Development of Generic Train Operation Model Based on Korean Urban Transit Regulations

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ABSTRACT: This paper discusses the development of a generic train operation model from a set of Korean Urban Transit Regulations such as Regulation for Train Operation of Urban Transit, Regulation for Safety Requirements of Urban Transit and so on. It is to communicate with various stakeholders on urban transit system, and to elicit copious requirements of problems in performance of the urban transit train operation based on the model.

1 INTRODUCTION

Train operation is to manipulate the vehicle or train to be driven on the basis of the facilities such as track, power, communication, signaling and so on. It could be performed on manual or automated, or manned or manless mode with the system built for the line. Because of the heavy impact to the passenger safety, it has been managed strictly by Regulation for Train Operation of Urban Transit (RTOUT) for the train operation, and Regulation for Safety Requirements of Urban Transit (RSRUT) for the vehicle structure and its equipment according to Urban Transit Act (UTA). There are various urban transit systems in Korea developed from other countries. The function model of train operation has been established on the basis of standards and regulations to analyze the requirements and behavior of the operation.

While the former regulations (RTOUT, RSRUT) specified the manual operation mainly, the revised regulations include the manless operation noticed at August 2010. But, there are some limitations on them for manless operation. Thus, the cases of manless operation were reviewed to complement the train operation model, to be referred for revising the regulations further.

In this paper, a generic train operation model of urban transit was discussed based on urban transit regulations. We also reviewed the cases of manless operation such as Busan 4th line, Shinbundang line, Busan-Kimhae line, based on the present regulations for considerations to complement the model with the manless operation.

2 FUNCTION MODEL OF TRAIN OPERATION

2.1 Modeling functions

Function model is to design the logical perspectives of a system and processes with analyzing. The model is a multi-tiered, time-sequenced, step-by-step flow diagram of a system. One of the well-known function models is the Functional Flow Block Diagram (FFBD), to visualize the time sequence of events in a system and its missions. It is further widely used in classical systems engineering to show the order of execution of system functions. In this paper, the Enhanced FFBDs (EFFBDs) were created to represent data triggering of functions with control.

Function models were created on the scope of generic level with subsystems of urban transit. Those models were integrated to top level of train operation. The model is constructed with the computer-aided systems engineering tool through requirements analysis. The CORE® software of Vitech company has been used to perform modeling showed in Figure 1. The hierarchy of requirements of train operation is shown in Figure 2. The rectangles with a small dot on them contain the lower-level requirements.

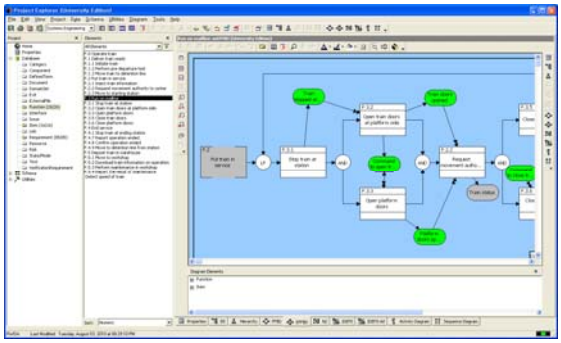

Fig. 1 Modeling functions of train operation.

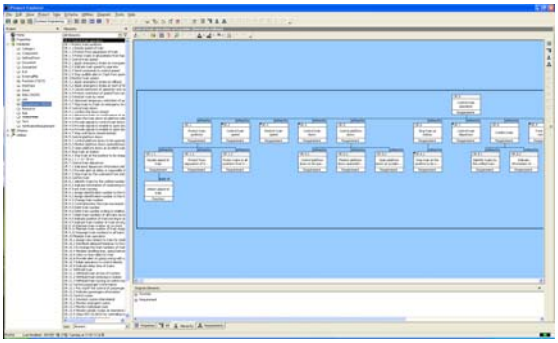

Fig. 2 Hierarchy of requirements for train operation

2.2 Function models

There is the top-level function model of train operation of urban transit in Figure 3, which is based on regulations and standards by Urban Transit Act of Korea. This model can be also decomposed to lower level of train operation in more detailed.

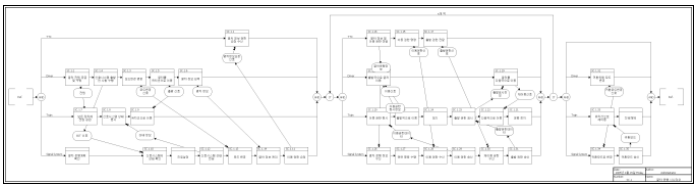

Figure 3 Model for train operation of urban transit

Once the function model is established from requirements, it can simulate the execution of system modeled to validate requirements. The function model was validated its behavior of train operation. It means the requirements are feasible logically through function model. But it should be validated of its performance for its behavior.

3 CASES OF MANLESS OPERATION

3.1 Requirements for manless operation

Manless operation defined in RTOUT is to control train not by a driver in the cabin but by the remote automatic control in the control center. The operation status shall be monitored and taken measures in real-time (Article 32 and 2), and battery-powered communication equipment shall be provided for passenger to the center (Article 11), and it shall be protected to be used in emergency condition (Article 78).

The train operation in Korea shall be limited to licenseholders (Article 32). To ensure the safety in manless operation, there are items to be observed such as use of lock for driver's desk in the train, prior approval for changing operation mode or opening driver's desk, checking communication in manual operation, and so on (Article 32 and 2). There are also exceptions for manless operation such as driving at the forefront of a train, driver's license, deployment of equipment for driver's visibility in the cabin, and so on (Article 32 and 2, 33, RSRUT Article 40). There are items of communication for passengers, monitoring the performance of brake system periodically, protection of departure with a door opened and so on in RSRUT.

3.2 Current state of manless operation of Korea

A. Shinbundang Line

Shinbundang line is the first case of a heavy railway system for manless operation. The line length is 18.5km, links Gangnam of Seoul with Jeongja station, Bundang district of Seongnam city. It has 6 stations, AC 25,000V of power supply, 90km/h of operation speed, based on CBTC system shown in Figure 4.

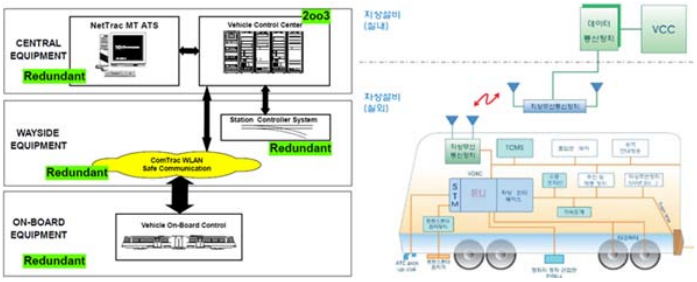

Figure 4 Operation system for Shinbundang Line.

The train runs in manless mode basically, the dispatcher in control center can monitor and control it. The operation mode can be changed with the exception of cases predecided, running back, or forced.

There are special operations in any abnormal case such as shuttle operation with one train repeating on specified route, line operation with specified headway on a section, and single line operation with one of the tracks. With a fault of CBTC or communication, the train should run under 25km/h.

B. Busan 4th Line

Busan 4th line designed on the basis of the K-AGT, Korean Light Rail Transit developed by KRRI, is the first manless urban transit system in Korea. The line length is 12.7km, from Minam to Anpyeong in Busan. It has 14 stations, 60km/h of operation speed, rubber-tired AGT vehicle, was opened at 30 March, 2011. It is operated in manless mode as common block system by ATP/ATO on the basis of the inductive loop shown in Figure 5, or it could not be operated. And also no manless operation in the case of failure of vehicles, trains, tracks or signals, rescue train operation, fail to stop at the station and so on. There are safety personnel in the train and the platform to monitor the passenger's safety and cope with any emergency situation. They can also drive the train with faults.

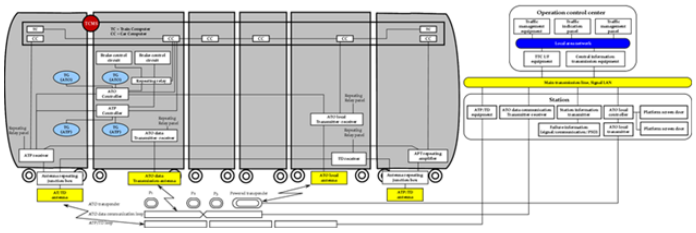

Figure 5 Control system for Busan 4th Line.

C. Busan-Gimhae Line

Busan-Gimhae Light Rail Transit (BGL) line is extended from Sasang to Gayadae station, the length is 23.5km with 21 stations, 70km/h of operation speed, DC 750V of power supply with the third rail and AGT steel-wheeled vehicle. The common block system of BGL line is the manless automatic block system performed by the CBTC system shown in Figure 6. The boundary of the block is separated by a specific block between trains, called 'logic block'. There are also safety personnel for the emergency and they can drive the train. The train shall run less 15km/h without signals in communication fail.

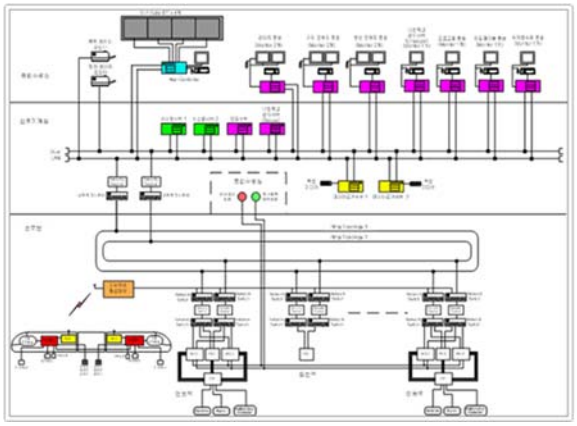

Figure 6 Control system for Busan-Gimhae LRT line.

BGL line designates by themselves the manless automatic block system which is not defined in RTOUT. And the driver can perform the role of messenger simultaneously. But the messenger can not be on the train in the case that the dispatcher can control the train, noticed in RTOUT.

4 COMPLEMENTS OF THE MODEL

The cases of manless operations above were reviewed to reflect on regulations to be revised and the model to be complemented. It was performed on the basis of the present regulations and standards

4.1 Review of manless operations

A. Terms related with manless operation

There are terms for manless operation; the driverless or the manless. The driver may be onboard in driverless operation for monitoring systems, while the driver is not onboard in manless operation which is also called the unattended operation. There needs to include concepts about a control center, dispatcher, safety personnel, etc. in RTOUT. And terms such as the dispatcher and safety personnel are also to be consistency with other regulations in different use. For instance, there is a term of dispatcher dedicated only for driving in BGL, but the dispatcher covers the operation comprehensively in others .

The term of safety personnel to support driving in emergency conditions is being used with difference by operation companies. That makes them difficult to be understood their work and to be managed them. Some companies deployed them as station staffs, but they are needed to be licensees to drive the train at any time.

B. Manpower management

The train can be driven manually by the dispatcher in control center. This should be regarded as a driver's work and the dispatcher needs a driver's license and some experience. But present RTOUT excepts the license for driving in manless operation. It has no clause about qualification of dispatcher for driving, only about the license for a driver. Operation companies are taking persons with licenses, training them for a period in manless operation and examing the management of driver through the safety check. The manpower management for driving should be required in RTOUT such as qualification, training, hours of duty, etc. on dispatchers and drivers for

manless operation, and the plans too. The fact about safety personnel is similar with the above, such as no qualification, management, plan, etc. The Shinbun dang line has a long distance tunnel of more than 8km between stations, the safety personnel in the train should be considered at all time for the tunnel.

C. Block Control

The transit mainline shall be divided to separated block sections, and installed with equipment to identify signals of the sections by RTOUT. The block control can be used as common or substitute system. In the case of manless operation, however, the block itself may not exist, the distance of each block may vary on the line and the signals may not be used. And it may not be applied with the automatic control or the cab-signal control of common block system. Therefore, the block control system dedicated for manless operation should be considered in RTOUT.

D. Signal

The type of signal for urban transit is classified into signal, sign and indicator in RTOUT. Signal is to show conditions for train running, sign is to exchange understandings among employees and indicator is to show the positions, directions, conditions of things. These are mainly for the manual operation, could restrict train control in manless operation. The train stopped on the line shall not start until the related signal turns green by RTOUT. The motion sign shall be given to the train with no signal installed.

However, the signal is not installed in most case of manless operation, so it should be considered for manless operation in RTOUT. The expanded concept of signal use should be taken into account

E. Others

The train shall be organized with the train number for driving on the line in RTOUT. But the train numbers are treated on different basis of manless operation cases. For example, there is no train number for the train in Busan 4th line and Shinbundang line but vehicle numbers. And the train operation shall be performed upon the timetable noticed (Article 34). It is performed by the system with flexibility for train planning in manless operation. The timetable should not make the passenger not wait for the train long time and expect the time of train coming easily.

The operation delay of more than 10 minutes shall be treated as a failure by the law. However, without driver in manless operation, access time of personnel in an emergency should be considered. And the time of communication check, approval of dispatcher, etc. related to the time-consuming to perform such procedures should be included.

4.2 Function models

There is the top-level function model of train operation of urban transit in Figure 7, It contains the generic functions decomposed to lower level in more detailed as shown in Figure 8.

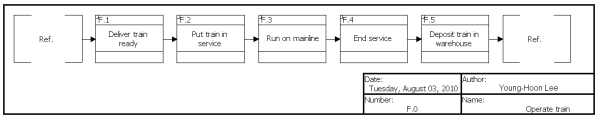

Figure 7 Model of train operation as top level

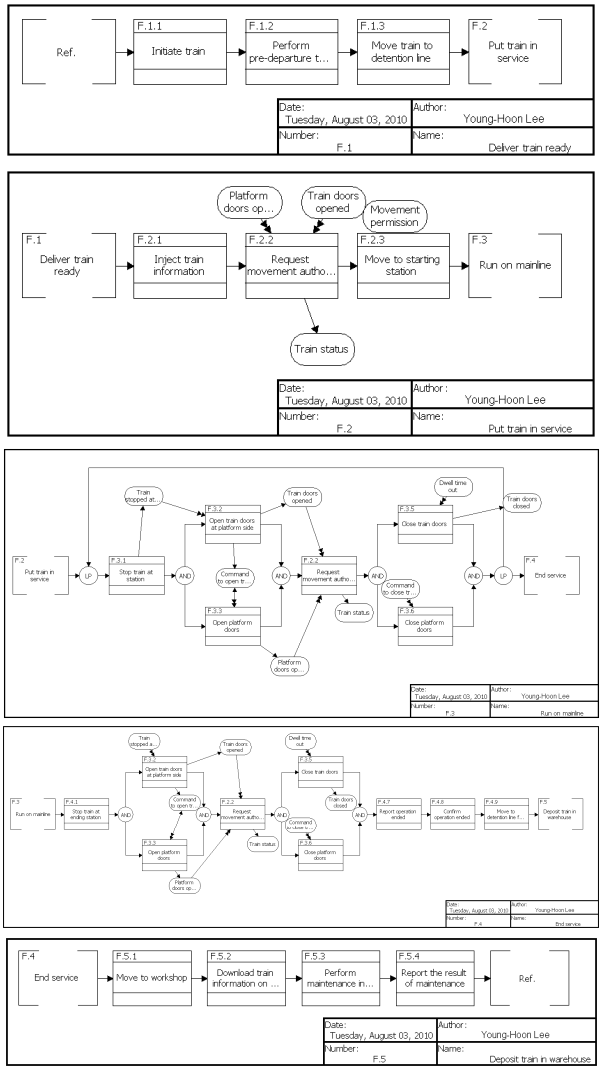

Fig. 8 Models for detailed functions decomposed.

Once the function model is established from requirements, it can be executed for a simulation to validate requirements. The function model was validated its behavior of train operation. It means the standard requirements are feasible logically through function model. But it needs to be validated its

performance for its behavior, it can be also executed on the tool, CORE®.

5 CONCLUSIONS

Trains or vehicles run on the facilities of urban transit and the operation of them impacts to the passenger directly, so the safety standard should be concerned in advance for the safe operation. The present regulations such as for train operation (RTOUT) and for safety requirements (RSRUT) have some limitations for manless operation. We had to review the regulations for further revision of them with manless operation of urban transit. And the real cases of manless operation such as Busan 4th line, Shinbundang line and Busan-Kimhae line which are in preparation to open or were opened recently

We have established a generic model of train operation based on urban transit regulations as requirements and complemented it with manless operation from the real cases. We analyzed the requirements and behavior of the operation, and showed the feasibility of requirements through the model. This generic model is also to support the test and evaluation of the urban transit system in conformity with the standards of urban transit. It needs to be tested further with performance parameters of urban transit, and it could be simulated by a computer-aided systems engineering tool such as CORE® software used for modeling.

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