Development of Railway Safety Support System
Using Railway-operating Data

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Abstract

‘Man-made Hazard’ refers to an accident type, such as driving violations, negligence, and neglect, that occurs in developing countries. Especially, accidents caused by human error, such as deviation or pile-up accidents, can possibly be prevented. The recent increase in the volume of railway traffic and improvement in train operation speed has led to a rise in the national awareness of public demand for railway safety. Therefore, the establishment of safety measures is urgently required. Railway employees have a responsibility to protect the lives and property of passengers in terms of the decisions they make. This necessitates an improvement of the system to enable railway employees to handle the potential risk of an accident occurring or an actual incident. However, existing systems cannot effectively utilize much of the information generated by safety system sensors and instrumentation devices. This study involved the development of a real-time integrated railway safety support system using operating data to assist engineers and controllers with decision making when faced with the risk of an accident or incident.

Keywords: Railway safety, Safety management, Big-data

1. Introduction

According to recent data from Eurostat (Eurostat, 2016), there were 5.1% more railroad accidents in 2014 compared to 2013. However, the number of casualties decreased by 9.5%. This indicates that the number of accidents increased due to high speed and technological development of the railroad industry. The reduction in the number of casualties indicates that safety systems have been reinforced. In the past, railroad accidents and driving failures were triggered by hardware issues such as railroad vehicles or facilities, whereas recent accidents stemmed from human errors with respect to passengers and engineers, due to the development of hardware. This can be verified, since the overall number of accidents and failures have decreased, whereas the proportions of accidents triggered by human errors including the violation of a regulation, poor maintenance, and mistakes are overwhelming. Geographical morphology, climate, outdated facilities, track failure, as well as ‘Man—made Hazard’ are increasingly involved, increasing the chances of an accident.

Other than the above, checking the status of the railway track and controlling equipment for signal maintenance are essential to ensure that railroad vehicles can be operated safely. The current system for delivering train signals during maintenance work by using radio transmissions threatens the safety of the workers, either by increasing the rate of information transfer or by preventing the recognition of a worker by an approaching train.

Likewise, the main reason for human errors is their working environment, and can be prevented through improvement of the system. If an unwanted event occurs, the efficient determination of the problem by an engineer is of the utmost importance (Pellegrini, 2013) to make the running vehicle stop or detour or to minimize the effect of and avoid collisions with other vehicles. However, an independent decision alone can cause uncertainty. Therefore, the railroad network should be reinforced by funda-
mentally improving the system. In this study, to guarantee that a train is driven efficiently and safely, visualization of railroad information based on big data, which is a collection of relevant data, was provided to the engineers in advance to induce safe railroad driving, thereby preventing railroad accidents.

2. Accident Analysis

2.1 Human error stress

In recent years, the number of engineers experiencing panic disorder as an aftermath of human stress has been increasing. Without any specific cause except stress, patients feel extreme fear with faster heartbeats and they experience despair. The mental disease can even cause patients to commit suicide when not dealt with properly. Considering that engineers work long hours in limited spaces, and that some of them work underground all day long, they are very vulnerable to such mental disorders. Depression among engineers is approximately twice as common as in ordinary persons (2.6%), whereas panic disorder was about seven fold (0.7%) higher than in ordinary persons (0.1%) (Saint Mary’s Hospital, 2007). Moreover, those who worked aboard high-speed trains perceive a greater mental burden due to the higher speed of over 300 km/h. Therefore, rather than approaching human error as an individual flaw, it should be considered a problem of the work environment, group, and the system. Human-error related stress experienced by engineers requires fundamental improvement for individual engineers and also for the safety of passengers.

2.2 Big-data acquisition

Recent developments in IT have led to the generation of huge amounts of data of numerous kinds. Analysis methods developed to process big data (Kim, 2014) reinforce the competitive power of businesses by predicting the once-impossible future, and enables business innovation. These technologies based on the use of big data are connected to the railroad industry, to enhance the security level of railroad operation.

The railroad information was obtained from the recent one-year data of XROIS (eXtended Railroad Operation Information System) for the analysis.

2.3 Real-time integrated decision support system

Mitigation of the effects of human error requires an institutional improvement that prevents error in judgment. It is clear that the computational skills of artificial intelligence are much swifter and more efficient than those of a human. However, issues regarding human dignity can be overlooked, especially, when all possible situations are calculated through probability only. Furthermore, countermeasures for new kinds of disasters, such as terror by hacking are needed. Therefore, rather than being fully automated, the system constructed to support the engineers to avoid making judgmental mistakes, should pre-
vent accidents that stem from human errors. All accidents show precursors, before emerging. By analyzing railroad information accumulated for several years and extracting closely relevant factors, these factors can be acknowledged by the engineers and can be constantly dealt with, to induce safe driving. Figure 1 presents the architecture of a real-time decision-making supporting system. By collecting various kinds of railroad information, a big data-integrated platform can be constructed. Based on this, the analysis and prediction of an accident can be conducted. Along with the system for monitoring risk factors, an additional system for acknowledging the risk intervals of engineers in real-time scale will be developed.

3. Results and Discussion

3.1 Analysis of human error

Figure 2 shows the results of a survey conducted among 60 unspecified engineers, to probe their mental status. The questions are listed below.

1. When looking at relevant matter, I feel the emotion that occurred at the moment.
2. I do not get regular sleep
3. I am suddenly reminded of the video or emotion at the moment.
4. I easily feel angered
5. I try to remove it from my memory

In the Other Opinions section, approximately 34.5% of all the engineers confessed to severe stress levels, accompanied by feelings of palpitation, and cold sweat regarding the indirect factors that could make the engineers picture the accident. The symptoms of mental disorder differed among individuals. Although some engineers tried to ease mental pressure through consultation, it is clear that the number of engineers experiencing mental disorders such as depression or panic is increasing. Fundamental resolutions, including improvement of the work environment, and enhanced reliability of the operation system, along with appropriate treatment, are required.

3.2 Big-data analysis

Figure 3 refers to recent one-year data measured by a track-surveying car. Track failure and anchoring failure are shown, based on the standard of high-speed train railways. Bogie instability is shown in a progressively darker color as the area of track failure and the number of anchoring failures increase. Considering the overall distribution of the entire route, the Seoul to Dong-Daegu section along the route shows a concentration of track failures, contrary to the sections from Dong-Daegu to Busan and from Osong to Gwangju-Songjeong. This is because the Seoul to Dong-Daegu section was constructed with a ballasted track, whereas the other two sections were constructed with a concrete bed track. For the same reason, the anchoring defects showed similar distributions. The gravel track possesses elasticity, thereby reducing noise and vibration. Since it disperses the load delivered to the rail, the riding quality is excellent. However, due to abrasion and disintegration of the gravel, stone flour is generated, and the linear formation easily worsens, thus leading to an increase in maintenance costs. A concrete bed track is approximately five times more expensive than a gravel track, and additionally requires the construction of filling material, to reduce the noise, vibration, and to complement the elasticity. However, since the track is less irregular, almost no further maintenance is required (Jang, 2016). Therefore, immense defects often occur on the gravel track.

In addition, even though the concrete bed track accompanied by bogie instability was the cause of tunnel. High-speed trains inevitably require tunnels to be constructed.
along the route. Therefore, a comparison of position sensor data obtained for tunnels and bogie instability showed that these two factors were similar causes and indicated that the unstable airflow balance changes due to a pressure wave created when trains enter the tunnel at high speed.

Furthermore, the history of failure recorded by the sensors of a high-speed train operated during the same period included bogie instability regarding the recognition of torsion in the balance of the train. As a result, the track sections with most frequent failures, and the points with bogie instability almost corresponded to each other. Failure information such as bogie instability is an important aspect of failure history and can lead directly to an accident, which mostly induces deceleration and, subsequently, delay.

3.3 Expected effect

Currently, train operations are being monitored in real time by the control system. However, in case of emergency, orders are delivered by radio. This not only raises the probability of delivery errors, but also delays necessary countermeasures, which in turn raises the possibility of accidents. The real-time decision-making supporting system is operated under the control system. However, since the engineer of the train can immediately contribute to restoring order to the system, countermeasures such as an emergency stop can be implemented immediately when an unwanted event occurs. Moreover, the reinforced railroad network would enable constant delays and system reliability to be improved to guarantee that the railroad vehicle is driven efficiently and safely. This is expected to additionally reduce the occurrence of mental disorders among engineers, and reduce human errors.

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