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Methodology for the prioritization of environmental sensor station installation (case study of South Korea)

Choong Heon Yang [a,*], Amelia C. Regan [b]

[a] Highway & Transportation Research Division, Korea Institute of Construction & Technology, 2311 Deahwa-Dong, Ilsan-Gu, Goyang-Si, Gyenggi-Do 411-712, Republic of Korea

[b] Department of Computer Science and Institute of Transportation Systems Engineering, University of California, Irvine, 4068 Bren Hall, Irvine, CA 92627, USA

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ABSTRACT

A road weather information system is increasingly recognized as a critical proactive tool for winter maintenance because of recent unexpectedly heavy snowfalls and continuously colder temperatures in Korea. Therefore, effective operation of this system is a high priority. Environmental sensor stations are important components in such systems. However, resources do not permit the installation of an unlimited number of these sensor stations so some method of site prioritization must be implemented. To date however, no explicit method has been adopted. Therefore, this study proposes a decision support methodology to enable the prioritization of installation of new environmental sensor stations and then demonstrates the effectiveness of the methodology by applying it to road sections in South Korea which are especially vulnerable to snow. The primary feature of this methodology is that it provides a rational ranking for prioritizing these installations. This method can readily be applied to other geographic locations.

1. Introduction

Adverse weather such as temperatures cold enough to cause road freezing and unexpected heavy snowfall significantly impacts the safety and traffic flow of transportation systems. Even though these cannot be perfectly prepared for, resulting damage can be dramatically reduced through interventions involving technologies and public policies. A road weather information system (RWIS) is a network of meteorological and pavement sensors located along the roadway system, used to monitor and then minimize damage caused by harsh weather conditions (Boselly and Doore, 1993; FHWA, 2004). A RWIS consists of many environmental sensor stations (ESS) which are connected to a traffic management center as shown in Fig. 1. ESSs are generally installed at strategic locations to provide accurate real-time road weather information and critical observations for weather forecasts (FHWA, 2005,2008). Unfortunately, no specific policy or guideline for the prioritization of ESS installation has been developed. Therefore, this study proposes a methodology for prioritizing ESS locations so that a limited budget can yield the most useful results. In South Korea, the application of RWIS is still in its infancy. This is because road agencies did not earlier recognize the significance of practical use of road weather information, and resources for developing such systems were insufficient. However, during the last five years there have been unexpectedly heavy snowfalls and continuously colder temperatures in South Korea (MLTM, 2011a,2011b). Therefore, effective operation of a road weather information system is a higher priority than in the past. In the U.S. for example, ESSs are well established along major freeways to collect road weather observations. This is because road agencies consider general weather forecast information insufficient for maintaining highways, especially during the winter season. In the 1970s, Surface System Inc. developed a RWIS, and then applied this to airport runaways and some freeway ramps. In the beginning of the 1980s, RWISs had been tested in the highway, and appeared to be a success (Boselly, 2001). In addition, specific guidelines were developed to guide the installation of environmental sensor stations based on various factors such as installation cost, road manager's experience, and topographic conditions (FHWA, 2005). In Northern Europe where the winter weather is similar to that of South Korea, such systems were a priority much earlier in North America (Eriksson and Norrman, 2001). The UK's National Weather Service (called Met Office) has provided road weather information service for highway managers for nearly twenty-five years. In Austria, road weather observations are collected through diverse sensors and equipment along the roads at intervals of approximately 10–15 km. In addition, Switzerland and Germany use road weather information extensively for highway management. Recently, in Sweden, a probe car has been used to observe road weather and then transmit observations at real-time to road agencies (Bogren and Gustavsson, 2012).

Ideally, ESS would be installed on all road sections vulnerable to snowfall or freezing, but that would be prohibitively expensive. Therefore these systems are implemented and operated at sections

* Corresponding author. Tel.: +82 1020260772.
E-mail address: chyang231@gmail.com (C.H. Yang).

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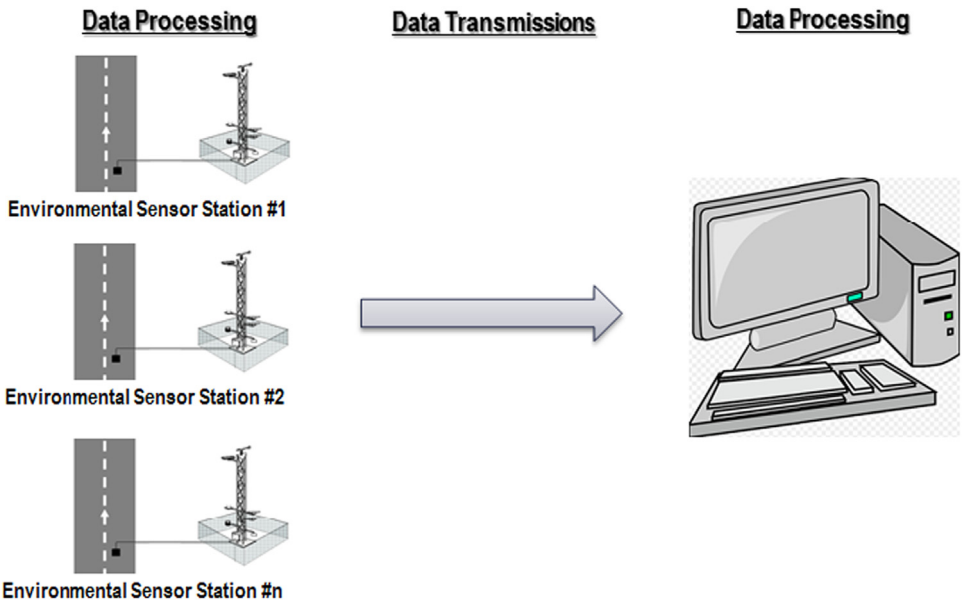

Fig. 1. Conceptual diagram of road weather information system.

deemed most vulnerable based on the experience, knowledge and judgment of road agencies. According to the Korean snow removal manual, the following conditions should be considered when selecting locations to install ESSs (MLTM, 2011b).

(1) A road section where in case of heavy snowfall or snowdrifts, traffic interruption is expected due to road topography and temperatures.
(2) A road section where disconnection between the local regions is expected or a route where snow removal is difficult due to its location far from a road administration.

In addition to (1) and (2), road agencies must prioritize ESS installation based on their subjective judgment within a limited budget. As mentioned previously, since the RWIS project in South Korea is still in the early stages, tools are needed to assist decision makers to develop effective and efficient operations. Effective ESS installations will lead to improved RWIS operations.

2. Methodology

The methodology is designed to prioritize ESS installation for national highways in South Korea though it can be easily applied to other geographic regions. Management responsibility for the RWIS belongs to the Ministry of Land, Transport and Maritime Affairs. Thus, our study considers eighteen regional offices under the Ministry of Land, Transport and Maritime Affairs which are collectively charged with snow removal operations on national highways. Fig. 2 shows the Korean peninsula and the locations of the regional offices.

The overall methodology consisting of four steps is presented in Table 1.

2.1. Data collection and display using GIS tool (step 1 and 2)

ESS should be installed at sections vulnerable to snow on national highways. To begin with 113 sections were identified by regional offices and the data on their first and last points was collected. These sections vary in length, ranging from 10 km to 40 km. Additional information such as landslides, the number of lanes, and the relevant topography were obtained as well. Snow

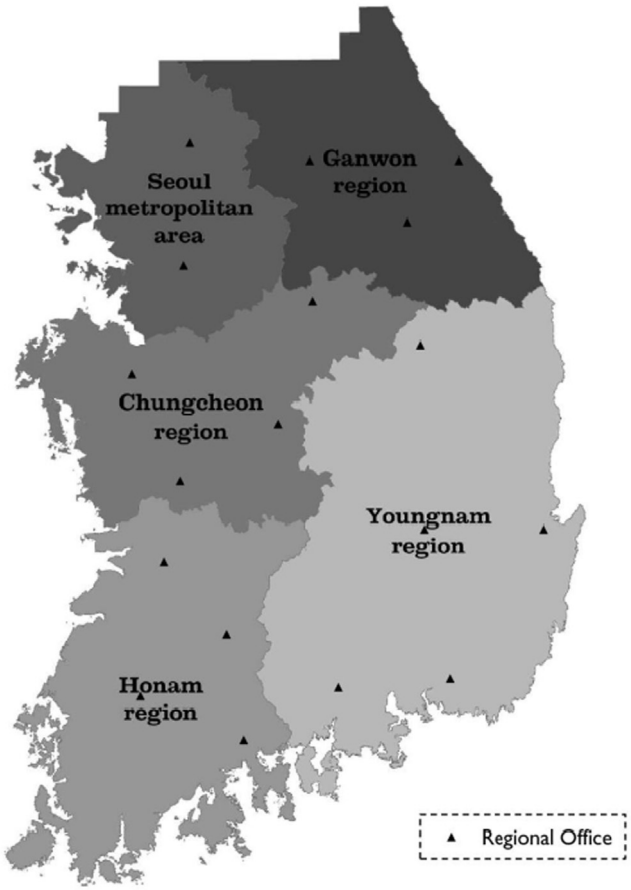

Fig. 2. The Korean Peninsula and the locations of the regional offices.

removal operations in South Korea are usually dependent upon regional weather forecasts provided by the Korea Meteorological Administration (KMA) rather than actual road conditions. Most of these forecasts are derived from observation data of automatic weather stations (AWS) that are operated by KMA. An AWS is an automated version of the traditional weather station, employed either to reduce labor requirements or to enable measurements