A Systemic Approach to a Railway Accident Scenario Analysis Using a Quality Function Deployment

2 December, 2005, Hong Kong

Chanwoo Park, Jongbae Wang, Sanglog Kwak, and Joonam Park
Contents

I  Introduction

II  Preliminary Hazard Analysis (PHA) & Quality Function Deployment (QFD)

III  Railway Accident Scenario Development using a Quality Function Deployment

IV  Conclusions and Recommendations
1. Introduction

**Background**

- **Risk assessment of Railway system**

  - Hazard Identification / Preliminary Hazard Analysis (PHA)
  - Frequency Analysis
  - Consequence Analysis
  - Interaction analysis between hazardous events and hazardous condition
  - Hazard Identification / Preliminary Hazard Analysis (PHA)
  - Accident Risk Analysis

**Risk Assessment**

- **Prerequisite to understanding how hazardous events and hazardous condition contributes to an accident**
- **Examining the etiology of accidents and analyzing the detailed sequence of events**
- **Provide a clear picture of accidents**

**Safety regulations, Published sources**

**Accident related reports**
1. Introduction

Background

- **Accident Analysis Method**
  - FMEA (Failure Mode and Effect Analysis)
  - FTA (Fault Tree Analysis)
  - MORT (Management Oversight and Risk Tree)
  - Fault Hazard Analysis
  - STEP (Sequentially Time Event Plotting)
  - SCAT (Systemic Casual Analysis Technique)

  “At the early stage of risk assessment, these methods can be subjective depending on analysts' personal experience and be difficult to make a systematic analysis in a general view.”

- **Accident Scenario Analysis Method**
  - “Process of understanding, analyzing, and describing accidents and the behavior patterns of hazardous conditions” - Cushman and Rosenberg, Human Factors in product design, 1991-
  - “Devise a limited number of accident scenarios with descriptions of victims, products, environment, and task” - Drury and Brill, Human Factors, 1983-
Research Objectives

“Although much work has been done to apply scenario analysis to railway accidents, 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.

Devise an accident scenario analysis method for creating Railway accident scenarios at the PHA step of a hazard analysis for railway system

- Inspired by the Quality Function Deployment (QFD) method
  - conventionally used in quality management
  - used at the systematic accident scenario analysis (SASA) for the design of safer products
- The QFD provides a formal and systematic schema to devise accident scenarios while maintaining the objectivity.
2. Preliminary Hazard Analysis (PHA) & Quality Function Deployment (QFD)

Risk Assessment Process

“Risk assessment entails a systematic analysis of the potential losses associated with the change and of the measures for reducing the likelihood or severity of the losses.”

- Railtrack, Yellow Book 3: Fundamentals and Guidance, 2000 -

“Risk assessment is tightly coupled with hazard identification and risk reduction”

- The PHA, often called hazard identification, is used in the early life cycle state
  - Identifying critical system functions and system hazard factors.
  - Understanding how hazard factors contribute to railway accidents
  - Understanding, analyzing, and describing the accident process
  - This can be accomplished by applying the accident analysis method
Preliminary Hazard Analysis (PHA)

**Input Data for Analysis**
- Hazardous event lists generally considered for railway system
- Hazard analysis scope
- Definition of severity and frequency levels for hazardous conditions
- System Description

**Preliminary Hazard Analysis**
- Selection of a hazardous event from hazardous event lists
- Evaluation of the frequency and the severity for the hazardous event
- Definition of hazardous conditions to initiate the hazardous event
- Description of hazardous conditions
- Analysis of influence on the hazardous event for each hazardous condition
- Evaluation of hazard levels for each hazardous condition
- Definition of control measures for each hazardous condition
  - Corrective or preventive measures, possible safeguard, and recommended action
- Verifying that control measures effectively control hazardous conditions

**Expected Output**
- Severity and frequency levels of hazardous conditions related to a hazardous event
- Potential hazard factors
- Risk reduction alternatives
The QFD method is conventionally used in quality management. 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 House of Quality (HOQ).
3. Railway Accident Scenario Development using a Quality Function Deployment

Railway Accident Scenario Analysis Approach

Step 1: Identifying hazardous events

Step 2: Determining hazardous conditions

Step 3: Evaluating relationships between hazardous conditions and hazardous events

Step 4: Devising the accident scenarios

Step 5: Testing the feasibility of the relationships

Step 6: Calculating the total weighting

Step 7: Clustering and Patterning the accident scenarios
### Step 1: Hazardous events Identification

- This step is probably the most important in that it can pinpoint the safety problems.
- 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.

### Step 2: Hazardous Conditions Determination

- Characteristic and circumstances surrounding a railway accident.
- In case of a product use accident, Drury and Brill makes hazardous conditions composed of 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.

### Hazardous Conditions Table

<table>
<thead>
<tr>
<th>Hazardous Events</th>
<th>Victim Characteristics</th>
<th>Task Characteristics</th>
<th>Environment Characteristics</th>
<th>Cause Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>1</td>
<td>2</td>
<td>**</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Relationship Rating Indication

- ⊙: Strong relationship (5)
- △: Moderate relationship (3)
- ○: Slight or possible relationship (1)
### Evaluating Relationships

<table>
<thead>
<tr>
<th>Hazardous Events</th>
<th>Hazardous Event 1</th>
<th>Hazardous Event 2</th>
<th>Hazardous Event N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>1</td>
<td>2</td>
<td>•</td>
</tr>
</tbody>
</table>

### Relationship Rating Indication

- ◎: Strong relationship (5)
- △: Moderate relationship (3)
- ○: Slight or possible relationship (1)

#### Step 3: Evaluating Relationships

- The QFD method is rated based on the results of questionnaires and the direct experience of the QFD development team.
- The proposed method:
  - rates the importance of a hazardous event by computing the severity of the hazardous event (e.g. equivalent fatality per year)
  - evaluates relationship by computing the frequency.
  - the ratings are generally weighted with 1 to 5 or 1 to 9 scales with the larger number indicating greater importance or stronger relationship.
### Devising the accident scenarios & Testing the feasibility of the relationships

#### Step 4: Devising the accident scenarios
- The scheme, ‘railway accident analysis tableau’, creates scenarios from a matrix of all the possible relationships.
- For example, if any hazardous event is related to:
  - four victim characteristics, two task characteristics,
  - three environment characteristics, and one cause characteristic,
  - devise a total of $4 \times 2 \times 3 \times 1 = 24$ accident scenarios.

#### Step 5: Testing the feasibility of the relationships
- Filter out infeasible relationships between elements of the hazardous conditions.
  - Mitigating the need to devise and analyse the accident scenarios.

#### 3. Railway Accident Scenario Development using a Quality Function Deployment

<table>
<thead>
<tr>
<th>Hazardous Conditions</th>
<th>Victim Characteristics</th>
<th>Task Characteristics</th>
<th>Environment Characteristics</th>
<th>Cause Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous Events</td>
<td>Importance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazardous Event 1</td>
<td>1</td>
<td>2</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Hazardous Event 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazardous Event N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Relationship Rating Indication
- ◎: Strong relationship (5)
- △: Moderate relationship (3)
- ○: Slight or possible relationship (1)
### Calculating the total weighting & Clustering and Patterning the accident scenarios

<table>
<thead>
<tr>
<th>Hazardous Events</th>
<th>Importance</th>
<th>Victim Characteristics</th>
<th>Task Characteristics</th>
<th>Environment Characteristics</th>
<th>Cause Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous Event 1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hazardous Event 2</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Hazardous Event N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Relationship Rating Indication
- ◎: Strong relationship (5)
- △: Moderate relationship (3)
- ○: Slight or possible relationship (1)

**Step 6: Calculating the total weighting**
- 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,
  - then added together to get the total.
- The highest ranked railway scenario describes the most hazardous case.

**Step 7: Clustering and Patterning the accident scenarios**
- The process may create too many railway accident scenarios to be dealt with.
- In order to understand the hazardous condition thoroughly, the clustering and patterning processes are introduced.
- These processes make the proposed method an easier and simpler railway accident analysis method.
Conclusions

“devise an accident scenario analysis method for creating accident scenarios at the PHA step of a hazard analysis for railway system”

- 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

“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”

- This method is useful in building better accident prevention strategies.
- This study could serve to reduce railway accidents and could be an effective tool for a hazard analysis.
Thanks for the attention!