Modeling and Assessing of Train-Person Collision Accidents on the National Railway of South Korea

Chan-Woo Park · Jong-Bae Wang · Sang-Log Kwak· Don-Bum Choi

Korea Railroad Research Institute, Uiwang, Korea

Abstract

This paper investigates analytically accidents in the frequency and number of injured/fatal persons in train-person collision accidents on the national railway of South Korea. These accidents take more than 40% of railway accidents occurred in South Korea and 80% of injured persons. Consequently, research on these accident scenarios that more thoroughly takes into consideration and models actual circumstances of these accidents in railway system is necessary. In this research, accident scenarios are developed using the Quality Function Deployment (QFD) method to analyze systematically and evaluate quantitatively fatality accident scenarios for passengers, railway staffs and MOP (Member of public). In this study, the QFD method provides a formal and systematic schema to devise accident scenarios while maintaining the objective.

Key words: Accident Scenario, Risk Assessment

1. Introduction

This paper investigates analytically accidents in the frequency and number of injured/fatal persons in train-person collision accidents on the national railway of South Korea. These accidents take more than 40% of railway accidents occurred in South Korea and 80% of injured persons. Consequently, research on these accident scenarios that more thoroughly takes into consideration and models actual circumstances of these accidents in railway system is necessary.

An accident scenario analysis is conducted to understand, analyze, and describe the process of and the behavior pattern of accidents. The accident scenario analysis can be used to provide a clear picture of accidents that arise from hazardous events and hazardous conditions. Although much work has been done to apply scenario analysis to accident, there is still no systematic and formal methodology which identifies generates, analyzes, and verifies accident scenarios, in our view. The absence of such a methodology raises questions regarding accuracy and objectivity; i.e. the systematic reflection of the interaction between hazardous events and hazardous conditions is not employed. Since the validity of the accident scenario can be subjective, depending on the analysts' personal experiences, this method has been not widely used in accident analyses. Therefore, a new method which is more systematic as well as objective is needed to better identify and give a clearer picture of the accidents arising from the interaction between hazardous events and hazardous conditions. In this research, accident scenarios are developed using the Quality Function Deployment (QFD) method to analyze systematically and evaluate quantitatively fatality accident scenarios for passengers, railway staffs and MOP (Member of public). The QFD method has been conventionally used in quality management and was used at the systematic accident scenario analysis (SASA) for the design of safer products. In this study, the QFD method provides a formal and systematic schema to devise accident scenarios while maintaining the objective. The accident scenario analysis method first identifies the hazard factors that may cause an accident and explains the situation characteristics surrounding the accident. This method includes a feasibility test, a clustering process and a pattering process for clear understanding of the accident situation. The main part of the paper is based on the movement and non-movement accidents of the 6-year period 2003-2008. The results of this research can be used in analyzing the major causes and contributing factors of movement and non-movement accidents at the step of hazard identification, and assessing quantitatively the frequency and severity.

2. Risk Assessment Procedure

To develop the Korea railway risk assessment models, various risk management procedures such as ISO/IEC Guide 51 were reviewed and the risk management procedure applied to this study was developed. The developed risk management procedure followed the requirements of the common safety methods (CSM) suggested by EU. Figure 1 presents the risk assessment procedure of the risk management. In this study, the hazard identification of railway accidents had been carried out by gathering various accident reports and information and having several workshops with railway safety experts. Then, accident scenarios and railway accident analysis code system have been built up. The railway accident scenarios are consisted of railway accident appearance scenarios and railway accident progress scenarios. Both scenario groups are divided by initiating hazardous events. Here, the hazardous event means one that has the potential to lead directly to death or injury. The railway accident appearance scenarios refer to the occurrence processes of accidents before hazardous events. These scenarios provide the base of FTA model structure for frequency evaluation on railway accidents. The railway accident progress scenarios mean the progress processes of accidents after hazardous events. These scenarios provide the base of ETA model for severity evaluation on railway accidents.

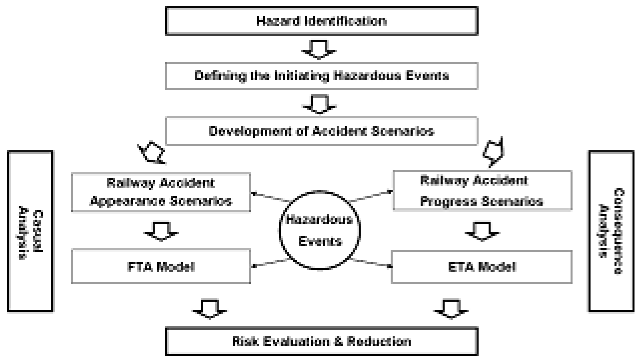

Figure 1. Railway Risk Assessment Procedure

3. Quality Function Deployment (QFD)

The QFD method provides a way to incorporate customer needs into product development and production. In QFD, the relationship between customer needs and the quality requirements necessary to produce those needs are charted, as are the component characteristics, process planning, and production planning. This process may help reduce product development time and give the product a competitive advantage. It could also maximize customer satisfaction by reflecting customers’ needs in the final products .

The QFD method contains one or more matrices called ‘House of Quality’, termed QFD matrix for convenience. It displays the customers’ needs along the left column and the development team’s quality requirements in the top row. The QFD matrix consists of several sub-matrices joined together in various ways- e.g. relationship matrix, market evaluation matrix, and roof matrix (see Figure 3).

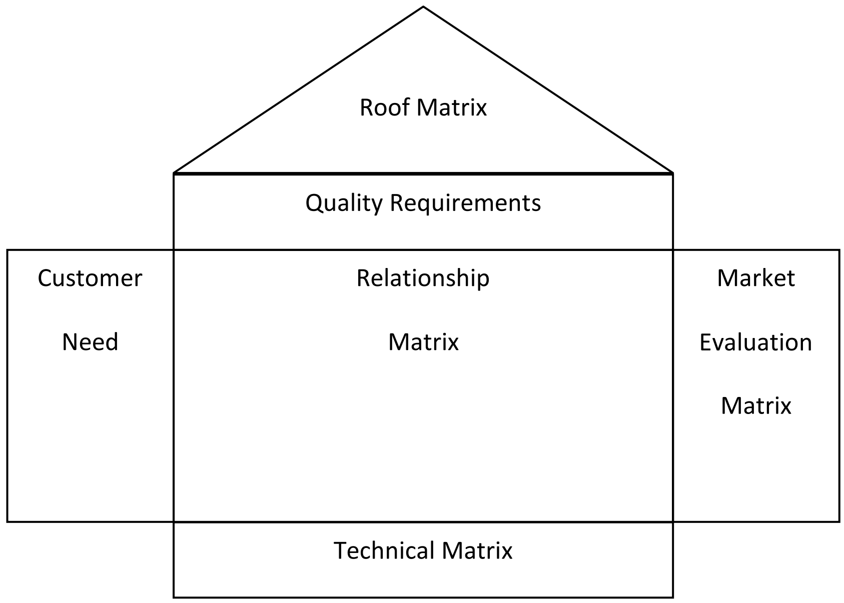

Figure 3: House of Quality (HOQ)

4. Railway Accident Scenario Development using a Quality Function Deployment

The used method was based on a modified QFD matrix. The used method replaces the customer's needs and quality requirements on the QFD matrix with hazardous events and hazardous conditions. However, the used method keeps the meanings for the relationship matrix the same. The market evaluation matrix, technical matrix, and the roof matrix are neglected in the used method. The used method adopted the modified QFD matrix as a tool for devising accident scenarios. Figure 4 shows a complete process of the used method. There are seven key steps.

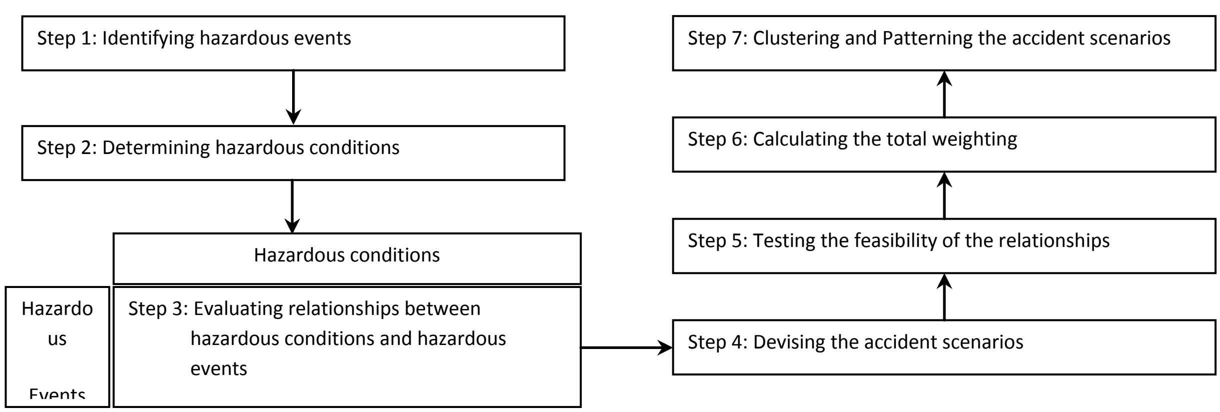

Figure 4: Railway Accident Scenario Analysis Approach

3.1. Identifying hazardous events (Step 1)

This step is probably the most important in that it can pinpoint the safety problems of a railway system; only a successful identification of the problem can lead to improved and safer railway system. Identification of the hazard factors, defined by railway accidents, is carried out mainly by gathering various accident-related reports and information to define hazardous events such as collisions, derailments, explosions, etc. A series of hazard evaluation approaches as FMEA, FTA can be also used in this step.

3.2. Determining hazardous conditions (Step 2)

Hazardous conditions are the characteristics and circumstances surrounding a railway accident. Drury and Brill show that a product use accident involves the interaction between a product, a user, a task and an environment. For railway accidents, this study makes hazardous conditions composed of the four parts: (1) victim, (2) task, (2) environment, and (4) cause. For each part, detailed hazard conditions can be defined. For example, gender, age, height, weight, injured body parts, and injury types are used to describe victim characteristics.

		Hazardous Conditions											
		Victim Characteristics			Task			Environment			Cause		
Hazardous	**Importance**	1	2	••	1	2	••	1	2	••	1	2	••
Hazardous													
Hazardous													
.													
.													
.													
Hazardous													

Relationship Rating Indication

◎: Strong relationship (5)

Figure 5: Railway Accident Analysis Tableau

3.3. Evaluating relationships between hazardous conditions and hazardous events (Step 3)

In the original sense of the QFD method, the importance of each the QFD method, the importance of each customer's needs is rated based on the results of questionnaires and the direct experience of the QFD development team. Consumer's needs are then matched with quality requirements to determine the influence of the latter on the former. The QFD team, consisting of marketing people, design engineer, and manufacturing staff, seeks a consensus on these evaluations based on expert engineering experience and results from statistical studies or controlled experiments.

On the basis of railway accident data, the used method rates the importance of a hazardous event by computing the severity of the hazardous event (e.g. equivalent fatality per year) and evaluates between the hazardous events and hazardous conditions by computing the frequency. That is, the most severe hazardous event is assigned the highest weight and the most frequent relationship between the hazardous events and hazardous conditions is assigned the highest weight.

A review of various literature shows that in the QFD method, the ratings are generally weighted with 1 to 5 or 1 to 9 scales with the larger number indicating greater importance or stronger relationship. There is no established scientific basis to determine the superior rating system. In the study, the used method adopts the 1-5 rating scale, meaning a hazard factor weighted '1' indicates the least important, and '5' the most important. The relationship between the hazard factors and situation characteristics is weighted '5' if the relationship is strong, '3' if moderate, and '1' if weak.

3.4. Devising the accident scenarios (Step 4)

Figure 5 shows a complete scheme for devising railway accident scenarios. The scheme, 'railway accident analysis tableau', creates scenarios from a matrix of all the possible relationships; the relationship of each hazardous event with its corresponding hazardous conditions. For example, if any hazardous event is related to four victim characteristics, two task characteristics, three environment characteristics, and one cause characteristic, the accident analysis tableau can devise a total of twenty-four accident scenarios.

3.5. Testing the feasibility of the relationships between a hazardous condition and hazardous conditions (Step 5)

The used method filters out infeasible relationships between elements of the hazardous conditions, therefore, mitigating the need to devise and analyse the accident scenarios. For example, consider the victim characteristic, 'passenger' and the task characteristic, 'train maintenances'. The victim characteristic, 'passenger' can not be related with the task characteristic, 'train maintenances'. Therefore, the railway accident scenario including these terms is classified infeasible.

3.6. Calculating the total weighting (Step 6)

After the railway accident scenarios are created, the total weight is calculated to determine the prominence of railway accident scenarios. To calculate the total weight for each railway accident scenario, the importance of the hazardous event is multiplied by each of its corresponding hazardous conditions and then added together to get the total. The railway accident scenarios for each hazardous event are prioritized by their relative rankings based on total weights. The highest ranked railway scenario describes the most hazardous case.

3.7. Clustering and Patterning the accident scenarios (Step 7)

As mentioned above in step 4, the railway accident analysis tableau devises the railway accident scenarios based on all the possible relationships between the hazard factors and situation characteristics. The process may create too many railway accident scenarios to be dealt with. In order to understand the hazardous condition thoroughly, the clustering and pattering processes are introduced. These processes make the used method an easier and simpler railway accident analysis method.

5. Conclusion

This paper investigated analytically accidents in the frequency and number of injured/fatal persons in train-person collision accidents on the national railway of South Korea. This approach was inspired by the QFD method. In this study, the QFD method provides a formal and systematic schema to devise accident scenarios while maintaining the objectivity. The accident scenario analysis method first identifies the hazardous events and explains the hazardous conditions that surround the accident and cause railway accidents. This method includes a feasibility test, a clustering process and a pattering process for a clearer understanding of the accident situation. Since this method enables an accident scenario analysis to be performed systematically as well as objectively, this method is useful in building better accident prevention strategies. Therefore, this study could serve to reduce railway accidents and could be an effective tool for a hazard analysis.

References

[1] European Commission, “Safety Management in Railway, D.2.3: Common Safety Methods”, 2004.

[2] European Commission, “Safety Management in Railway, WP.2.4: Acceptable Risk Level”, 2004.

[3] European Commission, “Framework for identifying sources, stakeholders and the nature of risks, SAMNET / LSA / PhG / WP2.3 / D2.3.1 / V4, 2004.

[5] Korea railroad research Institute, "Establishment of Risk Analysis and Assessment System for Railway Accidents and Hazards", Annual report of an Integrated R&D Plan for the Railway Safety, Ministry of Construction and Transportation, Korea, 2006.

[6] Rail Safety and Standard Board, "Investigation of common safety methods", 2005.

[7] Rail Safety & Standard Board, "A statistical review of the RSSB Safety Risk Model (WP1)", 2004.

[8] Rail Safety and Standard Board, UK (2004), "Rail-specific HRA technique for driving tasks", Final report.

[9] Rail Safety and Standard Board, "Profile of Safety Risk on the UK Mainline Railway", issue 5, 2006.

[10] ISO/IEC Guide 51, "Safety Aspect-Guidelines for their inclusion in standards", 1991.