 people) involved in the **pilot activities during the winter season 2014-2015**;
- organization of a second **questionnaire destined to local stakeholders**, carried out during the second project workshop (February 2015), with similar intentions to the previous monitoring initiative. Thanks to this action, other 19 feedbacks were received.

- **ex-post impact evaluation**. During this final monitoring analysis, a final quantification of the monitoring indicators was completed. Following "direct" monitoring initiatives were in particular completed:
    - organization of a **fourth public online survey** destined to **local travellers**. This survey was organized after the kick-off of the final pilot winter season 2015/2016, with the purpose to evaluate the ex-post feedback of travellers concerning the use in real-life situations of the final version of the pilot end-users application and the future possible exploitation scenarios. The survey got an increased acknowledgment with respect to previous monitoring checkpoints, with 264 people providing their comments to the proposed questions.
    - fulfilment of a final specific action of **feedback collection** with the **team of road operators** (6 people) involved in the **pilot activities during the winter season 2014-2015**;
    - organization of **an ex-post survey** targeting **local stakeholders**, including not only other road network operators but also all other interested parties willing to continue to cooperate with CLEAN-ROADS even after the project's end. Thanks to this monitoring activity, information provided by ten local stakeholders were collected.

Results of these social monitoring activities can be summarized as follows.

Local travellers. The execution of the project found a positive appreciation by the local travellers. The majority of people revealing to appreciate the winter road maintenance service of PAT passed from the 60% of the ex-ante evaluation to the 80% of the following direct assessments. The usage trends of the end-users application is continuously growing, and reached already about 2.000 active users in winter season 2015/2016, with about 75% of respondents of the final survey willing to maintain these services even after the project's end. Local travellers are also showing, at least in the monitoring site of Cadino, to adapt trip choices and driving behaviour already in a satisfactory way when bad weather conditions occur, even if patterns reveal how different situations are mostly dominated by the current level of mobility demand.

Road operators. The execution of the CLEAN-ROADS project was welcomed very positively by the entire road operators' staff, with an appreciation that further increased when the pilot system was started to be tested in real-life operations. **About the 80% of the operators (85% at the project's end) revealed to have enhanced the efficiency of their maintenance activities thanks to what learnt during the project**. The feedback was enthusiastic in particular by the road operators' team responsible for the winter road maintenance on the case study road, in particular after the introduction of the CLEAN-ROADS system during the winter season 2014/2015. The appreciation of the system prototype was in general very good, with the majority of road operators confirming that thanks to the system they were able to reduce the number of treatments.

Local and international stakeholders. The initial surveys with **local stakeholders** revealed on one side that the winter road maintenance is a topic of high interest for the administrations responsible of this service, as demonstrated by the audience and participation to the project workshops; on the other side, the current practises are very strongly influenced by the limited budget at disposal of these administrations. The highest investments are mainly at regional level, with both the **A22 highway** and the **Autonomous Province of Bolzano** already availing of a similar RWIS and producing efforts to reduce the negative impacts associated to road salting. With those stakeholders, there are the greater opportunities after the project to improve synergies by linking and aligning technological systems in place and road maintenance procedures, so to harmonize the road level of service perceived by travellers. Another important commitment was those of **local municipalities**, who have expressed to contribute (even financially) to the future system exploitation by buying further static RWIS stations to be placed in the urban road network under their control. The exchange of data and information provided by the system to operators of municipal administrations in the case study road (e.g. the municipality of **Lavis**) already positively started during the winter season 2015/2016. Several contacts were developed with other external companies and other local research centers to further improve the knowledge and advance the current state-of-art solutions deployed. The plan is to maintain the activated working tables, and maintain the case study road as open test bed for future R&D initiatives. As far as the **international stakeholders** are concerned, the number of relevant initiatives worldwide in this sector has significantly increased in the past years as a consequence of the higher maturity reached by RWIS technologies. The gap between international and Italian state-of-art is confirmed to be quite high, but the kick-off of a couple of new interesting (research) projects such as the ESA ASSIST project was observed. Thanks to the new international contacts established, also with other LIFE projects (e.g. **LIFE11 ENV/ES/000584 AIRUSE**) the CLEAN-ROADS project has consolidated a role of leadership on this topic at national level, with many national stakeholders willing to try to exploit CLEAN-ROADS's results. The main limitation for that is unfortunately due to the uncertain future of Provinces in Italy, which are probably going to disappear in the next years (except for the autonomous ones like PAT): since it is still unclear who will take care the competence of road maintenance in the new governance framework, significant investments in the directions suggested by CLEAN-ROADS are for the moment to be excluded.

Expected vs. achieved outputs: the expected outputs of Action C1 are five reports, presenting the results of the different monitoring actions. Deliverable D.C1.1. was already submitted in annex to the Inception Report, deliverable D.C1.2 was delivered together with the Progress Report and D.C1.3 with the Mid-Term Report. Together with this Final Report deliverables D.C1.4 and D.C1.5, covering respectively the second process evaluation of the project impacts and the ex-post assessment are finally delivered.

Indicators of progress: the evaluation of the proper achievement of the milestones set for this action is discussed in Table 9.

Milestones	Means of verification	Comments	Reference report
M.C1.1 "Indicators for the target audience defined"	Target audience monitoring methodology defined	This milestone is achieved. Target groups, indicators and measuring methodologies have been specified.	D.C1.1
M.C1.2 "Ex-ante monitoring activity covering the winter season 2012/2013 performed"	Application of monitoring methodology to first project winter season	This milestone is achieved. The full assessment of the ex-ante situation has been carried out.	D.C1.2
M.C1.3 "First process monitoring activity covering the winter season 2013/2014 performed"	Application of monitoring methodology to second project winter season	This milestone is achieved. The first project impacts have been estimated.	D.C1.3
M.C1.4 "Second process monitoring activity covering the winter season 2014/2015 performed"	Application of monitoring methodology to third project winter season	This milestone is achieved. The second project impacts have been estimated.	D.C1.4
M.C1.5 "Ex-post monitoring activity covering the winter season 2015/2016 performed"	Application of monitoring methodology to final project winter season	This milestone is achieved. The full assessment of the ex-post situation has been carried out.	D.C1.5

Table 9: Indicators of progress – Action C1.

Comparison with the time schedule and problems encountered: the Action was completed in May 2016 (M45). The execution of this action was carried out without any significant inconvenient, in particular thanks to the good level of relationship that the project established with the different target groups.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: in order to continuously evaluate the impact of the CLEAN-ROADS system on the local target audience, the plan is to continue to apply the proposed monitoring methodology in a slightly reduced form, even after the project's end, as indicated in the After-LIFE communication plan (D.D6.1)

4.1.8 Action C2: Monitoring the environmental improvement of the project

Status of the action: the Action was successfully completed in May 2016 (M45). The activities of this Action were mainly carried out by the Environmental Agency of the PAT, which has availed of a significant external scientific assistance (the **Environmental Engineering Department of the University of Trento**) for the whole monitoring activities on the aquatic systems. The main activities and results of the different tasks of this action can be summarized as follows:

- **completion of the initial impact evaluation**. During this preliminary analysis, the environmental problem was characterized, in particular as far as the impacts on matrixes air quality and aquatic systems are concerned. A selection of the environmental pollutants to be monitored was moreover performed. Specific technical indications for the proper measurement of these pollutants in the monitoring site of Cadino were finally consolidated and shared with Action A1.

- **completion of the ex-ante and intermediate impacts evaluation** in which the environmental monitoring methodology was applied during the winter seasons 2013-2014 and 2014-2015, respectively.
- **completion of the ex-post impact evaluation** in which the environmental monitoring methodology was finally during the winter seasons 2015-2016.

Results of the monitoring activities can be summarized as follows.

Air quality. Winter season 2013-2014 was **meteorologically speaking very anomalous**. On the regions of central and northern Italy, in particular, this season was one of the hottest and rainiest observed in the last 100 years, characterized by temperatures well above the average and by frequent and abundant rainfall, especially on alpine areas. This significant meteorological anomaly strongly impacted also **air quality levels**: in all official air quality monitoring sites in the PAT, low pollutants concentrations were observed, not representative of a "normal" winter. Also in Cadino, PM_{10} concentration were low, with only two situations of exceedance of the admitted daily limit.

Even if also during **winter 2014-2015** PM_{10} concentration was not very high, a more typical winter trend was observed. In absence of wind and rain, weather conditions facilitated the pollutant accumulation, and only the arrivals of a perturbation caused the pollutant dispersion. This alternation of concentration peaks and daily average next to zero was clearly evident in the collected measurements and were responsible of five situations of exceedance.

During **winter 2015-16,** higher PM_{10} concentrations were observed, especially in December 2015. This trend was detected in the whole northern Italy. Winter average concentration was higher than previous winters, 24 µg/m^3, and the daily limit was exceeded 7 times.

In PAT, high PM_{10} concentrations are typically observed in February, due to increase of secondary particulates. During anomalous winter 2013-14, this typical trend was not observed, whereas in February 2015 and February 2016 the highest PM_{10} concentration of the whole winter was measured. As a further demonstration of the exceptional nature of winter season 2013/2014, the correlation between chlorine and sodium ions is reported (Figure 17): while it is completely absent during winter 2013-14, it is evident during winter 2014-15 and winter 2015-16, with both low and high concentrations. Considering days characterised by high Cl^- and Na^+ concentrations, the Cl^-/Na^+ ratio is about 1.5, similar to the stoichiometric ratio of chlorine/sodium in NaCl. In light of these exceptional meteorological conditions, it was **not possible to correlate air quality levels with road salting activities during the winter season 2013/2014**. This correlation is however very clear if winter season 2014/2015 and 2015/2016 air pollution concentrations vs. salt spreading activities dataset is considered (Figure 18). It is also possible to appreciate a clear dependence, after spreading, between weather condition and salt concentration in air. Without rainfall, salting increases NaCl concentrations in air immediately (Figure 19a). After light rain, only low concentrations of NaCl in runoff are found. PM_{10} is then resuspended from road to air and high NaCl concentrations in air (some days after spreading) are observed (Figure 19b). If rainfall occurs immediately after salt spreading salt is washed away from the road, so is found only in runoff water.

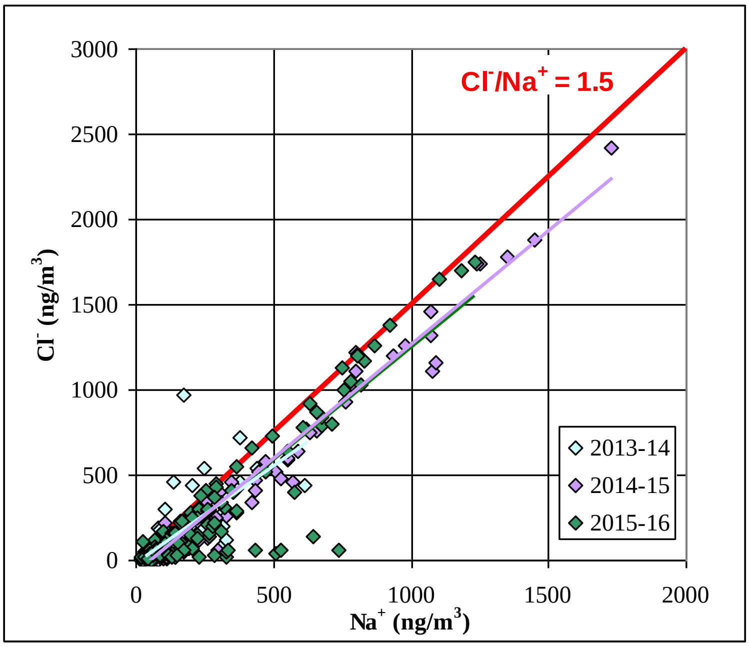
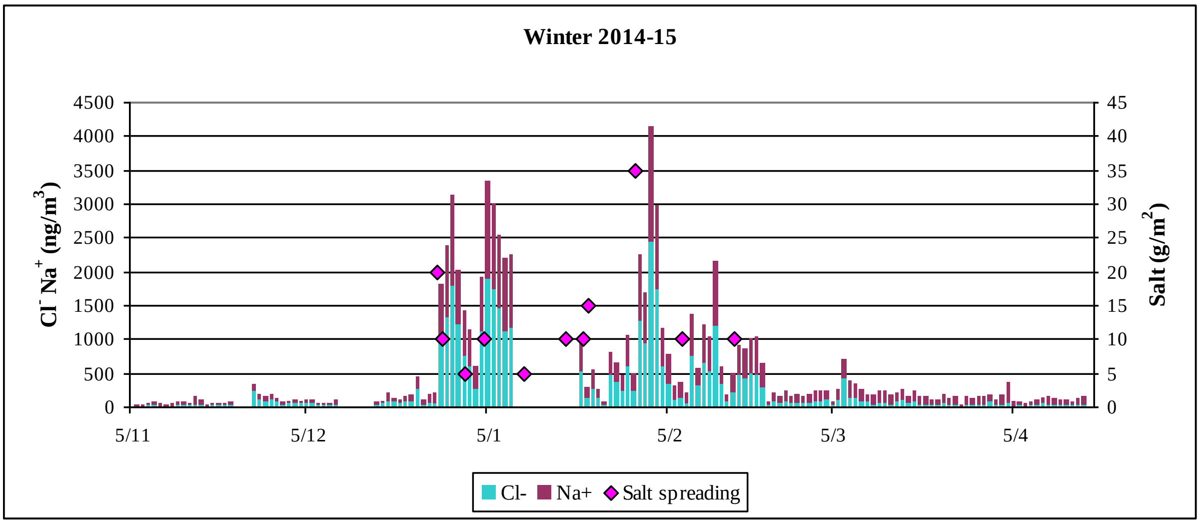


Figure 17: Correlation between chlorine and sodium ions in PM_{10} samples collected in Cadino.



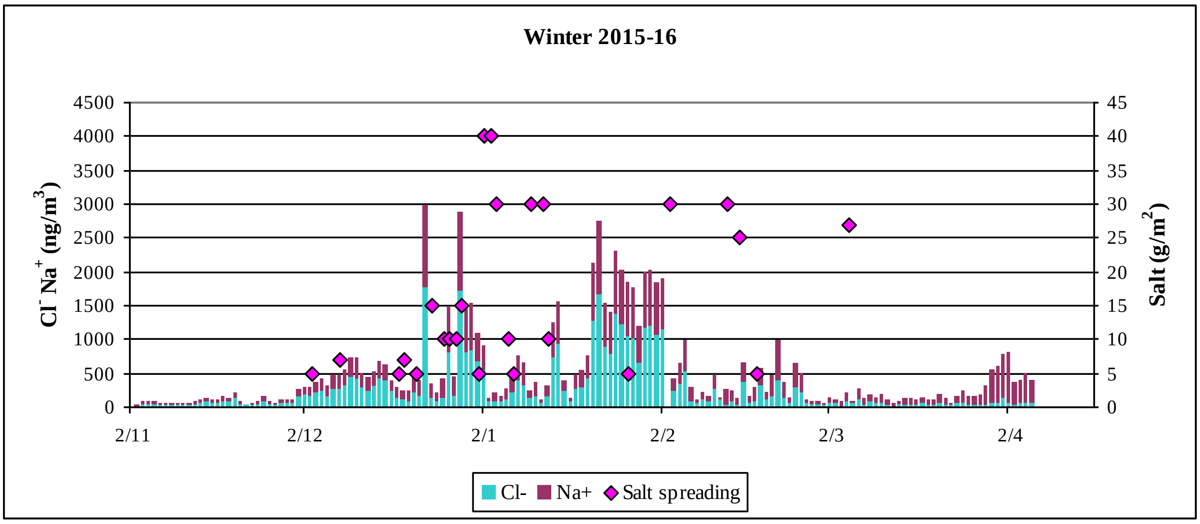


Figure 18: Chlorine and sodium concentrations compared with road salting activities during winters 2014/15 and 2015/16.

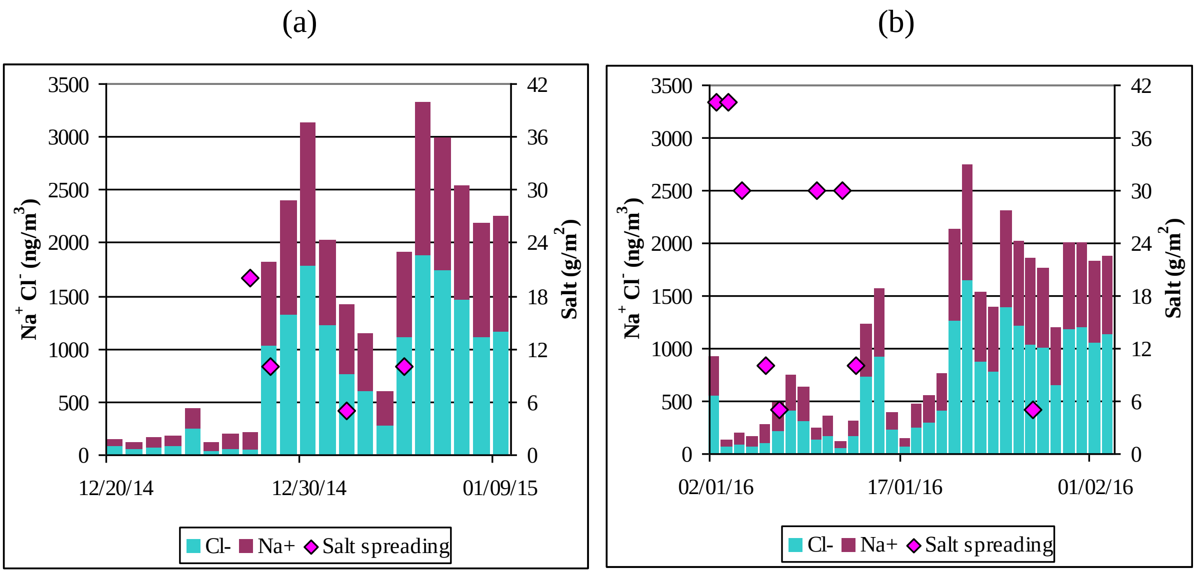


Figure 19: Salt spreading days and NaCl concentration in PM_{10} without rainfall (a) and after light rain (b).

As both Chlorine and Sodium in PM_{10} could, in principle, be due to other sources than NaCl used for road salting, the analyses of a number of chemical species and compounds in samples collected in Cadino was performed. Afterwards, multivariate analyses methods such as **Positive Matrix Factorization** (PMF) was employed for *source apportionment*, namely to identify the sources of PM_{10} and to quantify their impact. PMF analyses performed on the dataset collected during winter 2015-16 highlighted 8 main sources of particulate matter, namely biomass burning, crustal dust, biogenic aerosol, secondary nitrate, secondary sulphate, traffic, road salting and Na-rich. In Figure 20 the total PM_{10} mass attributable to road salting practices is reported. It can be observed that concentration of PM_{10} increases since beginning of December 2015, in agreement with the beginning of the winter road maintenance practices. **Contribution to PM_{10} due to road salting is of the order of some µg/m^3 during the days following intense salt distribution, with maxima exceeding 3 µg/m^3**, but PM_{10} concentrations can also rise remarkably when repeated distribution of sea salt and favourable wheatear conditions suddenly promote the formation of NaCl aerosol. Also, it has to be noted that concentration fo NaCl in PM_{10} due to road salting can last for several days and that NaCl aerosol can be produced even several days after salt distribution.

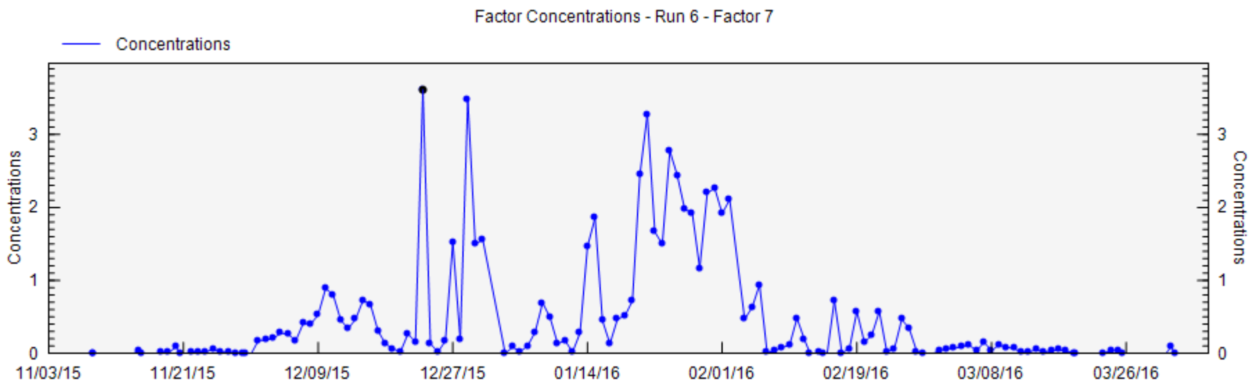


Figure 20: Results of source apportionmnent analyses.

Road salting contributed the 78% to the concentration of Cl^- in the atmosphere, the rest being essentially attributable to biomass burning. Conversely, de-icing operations only determines about the 30% of the Na^+ concentration in air, the rest being described by an additional source. According to Directive 2008/50/CE, PM_{10} concentrations attributable to winter salting can be subtracted from mean daily PM_{10} concentration when assessing compliance with air quality limit values. In general, however, the results of the analysis show that **in winter 2015-16 the fraction of PM_{10} due to road salting is not sufficient to reduce the number of days when the PM_{10} limit value is exceeded**.

Aquatic systems. During **winter season 2013/2014**, all runoff events occurred in the period December 24th 2013 - March 1st 2014 were monitored. The exceptional meteorological conditions unfortunately negatively affected even this environmental monitoring analysis. In particular, the abundant quantity of rainy precipitations significantly limited the duration of dry periods with accumulation of pollutants on the road surface. Water quality measurements however managed to provide initial indications about the level of pollution of run-off waters; in particular, the concentration of chloride obtained in the **first portion of runoff waters** has demonstrated to empirically **exceed the standards for freshwaters**, indicating a **potential impact on the aquatic life**.

As far as **water quality in winter season 2014/2015** is concerned, all significant rainfall and snowfall events occurred were monitored (December 27th 2014 - February 21st 2015). During this winter season 2014/2015 rainfall and snowfall events were fewer than in 2013/2014 (7 and 11 events, respectively). A more advanced methodology was introduced during second monitoring analysis in order to more accurately evaluate the environmental impact. Together with the chloride and sodium concentrations, the **masses of chlorides and sodium discharged with the runoff waters** was indirectly calculated as a function of the measurements of electrical conductivity, as summarized in Table 10.

WINTER 2013/2014		
N° of event	**Mass of Cl^- (g)**	**Massa of Na^+ (g)**
Event 1	13.1	11.7
Event 2	1.2	1.5
Event 3	0.1	0.1
Event 4	157.8	112.0
Event 5	218.8	144.4
Event 6	1.0	0.7
Event 7	11.5	7.7
Event 8	170.7	114.3
Event 9	209.4	133.3
Event 10	285.0	192.5
Event 11	24.5	17.9
TOT	**1093**	**736**

WINTER 2014/2015		
N° of event	**Mass of Cl^- (g)**	**Mass of Na^+ (g)**
Event 1	0.1	0.0
Event 2	344.0	222.0
Event 3	0.0	0.0
Event 4	13.7	8.6
Event 5	126.6	80.3
Event 6	6.6	4.1
Event 7	3.9	2.5
TOT	**495**	**318**

WINTER 2015/2016		
N° of event	**N° of event**	**N° of event**
Event 1	0	0
Event 2	45.7	32.9
Event 3	37.1	23.8
Event 4	7.1	5.5
Event 5	90.5	68.0
Event 6	0.43	0.35
Event 7	50.5	32.5
Event 8	22.6	17.6
Event 9	61.9	43.6
TOT	**316**	**224**

Table 10: Mass of chloride and sodium during each runoff event during the winter seasons 2013-14, 2014-15 and 2015-16.

The mass of salts, in terms of chlorides and sodium, is a key parameter to evaluate impact instead of the absolute concentration in the runoff water flow. It can be observed that the

discharge of chloride and sodium ions decreased significantly in winter 2015-16 (316 and 224 [g], respectively) **and in winter 2014/2015** (495 and 318 [g], respectively) **in comparison with winter 2013/2014** (1093 and 736 [g], respectively). This is the result of two concurrent causes:

- a **decrease in the amount of de-icing salts** used on the road, which passed from 115 [kg] in winter 2013/2014 to 76 [kg] in winter 2014/2015 and 90 [kg] in winter 2015/2016, coupled with a **better use of salt during the pilot activities in correspondence of a rainy precipitation event;**
- a **smaller precipitation amount** which caused a less washing of salts from the road, leading thus to a reduction in the amount of salts in the runoff water.

Expected vs. achieved outputs: the expected outputs of Action C2 are four reports, presenting the results of the different monitoring actions. The ri-distribution of the outputs of Action C2 was already discussed and approved by the EC in occasion of the Inception Report delivery. Deliverable D.C2.1 was already submitted with the Inception Report, D.C2.2 was annexed to the Mid Term Report, and D.C2.3 and D.C2.4 are delivered together with this Final Report.

Indicators of progress: this Action managed to finalize the initial impact evaluation, the ex-ante monitoring analysis, the intermediate monitoring process and the ex-post impact evaluation analysis for both air and water components.

Comparison with the time schedule and problems encountered: the Action was completed in May 2016 (M45), in line with the planning defined in the recovery plan. The execution of this Action suffered of different issues, from the delayed activation of the monitoring site in Cadino, which determined the impossibility to collect useful environmental data during the winter season 2012/2013, to the non-representativeness of the winter season 2013-2014 caused by the exceptional meteorological conditions observed. In light of these problems, the **entire environmental impact evaluation structure was completely revised**. The key point of the recovery plan submitted and accepted by the EC in the formal request of amendment is related to the decision to focus on the quantification of the impacts associated to each treatment in the different meteorological conditions, in particular as far as the impact on air quality levels is concerned. This has also led to the **improvement of the monitoring methodology defined at the project's start,** with the introduction of a different sampling strategy and more advanced analytical procedures for the detection of chlorine and sodium concentrations.

Objectives achievability: all the objectives of this action have been properly fulfilled.

Perspectives for continuing the action after the end of the project: the perspective for the Environmental Agency of the PAT is to step-by-step include this environmental monitoring action within its set of operational monitoring activities, in particular as far as the contribution of road salting to PM concentrations is concerned. This aspect is of particular importance, since according to Directive 2008/50/EC the contribution to PM due to natural sources, including salt deriving from road salting activities, could be subtracted from the total concentration of particulate matter provided that it is clearly discriminated from that of any anthropogenic sources. On the other side, the perspective is to continue, at least in the site of Cadino, the monitoring of the environmental impacts in order to further understand the negative impacts of road salting activities on the environment near the road infrastructure and continuously quantify the improvements associated to a more efficient use of road salting resources.

4.2 Dissemination actions

5.2.1 Objectives

One of the annexes of the Inception Report delivered to the EC was the dissemination plan (D.D2.1). In this document, many elements were finalized in order to prepare the local and international dissemination campaign planned by the project. In particular (i) the **target groups were identified** (i.e. road management operators, local travellers and drivers, local and international stakeholders) and (ii) the **objectives of the dissemination strategy** were consolidated, being in particular:

- to create a local **awareness-raising campaign** about the **environmental impacts caused by an excessive use of salt** during the winter road maintenance operations;
- to guarantee that the project's expected results can not only be achieved through interventions of technical nature (i.e. through the introduction of an advanced RWIS system), but also (and above all) through a **real and committed change in the target users' habits**.

5.2.2 Dissemination: overview per activity

A large set of dissemination activities was carried out in the scope of the project, mainly by the Road Management of the PAT (the main institutional partner in the consortium), with the active cooperation of the other services of the Coordinating Beneficiary involved in the project. IDM mainly covered the preparation of the dissemination products and the maintenance and update of the web-based dissemination channels, while FAMAS mostly had an active role in the establishment and maintenance of contacts with national and international stakeholders, also in perspective of future business partnerships.

Action D1: Project website

The **project web site** is accessible at the link www.clean-roads.eu, and during the project execution it was continuously enriched in terms of information, news and multimedia content. It also represents the starting page for accessing the prototype end-user application and has been used as interface with the general public, in particular during the execution of the public on-line surveys. In the period covered by this Final Report, about 10.000 visits have been counted, with about 4.000 visits coming from outside Italy – as a demonstration of the international character reached by the project.

Action D2: Local stakeholders involvement

Task D2.1 *"Road management operators involvement and training"*. Thanks to the activities carried out in this task, it has been possible to establish an excellent cooperation with the entire road operators' staff, in particular the team chosen for the demonstrative activities of the project on the case study road. The **process of involvement** started very early, already before the kick-off of the winter season 2012-2013. Road operators were actively involved in different technical project activities, including the preparation of the monitoring site in Cadino, the skid measurement tests, the activation of the notice boards and the execution of the thermal mapping surveys, but also in other involvement activities such as the recording of scenes for the production of the project video. This has been very important, since in this way the team positively felt to be an integral part of the project staff and to be in the conditions to give useful contributions to its successful implementation. Important milestones have been in particular:

- the smooth **introduction of the automatic monitoring tool** (**trackoid**) before winter season 2013-2014 for the recording of their road maintenance activities during the winter;
- the successful **introduction of the CLEAN-ROADS prototype** system before winter season 2014-2015, which determined a first improvement of the efficiency of their actions, and **of the enhanced CLEAN-ROADS prototype** system before winter season 2015-2016, which has not only contributed to consolidated the early improvements, but most important to put the basis for significant future enhancement in the modalities of winter road treatments during the incoming winter seasons.

This process would have probably been less easy without such level of involvement, since the operators could have felt the project's requests in a negative way, for example as a modality to control their work or to substitute them.

Involvement activities have not been limited to this specific team of road operators, but to the whole staff of the PAT. In particular, **two training courses** were organized: the first one before the kick-off of the winter season 2014-2015, and the second one before the kick-off of the winter season 2015-2016. More than 200 road operators, split up in three different days, had the opportunity to attend it. The course has been specifically thought in order to consolidate their knowledge of meteorology basic concepts, with a particular attention to ice formation on roads. The course has also be the occasion for properly introducing the project and the added value that a system like the one deployed in CLEAN-ROADS can provide.

Figure 21: The involvement of road operators: the team testing the CLEAN-ROADS system prototype (top figures) and the whole staff during the first and second training courses (bottom figures).

Task D2.2 *"Local dissemination and local population awareness-raising campaign"*. A variety of local dissemination activities was carried out. The most effective means towards the local population revealed to be a massive set of **media actions**, in particular in occasion of significant project milestones (e.g. the launch of the public surveys, the kick-off of the winter season). The wide presence of the project during these key moments of the year created a very broad interest and active participation in this project initiative.

Figure 22: One of the two TV interviews specifically dedicated to the project (TV transmission "Europa 2014", broadcaster Trentino TV).

Different dissemination outputs have been prepared: the **project video**, with more than 500 on-line visualizations, and **two flyers**, one more focused on the technological part of the project and one more focused on presenting the environmental impacts on road salting. This project material was used and widely distributed in cooperation with local stakeholders and during various dissemination events. The **Layman's Report**, together with other after-LIFE dissemination outputs defined in the after-LIFE communication plan, is going to **support the process of involvement of local end-users from winter season 2016 / 2017 on**, with the objective to inform on a broader scale about the project's results and above all on how the project is going to continue even after its end.

Task D2.3 *"Inter-regional stakeholder involvement"*. The most relevant output of this task was the creation and consolidation of an extended **network of contacts with reference organizations which are active in the winter road maintenance domain**. This result was mainly achieved thanks to two different actions: (i) the active involvement of local and national stakeholders in the activities of the project; and (ii) the organization of high-level workshops. In particular, **two international workshops** with about 80 participants have been already organized, one in January 2014 and one in February 2015. The purpose of these networking events was to increase the visibility and the weight of the topics touched by the project, and to strengthen the link between local and national state-of-art and international best-practices. The **final event** in May 2016, more destined to a local audience (70 participants), aimed on the contrary at presenting the major achievements of the project and at putting the basis for follow-up cooperations.

Figure 23: The participants to the project workshops.

<u>Action D3: Networking and transnationality</u>

The project also managed to build an **international dimension** in the context of reference EU networks and organizations dealing with winter road maintenance. The first significant international networking activity took place through the presentation of the project at the main conference on RWIS systems in the world (**SIRWEC Conference 2014**, Andorra) and the participation to two big congresses, dealing with winter road maintenance in a broader sense (**PIARC XIVth International Winter Road Congress 2014, Andorra**) and ITS technologies, applied in particular for the smart maintenance of the road networks during exceptional winter conditions (**ITS European Congress, Helsinki 2014**). Thanks to the wide set of contacts established, it was possible to give a real international scope to the **second project workshop**. International speakers such as mr. Lee Chapman, one of the key members of the SIRWEC Steering Committee, and mr. Dominici, one of the Italian speakers encountered during the PIARC Winter Road Congress, warmly welcomed the invitation to share their vision and their current activities in the RWIS field. A speaker representing the Spanish **LIFE 11 ENV/ES/000584 AIRUSE** project was invited as well for a sharing of the environmental monitoring activities on road salting that this transnational project is carrying out. A closer networking event completed this project initiative: an occasion to discuss with these international RWIS experts the technical details of the project, and to collect useful feedbacks for improving the quality of the project implementation. Relevant comments have been received in particular as far as the calibration of the forecasting chain is concerned, and the added value that the mobile RWIS station demonstrator can provide.

Figure 24: Mrs. Ilaria Pretto presenting the CLEAN-ROADS project during the SIRWEC 2014 Conference.

The sharing of the CLEAN-ROADS results within the scientific community was further improved during 2015-2016. The project was presented in occasion of:

ITS World Congress 2015 (Bordeaux, 05-10/10/2015), the main conference of intelligent transport systems in the world, in which a presentation was given by IDM on the novel ITS technologies used in the system;

the **International Conference on Alpine Meteorology 2015** (Innsbruck, August – September 2015), an important international conference on alpine meteorology in which the road weather forecasting tools were presented by the Weather Service of PAT;

the **Conference on Remote Sensing and Geoinformation of Environment (RSCY) 2016** (Cyprus, 04-08/04/2016), an international conference on remote sensing, in which the mobile RWIS station concept and the associated route-based elaboration and forecasting tool was presented by PAT;

the **European Geosciences Union (EGU) General Assembly 2016** (Vienna, 18-22/04/2016), the European geophysics Union conference, in which PAT presented the combined road weather forecast system consolidated at the project's end as well the environmental impact of road salting activities on air pollution;

SIRWEC 2016 (Colorado, 25-29/05/2016), in occasion of which a CLEAN-ROADS poster was kindly shown by the conference organizers, despite the **non-participation of any representative of the CLEAN-ROADS staff**;

PM 2016 (Roma, 16-20/05/2016) the national conference on atmospheric particulate, in which the Environmental Agency of PAT presented the results of the environmental assessment of the project on air pollution;

SIDISA 2016 (Roma, 20-25/06/2016) an international conference on sanitary and environmental engineering, in which the Environmental Agency of PAT presented the results of the environmental assessment of the project on run-off waters.

Action D4: LIFE+ Information Boards

The broad visibility of the project in the area addressed by the project activities was also ensured through the **activation of several notice boards**, not only in the case study road. The project poster together with other relevant project material was available since the preliminary dissemination phase in points at high visibility for the end-users, in particular the headquarters of **ACI** (Automobile Club Italia) in Trento, Pergine and Rovereto and various **tourist promotion office**s in the PAT.

Figure 25:The CLEAN-ROADS posters in the ACI headquarters of Trento, Pergine e Rovereto.

Figure 26: The CLEAN-ROADS dissemination material in different touristic promotion offices.

4.3 Evaluation of Project Implementation

Several comments can be made concerning the value and applicability of the adopted methodology with which the work plan was initially conceived, and the cost effectiveness of each single activity taken to support its technical, organizational or dissemination achievements.

The first consideration is related to the **proper integration of technical and non-technical actions** while executing a project with similar ambitious targets and complexity. The activation of a committed involvement of key target groups already from the project start revealed to be fundamental in order to ensure that the technical solutions that the project aimed to introduce were widely accepted and taken in consideration, with a high possibility for future larger exploitation. In particular, this process revealed to be crucial in particular as far the road operators are concerned, since it is now automatic to see a high level of user acceptance when a new IT system is planned to be introduced. This is the reason why **certain project results have been immediately visible**, in particular the possibility to **reduce the number of road treatments** by the staff involved in the project demonstration. Other impacts such as the responsible driving of local travelers are going to be more visible only in the incoming years, in particular if certain technical and awareness-raising activities will be followed-up and scaled up even after the closure of this project initiative.

A second consideration is related to the **technical implementation** of the project only. The proposed plan for the preparation, implementation and empirical evaluation of the CLEAN-ROADS system has demonstrated to be appropriate for a demonstrative project like this. The only significant inconvenient that have been encountered have been related to **limitations to planned activities during the winter seasons covered by the project**. A project in which most of the monitoring / demonstrative phases is carried out in a specific period of the year is intrinsically more at risk of unforeseeable circumstances, like the ones encountered by the project during the winter season 2013/2014. The proper temporal planning of such field activities has revealed to be a critical task, and it's absolutely not easy to identify in advance all risks that may take place and the proper recovery plans to be actuated. On the other side, the **unforeseeable events** caused by external factors such as exceptional meteorological conditions are not only a moment with high level of criticality, but can also be an **important step of growth for the project**. In particular, in the case of CLEAN-ROADS, the collection of an extensive data set related to a very mild winter season, followed by a more "standard" winter, has given the opportunity to more broadly cover the full set of road weather situations, with the possibility e.g. to improve the range of calibration of the road weather forecast models, or to analyze the optimization margin in the road salting activities associated to different climatological situations.

Another choice which has confirmed the expected positive results has been the decision to give to the project a clear **multi-disciplinary soul**, with the joint collaboration of experts in the ITS, meteorological and environmental domain. In this way, it was possible to properly tackle all the complex aspects managed by this project. A significant added value has been given by external assistance companies as well, who have furthermore increased the amount of complementary expertise of the project staff.

In light of the **project amendment** acknowledged by the EC, all project objectives have been confirmed, and in some aspects even overcome, as widely discussed in the Executive Summary of this report. The possibility to have one more winter season to be monitored gave the possibility to quantify the optimization margins and the environmental impacts of road salting activities under a wider range of boundary conditions, with the possibility to significantly **enhance the comprehension of the local targeted problems**. On the other side, final dissemination activities could more properly cover the whole winter season 2015-2016, including the first months of the year 2016. The complete comprehension of all targeted issues and the proper assessment of the benefits achieved in the project would not have been possible without the project prolongation grant. For a more exhaustive evaluation of the added value provided by the project prolongation, please refer to the administrative part of this report.

Last but not least, the **dissemination activities** revealed to be effective in order to reach the project's goals. The main drawback experienced in a project like CLEAN-ROADS which has had the need to introduce a new system from zero is that at the project start it is not easy for the target users to exactly understand the tools and instruments proposed to solve a specific issue without any prototype available for testing. A real change in the behavior and in the perspective of people can be more simply achieved if they can immediately appreciate the concrete measures developed. The advantage of future local project initiatives building upon CLEAN-ROADS will be that this preliminary phase is going to disappear, with the possibility to foster the change with a quicker and easier process.

4.4 Analysis of long-term benefits

Useful insights to the LIFE+ programme and other EU organizations to replicate and further extend the demonstrative activities organized in the scope of the project can be derived from this project experience. Since a comparison between expected and achieved results is already included in the Executive Summary of this report, this section is more focused on the understanding of potential long-term impacts, in particular at an EU scale.

Environmental benefits.

Air quality. Despite **Directive 2008/50/EC** allows to subtract the contribution of road salting from each measured daily mean PM_{10} value, it would be beneficial to have methodologies in place to avoid that an unnecessary treatment is responsible of a peak of particulate matter concentrations, as empirically confirmed by the project. The CLEAN-ROADS system has already demonstrated that a **more efficient and environmental-aware use of salt** can significantly contribute to **better air quality in winter**, in particular during unfavorable meteorological circumstances which favor the resuspension of salt in air, that can cause increases of pollutant levels greater than 3 $\mu g/m^3$. Significant **benefits in the EU air levels near the road networks**, in particular in inter-urban and extra-urban scenarios, could be obtained by properly adopting the CLEAN-ROADS tools and logics. A practical recommendation is to always link proper environmental monitoring sites at the roadway side, quantitative tools for the registration of treatment activities and decision support tools. Environmental monitoring methodologies should also be defined by taking advantage of the assessment methods considered in CLEAN-ROADS. **Meteorologists** and **environmental experts** should be **more deeply involved** in the maintenance tasks of road authorities, and if possible also share the **liability** of maintenance actions.

Aquatic systems. The environmental monitoring of **water quality** caused by road salting is a topic much less developed by both scientific studies and international best practices. Empirical results have clearly shown that **environmental concern** related to road salting can be significantly higher on aquatic systems than air pollution. CLEAN-ROADS has confirmed that unfortunately it is likely to have situations in which a road treatment is completely washed out by a following precipitation event. Climate changes are moreover going to increase the number of these events, with more frequent rainy events rather than snowfalls. The recommendation of CLEAN-ROADS is to encourage the use of **pre-wetted salt** instead of dry salt, supported by a decision support system: this can bring to a use of salt only when effectively needed, with potential significant reductions of unnecessary treatments that do not have any benefit on road safety but only produced environmental damages to aquatic systems near the roadway. The use of pre-wetted salt is more expensive than dry salt because of the equipment for pre-wetting salt, **but** it **is** very likely that the reduced amount of salting resources makes this option **economically viable**. Again, a more structured and deeper involvement of **meteorologists** and **environmental experts** in the **decision-making process** of road treatments is fundamental and is strongly recommended, in order to have a clearer picture of evolving meteorological conditions and environmental impact risk, and therefore to have the chance the take the optimum choice. **Liability** is a major driver in winter road maintenance, which should be properly better handled and re-thought. Currently road maintenance service and road operators in particular are the only responsible of winter road safety, and must respond in first person in case of disputes associated to accidents. On the other side, possible environmental impacts associated to winter road maintenance have still a little role in the decision-making process, since there are no similar external “pressures”, despite current environmental liabilities regulated in Environmental Liability Directive 2004/35/EC. A **more shared and standardized liability among different actors**, including drivers as well (as is already happening in the north of Europe, where certain types of roads are not treated in winter, and associated “levels of service” are defined) could for sure bring to a more rational and comparable use of de-icers in all Europe.

Long-term / qualitative environmental benefits. The added value of the project has been mostly in terms of increased visibility of the targeted environmental problem. Reference studies about the environmental impacts of road salting, in particular as far as certain matrixes is concerned, have been little investigated yet, and still need to be further analyzed and evaluated. The project has demonstrating the added value of environmental monitoring sites capable to monitor the effects in different environmental areas, with the further possibility to better understand the environmental phenomenon by properly correlating the collected measurements. On the other side, the proposed solutions introduced in CLEAN-ROADS confirm to be a technology that can be deployed on the longer term, eventually to **address further potential issues** taking place during other periods of the year (e.g. the evaluation of road conditions in order to decide when to carry out a specific maintenance activity, which may have certain negative consequences on the local road environment). In general, this system has the potential to cope the management of a road network during the whole year, and **address the increasing maintenance needs related to climate changes**, which cause very intense but short weather events during all seasons. A system like the one implemented in CLEAN-ROADS could be easily exploited to a **weather responsive traffic management system**, which could properly handle the occurrence of such sudden events. The environmental sustainability of the solution is also guaranteed by the very low energy consumption of the monitoring sites and the use of renewable energy sources to power them.

Long-term / qualitative economic benefits. CLEAN-ROADS has already demonstrated that the **application of advanced RWIS technologies can lead to significant long-term cost savings** to road operators and public administrations. Such savings, to be considered in terms of reduced road operators effort, salt consumption and maintenance equipment use, are determinant for the long-term economic sustainability of the system, in particular if then designed for larger road networks. Final cost / benefit studies suggest that at present direct cost savings are not able to cover maintenance costs of the MDSS – an aspect which currently holds the immediate expansion of the system on a larger scale. As already stated in Action B4, however, one should consider also indirect cost savings (environmental benefits, costs associated to accidents, congestions, increase vehicle usage and corrosion), which are unfortunately not immediately and accurately computable. The involvement of an **industry-partner** in the consortium such as FAMAS System but also the contacts established with other small local companies with very specialized competences, e.g. in the road weather modeling domain, ensures that the innovations trialed in the project can put the basis for future business opportunities, and that the increasing demand of winter maintenance organizations can be properly fulfilled by the industry offer.

Long-term / qualitative social benefits. In the road weather community, excepts for topics related to road safety, little attention was put in the past on aspects like the **training** and **inclusion** in innovation projects **of end-users**, in our case road operators and the traveling community. In recent years, thanks also to the mass diffusion of ICT technologies, such traditional approach is quickly changing: more and more attention is put on decision support systems for road operators, with the new challenge to understand how best visualize relevant information and alarms; and on informing on a real-time basis the traveler, both during the pre-trip phase while also on board, while he / she is driving in his / her vehicle. This novel approach is not only related to the new perspective of new service opportunities: road weather events can still be hard and difficult to predict and manage with traditional RWIS, and new **connected scenarios** are needed to cope with the still remaining issues. The role of users and Internet Of Things technologies can be determinant on this: people and their cars can not only be information consumer but also information producer. Several worldwide initiatives, in particular in the US, clearly demonstrate that there is this willing to create connected communities and networks, not only of intelligent systems but also of users. Many inefficiencies observed on the roads are still related to wrong behavior and choices of drivers: **increasing awareness and education** is therefore fundamental for increasing the efficiency of the road maintenance system as well. From this point of view, CLEAN-ROADS can be considered as one of the first initiatives worldwide trying to explore these future perspectives in such an extensive way. The mission is to foster this shift in the local feeling of road operators' staff and travelers towards the winter road maintenance challenges, and put the social preconditions for such future connected scenarios.

Continuation of the project actions by the beneficiary or by other stakeholders. As already underlined, in order to properly capitalize project results and further investigate a possible business case for the large-scale implementation of CLEAN-ROADS, PAT finally agreed with the other associated partners, to **continue the pilot project activities during the next three winter seasons**. During this phase, the test bed area and activities will be consolidated, and **partnerships with local stakeholders** (e.g. local municipalities, neighbouring road operators) strengthened, so to increase the scope and the community working to this initiative and to ensure its long-term sustainability and exploitation.

Replicability, demonstration, transferability, cooperation. The technical solutions developed in CLEAN-ROADS have a great potential for technical and commercial applications. Many **local and national stakeholders** are interested to be actively involved in the **follow-up activities** of the project, also to find out how to make CLEAN-ROADS economically viable and sustainable. Despite the huge investments in road maintenance activities, in Italy, differently from other European countries, RWIS technologies are still little widespread, with the potential for significant business opportunities for commercial project partner FAMAS. On the other side, the main barrier to this large-scale diffusion is unfortunately due to the **uncertain future of Provinces in Italy**, which are probably going to disappear in the next years (except for the autonomous ones like PAT): since it is still unclear who will take care the **competence of extra-urban road network maintenance** in the new governance framework, significant investments in the directions suggested by CLEAN-ROADS are for the moment to be excluded. More immediate transferability opportunities are to be found in **highway scenarios**, in which however RWIS are more common; existing systems could be however enhanced with tools and methods developed in the project, properly adapted as a function of the different application domains.

Best practice lessons. Before starting with the technical implementation of the project, a non-negligible effort was put onto the consolidation of the international state-of-art and the detailed evaluation of reference best-practices in Europe and North America. The conception of the CLEAN-ROADS architecture is the result of the effort to develop a system which is in line with the current existing implementations, but also easily scalable for further improvements when certain ITS technologies (e.g. vehicular communications, autonomous driving) will more closely enter the market. The strict cooperation with the reference RWIS scientific community has also given a significant added value to the project, in particular in the definition of the new entire process of intervention of road operators based and data and forecasts available.

Innovation and demonstration value. The solutions developed by the CLEAN-ROADS project are characterized by a very high level of innovation, not predominantly from a technological perspective, but mostly in the new processes and approaches introduced, which are significantly impacting the overall organization on how winter road treatments activities are currently managed. The multi-disciplinary approach supported by the LIFE funding, with the primary focus on the environmental aspects, was positively welcomed when presented to the international community.

Long term indicators of the project success. The long-term success of the project could be measured according to the following indicators: (i) the maintenance and expansion of the demonstrative system; (ii) the number of stakeholders involved in the system exploitation process; (iii) the number of system's replications in other road networks; (iv) the consolidated activation of road maintenance procedures based on CLEAN-ROADS MDSS; (v) a continuous and structured involvement of the Weather Service and the Environmental Agency in the winter road treatments' decision-making process (vi) a continuous reduction of road salting activities and of the negative environmental impacts associated to road salting, being the meteorological conditions of winter seasons similar; (iv) the inclusion of project environmental monitoring activities in the ordinary tasks of the local Environmental Agency for the Environment.