Research on the application of road weather stations on expressway in China

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ABSTRACT: Based on the investigation and data analysis, the objective indicators of applicability analysis was studied out, and the applicability of Road Weather Stations (RWS) on expressway was discussed. The main conclusions are as follows: (1) the distribution of RWS among different cities is nonuniform. The special RWS in most cities is rare except Jiangsu, Beijing and Hainan, which owned relatively dense stations. (2) The stations with the ability to monitor specific factor matched relatively well with local meteorological disasters. However, it calls for refined layout. (3) At present, the practicable layout guidance of RWS is not good enough, because the characteristics of traffic weather have not been considered sufficiently. (4) RWS is not the only and optimal way to monitor the traffic weather. (5) Although the observation data have certain accuracy, the monitoring of surface condition and rain strength and visibility based on light-induced and remote sensing can be easily affected by environment. (6) The main application of data includes real-time observation, primary products and scientific research. At present, the data have not been shared fully and further applied and there are no specific products for guiding users. At last, some practical suggestions about traffic weather monitoring are presented, such as introducing data assimilation and inversion technology, improving of forecast and warning skills and defining roles of each agency in cooperation, etc.

1 INTRODUCTION

By the end of 2009, the mileage of expressway in China had amounted to 65,000 km, which ranked the second place in the world. According to 'National expressway network planning' (Transport Planning and Research Institute), the mileage of expressway in China will reach to 82,000 km by 2020, which could cover over 1 billion people. Compared to other kinds of road, expressway has several advantages with higher design standards, larger traffic flow and fast vehicle speed, etc. However, expressway traffic system is influenced and restricted greatly by weather. The frequency and intensity of meteorological disasters is increasing because of global warming (Ding and Wang, 2008). And in this background, heavy fog, torrential rain, road icing, snow cover, high wind and landslide have become the biggest non-artificial factors (Pan 2006, Zhang 2002, Tian 2010) which threaten the safe operation of expressway. In recent years, the mean annual casualty of expressway traffic accident in China is close to 120,000, 70% of which is related to meteorological factors (Liu and Bian, et al. 2009). The quality of traffic weather service could influence the safety, efficiency and economic benefits for expressway traffic, which could benefit the traffic both in safety and economy.

In order to minimize the adverse effect of meteorological disasters, it is necessary to establish a reliable Road Weather Information System (RWIS) and operational management. Countries like Finland, USA and Japan have established advanced RWIS, which could observe high-impact weather along highways and automatically transfer the data to RWIS within several minutes. By analyzing these data, the managers could estimate the possible effect of present and coming weather on the traffic operation and...
take appropriate measures. China also made a goal to establish a modern traffic weather monitor system (CTD and CMA). Since 2006, the layout of RWS has been developing with high speed. RWS has become the standard configuration of expressway gradually. However, there is still no study on the layout and application of RWS for expressway. In this paper, macro-applicability analysis indicators are established based on massive investigation and data analysis. The macro-applicability of RWS is analyzed based on these indicators.

2 DATA


3 MACRO-APPLICABILITY ANALYSIS INDICATORS

Here, the applicability of equipment is defined 'whether the equipment has satisfied the intended capacity under normal use'. The applicability analysis of equipment can be divided into two levels: macro and micro. The macro-applicability of RWS is analyzed according to the actual situation in countrywide, and an indicator of macro-applicability analysis is studied out.

1. The matching of equipment setting and observation needs

2. Layout rules and operation status of the RWS
   As same as common weather stations, the layout of RWS must follow certain rules, in order to ensure the exactitude and representative. The cost and operating status are also important indicators.

3. Application of observation data
   The most essential role of RWS is gathering data. The accuracy of observation data is the first factor to be considered. Secondly, the potential value and the sharing condition are also important.

4 SPATIAL DISTRIBUTION OF TRAFFIC WEATHER DISASTERS

The accurate spatial analysis of traffic weather disasters is the foundation of scientific planning, and is also the basic background to assess the applicability of RWS. The traffic weather disasters are always deduced from the climate features indirectly. In order to understand the sensitivity of traffic weather disasters directly, the rational questionnaire are issued to meteorology and transport division in each province. The questionnaire provided thirteen kinds of traffic weather disasters, and the top 4 disasters are shown in Table 1.

According to the result of questionnaire, traffic weather disasters caused by fog, snowfall, pavement icing and rainfall had great influence on expressway transportation. The majority choose fog or other low-visibility phenomena, especially where are along Yangtze River (light shaded in Table 1). And the north of China almost chooses snow and pavement icing (deep shaded in Table 1). Meanwhile, it should be noticed that the investigated provinces mostly located in east of China, so the representativeness of this questionnaire is limited in west of China.
Table 1. Expressway weather disasters distribution.

<table>
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<tr>
<th>Province</th>
<th>Sensitivity order</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Beijing</td>
<td>SF</td>
<td>PI</td>
</tr>
<tr>
<td>Liaoning</td>
<td>PI</td>
<td>FR</td>
</tr>
<tr>
<td>Shanxi</td>
<td>SC</td>
<td>PT</td>
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<tr>
<td>Shaanxi</td>
<td>PI</td>
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<td>Hebei</td>
<td>AF</td>
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<tr>
<td>Shandong</td>
<td>AF</td>
<td>PI</td>
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<tr>
<td>Sichuan</td>
<td>SF</td>
<td>SC</td>
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<td>Fujian</td>
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The candidate disasters included Pavement Icing (PI), Fog and Haze (FH), Snowfall (SF), Snow Cover (SC), Freezing Rain (FR), Rainfall (RF), Crosswind (CW), Pavement Temperature (PT), Agglomerate Fog (AF), Low Temperature (LT), High Temperature (HT), Typhoon (TP), and Thunderstorm (TS).

5 MACRO-APPLICABILITY OF RWS

5.1 The matching of equipment setting and observation needs

According to the statistical number of RWS by China Meteorological Administration (CMA), the first RWS in China was built in 1999 on the Songjiang-Rongle section of Shanghai-Hangzhou expressway. Figure 1 showed that only four RWS were built in China from 1999 to 2005. Since 2006, a large number of RWS have been built. Fifty-six RWSs were built in 2006. By the end of 2009, there were 130 RWSs in China. The distribution is very nonuniform (Fig. 2). Jiangsu, Hainan and Beijing have more RWS, and the numbers of which are 43, 18 and 13 respectively. Twenty-six RWS distributed in banded shape along the 274-km-long Jiangsu section of Shanghai-Ningbo expressway. The RWS of Hainan surrounds the island, and the RWS in Beijing distributed radially.

RWS has the special capacity to observe road surface temperature (T), visibility (V) and road surface condition (S), and directly provides the driving condition. The numbers of stations which could observe visibility, road temperature and surface condition are 73, 53 and 17 respectively (Fig. 2). The stations could observe all the three factors were only built in Beijing and Guiyang-Zunyi expressway. According to the distribution of RWS in China, most observed factors are matched with the local traffic weather disasters (see Table 1 and Fig. 2). For example, there is less pavement icing but more fog in Jiangsu, so the main function of RWS is to observe visibility. Beijing has more mountain regions where icing occurs frequently, and there is more fog in its southeastern region, so it is necessary to observe all the three factors. Dalian locates on the south end of Liaoting peninsula, and is easy to be influenced by fog, so the main purpose of RWS is to observe visibility.

Expressway is with a distinct feature of banded distribution, but a RWS represents the weather condition within certain area. So they could not match each other well, and the effective observation radius will change according to the sort of weather situation. Not only should the quality of the equipment, but also the local spatial scale of meteorological disasters and traffic flow be considered, when the density of RWS is determined. Fog is the primary disaster whose spatial scale is from dozens of meters to dozens of kilometers. It is requested that the minimum density of stations should be less than 10 km for detecting fog, but only very few of expressway sections can be up to this standard. Agglomerate fog is a very local phenomenon, and it is hard to detect and forecast. When vehicles drive into an agglomerate fog, it can rarely get notice or alarm, and there is no time for drivers to slow down. So, agglomerate fog often resulted in severe traffic accidents. The density of RWS in agglomerate-fog-prone areas should be much higher than present.
5.2 The layout and operation

The layout of RWS is quite different from that of normal weather station:

1. The layout environment is quite different: the environment around expressway usually does not meet the requirement of the specification for normal weather observation. The high-speed vehicle flow, thermal characteristics of the pavement, bridge and slope could
have great disturbance on the observation, which cause great gradient of meteorological elements between the expressway and the nearby environment.

2. The purpose of observation is quite different: the normal weather stations are usually avoided to be built on the location where the extreme values are prone to happen in order to represent the mean condition of the environment to the largest extent. However, to monitor disastrous weather is more important in traffic weather service. So, RWS are often built on the location where crosswind, dense fog and other disastrous weather always occur.

3. The observation factors are quite different: factors such as visibility, pavement condition and temperature provide the most directly monitoring data for driving. But the above mentioned factors are not needed in normal weather forecast.

At present, the layout guidelines for RWS are all constituted according to that of normal weather station. Those specifications are greatly limited because they did not consider about the characteristic of road weather. For example:

1. Lack of identifying the density. Each weather disaster has quite different spatial scale, so the density of RWS should not be constant. Now, there is no reasonable standard for the layout density, especially when various disasters occur at the same time.

2. Lack of guidance for setting process. The layout of RWS needs the cooperation of meteorology and transportation divisions. It is important to determine the role of the two divisions and to make reasonable setting process.

3. Lack of pertinence for factors selection. The factors selection should be different according to significant traffic weather disasters. Otherwise, the fixed factors with no consideration about weather impact are unnecessary.

The territory of China is vast and the mileage of expressway is huge. But the instrument, maintenance and human cost of RWS are quite high. So RWS is not the only and optimal way to monitor the traffic weather. Whether the RWS worked stably should be analyzed in meteorology and transportation agency respectively. The RWS are usually built alongside the road, and the non-professionals can approach so easily that damage often happened. Building and maintaining of expressway could also cause damage. The meteorological stuff is quite familiar with the RWS maintenance. And the observation data is important to them, so the RWS built by meteorology branch are usually well maintained and adjusted. Meanwhile, the transportation division may be not familiar with the equipment and the observation data. They may lack the technique and ardor to maintain. According to our investigation, only a few of the RWS built by transportation division are still working, and the data sent back is of low reliability.

5.3 The application of observation data

The most direct function of RWS is to gather data, so the exactitude, potential value and sharing condition are most direct indexes to test the applicability. In this paper, the data from RWS in Beijing are chosen to be the test sample. It should be pointed out that observation of Beijing is first-class all over China, so this sample may not represent the applicability in some road section with other level.

At present, the main value of traffic weather data is to provide the real-time condition on the expressway. The real-time condition is very important to drivers, operators, managers and rescuers, especially on instant decision. The accuracy of observation data is tested according to the closure of Jing-Jin-Tang expressway. Three RWS on the expressway are used. The selecting of closure events followed the two principles below: (1) The Beijing section was closed and it was caused by the local weather in Beijing. (2) Only the events caused by low visibility were chosen, because the events caused by pavementicing were too few.

After filtering, there are 61 closure events available here. Figure 3 shows the minimum visibility detected in each closure event. It was found that in 80% of the events the minimum visibility is below 1000 m and in 60% events it is below 500 m. However, in several closure events, the visibility exceeded 2000 m. The reason might be that the layout density
and accuracy are not enough. On the other hand, the transportation division did not make the decision of closing road strictly according to the visibility in order to reduce accident.

The stable observation had accumulated great mass of data for traffic weather forecast. At present, the traffic weather forecast is still copying the technique and thinking of traditional large-scale forecast. Most of the forecast results were gotten by interpolation, without substantial improvement. After the accumulation of observation data for years, the research on expressway weather forecast is ongoing, such as the research of visibility, pavement freezing, snow cover and surface waterlogging. In addition, the observation data was used in velocity control and scientific research.

The data sharing was limited because of devices’ inconsistency, complex parameters. The meteorology and transportation divisions are of different profession, so it is hard to coordinate and share data, which greatly limited the efficiency of data and hinder the development of traffic meteorology.

6 CONCLUSIONS

Based on the investigation and data analysis, the objective indicators of macro-applicability analysis was studied out, and the applicability of RWS on expressway was discussed. The main conclusions are as follows:

(1) The distribution of RWS on expressway among different cities is nonuniform. The special RWS in most cities is rare except Jiangsu, Beijing and Hainan, which owned relatively dense stations. (2) The stations with the ability monitoring specific factor matched relatively well with local meteorological disasters, however, it calls for refined layout. (3) At present, the practicable layout guidance of RWS is not good enough, because the characteristics of traffic weather have not been considered sufficiently. (4) RWS is not the only and optimal way to monitor the traffic weather, which could cause high cost in human resource, equipment and maintenance due to wide territory. (5) Although the observation data have certain accuracy, the monitoring of surface condition and rain strength and visibility based on light-induced and remote sensing can be easily affected by environment. (6) The main application of data includes real-time observation, primary products and scientific research. At present, the data have not been shared fully and further applied.
7 DISCUSSION AND SUGGESTION

According to the macro-applicability analysis and actual condition, the suggestion for the development of traffic weather observation and was given:
1. Some techniques of data fusion with other observation data are needed.
2. Some professional traffic weather forecast and warning techniques would be developed.
3. The role of different division in charge of traffic weather should be defined.

REFERENCES