# A Risk-Based Technique to Support Decision-Making on Falling Stone Preventive Measures

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## 1. Background and purpose

As railway lines are regularly subjected to falling stone (also known as rock fall or landslide) disasters, railway operators are now determining the priority order of falling stone preventive measures based on different empirical indices of (1) the risk of falling stone and (2) the loss assumed when a falling stone incident has taken place. The empirical nature of the methodology creates uncertainty for operators. Mindful of limited railway budgets we established a more effective methodology to determine the priority order of preventive measures. This methodology can be used to support the decision-making process. It uses a quantitative index based on evaluating the danger of falling stone as a risk. An outline of the methodology is presented below.

## 2. Evaluation of the risk of falling stone incidents

We first summarized the events that would lead to falling stone incidents in an event tree formation (fault tree), while setting uncertain phenomena, such as rock falls, rocks reaching a railway track and damage to railway facilities, as probability events shown on the right side of Fig. 1. We then calculated the predicted frequency of events (Pi) from (1) the predicted stone falling frequency based on inspection results obtained by railway operators, (2) the probability of stone reaching a railway track by using a falling stone simulation model and (3) the probability of the damage to railways. We also determined the loss at an incident from the results of statistical analysis of disasters in the past. Based on the predicted frequency $P_i$ (times/year) thus obtained and the loss $C_i$ (yen/event) of each event, the risk $R$ (yen/year) of falling stone incidents is given as $R = \sum P_i \cdot C_i$

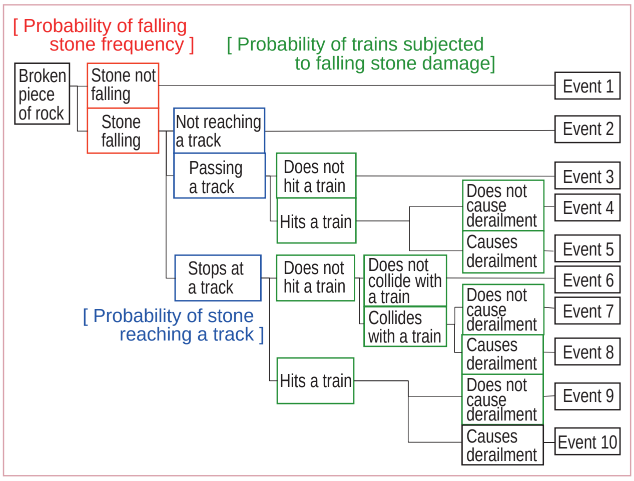


Fig. 1 Events assumed at stone falling incidents


Fig. 2 Results of an experimental risk calculation for falling stone incidents

## 3. Decision-making supporting technique for disaster prevention

Figure 2 illustrates a risk calculation applied to three falling stone (rock fall) incidents. The analysis helps the operator to determine the priority order of falling stone preventive measures by evaluating the danger of falling stone. Figure 3 illustrates the results of a risk calculation before and after the application of preventive measures. As both the cost $C_T$ and the effect of risk reduction $\varDelta B$ differ with different measures, we calculated the ratio of $\varDelta B$ to $C_T$ ($\varDelta B/C_T$). This index clarifies which preventive measures have the greatest cost effectiveness. This means that a comparison between the risks before and after application of preventive measures determines advantageous preventive measures in quantitative terms. Thus application of risk evaluation results help to support decision-making on prevention of falling stone incidents.

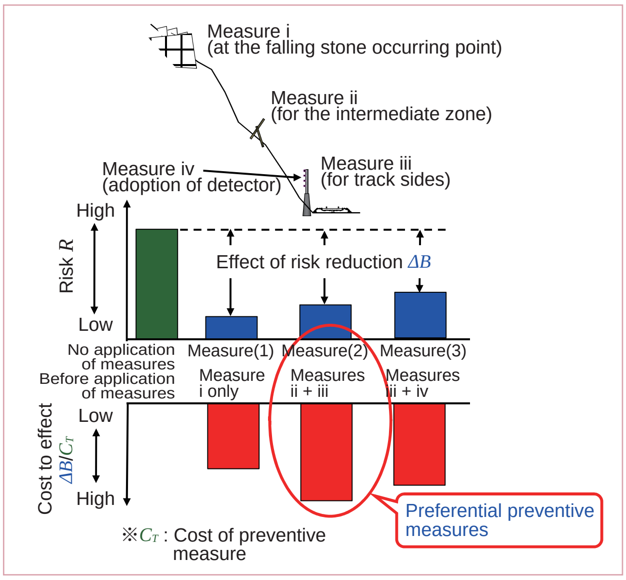


Fig. 3 Results of experimental risk calculations for falling stone incidents before and after application of preventive measures