Discussion on environmental sensors station sitting for expressway

Li Changcheng & Bao Zuo-jun

Research Institute of Highway,MOC
No 8 Xitucheng Rd., Haidian District, Beijing
100088 Beijing, China
Phone: 86-10-82022479
Fax: 86-10-82013867
E-mail: cc.li@rioh.cn

Abstract

Adverse or inclement weather has significant impact on traffic operation and road safety. According to statistics, more than thirteen percent crashes involved in adverse weather in China. In order to improve operating safety of expressway under adverse weather, several expressway agencies have established road weather information system, such as system on Huning Expressway, Jingjintang Expressway and Jingzhu Expressway in north Guangdong province. These systems have basic weather monitor function and some event detecting and forecasting capacity especially for dense fog. At present, many expressway agencies want to construct similar system in cooperation with meteorology department. But few paradigm systems can be referred in China, and engineers also lack practical experiences to plan and develop such systems. Thus, this paper is intended to discussion on some key issues in road weather information system implement. The aspects cover: requirement of road weather information system, category of road weather station (RWS) for expressway, major principles and considerations when siting RWS, tools used to select more appropriate RWS position.

Key words: expressway, weather, environment sensors station (ESS), safety

1Road Weather Monitoring System Demand

Environmental sensor station (ESS) consists of a suit of sensors or equipments capable of weather monitoring, data storing and transmitting. Road weather station (RWS) is similar to ESS in structure. The major deference lies that RWS is developed and deployed to satisfy specific requirements from traffic operation management, road maintenance management, public travel information service, etc. RWS is usually sited along the road; sometimes it can be equipped on a vehicle and becomes portable. Conditions of interest include pavement condition (e.g., wet, snowy, icy, flooded, plowed), pavement chemical concentration or pavement freeze-point temperature, pavement temperature, soil (sub-surface) temperature, air temperature, wind speed and direction, precipitation, (e.g., amount, occurrence, type), humidity, atmospheric pressure, radiation (solar and terrestrial), and visibility. Feature 1 shows a typical RWS in China.

Feature1: RWS along expressway in China

RWSs are basic integral parts of weather monitoring system for expressway in China, and their function in Road Weather Information System (RWIS) is mainly to collect data. RWIS can be defined as a combination of technologies that uses historic and current climatological data to develop road and weather information (for example, nowcasts and forecasts) to aid in roadway-related decision making. The three main elements of RWIS are

- environmental sensor system (ESS) technology to collect data;
- models and other advanced processing systems to develop forecasts and tailor the information into an easily understood format; and
- dissemination platforms on which to display the tailored information.

Four road weather information requirements are emphasized at present in China:

(1)Traffic operation management--improve traffic safety by optimizing the traffic signal, make traffic flow more uniform by adjusting speed limit based on real weather and road condition, enhance traffic safety by disseminating driver warning via radio or changeable message sign, increase mobility by reducing duration of road or lane closure;

(2)Road maintenance management--winter road maintenance managers may benefit from such a system during winter storms by making optimal use of materials and staff, selecting appropriate treatment strategies, utilizing anti-icing techniques, and properly timing maintenance activities. Thus, productivity is increased.

(3)Public travel information service--real time road weather information help public travelers observe how adverse weather is currently affecting the highways and assess future impacts, plan their journey, provide decision support for route selection. Such a system can avoid unnecessary travel as well as improve traffic safety,

(4)Emergency incident management--emergency agency also needs road weather information to optimize their rescue route to gain more time for injured persons, select the most efficient evacuation route when disaster occurs.

Besides aspects mentioned above, road weather information collected by RWS can be utilized in several other fields illustrated by figure 2.

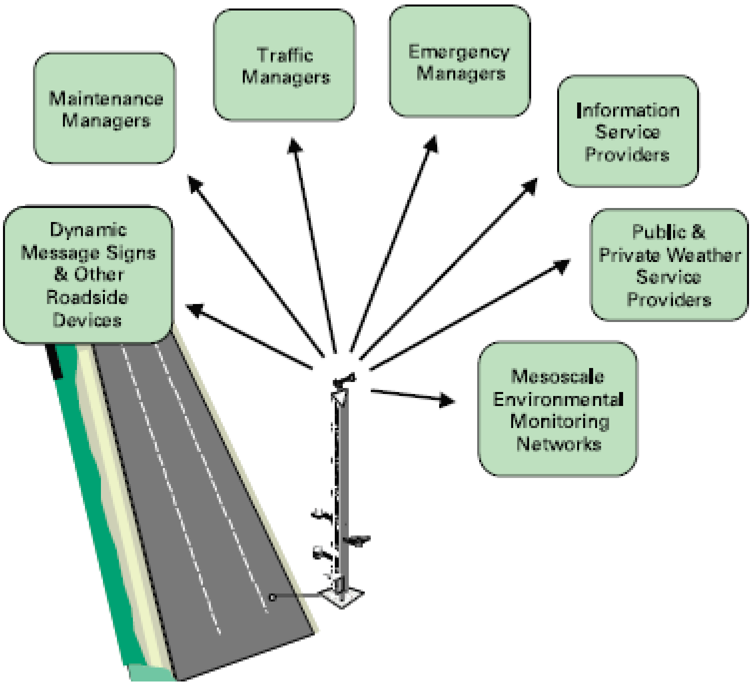

Figure 2: road weather stations operational applications

2 Site Selection

Correctly selecting an RWS site is very important to the overall effectiveness of the sensor suite and the representativeness of its observations. The site selection objective is to locate the RWS where its observations will be most representative of the area or roadway segment of interest.

2.1 Forecast Site

Forecast sites are designed to provide road weather observations considered to be representative of the conditions along a given road segment or road network. The observations from the forecast RWS can support monitoring road conditions throughout the highway system and running road weather forecast models, such as those used in highway maintenance decision support systems. The forecast site can also provide additional data for incorporation into more general weather forecast models such as those employed by the NWS, help to increase the forecast accuracy and resolution.

The scope, which is likely to experience uniform weather condition on any given day, represented by an RWS is a function of several determinants: terrain, climate, time and space scale of weather observation. No research tells us an optimistic spacing between RWSs used to monitor weather incident and as input to weather forecast. Forecast mesh has reached to 15km in urban condition in China, but this scale even can't meet the needs under some special conditions. For example, the Olympic Committee demands that meteorology forecast mesh is 1km for host city. Though forecast solution can be increased with assistance of super computer, improving the monitoring system density is still of necessity. Road weather forecast can benefit from spacing of 15km or less of RWSs, but deployment cost may make it impracticable.

To ensure the forecast RWSs provide data representative of the area, they should be located along uniform roadway conditions selected to minimize local weather effects and the influences from outside non-meteorological forces such as local heat and moisture sources and wind obstructions. A forecast RWS should be sited on relatively flat, open terrain. To reduce the effects of traffic and road maintenance activities, forecast RWS sites should be sought on the upwind side of the road based on predominant wind directions, e.g., on the north side of the road if winter conditions are the primary focus and the prevailing wind is northerly.

Observation elements of forecast site generally include air temperature, humidity, wind speed and direction, atmospheric pressure and precipitation. RWS is composed of RPU (remote process unit) and sensors usually mounted on an observation tower. Additional pavement sensors may be added into RWS to provide valuable information for road maintenance in winter. Pavement sensor may be located adjacent to the tower and constitute a RWS with other sensors; it may also be set individually apart from the tower and become a RWS itself that communities with center compute via individual RPU.

2.2 Non-Forecast Site

Non forecast sites are usually located close to the point of interest on the roadway or bridge deck. A point of interest is typically the result of topographic variations, road construction techniques, pavement types, or roadway geometry. Specific site traffic safety is major installation concern for non-forecast RWSs, which can monitor weather and road surface condition for segment or bridge deck of interest, send alarm information to motorist or operators automatically via changeable message sign or short message system. Non-forecast sites can also provide predictors for conditions at the site. However, the point of interest may also be subsurface characteristics that influence or are influenced by specific weather situations (e.g., high humidity, low solar heating, residual surface moisture, and high water conditions). Because non-forecast RWSs are installed to measure specific events of interest to transportation operations and road maintenance personnel, the resulting observations may be pessimistic as compared to observations representative of a larger area.

By definition, non-forecast site is one where the weather conditions of interest are for a specific short segment of roadway, a topographic feature, or designated bridge structure. However, certain general road and bridge deck sites may be considered representative sites for other similar segments or structures within the same general weather area. For example, a pavement temperature sensor on a bridge deck can be considered representative of conditions on other bridge decks over the same body of water or topographic feature, or of other bridges or ramps in the area.

Non-forecast sites are those that require sitting of sensors that satisfy specifically traffic safety requirement in following situations: (1) road surface conditions such as historically cold spots that create slippery conditions or a location where significant blowing, drifting, or heavy snow accumulation occurs, (2) visibility distance where the local environmental conditions contribute to low visibility (e.g., a large local moisture source such as river, lake, reservoir, swamp), (3) high winds such as those occurring in coastal or desert area and terrain-induced crosswinds along a confined valley or ridge top, or (4) surface flooding on low lying road segments.

Sensors selection for non-forecast RWS is mainly determined by specific requirement of interest. Pavement sensor may be included under conditions such as segment or bridge deck that are susceptible to slippery surface caused by ice, frost or snow accumulation. Air temperature, relative humidity and subsurface temperature sensors can be supplemented to improve accuracy of road surface temperature prediction. Visibility sensor should be included when low visibility is problem. Air temperature, relative humanity, wind speed and direction sensors can help to monitor visibility and predict its variance in low visibility application.

3 Siting Principle And Other Considerations

Ideal positions for RWS are hard to find. Sensors usage is influenced by many factors such as terrain, features, availability of right-of-way, traffic flow, local climatological aspects (e.g., large amount of smoke and dust emissions from factory or power plant, huge buildings, urban heat island effects). Additionally, power supply, communications, aesthetics, convenience and personal safety when maintenance, security of sensors should also be considered when positioning and installing. Planners will most often be in the position of making tradeoffs when selecting the RWS site and even when making decisions on individual sensor placement.

3.1General Principle

The site selection objective is to locate the RWS where its observations will be most representative of the area or roadway segment of interest. Meeting this objective requires the planning team to minimize non-weather influences such as those that may result from nearby buildings, billboards, tall vegetation, elevated portions of the highway, bridges. If possible, to locate RWS apart from large water body or moisture source or site topography that is significantly different from surroundings unless special requirement is a concern.

RWS should be positioned in a place where it is not susceptible to damage. Flooding in low lying segment and adverse geological site where landslide, avalanche may occur frequently can damage to RWS. Planners also consider minimizing the damage when plowing snow in heavy snow areas.

Making RWS siting decisions should consider the seasonal characteristics of the sites. Site conditions can change significantly from summer to winter when sun angles are low and trees lose their foliage.

Sensors configurations are dependent on site characteristics and specific road weather information requirement. If strong crosswind's impact on traffic is a major consideration and drivers warning instruments are equipped upstream to enhance operation safety, perhaps single type of wind speed and direction sensors are enough to satisfy the requirement when they installed at a place experiences frequent strong wind. Sometimes, one site may have two or more same sensors to satisfy multiple demands. For example, two wind speed and directions may set in one site but at different height 3 and 10 meters respectively. The sensor positioned at 3 meters high is mainly used to measure strong wind that influences traffic dramatically especially for high-profile vehicles while the other one sited at 10 meters high normally observes wind element meteorologically that can be as an input into forecast model. Adding additional sensor is beneficial to satisfy specific requirement of interest and ensure the representativeness, but this may further complicate the RWS siting and increase cost.

Ease of maintenance and accessibility should be considered when siting RWSs. If possible, planners should avoid locating RWSs on steep slopes, close to ditch or other place that maintenance personnel are not easy to access. Siting too close or too far from the roadway may seriously complicate maintenance procedures or unnecessarily jeopardize maintenance personnel safety. Installations too close to the pavement may make the data more representative of the actual roadway conditions but increase the hazard to maintenance personnel. Installations too far from the roadway may decrease the value of the data by making the data unrepresentative of the roadway environment.

RWSs siting should not omit aesthetics. In some cases, RWSs have been moved or painted in order to minimize how much they stand out from the surrounding terrain and vegetation.

Traffic barrier may be warranted to protect RWS too close to traffic from being crashed. Extra security measures should be taken in areas where the threat of vandalism is present. These may include a security fence around the RWS, anti-climb panels, or even security cameras.

3.2 Power Supply

All sensors require some level of power to operate (e.g., signal voltages, sampling cycles, storage of data, and possibly heating elements). Power is also required for the collection of the data at the RPU and for transmission of the road weather data to its intended users. Power options include commercial power, wind power, or solar power with batteries.

The selection of the appropriate power option is dependent on the availability and dependability of the source. A commercial power connection is usually the most economical and reliable source of power. Solar power can support nominal loads but is typically not capable of sustaining heavy power consumption for heated sensors.

Solar power may be a good choice if RWS is located in sparse population areas where commercial power is not available. Power consumption will increase significantly if sensor needs heating or large amount of data needs to be transmitted frequently. Choosing solar power required to be reevaluated under such condition. The extent of rich solar energy at local site is a concern where determined to use solar power. Care should be taken to ensure solar panels do not block or interfere with the operation of the atmospheric sensors.

3.3 Communications

Amount and frequent of data transmitting is dependent on information requirement, and data mount is the key factor when selecting communication mode. Communication options can be classified into two categories: wire (e.g., hardwired telephone, DDN, X.25, PSTN) and wireless (e.g., radio, microwave, GPRS, GSM, SMS).

For sites with low bandwidth requirements (i.e., no video camera and infrequent reporting), telephone lines or some type of wireless communication may be more economical than hardwired options. For high data volumes, a hardwired communication system (wire or optical fiber) appears more appropriate, although installation costs could be increased considerably.

A complete analysis of communication options and possible interfaces with the present or planned ITS should be performed early in the siting process. In some cases, RWSs can be located near other ITS devices (e.g., traffic counters, dynamic message signs, traffic signal controllers) to share power and communications costs. For critical sites, backup sources of power or communications may be needed.

An analysis of communications should also consider the weather information requirements of partnering agencies, such as NWS. Partnering agencies may need weather observations at a greater reporting frequency than the transportation agency. Such requirements may influence the communications solution. If road weather data are incorporated into meteorology agency, sample rate and reporting frequency should meet relevant meteorological standard. If observation data are confined to provide information and decision-making support in transportation domain, communication option needs to satisfy specific requirements.

4 Tools To Optimize Siting

Local road maintenance personnel can provide valuable insight into weather-related safety and mobility concerns along the roadway they maintain. Expert and technician from meteorology agency involvement in sites planning is a key element. In addition, the site selection team can employ thermal mapping to help identify locations suitable for an RWS installation.

Thermal mapping can be a useful tool in planning the installation of an RWIS RWS network and in selecting RWS sites. Thermal maps of roadway or road network are factually thematic maps on which relative road surface temperatures (RST) are decoded into deferent color according to magnitude of specific spot or short segment RST deviated from average RST. Using thermal map, problematic spots such as very code place where slippery and dangerous road surface may occur are ready to be identified. Thermal map analysis can benefit planner at three major aspects: (1) better define the thermal characteristics of road segments (e.g., cold spots) and aid in the selection of locations to site roadway sensors for monitoring and forecasting surface icing conditions, (2) help identify locations that are representative of other locations, thereby possibly reducing the number of RWS installations required, and (3) assist in the determination of RSTs at locations where there are no pavement sensors. Temperatures can be interpolated between sensors using profiles for the proper weather conditions. In addition, pavement temperature forecasts can be constructed for entire road segments or networks rather than just for sensor locations.

Data collection usually involves driving an instrumented vehicle over a road network to measure pavement temperatures. An infrared radiometer on the vehicle measures RSTs, and these are correlated to distance along a road. Data are gathered about every ten meters. Typically, notations are made of important features in the road environment which can affect road temperatures, such as road elevation and sky-view blocking by trees, buildings, cuts and fills, and overpasses.

The thermal mapping data are usually collected in the early morning, before sunrise, when surface temperatures are the coldest. Data are usually collected under clear sky, cloudy sky, and wet pavement conditions, as roadway temperature patterns differ under each condition.

Now, thermal mapping technique bas been introduced in China be vaisala company. This technology will promote RWIS applications and helps planner to optimize their plans because of its broad prospects although thermal mapping is still in early stage.

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