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Development of the Assessment Indicators for Railway Safety

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Abstract

This study proposes a model for railway safety assessment with which the safety of whole railway system can be evaluated. The purpose of the assessment model is to generate safety indicators which quantitatively represent the degree of railway safety. Safety indicators were proposed as three indicators according to their functions; accident indicators, safety management indicators, and safety culture indicators. This paper describes the first result on the safety target which will be a key starting point toward the development of safety assessment model. It is recommended that the safety target to be composed of several sub-targets are apportioned to constituent components. It is concluded that the classification of safety target has influence on deciding components or attributes that constitute each sub-indicators; accident indicators, safety management indicators, and safety culture indicators. Based on this study, a railway safety assessment model will be developed in the following study.

Keywords **:** *Railway safety law, Acceptable risk, Evaluating railway safety, Railway safety indicators, Safety objective*

1. Introduction

As described in Article 4 of Railway Safety Law, the nation strives to secure safety of railway users by applying the concept of allowable risk indicators. The number of deaths and injured is calculated through railway accidents data analysis each year to assess railway safety, and various safety policies and safety management methods are performed to minimize accidents by finding causes of accidents and details of risk occurrence. Resultingly, safety of railway field has greatly improved with 47% decrease in mortality and more than 64% decrease in the number of accidents for last 10 years [1].

However, it is insufficient to express railway safety indicators simply with the total number of accidents and accident damages through accident statistics. Assessment on the final results called accident statistics and assessment results about environmental or conscious (psychological) factors for providing a causal factor for occurrence of accidents also can be a factor for railway safety assessment. Thus, a method to express railway safety indicators more solidly and quantitatively for establishment of more advanced safety policy and safety management is needed, and in order to achieve this, it is necessary to understand major influential factors about railway safety and develop quantitative railway safety indicators for the selected individual factors. This study aims to develop quantitative indicators that can assess railway safety indicators and provide a model to be used in the process of establishing a strategic direction and policies for improvement of railway safety such as establishing safety objectives and management.

2. Railway Safety Assessment Model

Indexed expression about factors contributing to railway safety are needed in order to assess railway safety. At the same time, it is necessary to establish assessment indicators and classification criteria, and develop an indexation method of assessment indicators. Assessment indicators shall be decided in consideration of influential factors that have an effect on railway safety, and Delphi analysis was used in the aviation field to set assessment indicators [2]. The Delphi method is a way of collecting opinions from experts through open-ended

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questions and selecting secondary important items by asking the limited items. There is other method [3] that classifies 4 sectors (management, operation, maintenance, planning) and 13 measurement items for measuring of safety performance, but the modeling of the railway field was preferentially set as below.

$RSI = f(AI, SMI, SCI)$
RSI = Railway Safety Indicators
AI = Accident Indicators
SMI= Safety Management Indicators
SCI = Safety Culture (consciousness) Indicators

Railway safety indicators are defined as a combination of accident indicators, safety management indicators, and safety culture indicators but an appropriate analytic method shall be used for verification. In this study, however, decided to perform discussions and reviews on its components by priority and postpone the selection of additional items or detailed items for each component. The above model was set by hypothesizing mechanism of accident occurrence as in Fig. 1. That is, functional or performance degradation or failure occurs in a normal operation condition but it also recovers back to a normal condition through management actions like a protective wall or maintenance. A system turns into a critical condition once failure occurs, but it was assumed to be in critical condition only when cutoff with a protective wall was passed. A critical condition was assumed to occur with near-miss that has insignificant accident loss and actual accidents. Besides from near-miss or actual accident, °Æincident°Ø could be considered after clarifying classification of events later on. It is because event classification is not an important matter to decide.

Such accident model should consider a general safety management aspect for suppression of accident occurrence besides from accident occurrence because a weak spot of safety management can always be led to an accident. More study is required for how to evaluate safety management factors of competent authorities with different responsibilities and roles, but indexation of safety management is essential in the first place. In addition to this, safety awareness indicators can be selected, and safety awareness here means safety awareness of the general people who use railway rather than railway workers since safety awareness of railway workers is assumed to be reflected on the safety management aspect of railway authorities. Railway accidents may occur due to error of railway system but there are many accidents caused by lack of safety awareness of general people such as a crossing accident.

Railway safety indicators are often decided according to

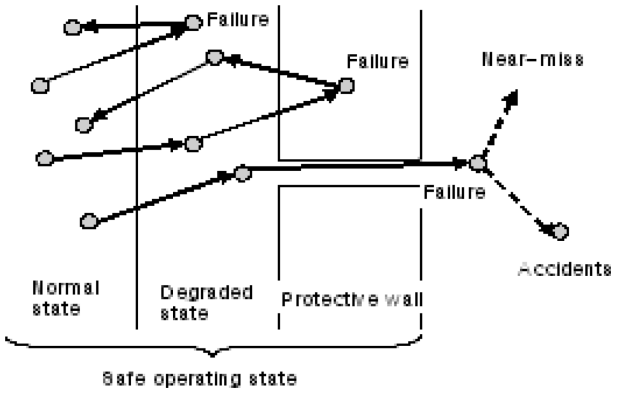

Fig. 1 Mechanism of railway accident occurrence

the degree of accidents on the surface but the degree of safety management and safety awareness was included in terms of suppressing and reducing accident occurrence. Composition items and classification of each factor shall go through a detailed analysis process and include the following principles.

First, analysis of accident data shall be performed objectively, and classification and analysis of incident and near-miss are also needed. Aviation field is separating and using incident and near-miss, but more research is needed to decide whether to apply the same definition to railway field or not. But it shall be classified into actual accident that caused severe damage and casualties and near-miss with insignificant damage in order to perform separate analysis and management. British railway is also classifying incident, near-miss, and accident but the important viewpoint is that occurrence of near-miss and incident in addition to statistics of actual accident is also an important factor for showing risk level of railway system. It is because such incidents become a sign of accident occurrence and it helps to prevent accidents by analyzing the cause of occurrence in advance. Fatal accidents actually have a sign of occurrence and the accidents often happen when the sign is ignored.

Second, assessment indicators on safety management shall be developed because the effect of safety management degree on railway safety indicators are large. For instance, management and financial ability of railway authorities and technical level of workers are important factors for preventing accidents. Standard composition items shall be selected by using the most objective data about these items. It is important to develop standardized safety indicators that consider work characteristics of railway authorities and can be commonly applied by considering differences of normal railway and city railway and characteristics of freight railway and passenger

railway.

Third, the weighted value of each factor shall be selected appropriately. Not only the weighted value about the degree of influential factors contributing to railway safety, but the weighted value about items composting each factor shall be properly selected.

The ultimate objective of this study is to analyze current management conditions of domestic railway accidents, and develop railway safety indicators based on this to express safety degree of the current railway system. Safety objectives shall be expressed in an indicators form in order to decide safety improvement policy and direction using railway safety indicators, and evaluate safety indicators for each field or organization. 3 assessment items (accident, safety management, and safety awareness) shall be included equally as railway safety indicators for expression of safety objectives in an indicators form in order to allow circular policy management by calculating the degree of railway safety indicators compared to railway safety objectives. This study suggested detailed assessment items of composition items (accident, safety management, and safety awareness) and application methods.

3. Safety Objective and Safety Indicators

Safety objectives are defined as 'safety level expressed as risk allowance degree standard that must be achieved by all kinds of railway systems (express, normal, freight, etc.) and the entire system'. According to Article 5 of Railway Safety Law, the railway safety master plan is regulated as below;

① The Minister of Land, Transportation and Maritime Affairs shall establish a master plan about railway safety every 5 years.

② Railway safety master plan shall include the followings.

1. Promotion target and direction of railway safety master plan
2. Matters about expansion§″improvement of facilities related to railway safety
3. Matters about maintenance and inspection of rolling stock
4. Matters about system improvements like modification of legislations relevant to railway safety
5. Matters about development of professional manpower and supply-demand management related to railway safety
6. Matters about education and training for railway safety
7. Matters about research and technology development for railway safety
8. Other matters about railway safety that are approved as necessary by the Minister of Land, Transportation and Maritime Affairs

'Promotion target and direction of railway safety master plan' shall be established in the railway safety master plan, and this shall include railway safety facility, maintenance and inspection, developing and educating professional manpower, and technical development. In other words, safety indicators for each field must be set to measure safety performance against safety target. In case of England, they define common safety target (CST) that can be applied commonly to EU through railway safety directive [4] and require definition of safety indicators that can asses it. A team that composes partners of SAMRAIL and SAMNET (RSSB, SNCF, Pro-Rail, CP, DB, Train Italia, TIFSA) performed a review on development of Common Safety Indicator (CSI) and found the following results.

A group of safety indicators shall be able to set safety objectives, and the integration of safety indicators

Table 1. Safety Target and Indicators (EU)

Safety target	Indicators (each year)	Unit	Note
Death and injury risk indicators of railway passengers by all causes	Number of deaths and injured by all causes	per passenger km	Including falling, etc. by fault acting of passengers at a station
Death or injury risk indicators of railway workers	Number of deaths and injured by all causes	per track km	Including contracted workers
Death or injury risk indicators of general public other than passenger or worker	Number of deaths and injured by all causes	per train km	Including users who violated crossing or residents living near the railway
Death or injury risk indicators of illegal public	Number of deaths and injured by all causes	per train km	Including illegal crossing and railway trespasser. Excluding a suicide

becomes safety indicators and safety indicators must express safety objectives quantitatively. In addition, it is necessary for efficient and consistent monitoring and management of railway safety performance in preparation for safety objectives set by safety indicators, and it is judged to be a basis for improvement of railway safety in addition to assessment of safety performance. Safety indicators calculated based on railway accidents and incidents data can be used for deciding risk profile of hazard. Based on this, setting of indicators about safety objectives was suggested as Table 1.

4. Current Status of Domestic Railway Safety Management System

4.1 Domestic railway safety management system

The purpose of Railway Safety Law is to contribute to improvement of public welfare by regulating necessities for securing railway safety and establishing railway safety management system. Requirements to establish railway safety management system are described in Railway Safety Law, and railway safety management system is composed of railway safety master plan (every 5 years), implementation plan, safety management regulations, emergency action plan, and comprehensive safety assessment as in Fig. 2, allowing railway operators to establish relevant plans and perform railway safety management activities based on them. These safety management activities of railway operators are generally evaluated and assessed through comprehensive railway safety assessment once in 2 years, and safety management of domestic railway has been establishing and performing safety management plans based on safety management regulations autonomously prepared by operating institutions like Korail in accordance with Traffic Safety Act and Railway Safety Law [5].

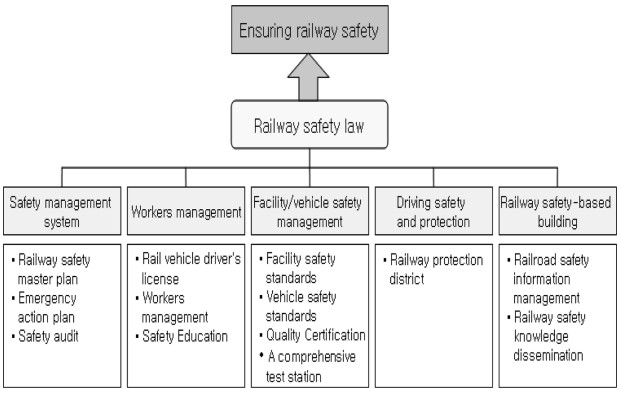

Fig. 2 Domestic railway safety management system

4.2 Domestic railway accident management system

A system for corrective measures and railway accident reports has been established.

For domestic railway accidents, Railway Accident Investigation Board under the Ministry of Land, Transportation and Maritime Affairs is in charge of severe accidents of a certain scale since 2005 based on Railway Safety Law and the rest of accidents are reported to the Minister of Land, Transportation and Maritime Affairs through the Guideline on Report of Railway Accidents, Etc. (2009) after self-investigation by railway operating company. Details are summarized as follows.

For reporting system and immediate report of railway accidents that require national-level accident handling and recovery, report to the Ministry of Land, Transportation and Maritime Affairs and Aviation and Railway Accident Investigation Board orally within an hour after occurrence of accident and submit an accident report within 15 days.

In accordance with Article 5 of the Guideline, it is not necessary to investigate the cause of accidents at a national level by regulating railway accident target that railway operators must investigate and report, and accident reporting method in details but accidents that must manage the cause of accident for safety management shall be reported within 2 days and its accident cause investigation report shall be submitted within 15 days.

In addition, separate classification system for accident type, accident causation, and scene situation was prepared to investigate risk factors thoroughly from the accident investigation/reporting stage by making a person in charge of accident to directly input the relevant data into railway safety information integrated system for efficient management of railway accidents.

4.3 Railway safety information management system

Ministry of Land, Transportation and Maritime Affairs (Korea Transportation Safety Authority) has established railway integrated safety management system to effectively perform prevention of railway accidents by standardizing and systemizing various information in relation to railway safety.

Railway safety information, railway safety master plan, safety integrated safety assessment, license test management, qualification management, accident statistics analysis, and safety policy support are currently established as the railway safety information integrated system and they are used in safety policy establishment of the nation and preventive activities of railway accident by railway operating agencies.

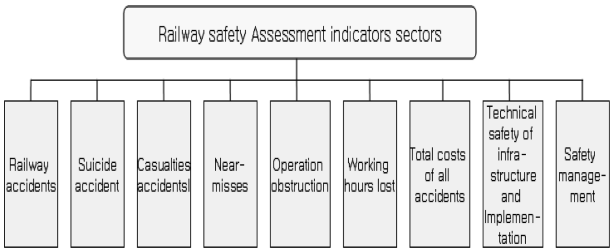

Fig. 3 Railway safety assessment indicators sectors

5. Suggestion of Railway Safety Indicators

Assessment items of railway safety indicators excluding safety culture indicators are suggested as follows by considering safety management system operated by domestic and overseas railway with applicable data of information connection results.

5.1 Items for railway safety indicators assessment

Total 84 indicators of 9 sectors including railway accidents sector, suicide accidents sector, casualties sector, near-misses sector, operation obstruction sector, working hour lost sector, total costs of all accidents sector, technical safety of infrastructure and implementation sector, and safety management sector based on the collectable items through the competent authorities among items that have been organized after reviewing the advanced studies [7-13] related to domestic and overseas traffic(road, aviation, railway) and expert surveys and advices to set items for assessing railway safety. Fig. 3 shows 9 assessment items of railway safety and Table 2 shows detailed indicators of safety railway.

5.2 Comparison of safety indicators by railway operation agency and country

Fig. 4 and 5 are showing development of detailed assessment indicators by suggesting the main representative indicators(◎) as not all of the sectional indicators based on the 84 indicators could not be included.

For the detailed safety indicators progress, railway accident data managed by the railway safety information integrated management system of Korean Transportation Safety Authority and the safety indicators data of 6 EU nations that has been accumulated since 2006 [13].

Fig. 6 and 7 show that safety level is increasing as safety indicators of driving accidents of 3 years (‘06~‘08) in Korea and the European Union tend to increase.

Railway safety culture index is excluded from this study

Table 2. Detailed Sectors of Railway Safety Assessment Indicators

Assessment	Assessment indicators
Railway accidents (6 indicators)	Number of (driving accidents, railway accidents (◎), train accidents, safety accidents(◎), persons seriously injured and killed in traffic accidents) per train km in million
	Number of persons, seriously injured and killed in traffic accidents per million total number of passengers
Suicide Accidents (2 indicators)	Number of suicide accidents
	Number of suicide accidents per train km in million(◎)
Casualties Accidents (Railway Accidents) (8 indicators)	Number of persons, (seriously killed, equivalent fatality, seriously injured, slightly injured) in railway accidents
	Number of railway accidents (seriously killed(◎), equivalent fatality, seriously injured, slightly injured) per train km in million
Casualties Accidents (Passengers) (12 indicators)	Number of passengers, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	Number of passengers, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million
	Number of passengers, (seriously killed, equivalent fatality, seriously injured, slightly injured) per passenger km in billion
Casualties Accidents (Employees) (8 indicators)	Number of employees, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	,Number of employees, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million
Casualties Accidents (Level-crossing Users) (8 indicators)	Number of level-crossing users, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	Number of level-crossing users, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million
Casualties Accidents (Unauthorized Persons) (8 indicators)	Number of unauthorized persons, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	Number of unauthorized persons, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million
Casualties Accidents (Publics) (8 indicators)	Number of publics, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	Number of publics, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million

Table 2. Detailed Sectors of Railway Safety Assessment Indicators

Assessment	Assessment indicators
Casualties Accidents (Railway safety accidents) (8 indicators)	Number of persons, (seriously killed, equivalent fatality, seriously injured, slightly injured)
	Number of persons, (seriously killed, equivalent fatality, seriously injured, slightly injured) per train km in million
Near-misses (2 indicators)	Number of incidents and near-misses
	Number of incidents and near-misses per train km in million
Operation obstruction (3 indicators)	Number of operation obstruction
	Number of operation obstruction per train km in million
	Number of operation defect per one hundred million total number of passengers
Working hours lost (2 indicators)	Total working hours of staff and contractors lost
	Total working hours per hours worked of staff and contractors lost
Technical safety of infrastructure and its implementation (5 indicators)	Percentage of tracks with Automatic Train Protection (ATP) in operation
	Percentage of train kilometers using operational ATP systems
	Total number of level-crossings
	Total number of level-crossings per line kilometer
	Percentage of level-crossings with automatic
Total costs of all accidents (2 indicators)	Total costs of all accidents
	Total costs of all accidents per train km in million
Safety management (2 indicators)	Total number of accomplished audits
	Percentage of audits accomplished /required(and/ or planned)

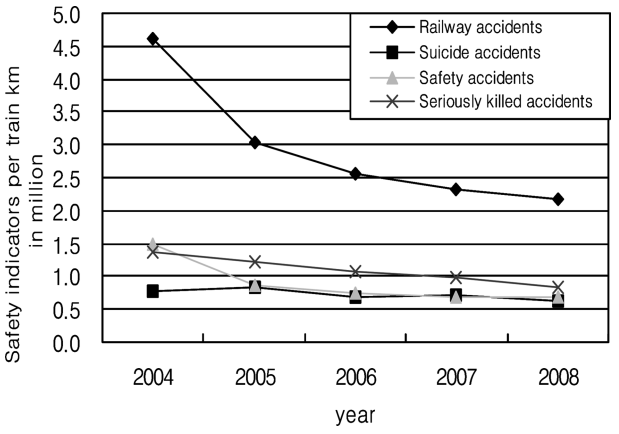

Fig. 4 Safety indicators progress of 4 fields in recent 5 Years

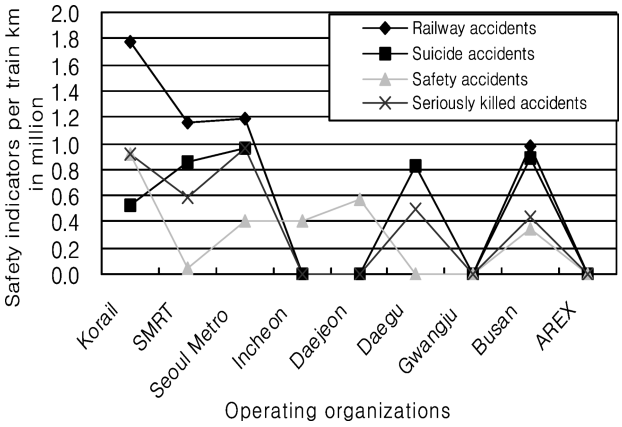

Fig. 5 Comparison of safety indicators of 4 fields per railway operation organization in 2008

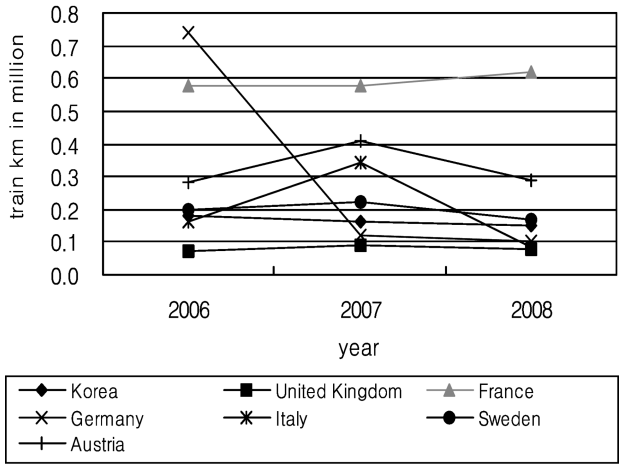

Fig. 6 Comparison of safety indicators of driving accidents per country in recent 3 years

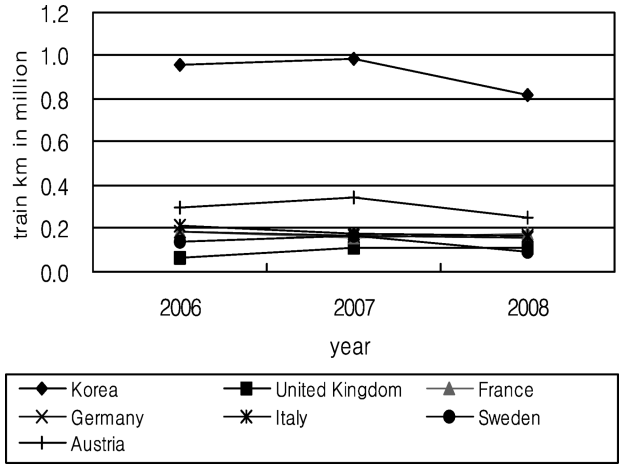

Fig. 7 Comparison of mortality of railway accidents per country in recent 3 years

as it is not a target to be managed systematically and it can only be calculated through survey on railway users.

6. Conclusion

Assessment items of the indicator model about 3 factors (accident occurrence, safety management, safety culture) for assessment of railway safety were suggested based on domestic and overseas advanced studies and applicable data. A fundamental reason for suggesting the indicators model of railway safety indicators is because it is a basic starting point for establishing railway safety management system. In other words, it becomes a criterion for setting a consistent and quantitative safety objective and safety assessment about long-term safety management measure within the safety management cycle of setting safety objectives-establishment of safety plan-safety assessment-establishment of safety measures. In order to achieve completeness and validity of this model, a review on how to set safety objectives was suggested by referring to cases of foreign countries and domestic aviation field.

This study has its significance for setting a direction to develop assessment model and indicators to objectively understand railway operation that is suitable for domestic condition and railway safety indicators of facility organizations. Safety of railway operating and facility organizations can be assessed with the railway safety assessment method in future in order to use it for safety management of the nation and railway operating and facility organizations, and efficient analysis and use of it can be achieved through railway safety information management system that is being established by the nation.

If safety indicators are deducted through assessment indicators for railway safety suggested in this study, it can be applied to safety objectives and safety management by linking with safety management system (SMS) of railway operating and facility organizations or the nation, and monitoring with safety and measuring through indicators management is possible. Application measures of railway safety information system can be prepared based on the study results, and it is expected to contribute to establishment of national safety management system (SMS).

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