High-speed Trains Driving Functions Analysis Using Systems Engineering

Hee Min Noh

Abstract

In this paper, driving functions of the Korea High-speed Trains were decomposed based on systems engineering architecture. In order to analyze the driving function, various systems engineering tools and methods were used. Moreover, interfaces of decomposed driving functions were analyzed to figure out purposes of the driving functions. Through activity modeling of driving function of the Korea High-Speed Trains, main functions were derived when starting, speeding and stopping. When the high speed train is speeding, pre-departure checks and wheel slide prevention are essential driving activities for the safety and when the high speed train runs high speed, maintaining driving stability by monitoring bogie hunting and monitoring drivers' safe operation by vigilance systems is important. Furthermore, when the train is braking, the driver should checks brake and suspensions as safety actions.

Keywords: Function decomposition, Systems engineering, Safety analysis

1. Introduction

Safety securing technology is one of the most important facts for ensuring operational safety of high-speed trains. Hazard identification and analysis of high-speed trains are beneficial methods to bestow safety on the operational systems of the train. By thorough and detailed hazard identification and analysis of the driving functions of the high speed train, we can figure out what is the most critical safety factor of the system.

Since Korea dose currently have a weak technological basis for safety evaluation and traceability of the accident causes, there are demands for a definition and procedure development of safety regulation system, organization of safety case system, establishment of detailed safety standard, evaluation technology development for safety, construction of test assessment basis, technology development for a prevention of critical accidents and construction of safety information management system, etc, then the developed technologies need to be incorporated into the overall system, in order to prepare an efficient enforcement mission of the railway law already taken effect.

2. Systems Engineering Methods

2.1 Systems Engineering Architecture

System engineering tools define and trace/manage implications of safety case/specification requirement as well as systems requirements, functions, behaviors and physical architecture, they help definitions and resolutions of the problems to be managed systematically and efficiently.

Architecture is defined as the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time. Generally, Architecture is classified as operational, functional and physical architecture in terms of architecture views. At first, operational architecture focuses on how a defined system is to be carried out. The architecture development processes must start with an operational Concept. As the architecture development process evolves, the operational concept becomes more specific. Second, a functional architecture is a set of activities or functions arranged in a specified order that, when activated, achieves a defined goal. Finally, the physical architecture indicates what is possible. Physical components are capable of carrying out processes and the interconnection between components indicates that a directed flow is possible. Fig. 1 shows relations between architecture views.
2.2 System Hierarchy

A top-down method is rigorous for determining an appropriate architecture for a system. In the top-down method as shown in Fig. 2, the system itself is placed on the top-layer and then the system is decomposed by selected architecture views into sub-systems on the lower-layers. This process continues until the entire system has been integrated and tested in terms of consistent architecture views.

Therefore, before system decomposition, system boundaries and layers should be considered thoroughly. From obtained system hierarchy, activities at each label can be figured out.

2.3 Relationships between System Functions and Activity Models

The Activity Model describes the applicable activities associated with the architecture, the data or information exchanged between activities, and the data or information exchanged with other activities that are outside the scope of the model. The models are hierarchical in nature; that is, they begin with a single box that represents the overall activity and proceed successively to decompose the activity into the level required by the purpose of the architecture.

The Activity Model can be derived from system functions analysis shown in Fig. 3. Activity implements or is implemented by system function. Also, the Activity Model contributes greatly to the definition and appropriate understanding of an operational architecture. Activity performs or is performed by operational elements shown in Fig. 3.

3. Driving Functions Analysis

3.1 Upper-layer Driver Activities

Driver activities can be classified as pre-departure preparation, driving operations and brake system operations in terms of the train speed. Firstly, in the pre-departure step, the driver conducts preliminary operations and checks, switching on (power supply) and various instruments tests. Secondly, in the driving operations step, the driver conducts train traction (starting), speed adjustment and driving statue monitoring. Finally, in the step of brake system operations, the driver conducts monitoring of brake operations, speed down operation (braking) and stopping operation.

3.2 Lower-layer Driver Activities

Despite decades of study there are many opinions, but
no general agreement, on which organizational form is most effective for a given type of enterprise. For this reason the organizations participating in a system development project are likely to employ a variety of different organizational styles. Each individual style has evolved as a result of history, experience, and the personal preference of upper management.

### 3.3 Activities Models Diagrams

Activity modeling helps us to understand the relationships among important activities within a system. Decomposed activities were analyzed by using a systems engineering program called BP-Win for finding out functional interfaces among the activities. Through this process, critical functions were derived when starting, speeding and stopping steps of high speed train.

When the high speed train is speeding, pre-departure checks and wheel slide prevention are essential driving activities for the safety and when the high speed train runs high speed, maintaining driving stability by monitoring bogie hunting and monitoring drivers’ safe operation by vigilance systems is important. Furthermore, when the train is braking, the driver should checks brake and suspensions as safety actions.

### 4. Conclusion

In this paper, driving functions of the high-speed train were analyzed by using systems engineering. Driving functions were classified as pre-departure preparation, driving operations and brake system operations and detailed functions at the each stage were derived. Furthermore, the functional interfaces at each stage were verified by analyzing interfaces among the detailed functions. This process helps us to find out critical safety factors of the high speed train.
Fig. 4 Pre-departure preparation activity model

Fig. 5 Driving operations activity model
Fig. 6 Brake system operations activity model

Reference