Study on Application of Radar Rainfall to Operation Control of Railways

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Summary

When the East Japan Railway Company (hereinafter called "JR East") detects heavy rain by using rain gauges installed in approximately 10 km intervals, JR East enforces the train operation control for securing safety. These rain gauges can detect heavy rain that occurs in any area along the railways. However, on the contrary, there are cases when these rain gauges cannot detect localized heavy rain. Therefore, we are developing a train operation control method by using the radar rainfall. This method can detect heavy rain that cannot be detected by the rain gauges.

1. Introduction

In order to ensure the safety of train from disaster caused by heavy rain, JR East enforce the train operation control such as suspending operations or reducing speed when the rain gauges detect heavy rain that could lead a disaster[1]. JR East sets the intervals between rain gauges at a standard of 10 km. This is because of the qualitative reason that the horizontal width of cumulonimbus is approximately 10 km[1]. The area one rain gauge covers is approximately 5 km on both sides of the rain gauge. JR East uses the effective rainfall amount in half-value periods of 1.5, 6, and 24 hours as the rainfall index for train operation control, currently.

Figure 1 shows the effective rainfall amounts[2] at the rain gauge spots and disaster spots concerning disaster occurred along JR East lines from 2006 to 2013. The effective rainfall amounts were calculated using analyzed rainfall from the Japan Meteorological Agency (hereinafter called "JMA"). Here, rainfall disaster means a disaster that occurs while the rain gauge detects rainfall amount of 1 mm or more. Figure 1 indicates that the points showing the relationship between effective rainfall amounts in rain gauge spots and disaster spots are often near 1:1 lines. Based on this figure, rain gauges can be assumed that heavy rain causing disasters along the railways are detected in most cases. On the other hand, there are cases when the rain gauges cannot detect heavy rain even if it is heavy rain as it could lead disasters. There are cases when the effective rainfall amount at the disaster spot becomes several times larger than the rain gauge spots, as shown in the dotted-line ovals in Figure 1, although the occurrence of such cases is rare. These cases occur when a linear-shape heavy rain area or localized heavy rain area exists between adjacent rain gauges as shown in Figure 2. In such cases, the rain gauges cannot detect heavy rain.

In view of rainfall observation, preparation of the radar rainfall data system is progressing through the years. Since 2006, JMA has been distributing the analyzed rainfall amount data in an approximately 1 km mesh over the entire area of Japan. In addition, XRAIN of Ministry of Land, Infrastructure, Transport and Tourism Japan (hereinafter called "MLIT") is distributing the rainfall amount data in a 250 m mesh since 2011, although the target area is still limited. These radar rainfall amounts indicate the data based on planar measurement while the data of the rain gauges indicates the data based on pinpoint measurement. Therefore, the radar rainfall information is effective for acquiring localized heavy rain.

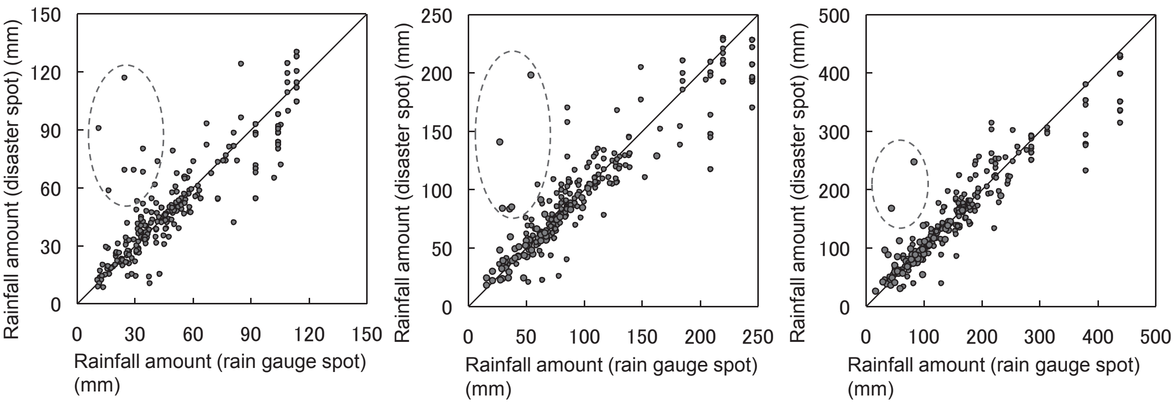
This study proposes a train operation control method against rain by using analyzed rainfall that can acquire the radar rainfall of the entire area of Japan. The analysis is conducted by using the analyzed rainfall and rainfall disaster cases that occurred in the JR East lines. The target years were from 2006 to 2013 when the analyzed rainfall data in the 1 km mesh was available.

2. Analysis Result

The basic principle of train operation control against natural disasters is to effectively avoid danger by the external force of nature (securing safety) and to secure normal operation of the train as much as possible (securing stability)[3]. Therefore, we decided to evaluate the train operation control with the radar rainfall in both aspects of safety and stability characteristics.

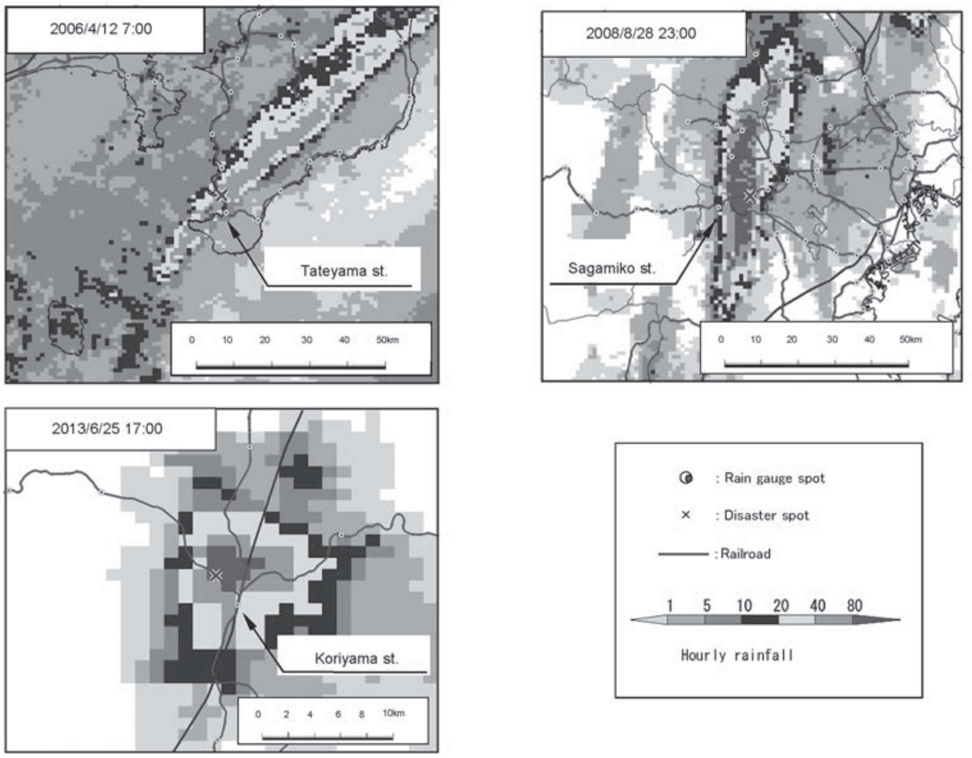
2.1 Standard value for train operation control

It is assumed that the train operation control method by using rain gauges can detect heavy rain that occurs along the railways. Therefore, we will continue to apply current train operation control



(a) Half-value period 1.5 hour
(b) Half-value period 6 hour
(c) Half-value period 24 hour

Fig.1 Relationship between effective rainfall amounts at the rain gauge spot and at the disaster spot



Linear heavy-rain area case accompanying with a cold front etc., on the left; Heavy-rain case accompanying with a thundershower on the right

Fig.2 Analyzed rainfall in cases where a heavy rain area fits within the range between adjacent rain gauges

using the rain gauges. At the same time, making use of the rader rainfall, we will also enforce train operation control by using the analyzed rainfall in each mesh that includes the railway line. As the standard value of analyzed rainfall for the train operation control we investigated the following two cases.

① When the current standard value for suspending operation by effective rainfall amounts is used for each control area of train operation control (areas covered by each rain gauge)

② When the hourly rainfall amounts of 30, 40, 50, 60, 70, 80, 90, and 100 mm are used for all lines uniformly

2.2 Evaluation of safety

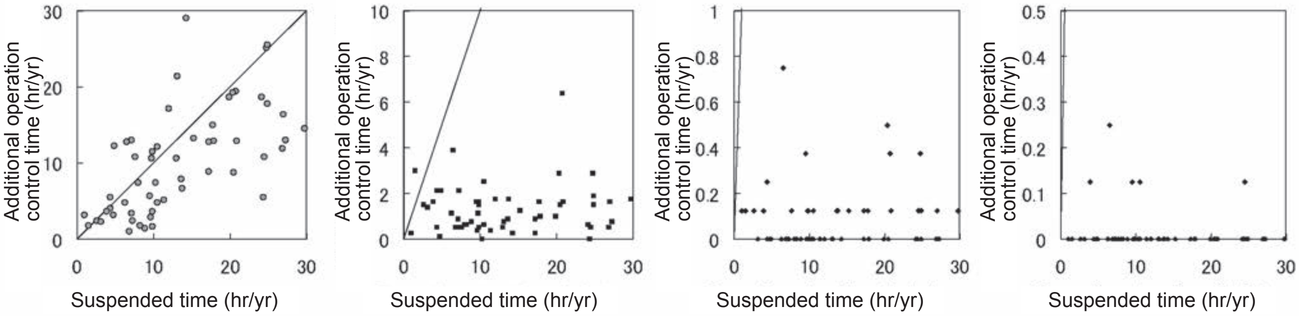
The Safety was evaluated by the following method. First, we extracted the rainfall disasters that occurred before suspending operation in the current train operation control using rain gauges (hereinafter called “disasters before suspending operation”), Next, we extracted the number of rainfall disasters which occurred when the analyzed rainfall amount in the mesh including the area where a disaster occurred exceeded the standard value in the case of ① or ② in the section 2.1

This is the number of additional capture disasters which can be additionally captured when the analyzed rainfall amount is used for the train operation control in addition to the disasters when only the rain gauges are used (hereinafter called “additional capture disaster”). Table 1 indicates the relationship between the standard values of the analyzed rainfall amount and the number of additional capture disaster.

2.3 Evaluation of stability

The stability was evaluated by using the suspended time that was added to the suspended time required by train operation control using the rain gauges, when the analyzed rain amount in each mesh including a railway line is applied to the train operation control.

First, the suspended time by the rain gauges (hereinafter called “suspended time”) was acquired. The suspended time is the amount of time when the effective rainfall amount exceeds the current standard value for suspending operations in any one of meshs area including the rain gauge spots in a line area. In the railway, when one of the rain gauges issues an order to control the train operation in a line area, the train operation of the entire line in that line is



(a) Current standard value (b) 40 mm (c) 60 mm (d) 80 mm

(a) When the current standard value for suspending operation is applied to the standard value of analyzed rainfall; (b) to (d) When a uniform standard value of hourly rainfall is applied to the entire line area.

Fig.3 Relationship between suspended time and additional operation control time in 55 line areas

Table 1 Number of additional capture disaster and ratios of additional operation control time

Standard value	Current standard value for suspending operations	Hourly rainfall							
		30mm	40mm	50mm	60mm	70mm	80mm	90mm	100mm
Number of additional capture disaster (A)	7	10	10	5	4	4	3	1	0
Ratio of additional operation control time (%) (B)	86.47	62.85	16.84	4.04	1.25	0.37	0.18	0.03	0.03
B/A	12.35	6.28	1.68	0.81	0.31	0.09	0.06	0.03	∞

affected. Therefore, this is thought as the suspended time.

Next, when the effective rainfall amount at the rain gauge spot is lower than the standard value for suspending operations (when suspending operations is not ordered), using the analyzed rainfall amount for the train operation control, and also using ① or ② as the standard value, we acquired the time that the effective rainfall amount in any one of meshs including a railway line is higher than the standard value (hereinafter called “additional operation control time”) . This is the operation control time added when the analyzed rainfall amount is used. Figure 3 indicates the relationship between the suspended time and the additional operation control time in 55 lines. Table 1 indicates the values averaged in the ratios of the additional operation control time the suspended time in 55 lines (hereinafter called “ratio of the additional operation control time”).

2.4 Evaluation

Table 1 indicates the ratio (B/A) of the additional operation control time ratio (B) and additional number of capture disaster (A). B/A is thought as the additional operation control time needed to capture one additional disaster. The smaller the value is, the more effective it becomes. As a result, it is thought that ② is more suitable than ① as the standard value of the analyzed rainfall amount. When ② is applied, the higher the standard value is, the more effective the disaster cases can be additionally acquired, up to a value of 90 mm of hourly rainfall amount.

On the other hand, preparation of the drainage facilities are progressing as follows; for example, the drainage facilities for 50 mm hourly rainfall amount is under preparation in Tokyo and Yokohama city, and 51 mm hourly rainfall amount for Akita city. When rain that is much heavier than the capacity of the drainage facilities occurs, the possibility of rainfall disaster is of concern.

As a result, when the analyzed rainfall amount is used for the train operation control, ② is more suitable than ① as the standard value of the analyzed rainfall amount. Therefore, it is assumed better that the current train operation control by using the rain gauge is continued, and the analyzed rainfall amount in each mesh including a railway line is also added supplementarily by using ② as the standard value. In addition, approximately 60 mm to 80 mm of hourly rainfall amount is thought suitable for the standard value when the analyzed rainfall amount is used. This is because disasters can be efficiently caputred from the relationship between the additional operation control time ratio and the additional capture disaster, and due to the consideration of progress of the drainage facility preparations inside and outside of the railway.

3. Conclusion

In this study, the train operation control method during rain is proposed, in which the current train operation control method by using the rain gauges is continued, and the train operation control by using the analyzed rainfall amount is supplementarily used. However, there are still practical issues as follows. The analyzed rainfall amount issued from JMA is updated every 30 minutes, and its distribution requires some more time. Thus, the real-time performance is poor. Therefore, using the analyzed rainfall amount of JMA to control train operation is difficult in the current state. It is necessary to use unique analyzed rainfall amount with shorter data update intervals and distribution time.

In addition, XRAIN of MLIT is available in the Kanto Plain within the area covered by JR East. We are thinking about utilizing XRAIN in addition to the analyzed rainfall amount in the Kanto Plain area.

[Reference]

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NEWS

○**Japan and Thailand sign Railway Cooperation Agreement**

On November 26, 2015 in the MLIT main building, Minister Keiichi Ishii spoke with Thai Transport Minister Arkhom Termpittayapaisith, and they signed an agreement for railway cooperation between the two countries. This agreement includes the development and improvement of the railway facilities in the southern corridor of the country, confirmation of railway freight transportation business, and Japanese support for human-resource incubation on the Thailand side.

Going back to the past technology cooperation in railway fields between Japan and Thailand, Akihiro Ota, MLIT Minister at the time, and Prajin Juntong of the Thai Transport Minister at the time, signed the *Agreement for Cooperation in the Railway Field*, which includes development and improvement of railway facilities in the southern economic corridor. The routes subject to cooperation cover Kanchanaburi, to Bangkok, to Chachoengsao, to Aranyaprathet/Laem Chabang, covering about 520 km. The contents for development and improvement are mainly for electrification and multi-tracking.

The actual project just launched investigation work for fixing the plan by the Japan International Cooperation Agency (JICA), which is welcomed in the agreement. What is specifically expected here is the business of freight transportation which has left very few practical commercial records in the country. The project aims to establish a new transportation means by making full use of Japanese railway technologies also from another viewpoint of a modal shift away from trucks.

For human-resource incubation, the Japan side will accept trainees from the State Railway of Thailand for operation control, track maintenance, and learning of signals and communication. In response, the Japan side is to dispatch experts to Thailand.

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