FOG WARNING SYSTEM IN VENICE REGION

Pekka Leviäkangas, Risto Öörni, Raine Hautala
VTT Transport and Logistics Systems
PO Box 1000
FI-02044, VTT, FINLAND
Andrea Rossa, Franco Zardini, Francesco Domenichini
Centro Meteorologico Teolo
Via Marconi 55
I-35037 TEOLO (PD), ITALY

ABSTRACT

The fog warning system build-up is one of the pilots of ROADIDEA project, under 7th Framework Programme of the European Union. The pilot was built and put in operation during the project. Fog Pilot is built by ARPAV, the meteorological service for Venice Region. This paper summarises the evaluation of the pilot and assesses the *ex ante* impacts. Especially the safety impact of the system is evaluated based on prior studies on similar systems and national accident statistics in Italy. Another emphasised evaluation line is the data and service output quality. System interface needs between Fog Pilot and other prospective systems hosted by other organisations, such as traffic *carabinieri* and traffic management centres of the region were assessed. Also some other technical and organisational aspects are evaluated. The challenges concerning the system architecture, looking at technical, organisational and economic issues, are discussed in the end.

BACKGROUND

Fog is a relatively frequent phenomenon in the Po Valley and constitutes a major issue for all road traffic. Fog monitoring is particularly difficult because of the phenomenon exhibits large horizontal variability and is measured at only very few sites as such sensors are not part of the standard equipment of the principal meteorological surface monitoring network. Satellite observations can partially contribute to observing fog and low visibility but they need to be combined with surface observations.

The basis of the fog warning pilot is on areal information on reduced visibility conditions. The potential for innovation given this availability can be related to several fields of application, and the innovation would be in taking visibility information as an additional element in the decision making process when assessing traffic conditions and deciding on traffic management operations.

The fog pilot (Fog Pilot hereafter) is specified to include information from a variety of data sources, such as satellite, direct visibility measurements, standard meteorological measurements, but also visibility estimates from web cams, visibility reports from traffic participants and other observers. This ‘open’ architecture of the visibility model allows, in principle, inclusion of data sources which may become available in the future.

OBJECTIVES AND SCOPE

EVALUATION COVERAGE

From the viewpoint of end-users, the fog-warning pilot is still a proof-of-concept under testing. Fog Pilot produces information on the visibility class within a given geographical area, but development of visibility-related services for end-users is a task which will continue after the ROADIDEA project. At present, instruments (visibilitymeters) measuring visibility have been installed at ARPAV (Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto) meteorological stations to collect real-time visibility information from ground stations and the development of information system performing data fusion for different data sources has been started.

In fact, one of the objectives of this ex-ante evaluation is to support the development of visibility-related information services. The other main objectives are: a) to identify the main user groups and their needs; b) to evaluate the technical aspects such as data quality and interoperability with other systems; c) to evaluate the main expected impacts and costs; d) to produce the general findings and recommendations to support the implementation of innovative services in Europe (1).

The viewpoints to be included in evaluation were selected by VTT and ARPAV in May 2009. Viewpoints to be included in this evaluation are (1): i) user needs, ii) data quality and availability, iii) technical implementation, iv) organisational aspects, v) cost-benefit assessment, and vi) degree of innovation.

The EasyWay template structure for Trans-European Networks (2) is roughly followed in this paper. First, some background information on the problem and Fog Pilot is presented. Then the objectives, methods and indicators of evaluation are depicted. After evaluation results, Fog Pilot’s success is summarised and further challenges discussed.

DESCRIPTION OF FOG PILOT

The principle of Fog Pilot is to combine visibility observations with satellite data and meteorological surface observations. In the future, also combining information from surface web-cameras and other meteorological reports is possible. The novelty of the pilot is the visibility information product that is being delivered to users. Also the modelling of visibility as one meteorological parameter is something not done previously for traffic management purposes. The principle architecture of the pilot is shown in Figure 1.

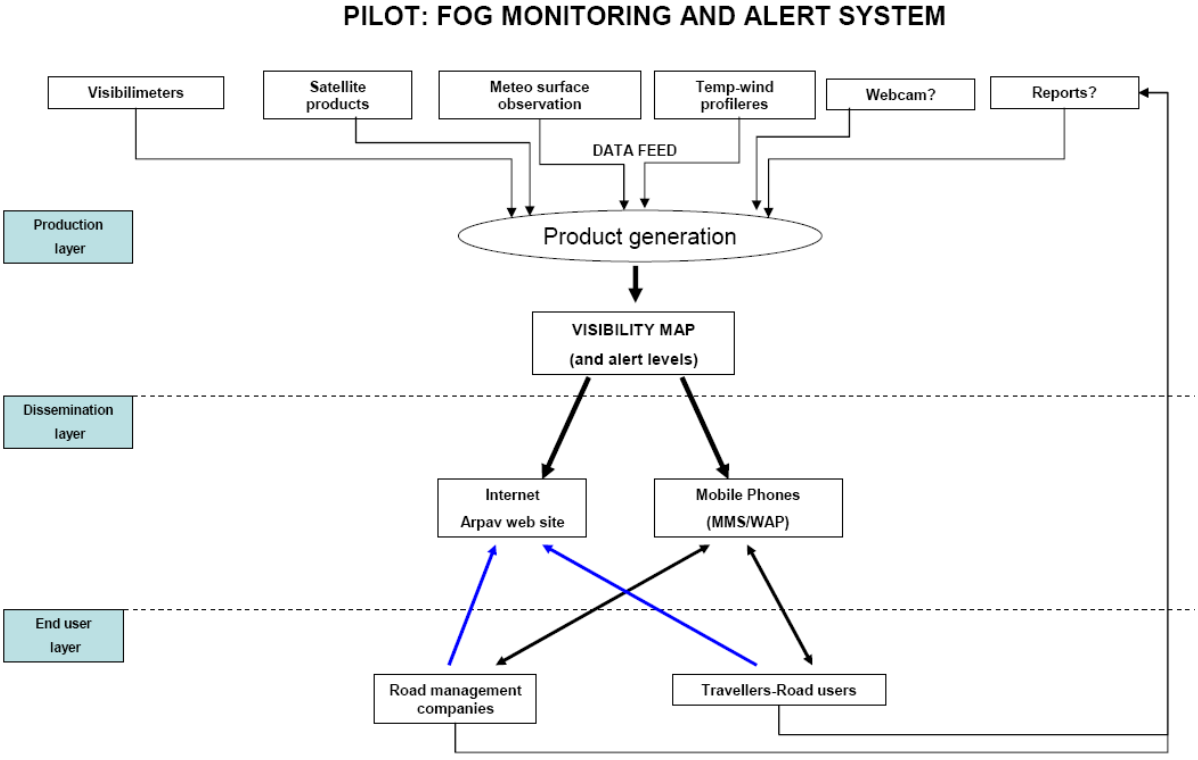

Figure 1. Fog Pilot conceptual architecture (3)

The visibilitymeters are installed in Venice region as shown in Figure 2. The coverage is now considered to be adequate for the pilot phase, but needs to be re-evaluated when actual services are to be delivered. Figure 3 shows the wider context and snapshots on the equipment installed.

METHODS AND INDICATORS

The evaluation methods and indicators have been summarized in Table 1. The EVASERVE tool has also been utilised in the planning and execution of the evaluation (www.evaserve.fi). No explicit performance threshold criteria were listed however, much due to the fact that such criteria were not required in the original project plan. Furthermore, it was expected that any truly pioneering system would hardly have plausible benchmarks on which to base the evaluation. In order to set some benchmarks though, a literature review (4) was carried out to study the functionalities and provided by other fog warning systems as well as to assess the *ex ante* impacts of fog warning systems.

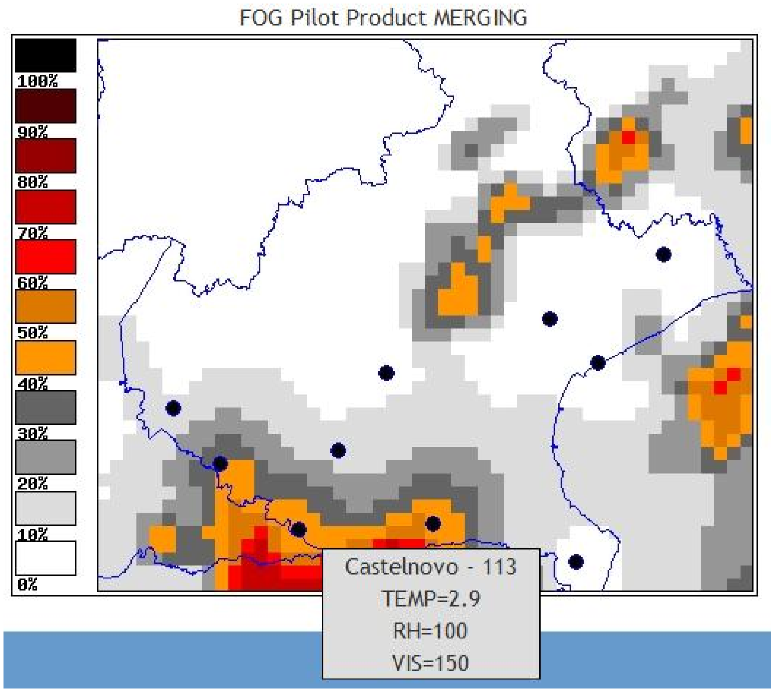

Figure 2. Visibilitymeter locations and visibility map over Veneto Plain. Black dots show the sites. The colours show the visibility reduction of 500 meters or more. The map is interactive and a selected set of meteorological data appears pointing the mouse on the points (stations).

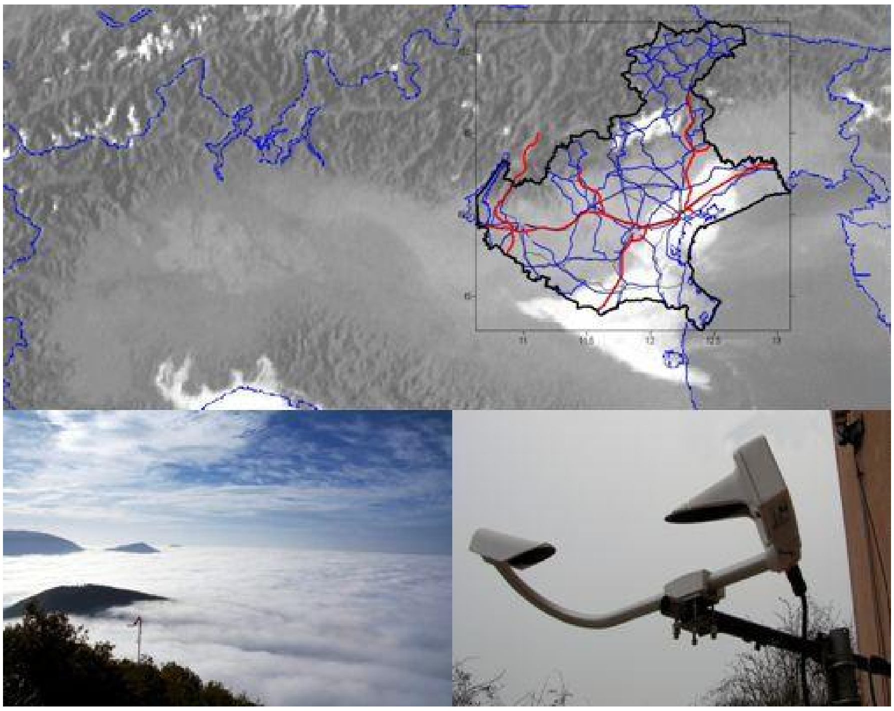

Figure 3. The Veneto Plain (upper panel); fog in the Plain (lower left) and the visibilitymeter (lower right). Notice the road network shown in the upper panel; red roads are motorways.

Evaluation viewpoint	Focus of evaluation	Indicators	Methods
User needs	Service concept	Stakeholder aspirations, end-user needs	Interviews, user seminars and literature review
Data quality	Realised fog warning pilot system	accuracy, availability, completeness and timeliness of visibility data (visibility class)	comparison of service output with human observations, system analysis
Technical implementation	Realised fog warning pilot system	Deviations from the plan, requirements for interoperability with other systems	expert assessment
Technical functioning	Realised fog warning pilot system	comparison between the defined functionality and actual system operation	expert assessment
Organizational aspects and business model	Service concept	Actors roles, connections and benefits, information flows, money flows	Assessment of service network description / service architecture
Costs	Service concept	Euros (additional cost of the pilot)	Realized costs and expert assessment
Socio-economic impacts	Service concept	Benefit-cost ratio and qualitative assessment	Cost-benefit assessment based on historical and ex-ante costs, national statistics and literature review on impacts
Degree of innovation	Service concept	Benchmarking with state-of-the-art, multiple use, scale and potential impact, benefits, etc. ROADIDEA “Innovation criteria”	ROADIDEA “Innovation criteria” analysis, expert assessment

Table 1. Evaluation coverage, indicators and evaluation methods for Fog Pilot (1)

The results are also used in ROADIDEA project to prepare recommendations for future activities to support the development and deployment of new innovative services.

EVALUATION RESULTS

USER NEEDS AND STAKEHOLDER ASPIRATIONS

The first user/stakeholder meeting was hosted by ARPAV and it was well participated by number of interested organizations, such as road concession companies, civil protection authorities, regional administration, and railways - 11 different organizations altogether. The meeting held in July 2nd, 2009, and initiated good discussion on the needs and demands for regional and local fog warning system. A short questionnaire was sent after the meeting to gather more information on participants’ needs and aspirations. The most relevant outcomes of the meeting and questionnaire are summarized as follows:

- low visibility was considered to result economic losses for the stakeholders or for the third parties within the mandate of participant organization
- as economic losses were acknowledged, many of the stakeholders were even willing to pay for visibility reports provided that the service is reliable and high quality
- most stakeholders preferred internet as the best means of channeling the info; also sms-alerts and messages were mentioned
- not surprising, especially short-term forecasting of fog was vital for stakeholders.

In addition to stakeholder meeting, which was to be repeated during 2010, there was a summary of end user needs based on previous studies and research. This list of needs was quite self-explanatory and gave no major revelations. Road users, operators of freight and passenger services, police, and maintenance service providers were on this end-user list emphasizing safety and operations efficiency aspects.

DATA QUALITY

A data quality evaluation framework was developed for the evaluation of the quality of visibility information produced by Fog Pilot. The framework was built on the basis of the first results of the QUANTIS project (Quality assessment and assurance methodology for traffic information services) (5) and a related ISO technical report published in 2008 (6). The evaluation of data quality was done according to Table 2. The table describes the quality elements and parameters chosen for evaluation, their definitions in the pilot context and the evaluation methods.

ROADIDEA Fog Warning Pilot – Evaluation Framework for Data Quality			
Element (ISO/PDTR 21707)	Parameter	Definition in the pilot context	Evaluation method
Completeness	Geographical coverage	The percentage of the Veneto region covered by the service.	Interviews of the system administrators and demonstration of the service.
Availability	Up time	The percentage uptime which has been reached a defined availability period	Interviews of the system administrators. The uptime of the system is divided by the length of the observation period
Veracity	Mean error	Comparison of the estimated probability of fog against realised probability of Fog. Probability of Fog detection is also provided as a function of false detection.	Cross-verification of the service output (probability of fog) against visibility data produced by visibilimeters. Fog situation is defined as a situation in which visibility is below 500 m.
Precision	Number of significant figures	Number of the significant figures of fog probability	Demonstration of the service output
Consistency	-	Not applicable	-
Timeliness	Data latency	The time between a detected change in visibility and update in the service output (fog probability).	Define the update intervals of various data types of the system. Perform ”worst case” analysis of possible delays

Table 2. Data quality evaluation frame

Completeness: geographic coverage

According the developers of the pilot, the visibility information service implemented in the pilot covers the whole Veneto region except the mountainous area in the north with less serious problems with fog. The Veneto region consists of seven provinces: Belluno (3,678 km2), Padua (2141 km2), Rovigo (1789 km2), Treviso (2477 km2), Venice (2463 km2), Verona (3121 km2) and Vicenza (2722 km2). A rough estimate for the geographical coverage can be calculated if the Belluno province and a third of the Vicenza province are assumed to be outside service coverage. With this assumption, the geographical coverage in the Veneto region can be estimated to be about 75%. The main road network is covered even better (see Figures 1 and 2).

Availability: up time

According the developers of Fog Pilot, the service availability during the trial period was about 90-92%. In practise, this corresponds to four or five days of downtime during two months. The downtime during the trial period was mainly caused by the lack of external cloud observation data which affected the operation of the meteorological interpolation model (synop) used in the pilot.

Veracity

The veracity of the visibility data produced by the system was assessed by comparing the actual probability of fog against the estimated probability. The output of the visibility information service was compared against visibility values measured with a visibilimeter not providing visibility data to the system. The visibility values provided by visibilimeters were assumed to be reliable and correct when making the evaluation.

The visibility values measured by visibilimeters have been compared against the first observations of visibility made by human users. Human observations on field, recorded until now, confirm in general the observations from visibilimeters. A network of human observers is becoming available on the territory.

The data collection started in September 2009 and lasted during autumn 2009 and winter 2010. The realised probability of fog as a function of the probability of fog estimated by the visibility information service has been presented in Figure 4 below. The probabilities of fog are presented for ten probability ranges provided by the service. The probability of fog detection as a function of the probability of false fog detection is shown in the same Figure.

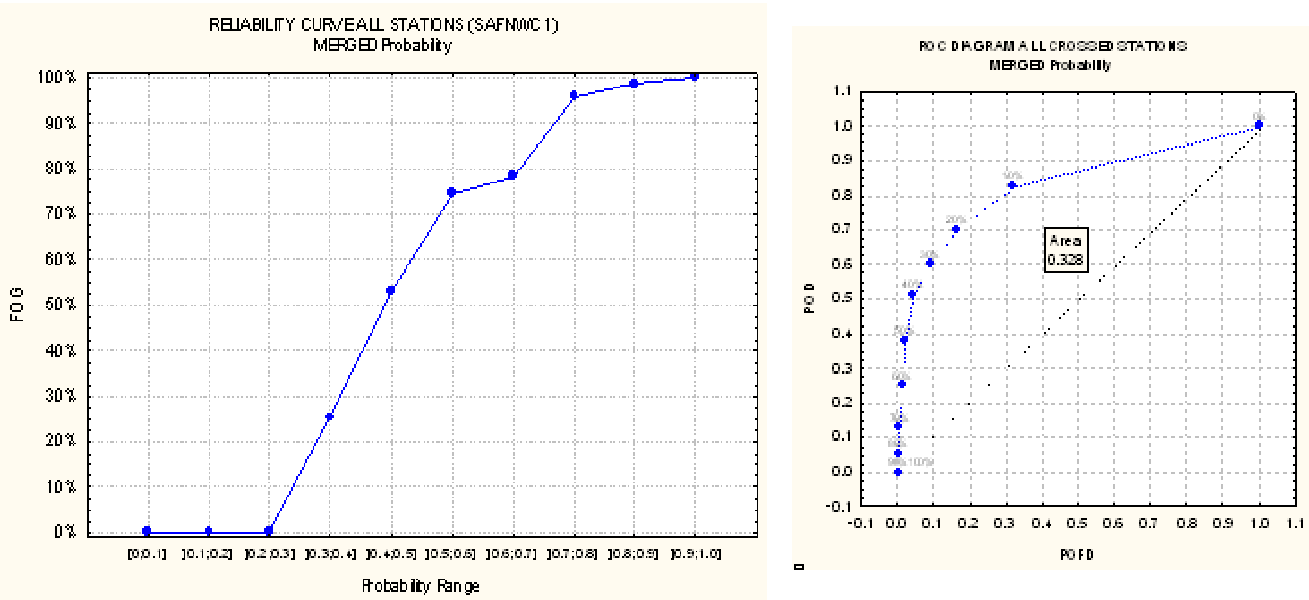

Figure 4. Left panel: reliability curve for the output of the visibility information service; right panel: probability of fog detection as a function of false detection

With the data collected during the evaluation, the probabilities of detection above about 60% cannot be achieved unless the probability of false detection is allowed to rise above 10%. With probability of false detection (POFD) of about 15%, the probability of detection (POD) reaches 70%. If the POD between the two last points in the right is approximated with a straight line between the points, one can see that the POD improves quite slowly after the point where POFD is about 30%.

Timeliness

The timeliness of the service was assessed on the basis of data latency. In this case, data latency was defined as a time between measured change in visibility or other meteorological conditions affecting visibility and a corresponding change in the service output. Data processing and visualisation takes about half an hour after an update from some data source has been received. Therefore, the time between measured change in environmental conditions and a change in the service output can be estimated to be about 1 hour and 30 minutes at most.

TECHNICAL IMPLEMENTATION AND FUNCTIONALITIES

According to the pilot description, the objectives of the pilot were to: 1) install specific sensors suitable for visibility measurement and/or estimation; 2) identify and collect data related to fog and low visibility conditions; 3) combine the identified data in an optimal way accounting for their relative quality; 4) generate visibility products suitable for various categories of end users; 5) test the dissemination of visibility products through various channels to various categories of end users; 6) obtain selected feedback from end users on reliability and usefulness of the visibility products.

The pilot system provides fog information as a real-time probability map on the basis of visibility measured on the ground, meteorological variables measured by ground stations and satellite images. Therefore, the two first objectives have clearly been achieved.

The pilot has produced relevant information about the strengths and limitations of the various data sources and data types which can be used to produce visibility information, and the pilot has successfully demonstrated the provision of area-based visibility information on the basis of a combination of different data sources. However, detailed analysis of the quality of the various data types used as inputs of the services has not been performed, and it has been considered to be out of the scope of the pilot evaluation. Even though the development of algorithms used to combine information from various sources will most probably continue after the pilot, the third objective can be considered to have been met.

The visibility information service implemented in Fog Pilot is now available on ARPAV and ROADIDEA web site, http://85.42.129.76/ROADIDEA/. The visibility information is presented as a probability map of fog. The mobile information services planned earlier are not available yet, but the operator of Fog Pilot is working with prospective users of the visibility information to gather information about the needs of various user groups. Even if the visibility information is currently available only as a web site, Fog Pilot has implemented a service which has potential to benefit several user groups. Fog Pilot can be considered to have generally achieved the fourth and fifth objective.

The interoperability requirements have been analysed for both incoming raw data and visibility information to be provided to users and other service providers as well as for integrating Fog Pilot to data processing platforms commonly operated by meteorological institutes and other meteorological service providers. Therefore, the main requirements for interoperability with other systems have been identified in the pilot.

The technical implementation of the service allows increasing the geographical coverage of the service at least to most regions in Northern Italy. While no major changes to the processing of information would be needed, increasing the geographical coverage would require installation of additional visibilimeters and cooperation with other meteorological services. For all regions covered by the service, meteorological ground observations and visibilimeter data would be needed.

ORGANISATIONAL ASPECTS AND BUSINESS MODEL

The principle of the first phase service model is shown in Figure 5. The dotted lines indicate subjects or activities not yet thoroughly considered.

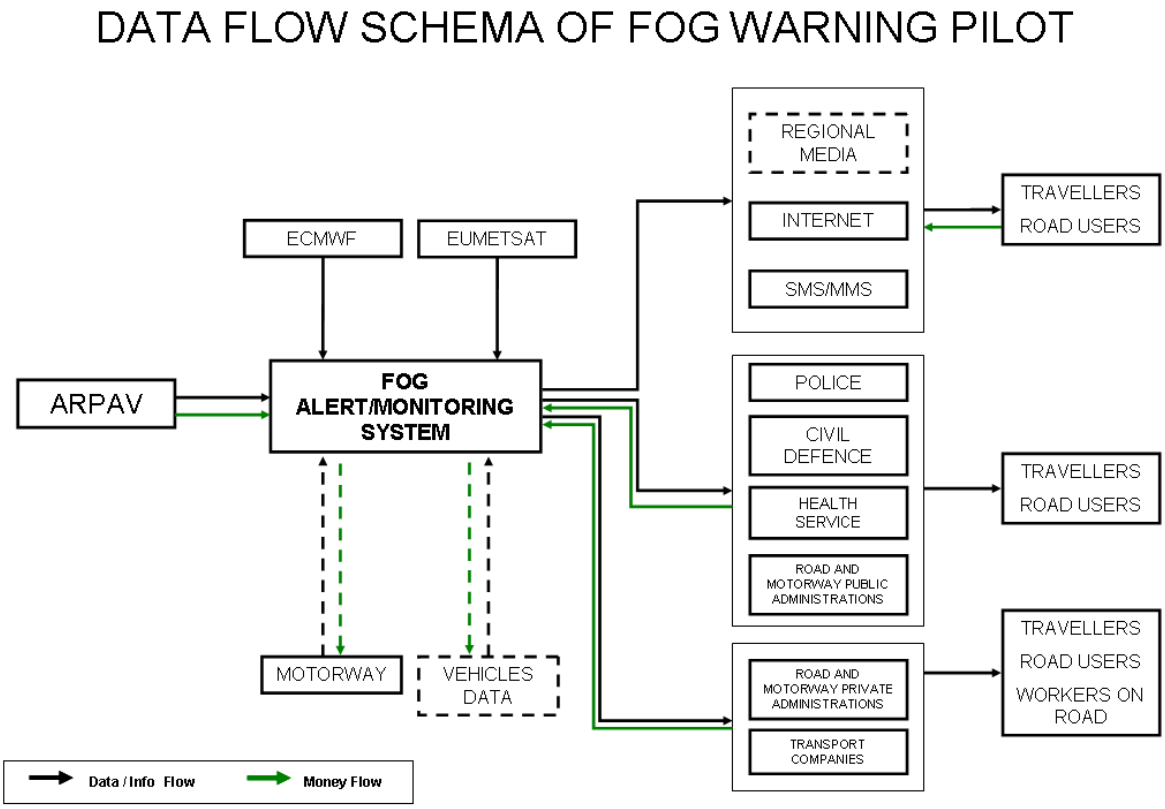

Figure 5. Principle of the Fog Warning service model (first phase).

The service is provided by ARPAV which is an independent public organisation on regional level. The organisation of ARPAV consists of Directorate General (DG) and regional departments, provincial departments and joint regional departments. The development and operation of the fog warning pilot takes place in Teolo Meteorological Centre which is one of the joint regional departments.

In present situation, the operations of ARPAV and the investments it makes are funded mostly by public sector. In other words, the revenue from services provided on commercial basis is only a small fraction of the total funding of ARPAV. Because ARPAV has a status of a public organisation, it does not have to pay for the licences needed to use some meteorological models and data types provided by ECMWF (European Centre for Medium-Range Weather Forecasts) and EUMETSAT for commercial purposes.

Extending service provision on a commercial basis might require changes in the licensing of data provided by ECMWF and EUMETSAT to ARPAV. It is possible that the revenue from the visibility information service would not cover the licensing costs at least in the beginning. Because of the uncertainty related to licensing costs and to receiving revenue from the service within ARPAV, launching a visibility information service as a commercial product is currently not an attractive option to the developers and operators of Fog Pilot.

COST-BENEFIT ASSESSMENT

Additional met-observation stations are not necessarily needed in order to set up Fog Pilot. The final fog warning service is another story and might well require new stations in critical points to ensure sufficient geographical coverage and to operate reliably even if some stations are out of order. By the end of 2009, ARPAV had installed 10 visibilitymeters in connection to existing standard meteorological observation stations.

The summary investment and operating cost budget was drafted on the basis of relatively detailed cost data. The base year is 2009 and for calculation purposes, all investments and procurement is assumed to take place in 2009 (in reality, 2009-2010). All costs are in 2009 prices. The annual operating and maintenance is expected to start in 2010 and the horizon for analysis is until 2020, i.e. 12 years altogether:

	Investments, procurements (1 000 €)	Maintenance and operating, day-to-day or annual efforts (1 000 €/year)
2009	169,0	0
2010-2020	0	18,6

The benefits from the fog warning system come from the accident cost savings, i.e. the reduced number of accidents in foggy road traffic conditions. This is the only significant benefit that is assessed. Based on other studies on similar systems there is a reduction in traffic accidents, although truly empirical studies are scarce. Caltrans (California Dept. of Transportation) reports 70% cut in accident numbers in foggy conditions on highway 120 (4). Dutch fog warning system using variable message signs yielded to a 20% reduction of accidents in foggy conditions (5). M25 fog warning system in London reduced driving speeds by 3 km/h when fog warnings were issued (5). The speed reduction alone has an impact on safety, but an adverse impact on time costs, which are disregarded in this analysis.

Automobile Club d'Italia (ACI) has estimated that in 2005 the total socio-economic losses of accidents resulted either directly or indirectly total for 34.733 billion € per year (source: http://www.up.aci.it/pesaro/IMG/pdf/Costi_sociali_incidenti_stradali_anno_2005.pdf). The Veneto Region represents about 10% of Italy's accident figures, but the region is more exposed to fog formation than most other parts of the country (Domenichini 2009). Looking at Italy's national statistics and Veneto Region's corresponding figures, it seems that about 1% of all accidents occur in foggy conditions (6).

The gravest uncertainty concerns the actual impact in accident reduction. If we look at point-specific or road stretch specific fog warning systems, like M25, we could further assume that Fog Pilot in its fully operational form could reduce 20% of the accidents in foggy conditions. However, the system is regional and does not provide exact location-based warnings but general info on reduced visibility when considering the Veneto region whole road network. 20% reduction could be a serious overestimate. Furthermore, the present Pilot does not cover whole Veneto region, but only about 75% of the region. Typically, weather –related warning systems reduce accidents by 1%-2%, according to available literature (7). We shall use the smaller reduction factor: 1%. The *ex ante* benefit-cost ratio of the full-scale system would then be in 2009 price level:

$$\sum_{t=0}^{n}\left[\frac{Acc_t \times Reg \times Imp}{Inv_t^e + Ope_t^e + Inv_t^s + Ope_t^s} \times \frac{1}{(1+r)^t}\right] = \frac{present\,value\,of\,benefits}{present\,value\,of\,costs}$$

where

Acc_t = aggregate accident costs of fog-related accidents in years 2010-2020, 10% of the national figure and 1% fog's share of all accidents = 35 000 000 K€/year × 0.1 × 0.01 = 35 000 K€ / year

Reg = regional coverage 75% × = 0.75

Imp = conservative reduction factor of warning systems based on literature review = 0.01

Inv^e_t = investments in detection and observation equipment in year 2009 = 70.45 K€

Inv^s_t = investments in model development in year 2009 = 98.55 K€

Ope^e_t = operating costs of detection and observation system between 2010-2020 = 7.6 K€/a

Ope^s_t = operating costs of other service systems and model updates and maintenance between 2010-2020 = 11.0 K€/a

r = chosen discounting rate 5%

t = time index in years, *t* runs from 2009 to 2020.

The outcome of the calculation shows clearly that the investment is very profitable and worth making, and even more so, because many of the benefit assumptions are on the safe side. However, we have to recall that the time cost savings due to reduced speeds is definitely negative and disregarded here. But on the other hand, including time losses in this context is somewhat doubtful even if theoretically correct. The benefit cost ratio is above 9 and the net present value shows 1.6 million €. Internal rate of return for nominal flows (i.e. non-discounted) is 77%. All indicators show the signs for extremely good investment. The longer time horizon is adopted, the more beneficial becomes the calculation result.

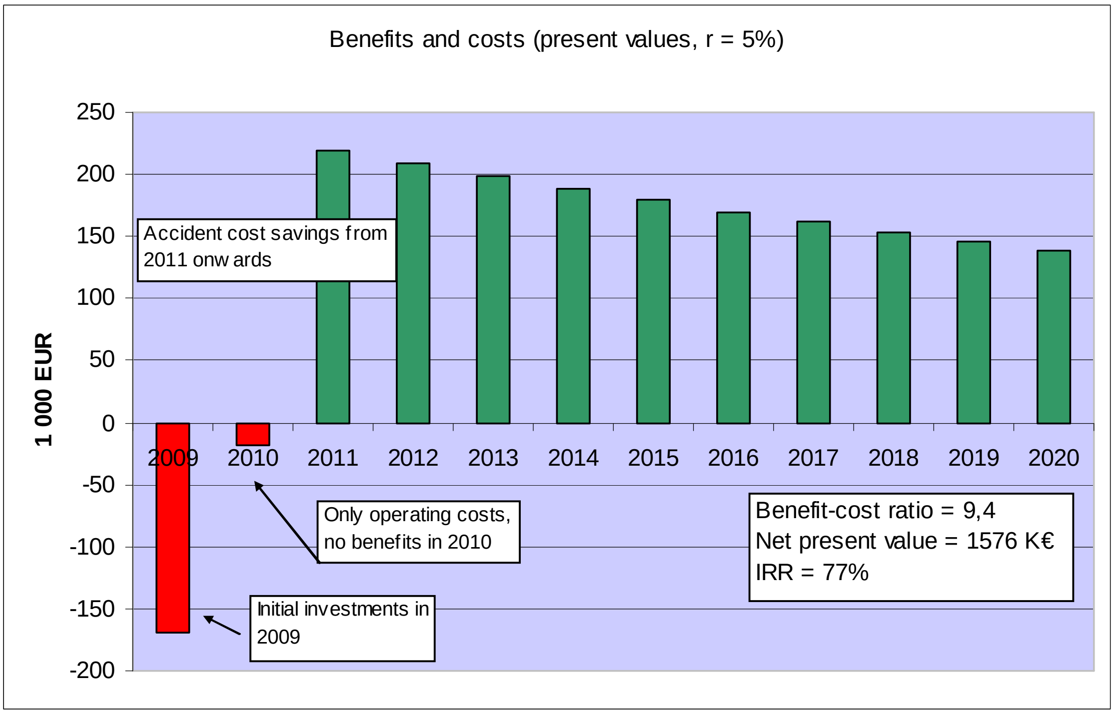

Figure 6. Profitability calculation results for Fog Pilot

Our analysis does not include other potential benefits, such as those resulting in from re-routing and avoiding parts of road network with reduced visibility and lower than expected speeds. Fog information could be well used for the benefit of other modes of transport, air traffic and rail transport in particular, perhaps the waterborne transport too to some extent.

There are still many uncertainties related to cost-benefit ratio. The most important is the forecasted traffic growth and general decline trend in accident numbers. The former increases the future benefits and the latter decreases them. To keep things at this stage simple, we assumed that these trends more or less annul each other. Furthermore, when Fog Pilot is put to service there are costs incurred to other stakeholders. These have been limited outside the scope of this analysis.

SUMMARY AND CONCLUSION

The fog warning pilot system is well under way to a useable and useful service system, clearly. What has been built so far, corresponds to the original plans and the *ex ante* cost-benefit analysis shows good return on investment. Also from technical viewpoints the system seems to be functional. What is still missing is the final service concept and sustainable finance model which in the end can of course be the current public financed model.

The overall evaluation results are shown in Table 3. The success rate in percentages is our perception of how successful the pilot has been so far. It should be emphasized that in general we consider the pilot both technically and economically a very successful one. The only thing that remains is to engineer the final service products according to the demand as cost effectively as possible. Then the first version of operational service is ready.

The challenges of Fog Pilot really relate to the utilization of a promising service product. This in turn requires constant interaction with users and end users. Architectural challenges are mostly associated with interfaces with user and other systems that could utilize the service and disseminate information further. With this comes along contractual aspects which have not yet been considered. However, as long as the service is public and delivered by ARPAV exclusively, the challenges are moderate.

Evaluation aspect	**Evaluation results**	**"Success rate"**
User needs	User needs were collected in a stakeholder meeting and through questionnaire according to the evaluation plan. The first meeting involved a good sample of different stakeholders and the need for fog warning service was acknowledged. The literature review on user needs confirmed the conclusions form the meeting and questionnaire. Another meeting is to be held in 2010.	99%
Data quality	In terms of completeness, availability and timeliness, the pilot system was regarded sufficient at this stage. For geographically the pilot system covers >75% of Veneto Region. The system up-time was >85%. Data latency was < 90minutes.	>80%
Technical implementation	The system was built in time and according to the planned budget and according to conceptual architecture and functionalities committed to in Roadidea project.	100%
Technical functioning	All the promised technical functions were present, although the actual service products must still be designed and marketed.	90%
Organizational aspects and business model	The service model relying on public finance is most probably the best to start with. Later commercialization aspects may come along as the service matures and enables 'service retailers' to step in. A marketing and financing long-term plan can be drafted as the service systems are fully operational.	80%
Costs	As planned.	100%
Socio-economic impacts	Benefit to cost ratio > 2.	100%
Degree of innovation	Similar systems appear in different parts of the world, but Fog Pilot is a regional system, which makes it unique.	90%

Table 3. Evaluation summary

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