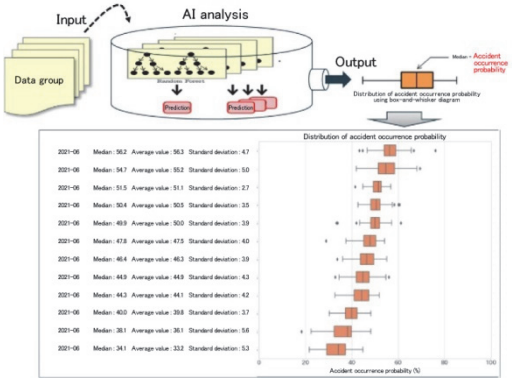
Safety Promotion Activities for Construction Work Using AI-based Occupational Accident Probability Prediction



HSE Management Office, Energy Systems
Digital Innovation Headquarters,
Mitsubishi Heavy Industries, Ltd.

Nowadays, the construction industry faces problems such as aging of the workforce, retirement of skilled workers and a decline in the number of workers. As a result, the temporary employment of inexperienced workers is increasing at construction sites. Furthermore, in the construction of a thermal power plant, which is one of the businesses of the energy domain of Mitsubishi Heavy Industries, Ltd. (MHI), Energy Systems, there are dangers such as heavy machinery, fire, and working in high places, and the risk of accidents is increasing since safety awareness is declining due to lack of human resources and lack of experience. On the other hand, social demands and other factors require we further strengthen safety management. Therefore, in cooperation with Digital Innovation Headquarters, Energy Systems has created an unprecedented indicator for predicting whether an accident will occur (hereinafter, leading indicator) as an indicator for examining safety management measures. This indicator is calculated and output by Artificial Intelligence (AI), machine learning model, based on information such as the number of workers, working hours, and supervisors at construction sites, and its prediction accuracy improves along with data accumulation. Using this system, we are working to reduce the number of accidents at construction sites by implementing proactive safety activities to prevent accidents from happening. This report describes the process of creating this leading indicator and its current utilization.

1. Human resource shortage issues and safety activities in construction

1.1 Circumstances of construction

Energy Systems provides one-stop service of design, procurement, and construction of thermal power plants including gas turbine combined cycle and steam power plants, and the performance of plants we built has been highly evaluated both in Japan and overseas. Construction is a process of building such plants by combining the design documents and components into actual operable facilities. These days, the construction industry is facing a shortage of human resources as described below, and also we have been preoccupied with responses to this problem.

Shortage of human resources in construction industry (*1)

- Decline in the working population

  After peaking in 1997, the number of workers has continued to decline, and is currently at 70% of its peak. As a result, it is not uncommon for inexperienced workers to be temporarily hired and employed at construction sites today.

- Aging of the workforce

  Of the current working population, 36% are aged 55 or older, and about 10% are aged 29 or younger, indicating that the industry as a whole is aging significantly.

- Decrease in the number of skilled workers

  The number of skilled workers in the industry as a whole is decreasing due to the retirement of aging skilled workers.

(*: Ministry of Land, Infrastructure, Transport and Tourism, "Current Status and Challenges of Workstyle Reform in the Construction Industry", 2021)

To address these human resource shortages, foreign workers and less experienced workers are being used in construction sites today and working alongside skilled workers.

1.2 Construction work and safety activities

Safety is especially important in the construction industry. This is because the construction industry often involves the handling of heavy equipment, heavy materials, and fire, as well as working in high places and confined spaces, so a moment of inattention can lead to a serious or even fatal accident. For this reason, a wide range of activities are conducted at construction sites, such as displaying safety awareness posters, visualizing hazardous areas, and carrying out safety awareness activities led by safety specialists. At today's construction sites, however, due to the recent shortage of human resources, not only skilled workers but also a wide variety of other workers, including less experienced workers and foreign workers, are working together, so more careful safety activities are necessary.

2. Safety activities in our thermal power plant work

Since we are a principal employer (prime contractor) for the construction of thermal power plants, we are required to ensure and promote safety at work throughout the construction site as the party responsible for all safety laws and regulations on site. Furthermore, as mentioned above, we are also affected by the shortage of human resources, so we are promoting safety activities at construction sites with the goal of eliminating occupational accidents (hereinafter referred to as zero accidents).

Our thermal power plant work is roughly classified into two types: construction of new thermal power plants and after sales service (AS) for the maintenance of existing thermal power plants. While most AS works are short-term modification work at specific locations, new construction works, which are carried out over a long period of about three years, include a lot of work such as civil engineering, installation of boilers, turbines, and other equipment, piping, electrical work, and commissioning. Therefore, in new construction work, it is important to implement safety activities appropriate to the work at that time in order to achieve zero accidents. For example, piping and equipment installation work often involves work at high, confined, and narrow locations, so on-site safety management and worker education activities are conducted to prevent accidents such as falls, lack of oxygen, and being caught in between surfaces.

3. Indicators of safety at work sites and prevention of accidents

Since the work details at new construction sites change over time, it is necessary for promotion of safety activities to formulate a policy for activities from a medium- to long-term perspective, in addition to day-to-day safety activities.

In formulating the policy, there are indicators to evaluate the safety of work sites, and these are used as references. Two commonly used indicators of safety are the total injury frequency rate (number of occupational accident injuries and deaths per 200,000 hours of work) and the lost time injury frequency rate (number of lost time injuries and deaths per 200,000 hours of work), and we use both of them.

However, these indices are numerical values calculated after the occurrence of an accident (hereinafter, ex-post indicators), and are intended to evaluate the degree of safety up to the present. In order to achieve our goal of zero accidents, it is necessary to formulate a policy for safety activities based on indicators that warn in advance of possible future accidents (leading indicators), rather than on the degree of safety up to the present. In the past, post-accident response where safety activities were strengthened after an accident occurs in order to prevent recurrence was carried out. However, with leading indicators, it is possible to conduct preliminary safety activities to predict possible accidents and prevent them from occurring, thereby bringing us closer to the goal of zero accidents.

4. Examination of leading indicators and their application to work sites

However, there are no leading indicators that warn of possible future accidents. Therefore, in order to formulate leading indicators, we collected on-site data and relevant data, and began to verify whether leading indicators could be defined using the relationship of the collected data such as the number of workers on-site, the total working hours, whether an accident had occurred, and the number of accidents.

Finally, we established a machine learning model (hereafter, AI) that uses primary data such as the total number of workers, number of supervisors, total working hours, and number of accidents in the previous month at each construction site and secondary data such as time series trends and rates of change in the primary data as feature value to predict whether an accident would occur in the following month, and used the accident occurrence probability as a leading indicator. The base prediction model adopted was a random forest model, which was relatively accurate at the time of the verification. This calculates accident occurrence probabilities based on hundreds of prediction models and outputs their median value as the accident occurrence probability for the following month at each construction site. **Figure 1** shows the outputs of prediction models, which are accident occurrence probabilities calculated by the prediction models, using a box-and-whisker diagram. The vertical axis represents the name of the construction site and the horizontal axis represents the accident occurrence probability. The median value of this box-and-whisker diagram is considered to be the accident occurrence probability at each construction site for the month.

Operation on construction sites started in 2020 after more than a year of trials, evaluation of the predicting accuracy, and explanation of the accuracy (i.e., accurate prediction rate and wrong prediction rate) and operational method for the construction-related departments. Specifically, at the beginning of each month, the accident occurrence probability in the current month is calculated using the previous month's data, and warnings are issued to the managers and local safety staff of construction sites with high probability values. In addition, safety staff from the headquarters visit such construction sites to carry out site patrol and safety awareness activities together with the site staff. By raising awareness of safety on the site more than in normal times through these activities, the operation is carried out to prevent accidents.

The AI-based leading indicator has been in continuous operation for two years for a thermal power plant construction site under our contract. The more data accumulated in this system, the better prediction accuracy can be expected. In addition, we are continuously improving our prediction models through evaluating and reviewing the accuracy of predictions, and adding and reviewing data to be collected, which contributes to the prevention of accidents in the future.

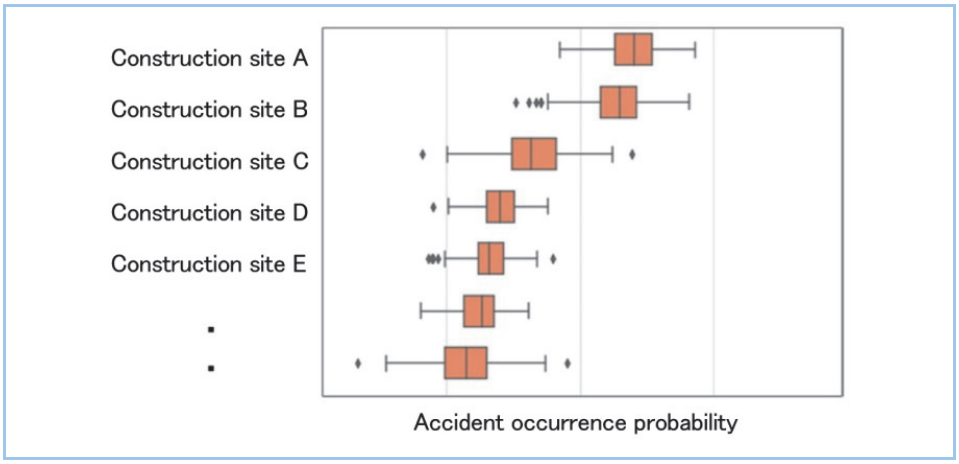


Figure 1 Distribution of accident occurrence probability at each construction site
This plots the predictions of hundreds of prediction models on a box-and-whisker diagram. The median value is considered to be the accident occurrence probability for the month.

5. Future prospect

At the present time, it cannot clearly to explain the rationale for why the prediction model calculated the predicted values, and it is not possible to predict specifically what kind of accident will occur in which work. Going forward, in order to solve these issues, we will change the system to one that can clearly present the evidence, and expand the data and improve the system so that it can predict the types of accidents that may occur. Furthermore, we would like to contribute to the realization of zero accidents by expanding this system not only for new construction works but also for AS works.