Cost-benefit analysis of road weather stations on highways

M. STREICH
Tübingen Regional Council (Regierungspräsidium Tübingen), Germany
markus.streich@rpt.bwl.de

C. HOLLDORB
Faculty of Architecture and Construction Engineering, Hochschule Karlsruhe – University of Applied Sciences, Germany
christian.holldorb@hs-karlsruhe.de

ABSTRACT

Road weather stations are a very important tool for winter services, to make a call-out decision in time and to control the operations according to the requirements. In Germany RWS are mainly used on motorways and multi-lane highways to collect data on weather and road conditions on these busy roads. With an increasingly economic orientation towards winter service on other highways and subsidiary roads, RWS are becoming more and more relevant for winter services. Because of the much larger network of these roads, special requirements have to be considered in this case.

A concentration of the RWS network, e.g. on highways, is currently not possible under economically acceptable terms. The investment costs would be too high, as the life-cycle cost analysis has shown. Under certain conditions, like reduced equipment and a smaller number of RWS, the RWS network on subsidiary roads can be concentrated under economically acceptable terms.

Special requirements also apply for the power supply. Autarkical systems must often be used, because an electricity grid is often not immediately available. When using this technique the focus must be on energy-saving equipment in order that the size of the power generators is not too large. In compliance with these special requirements, RWS can also be used in subsidiary road networks under economically acceptable terms.

1 INTRODUCTION

The road maintenance service in Germany, especially the winter service, has a very high importance for the perpetuation of a safe and efficient road network and the preservation of the structure of the road. This entails considerable expenses, which amounted to 1.2 billion euros for the maintenance service on federal highways in 2011. About 700 million euros were used for the maintenance service on motorways [1].

Currently, road weather stations (RWS) are used to detect wintery road and weather conditions mainly on motorways and increasingly also on multi-lane highways. These RWS should enable the operators of maintenance areas to assess the state of the road and to operate winter services according to the requirements. With an increasingly economic orientation towards winter service on these roads, RWS are becoming more and more relevant for winter services.

In contrast to the density of road weather stations on motorways and multilane-highways, the density of RWS on other highways and subsidiary roads is much lower. Due to the much larger network of highways, a concentration of RWS such as on motorways and multi-lane highways is constrained by economical and organisational reasons.

Based on this, the objective of this research is to allow a more simplified capture of road and weather condition data which will lead to a concentration of RWS on highways and subsidiary roads under economically acceptable terms. This report is based on parts of the research project carried out at the request of the Federal Ministry of Transport, Building and Urban Development (BMVBS) represented by the Federal Highway Research Institute (BASt) under research project No. 04.245/2011/KRB. It was carried out at Biberach University of Applied Sciences between October 2011 and September 2013 [2]. The authors are solely responsible for the content.

In the first step of the research programme, call-out decisions were documented in a selection of maintenance areas to ascertain which parameters of the RWS are used in practice. The next step was to capture and analyse the investment and operational costs of RWS and the necessary system technology from several road administrations in a life-cycle cost analysis. This should provide a statement about which sensors or components lead to high costs during their life-cycle. Based on the results of this analysis, the possibilities of an autarkical electrical power supply for RWS were analysed.

2 THE USE OF RWS AS A BENEFIT FOR WINTER SERVICES

During the winter period of 2011/2012, call-out decisions for winter service from an operation centre for two maintenance areas were documented. Both maintenance areas are responsible for highways and subsidiary roads - but no motorways - with a length of 240 km and -310 km respectively, and are located in the low mountain ranges of the Upper Palatinate Forest (Bavaria) and the Allgäu (Baden-Württemberg). The Bavarian maintenance area can access two RWS in their area of responsibility, and three RWS for the maintenance area in the Allgäu.

Each call-out decision was documented in a report where the operator could log the information which was used to make a decision. From this, it is possible to derive the benefit of RWS for the users and the necessary equipment of a reduced and adjusted RWS. The following options were available:

- Road weather stations including forecasting
- Roadside cameras
- Notifications from drivers, police, rescue services, other maintenance areas or road users
- The Road Weather Information System (RWIS) of the German Weather Service (DWD) including precipitation radar
- Radio / television
- Internet

The analysis shows that RWS are used on average in 70 % of all call-out decisions (see Figure 1).

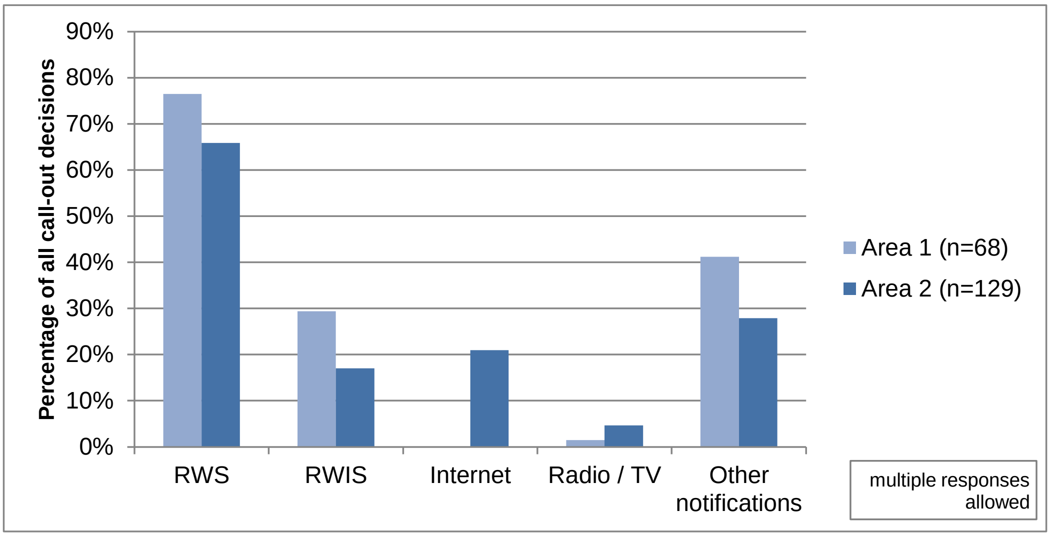

Figure 1 - Percentage of call-out decisions made by using the different sources of information in each maintenance area

The RWS are by far the most used source of information in both maintenance areas. Compared to other sources of information, RWS were often used in close temporal relation to wintery road and climate conditions because they allow an up-to-date and representative overview of the road network. In contrast, other sources of information like the RWIS of the German Weather Service (DWD) or information from the internet were frequently used for long-term decisions such as decisions for preventive operations.

When using the RWS as the source of information, the operator additionally logged which parameters the decision was based on. The analysis shows that the air temperature and the surface temperature are by far the most used parameters (see Figure 2).

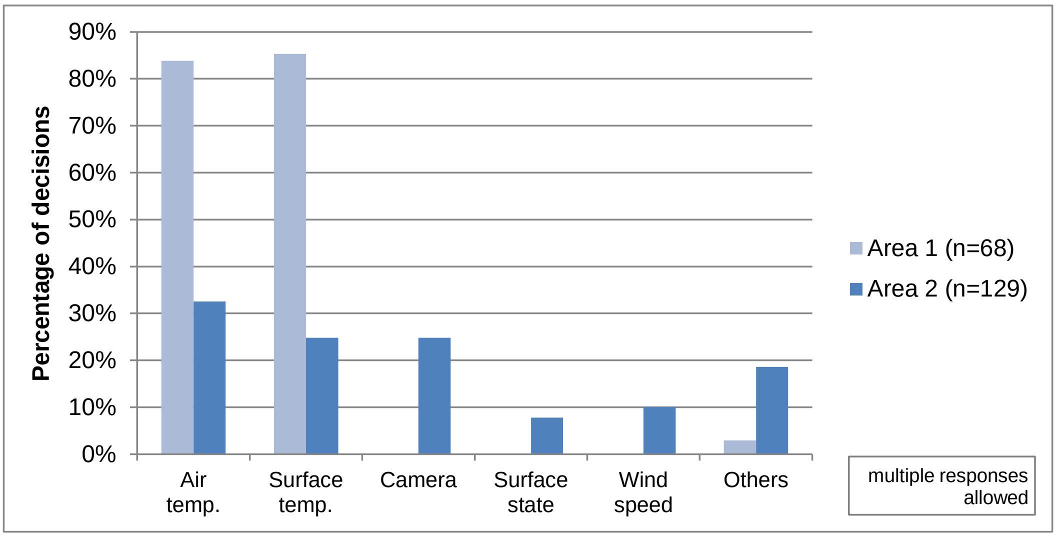

Figure 2 - Percentage of call-out decisions made by using RWS and the different parameters in each maintenance area

In one maintenance area (Area 1), over 80 % of all call-out decisions were made by using air temperature and/or surface temperature. Other parameters of the RWS were used only to a small extent by the operators although more parameters are available. In the second maintenance area (Area 2), air temperature, surface temperature and cameras were used almost to the same extent. Other implemented equipment and parameters like wind speed or the surface condition played a rather subordinate role in both areas.

The analysis shows that RWS are very important for efficient winter services, related to real conditions and requirements. They are often used because of their detailed references to the road network. It also becomes clear that often just a limited number of parameters are used to make a decision for or against a winter service operation. Because of these facts, it has to be examined in each case and each location which information is necessary for the operators and which equipment and sensors should be installed to make this information available. The information of several RWS can complement each other which is why fully-equipped RWS are not necessary in each location. This can lead to lower investment costs and better cost effectiveness.

3 ANALYSIS OF LIFE-CYCLE COSTS OF RWS

In contrast to this benefit, there are costs for the acquisition and the operation of the RWS and the background system, which have to be financed with unchanging or even decreasing budget resources. In the past, the use, the technology and the benefit of RWS were very well researched and documented, while costs, especially follow-up costs, were very rarely studied.

The University of North Dakota estimated the investment and construction costs at the equivalent of € 25,400 in an investigation report [3], HOLLDORB/RUESS calculated overall costs at an average of € 65,000 per RWS in a study in Switzerland [4].

For the life-cycle cost (LCC) analysis, data on the costs of RWS were collected in four road authorities in Baden-Württemberg, Bavaria and North Rhine-Westphalia. Cost data were provided for investment costs of 148 RWS and follow-up costs for 83 RWS. Costs of the RWS and the background system were recorded in the following categories:

- Cost of construction / implementation / extension
- Cost of replacement / repairs
- Cost of operation and use.

The analysis shows that road authorities have spent on average € 48,000 on investments (see Figure 3).

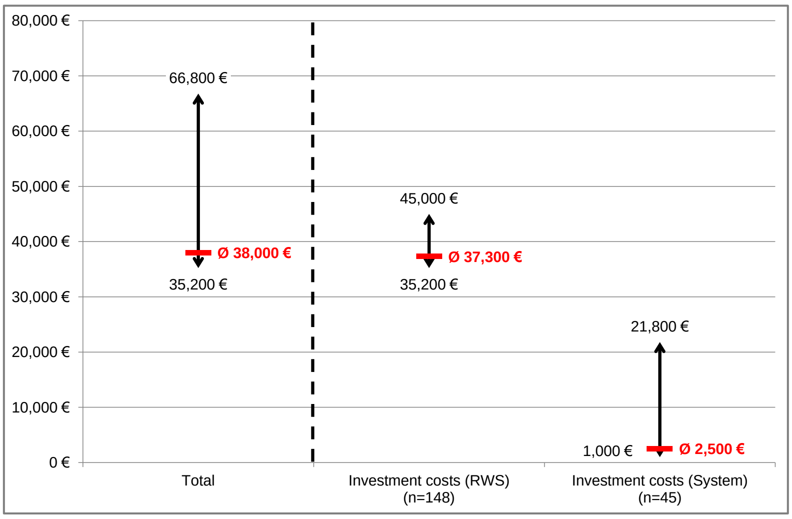

Figure 3 - Range of investment costs for an RWS and background system with maximum, minimum and average [€ / RWS]

RWS require an investment of € 41,500, while the background system only requires investment costs of € 8,100. The highest value of the total investment costs was influenced by very expensive and complex equipment and very extensive planning and development. It also becomes clear that the investment cost of an RWS does not have such a wide spread as the investment costs of the background system. The reason for this is the size of the whole system. With an increasing number of RWS, the one-off costs for planning and central equipment are shared by a larger number of RWS.

The investment costs for RWS are highly influenced by the purchase of the equipment, which requires over 58 % of the whole investment costs, while the planning, instruction and construction makes up just around 20 % of these costs each. Most of the acquisition costs are spent on the surface condition sensor, which costs around € 13,400 € (see Figure 4), followed by the meteorological equipment which costs € 7,500 on average. The meteorological equipment has been grouped together as the individual sensors are often built as all-in-one sensors.

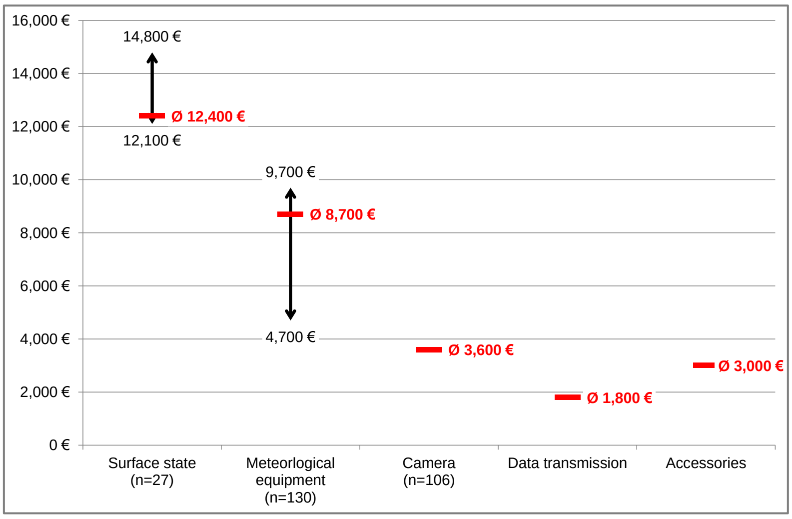

Figure 4 - Range of investment costs for sensor technology of an RWS with maximum, minimum and average [€ / RWS]

Compared to these large amounts, the costs for the camera (€ 3,400), the data transmission (€ 1,800) and other accessories like e.g. the sensor interface (€ 3,000) play a subordinate role.

In addition to the investment costs, the follow-up costs can also affect the life-cycle costs and therefore the efficiency of RWS. Figure 5 shows the range of follow-up costs of 83 evaluated RWS.

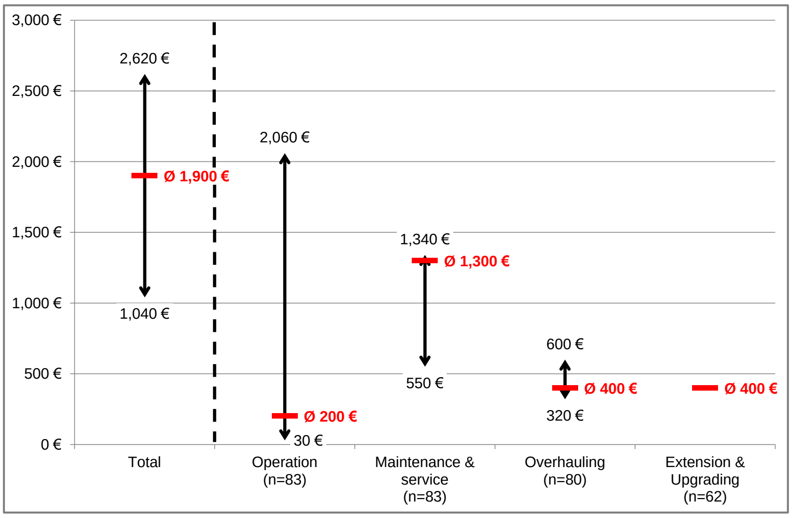

Figure 5 - Range of follow-up costs for sensor technology of an RWS with maximum, minimum and average [€ / RWS / Year]

The average annual costs are € 1,920 in total per year and RWS while the difference between maximum and minimum is quite large. It ranges from about € 1,000 to € 2,600. This large range is mostly influenced by the costs for operating the RWS and the background system. This cost element depends on the number of RWS in the system and the way the authority runs their system. A network with a lot of RWS and an in-house server is more cost-efficient than a network with less than 5 RWS and a complex internet-based user-interface. Also the costs for maintenance and service are highly variable with a difference of almost € 800. Some road authorities do not maintain and service their RWS at regular intervals what leads to lower costs in this cost element. Other authorities use the service of the manufacturer for the maintenance of the RWS which usually results in higher costs.

The analysis of the LCC of RWS shows that the cost of RWS mostly depends on the cost of the investment. The follow-up costs reach the sum of the investment cost after about 20 years, which is above the useful life expectancy of 10 to 15 years. From the investigation, the following cost drivers have emerged for the investigated RWS:

- Roadway Sensors (Surface condition, surface temperature, freezing point temperature)
- Exceptional meteorological sensors
- Installation of a camera (with / without night vision mode)
- Type of power supply.

Before installing this technology, a benefit or needs analysis should be carried out to justify the cost.

4 ANALYSIS OF RWS POWER-CONSUMPTION

Part of the LCC analysis showed that in addition to sensor technology, the power supply has a large share of total costs. On motorways, RWS can usually be connected to the existing grid. For RWS on subsidiary roads, this form of power supply is usually not available which is why expensive measures are necessary to supply the RWS either over a long supply line or a stand-alone power supply. This has the consequence that the costs of supplying energy to a RWS are up to € 13,200, and thus account for about one third of the total cost.

Before choosing a suitable power supply, the energy demand first has to be determined. In three RWS, measurement systems were installed to log the power consumption (see Figure 6).

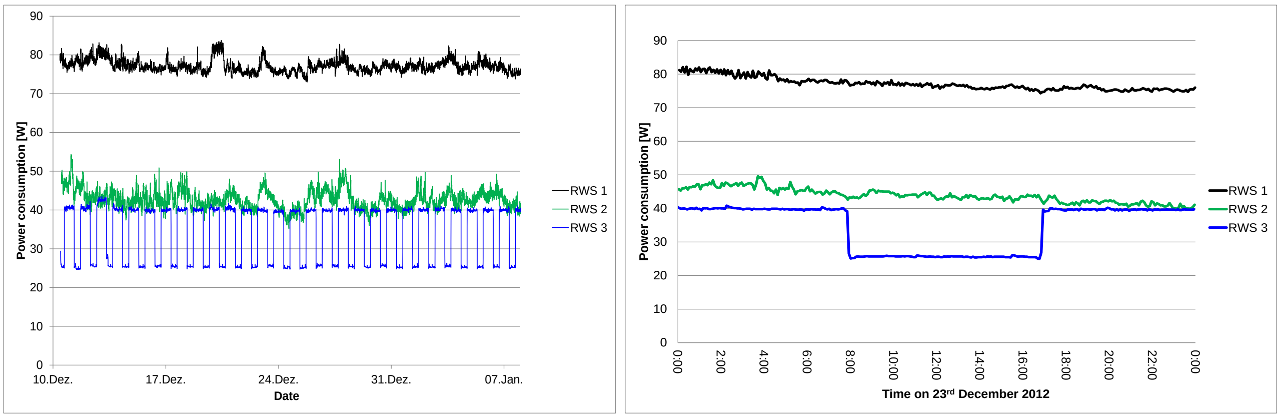

Figure 6 - Power consumption for 3 RWS over a period of 29 days in the winter of 2012 / 2013 (left figure) and on 23rd December 2012 (right figure)

The left chart shows how much the energy consumption of each RWS differs. RWS 1 has a constant power consumption of around 80 watts while the others both have less than 50 watts. In a comparison between the maximum amounts of power used by RWS 1 and RWS 3, the power consumption is more than halved, while RWS 3 has a power consumption of only 34 watts on average. From this, an autarkical electrical power supply would result in a doubling or halving of the capacity of the solar cell, the wind turbine, the fuel cell or the battery.

These results show the possible savings which could be made with energy-efficient equipment and intelligent controlling. The chart on the right (see Figure 6) shows how RWS 3 could achieve this low level of power consumption. From 8:00 am to 5:00 pm unneeded equipment like the infrared flood-light or the heating are disabled. This controlling leads to a saving of about 13 % during one day. Based on this knowledge, autarkical energy generation can be downsized, because in the time between 8:00 am and 5:00 pm, less energy is consumed directly and is available for recharging the batteries.

In summary, the analysis of energy consumption demonstrates that there is great potential for increasing the energy efficiency of the RWS first, rather than building further energy generators. Through this, the investment and the follow-up costs for an autarkical power supply could be reduced. The energy generator could have smaller dimensions and, in the case of fuel cells, the consumption of fuel is lower. These facts can simplify the installation of RWS and can lead to a higher density of RWS on subsidiary roads.

5 CONSEQUENCES FOR PRACTICAL SITUATIONS

The analysis of the data used in connection with the use of RWS has shown that RWS have a great benefit for winter services, allowing the operators to react adequately, timely and according to the requirements for wintery situations. However, the LCC analysis also made clear what costs occur with the investment in and the operation of a RWS. Especially in times of low budget, these costs must be considered in order to fulfill the requirements of economic activity. The investigations in energy consumption have shown that the installation of RWS outside existing power networks is possible. However, the use of efficient equipment and power-saving controlling should be ensured.

Due to the much larger network of subsidiary roads, it is necessary to pay attention to certain things when installing RWS:

- A differentiated coordination of the number, equipment and locations of RWS is necessary. A portion of the available information is not used by the maintenance areas, so the costs for these sensors can be saved. Information from multiple RWS can complement each other in order not to have to install the full range of equipment at all RWS. Additionally, RWS have to be located at representative sites in order to have a permanent practical benefit.
- To use an autarkical power supply, RWS must be optimized with regard to their power consumption. This can lead to both low investment costs and to lower expenses during the operative phase.

All these actions lead to lower costs for RWS, which simplifies and allows an economic and cost-effective concentration of the RWS-network on subsidiary roads.

REFERENCES

[1] Bundesministerium für Verkehr, Bau und Stadtentwicklung (2013)
Verkehrsinvestitionsbericht für das Berichtsjahr 2011
Drucksache 17/12230 des Deutschen Bundestages vom 25.01.2013, Berlin

[2] Holldorb, C.; Streich, M.; Uhlig, M.; Schäufele, I. (2013)
Regionalisierte Erfassung von Straßenwetterdaten, Forschungsbericht zum FE-Vorhaben 04.245/2011/KRB im Auftrag des Bundesministeriums für Verkehr, Bau und Stadtentwicklung (unveröffentlicht), Biberach/Karlsruhe

[3] University of North Dakota (2009)
Analysis of Environmental Sensor Station Deployment Alternatives: Final Report. Ed.: North Dakota Department of Transportation. University of North Dakota - Surface Transportation Weather Research Center, Grand Forks (ND, USA)

[4] Holldorb, C.; Ruess, B. (2007)
Optimierung der Verkehrssicherheit und des Verkehrsflusses im Winter durch den Einsatz moderner Kommunikationstechnologie im Strassenbetrieb. Eidgenössisches Department für Umwelt, Verkehr, Energie und Kommunikation; Bern (CH)