Model-Driven Study of Intelligent Passenger Information System for Urban Rail Transit

Tingli Huang[1], Baomin Wang[1](✉), Ningguo Qiao[1], Haifang Wang[2], Jiahao Zhao[1], and Qingyong Wang[3]

[1] School of Automobile and Transportation, Tianjin University of Technology and Education, Tianjin 300222, China
wangbaomin1982@126.com
[2] CRRC Tangshang Co., Ltd, Tangshan 064000, China
sjc-wanghaifang@tangche.com
[3] Tianjin Rail Transit Operation Group Co., Ltd., Tianjin 300392, China

Abstract. The passenger information system (PIS) of urban rail transit consists of three major functions: Public Address (PA), Closed Circuit Television (CCTV) and Passenger Information Display (PID). Their functions are independent of each other, with low integration and development efficiency. To solve these problems, the three functional modules of PIS were modularized, and the Model-based Systems Engineering (MBSE) concept was adopted to model the PIS, proposing the Intelligent Passenger Information System (IPIS). Based on the characteristics of classic MBSE and IPIS, a new modeling IPIS method is proposed in this paper, which will complete the design of complex systems after considering stakeholders, relevant requirements, and use case scenarios. A performance metamodel, functional metamodel, and system requirement metamodel of the IPIS system have been established to meet the modeling process of IPIS, which will improve the reuse rate of the model and shorten the design cycle. The performance metamodel, functional metamodel, and system requirements metamodel of the IPIS system have been established to meet the modeling process of IPIS, which will improve the reuse rate of the model and shorten the design cycle.

Keywords: MBSE · Urban rail transit · PIS · System modeling

1 Introduction

At present, passenger demand for urban rail information services is increasing. It is required the PIS to be updated more quickly, and at the same time, the PIS has the characteristics of a long development cycle and complex system. Therefore, the MBSE idea is used to design the PIS system.

MBSE is a modeling idea that drives systems with models, enabling modeling approaches to support activities, such as system requirements, design, analysis, verification, and validation [1]. This enables the faster development of systems and reduces the number of design iterations [2]. At this stage, it is widely used in large complex systems

M. Gong et al. (Eds.): EITRT 2023, LNEE 1138, pp. 153–160, 2024.
https://doi.org/10.1007/978-981-99-9319-2_18

and software development projects for different complex systems and industrial areas with different methods, languages, and tools [3]. The relatively mainstream methods are the Object-Oriented Systems Engineering Method (OOSEM), Arcadia, Magic Grid, and other methods, modeling tools such as Cameo Systems Modeler, Visual Paradigm, M-Design, and common modeling languages such as Simulink, STATEMATE, UML, SysML [4].

Peng Kun et al. [5] adopted the MBSE idea for the forward design of a manned lunar spacecraft system. Mei Qian et al. [6] applied MBSE to design the functional architecture of a civil aircraft. Liu Chang et al. [7] demand analysis of intake air damper control based on MBSE. Chao Tang et al. [8] used the Raphsody method to develop the function of a civil aircraft system. Baomin Wang et al. [9] applied the MBSE idea to simulate the control process of a pantograph. Yuan Wenqiang [10] built a functional knowledge base and component base for a high-voltage system for rolling stock based on MBSE. Chen Bo et al. [11] used the SYSML language to model and simulate the end-change scenario of a moving train set.

This research uses M-Design system modeling tool and SysML modeling language, combined with the characteristics of IPIS, proposes the BW of IPIS_IPIS modeling method. M-Design, as a modeling tool, can achieve syntactic modeling of requirements, behaviors, structures, and parameters, and build a metamodel library for secondary development of IPIS.

2 Methodology Applicable to IPIS

In modeling IPIS, the whole system is divided into two layers, B-black and W-white, B-black refers to modeling at the black box level and W-white refers to modeling at the white box level.

Analysis of the B-Black layer. In this stage, the stakeholders of the system (B1) are studied in depth, and their crowd-related requirements (B2) are deduced based on the stakeholder analysis. The system's usage scenarios are analyzed in detail, the corresponding use case scenarios are identified (B3). These use case scenarios were modeled by the black box activity diagram modeling method (B4).

Analysis of the W-White layer. Convert some activities in a black box activity diagram into a white box activity diagram (W1). For the activities in the W1 layer, cluster analysis was performed to determine the required functionality of the system (W2). The functional analysis of the W2 layer is studied in depth, the requirements of the system (W3) are refined. After completing the functional analysis and system requirements, analyze the system architecture (W4). The physical architecture (W5) is obtained by analyzing the physical components and structures that can implement the system functions in the W2 layer.

The detailed research methodology flow is shown in Table 1.

Table 1. The framework of the BW_IPIS method.

B-black layer	B1 for system stakeholder analysis	B2 crowd-sourced requirements analysis for stakeholders	B3 for system analysis of its specific use case scenarios	B4 black box activity diagram modeling for use case scenarios
W-white layer	W1 models the activities in B4	W2 functional analysis	W 3 system requirements	
	W4 system architecture	W5 physical architecture		

3 IPIS Modeling

To model IPIS, this study was developed using PA as an example. The stakeholders of IPIS, such as station staff, passengers, and drivers, were analyzed at the B1 layer, as shown in Fig. 1. Stakeholder requirements were analyzed at the B2 layer, 89 crowd-sourced requirements were obtained, and the requirements were itemized, as shown in Fig. 2.

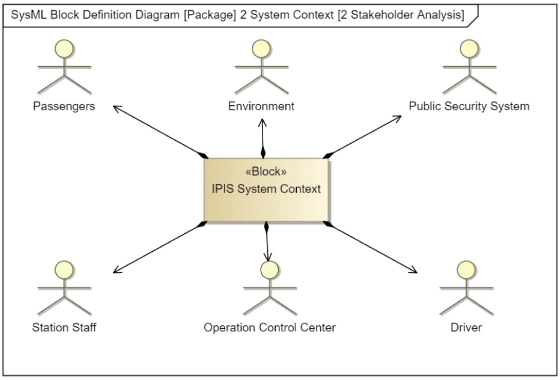

Fig. 1. Stakeholder analysis.

The use case scenario was abstracted at the B3 layer by analyzing the stakeholder requirements. The PA applications was distinguished by IDs. The first layer uses case ID x.x, and the second layer uses case ID x.x.x. The first layer includes ID 1.1 Public address content, ID 1.2 Public address method, ID 1.3 Intercom, and ID 1.4 Recordings in the case of a passenger pressing the emergency button, as shown in Fig. 3.

The black box activities of the ID1.2 Public address method were analyzed in B4 layer. ATC, Driver, TCMS denote the external environment participants under this use case, and the external participants of the system are assigned to different activities, as shown in Fig. 4.

The triggered Fully auto-play public address in Fig. 4. Was modeled at the W1 layer as a white box activity diagram, as shown in Fig. 5. The activity starts from the

ID	Name	Text
R- 1	Driver Requirements	Drivers' needs for IPIS.
R- 1.1	Display requirements	As a driver, I would like to be able to show me the name of the station, terminal, train number and operating range in the direction of the train.
R- 1.1.1	Driver's room intercom at two extremes	As a driver, I would like to be able to talk to the driver's room at both ends.
R- 1.1.2	Driver and passenger intercom	As a driver, I would like to be able to passenger intercom.
R- 1.1.3	Driver intercom with control center	As a driver, I would like to be able to talk to the control center.
R- 1.2	Driver's requirements for radio setting	As a driver, I would like to be able to broadcast.
R- 1.2.1	Public address in equipment failure state	As a driver, I would like to be able to make public announcements to passengers in the event of equipment failure.
R- 1.2.2	Drivers manually trigger overrun messages	As a driver, I wish I could manually trigger the Vietnam War message and make a public announcement to passengers.
R- 1.2.3	Manual cancellation of public address	As a driver, I would like to be able to manually cancel a public announcement in progress.

Fig. 2. Partial entry view of stakeholder requirements.

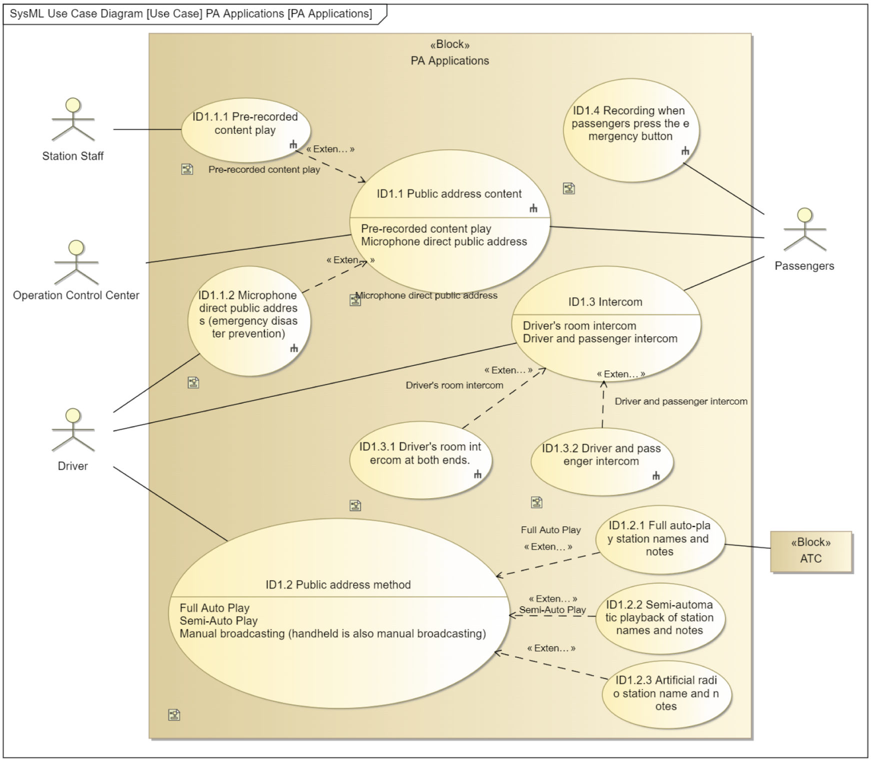

Fig. 3. Use case of PA applications.

external input of the Triggered fully automatic public address, Speed information, and GPS location (distance to station) signals. After receiving the signal, IPIS executes the activity in the following order: Pre-playing arrival information, Play the name of the next station, Play open door message, Play closing message, and finally the activity ends.

No functional Stereotype in the SysML predefined Stereotype was established for IPIS. Therefore, a functional metamodel was customized, as shown in Fig. 6.

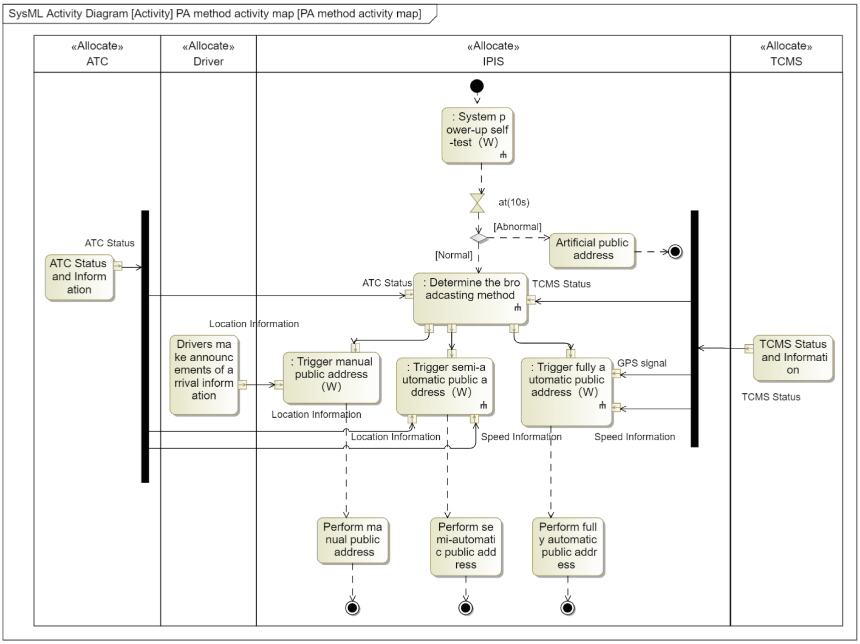

Fig. 4. PA black box activity diagram.

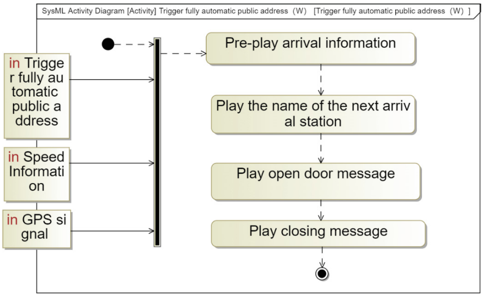

Fig. 5. Fully auto-play public address activity diagram.

Functional analysis of W2 layer yielded 12 PA functions as shown in Fig. 7. By analyzing the system requirements at the W3 layer, the PA needs to meet the system-level requirements for Storage Requirements, Intercom, PA output control, Radio broadcasting, Digital Annunciation/Closing Alarm, and Monitoring, as shown in Fig. 8.

The system architecture analysis of PA in the W4 layer is divided into Broadcast System, Intercom System, Control System, and, Emergency System.

After completing the architecture analysis of the PA, a physical architecture analysis was performed on W5 layer. The Control System of the PA was implemented to obtain the Driver Announcement Controller, Passenger Announcement Controller, and Carriage Controller, as shown in Fig. 9.

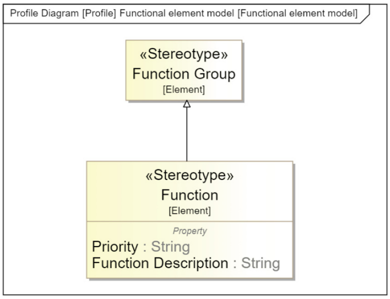

Fig. 6. Functional element model.

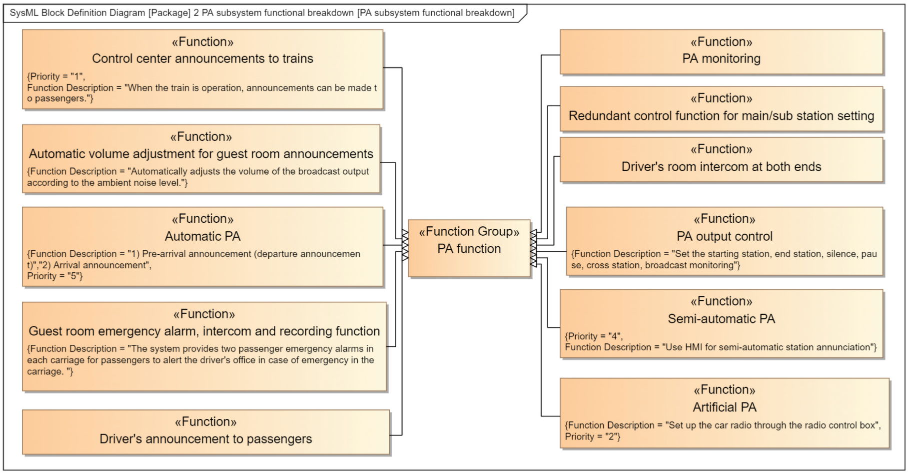

Fig. 7. PA functions.

4 Conclusions

In this study, the concept of MBSE was applied to the study of rail transit IPIS. The main contributions are as follows:

(1) Adopting a positive design concept from the perspective of stakeholders, with a demand oriented approach, meeting the needs of stakeholders, combining PA, CCTV, and PID functions to form IPIS, fully reflecting the characteristics of low resource consumption and high integration.
(2) Using M-Design for IPIS design, a MBSE based approach was proposed BW_IPIS modeling method for IPIS. IPIS is divided into two layers: first analyze the B-black layer, and then analyze the W-white layer. In the B-black layer, stakeholder and crowd participation needs, use case scenarios, and black box activities were analyzed. In the W-white layer, white box activities, functions, subsystem decomposition, system requirements, system architecture, and physical architecture were analyzed. This

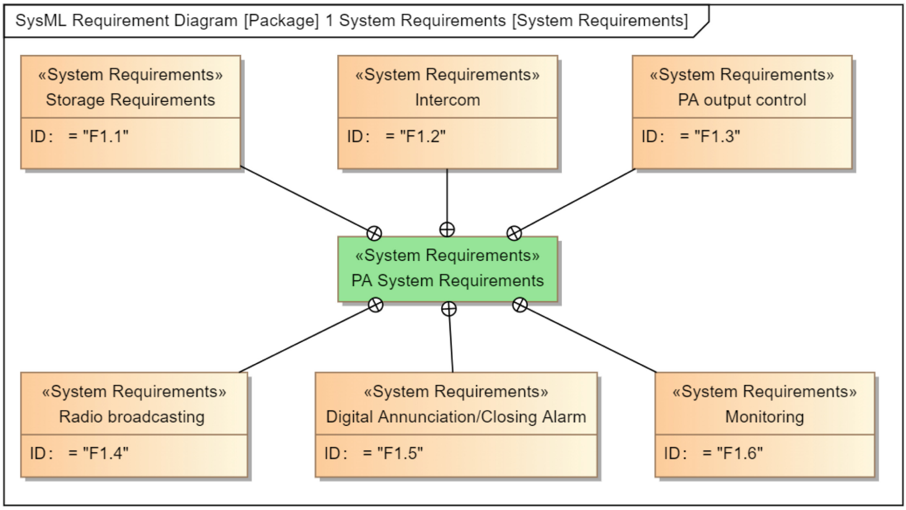

Fig. 8. PA system requirements.

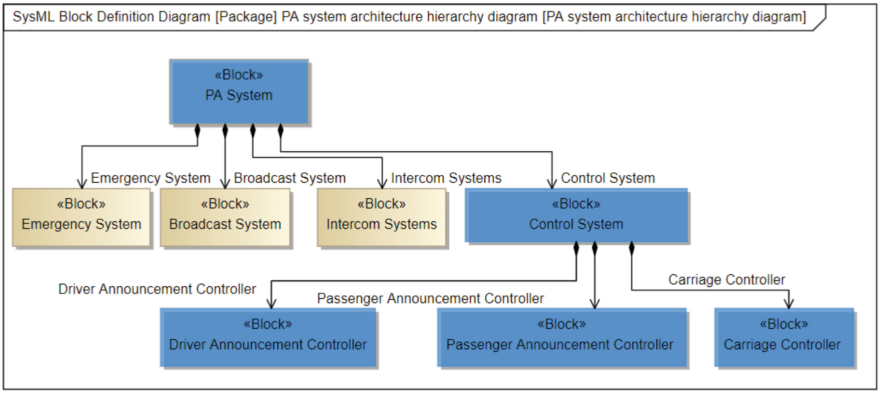

Fig. 9. PA physical architecture.

method belongs to top-down active design, and the results of each stage can actively drive the design of the next stage.

(3) According to the characteristics of IPIS, function meta model, performance meta model and system requirement meta model are established to improve the reusability of modeling elements and provide reference for the subsequent development of IPIS.

Acknowledgments. This study is supported by the Tianjin Municipal Education Commission Research Program Grant (2020KJ121) and the Tianjin University of Technology and Education Research Initiation Grant (KRKC012215).

References

1. Bashatah, J., Sherry, L.: Usability analysis of an MBSE model of standard operating procedures. In: INCOSE International Symposium, vol. 32 (2022)
2. Peng, Q.J., Zhang, H.L.: A model-based approach to the analysis of human space engineering requirements. In: Systems Engineering and Electronics Technology, 1–14 (2023) (in Chinese)
3. Khandoker, A., Sint, S., et al.: Towards a logical framework for ideal MBSE tool selection based on discipline-specific requirements. The J. Syst. Softw. **189**(2020)
4. Arifin, H.H., Morita, T., et al.: A pragmatic MBSE approach of Nissan powertrain team to minimizing document-based SE. In: INCOSE International Symposium, vol. 32 (2022)
5. Peng, K., Yuan, W.Q., Huang, Z., et al.: Exploring the application of model-based design of manned lunar spacecraft system. Manned Spaceflight **28**(1), 5–9 (2022) (in Chinese)
6. Mei, Q., Huang, D., Lu, Y.: MBSE-based functional architecture design approach for civil aircraft. J. Beijing Univ. Aeronautics Astronautics **45**(5), 1042–1051(2019) (in Chinese)
7. Liu, C., Han, B.J.: Demand analysis of MBSE-based intake damper control for auxiliary power units. Electronic Testing, (6), 57–58 (2020) (in Chinese)
8. Tang, C., Fang, J.W., X L, et al.: Application of MBSE in the design of civil aircraft landing gear system. Civil Aircraft Design and Research, (3), 56–60 (2015) (in Chinese)
9. Wang, B.M., Chen, B., Zhang, S.C., et al.: SysML-based pantograph control logic simulation study for moving trains. Railway Rolling Stock **40**(6), 11–18, 27 (2020) (in Chinese)
10. Yuan, W.Q., Wang, B.M., Chen, B., et al.: MBSE enables intelligent and efficient generation schemes in the field of high-voltage systems for moving trains. J. Comput.-Aided Des. Graph. **32**(6), 979–988 (2020) (in Chinese)
11. Chen, B., Yuan, W.Q., Jin, J.: SysML-based modeling and simulation of end change scenarios of rolling stock. Railway Rolling Stock **42**(6), 18–26 (2022) (in Chinese)