Study on Joint Regulation and Safety Supervision of Urban Rail Transit System

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ABSTRACT. The integration of urban rail transit system is an important stage of urban rail construction. By analyzing the relationship between the urban rail subsystems, this paper studies the project, content and process of each electromechanical system. From the perspective of large scale system, the linkage technology and specifications of the electromechanical equipment are verified to ensure the overall coordination function of the system. In addition, the system joint supervision mode is introduced, and the whole process management is carried out to ensure the orderly and safe operation of the system. The debugging service process of EMU is analyzed emphatically. And the contents of the safety supervision work are also studied. From the perspective of risk analysis of motor vehicle commissioning, taking the risk hidden danger and prevention and control measures of a certain Beijing rail transit line as an example, the main points of safety supervision are studied. It can provide reference for urban rail transit industry system joint management.

1. INTRODUCTION

As the urban rail transit system is a complex system, involving more than a dozen professional systems, includes Vehicle System, Power Supply System, Communication System, Signal System, Integrated Supervision and Control System(ISCS), Automatic Fare Collection System (AFC), Platform Screen Door(PSD), Ventilation and Air Conditioning System, Escalators System, Water supply and drainage system, Power Lighting System, Passenger Information System(PIS), Access Control System(ACS), Flood Gate/ People Defense System, Closed Circuit Television System(CCTV), etc. In order to supervise the systems integration test consulting service providers or motor vehicle debugging service providers to carry out the work of systems integration test and motor vehicle debugging safely and orderly, the supervision mode is introduced, through the whole process management of supervision, unified planning, quality control and progress control of work cooperation among joint dispatch service providers are carried out. In accordance with the contract, the service provider's resources, rules and regulations are reviewed, and the service implementation is mobilized, so as to ensure the safety and orderly conduct of the work during the systems integration test.
2. Systems Integration Test Functional Framework

Systems Integration Test is an important part of the operation and commissioning of each electromechanical system before it is opened and operated. It is a key process of project management and a key process for inspection project management. In the actual construction, the single system meets the function index and operation parameter in the factory, installation and debugging, which does not mean that the integrated system meets the high performance index. Urban rail equipment is a multi-objective complex system, each system is interconnected, interacts, and restricts each other, and has a strong correlation, so the overall coordination of the system must be carried out in order to ensure the overall matching of the system equipment. The functional diagram of coordination among the subsystems is shown below.

![Figure 1 Function and Coordination Diagram of each Subsystem](image)

The core of systems integration test is the coordination among subsystems, subsystems and the whole large-scale system, not the reconstruction of the system.

3. Research on Systems Integration Test and Supervision Service

Systems integration test mainly includes the linkage function verification of mechanical and electrical equipment and the reliability test of the system. The mechanical and electrical system integration test can be divided into three contents: the function systems integration test between the system and the system, the station level function systems integration test and the central level function joint adjustment test. The supervision shall organize and coordinate the implementation of the integration test between the systems, formulate the responsibilities and debugging contents of the commissioning implementation personnel and cooperating personnel of each unit, and participate in the formulation of the integration test plan and plan between the various systems. Organize and arrange suppliers and construction units to participate in systems integration test, and be responsible for coordinating the technical problems in the system.

3.1 Systems Integration Test work content

Systems integration test includes comprehensive adjustment within the scope of the project and among all equipment systems involved, it mainly includes point-to-point test, end-to-end test and pattern test. The specific functional systems integration test items are as follows.

| Serial number | Systems Integration Test | Systems Integration Test Project | Systems Integration Test Content | Master system | Correlation system | Time/d |
|---------------|-------------------------|---------------------------------|---------------------------------|--------------|--------------------|-------|
| 1             | System                  | Automatic train                 | Verify the automatic            | Signal       | Train              | 1     |
| Function Integration Test to Verify the Functions of the System After Connection | Operation Test | Operation Function of Train and Information System |
|---|---|---|
| 2 | Operation Test of Train and Platform Screen Door | Verify that the platform screen door operation meets the requirements when the train arrives and leaves the station | Signal Vehicles \ Platform Screen Door | 1 |
| 3 | Communication Wireless Subsystem and Signal and Vehicle System | Verify the Train Information Transmission Function between Communication Wireless Subsystem and Signal System | Communication Signal Vehicles | 0.5 |
| 4 | ISCS and Signal System | Verify that the signal system provides train interval blocking information for ISCS at the control center | ISCS Signal | 2 |
| 5 | ISCS and PSD Systems Integration Test | Verify communication connection, single debugging record and equipment status point-to-point test | ISCS PSD | 2 |
| 6 | ISCS and CLK Systems Integration Test | Verification of Communication Connection and CLK Standard Clock Signal Function | ISCS CLK | 1 |
| 7 | ISCS and PA Systems Integration Test | Verify communication connectivity, device status point-to-point testing | ISCS PA | 1 |
| 8 | ISCS and CCTV Systems Integration Test | Verify the manual selection of camera function, station PTZ function, station preset position function | ISCS CCTV | 2 |
| 9 | ISCS and PIS Systems Integration Test | Verify communication connection, ISCS monitor PIS status, PIS video delivery, etc. | ISCS PIS | 1 |
| 10 | BAS and FAS Systems Integration Test | Verify that ISCS, BAS, FAS, communication connections, device status point-to-point testing, and FAS are acting correctly | BAS FAS ISCS | 3 |
| 11 | BAS and Escalators Systems Integration Test | Verify ISCS, BAS, escalators, communication connection, equipment status point-to-point test, escalator correct operation | BAS Escalators System ISCS | 2 |
| 12 | BAS and Power Lighting Systems Integration Test | Verify that ISCS, BAS, power lighting, communication connection, equipment status point-to-point test, lighting is working correctly | BAS Power Lighting ISCS | 2 |
| 13 | PSCAD and ISCS Systems Integration Test | Verify that ISCS, PSCADA, communication connection, device status point-to-point test, PSCADA is acting correctly | PSCADA ISCA | 3 |
3.2 Research on the work flow of Systems Integration Test

In the systems integration test, each subsystem is in the systems integration test stage, including the single subsystem test, the linkage function test of each subsystem, the whole system function test. The linkage function test process is shown in the figure below.

3.3 Work content and flow of Systems Integration Test

Urban Rail Transit Systems can be put into operation only through the process of systems integration test, and the main contents of this process supervision work are as follows.

- Formulate the integration test quality control points between the systems, and supervise the quality control and progress control of the systems integration test.
- Define the responsibilities and division of labor of system integrator, equipment supplier, equipment installer and design unit, and confirm the systems integration test documents.
- Organize the systems integration test meeting, discuss and analyze the problems existing in the systems integration test, urge all parties to coordinate and solve the quality problems and progress problems existing in the process of systems integration test.
- When the test data is deviated, the supervisor coordinates all parties to put forward technical plans, track the problems, and retest the important links and key test supervisors to ensure the accuracy of the data.
- Review the progress debugging report submitted by the service provider, and within the scope of authorization, review and approve the service provider's debugging progress revision plan.
- Review the joint transfer test records of the service provider. According to the technical specification of the contract, standard for acceptance of equipment quality, evaluation and debugging, and give the qualification certificate report after the systems integration test is qualified.
- Deal with the faults and accidents in the systems integration test.
- When the debugging process and the debugging project specified in the systems integration test contract are completed, after reviewing the systems integration test records to meet the requirements, the systems integration test process and results should be summarized and evaluated, and an evaluation report should be issued to provide the basis for the trial operation of the system.

During the debugging of the system, the participating units cooperate with each other and divide their responsibilities, as shown in the following figure.
4. **Motor Vehicle Debugging Service**

The debugging of Motor vehicle is an important debugging content in the integration test of system, through the safety management of the closed area and the parking area of the electric bus, management of receiving, nursing and shunting of electric bus. To organize and compile the debugging plan of the relevant specialties, coordinate and organize all kinds of construction and debugging within the closed area, and unify the dispatching command, so as to ensure that the line can be opened at a high level according to the design requirements.

4.1 **Service Content of Motor Vehicle Debugging**

Motor vehicle debugging service providers should establish organizational structure and management rules, formulate relevant safety agreements, and carry out dispatch management, vehicle management, railway or station closed section management, logistics management, security management and so on. The main work includes: entrance preparation; on-site control right, dispatch right and management right take-over; organize cold running; care tram disassembly; organize hot running; carry out daily security, logistical support, transfer of three powers to operating units, etc..

4.2 **Motor vehicle debugging service provider workflow**

Preparations for motor vehicle debugging, preliminary construction investigation on site, formulate safety management measures, safety training for dispatchers.

Motor vehicle debugging Service provider and Construction Unit sign Safety Management Authorization Agreement for motor vehicle debugging.

Organize and hold a meeting on the implementation of the safety management measures for the debugging of motor vehicle before entering the country, and carry out safety training for the personnel of the construction units in each bid section.

Determine the time for the transfer of the three rights, and go through the procedures for the transfer of the three rights in the debugging area of the motor vehicle with the track specialty.

Sign a safety agreement with the construction units and commissioning units of each section and apply for the certificate of admission for the debugging of motor vehicle. After signing the construction agreement, each unit may apply to the plan dispatching for the construction and commissioning plan.

Security personnel stationed in closed management of motor vehicle debugging area. Station integrated control room personnel stationed, integrated control room and site management.

Organize the cold running test to check the limit size of the test area of the motor vehicle.

Organize hot running test to check the operation of each equipment.

The debugging of the motor vehicle begins, and the debugging unit carries on the debugging according to the debugging plan.
After daily commissioning, the construction unit enters the commissioning area of the motor vehicle according to the weekly construction plan, construction scheduling order and admission permit.

Figure 4 The overall flow of Motor vehicle debugging

5. Research on Key Points of Supervision Work for Motor Vehicle Debugging

5.1 Work Content of Motor Vehicle Debugging Supervision

The debugging of motor vehicle has the characteristics of necessity, urgency, safety and complexity. The safety supervision mode of motor vehicle debugging is adopted to uniformly supervise the debugging. Based on the analysis of the characteristics, contents and working process of the motor vehicle debugging, the following areas are taken as the key areas of safety supervision by the supervision units.

Table 2 Key area scope of Safety Supervision

| Serial number | Position | Management area                                                                 | Management mode                                                                 |
|---------------|----------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1             | Main line| Interval (including air shaft), return line, contact line, a section with the conditions for the debugging of a motor vehicle. | Closed Management of marked and controlled motor vehicle debugging service providers |
| 2             | Station  | Platform track area, station integrated control room, small platform equipment room, platform screen door within three meters line, platform mezzanine, connecting passage from station hall to track area | Closed Management of marked and controlled motor vehicle debugging service providers |
| 3             | Vehicle depot / Parking lot | Temporary control center (if there be), depot area, test line, rotary line, entry and exit section line, parking inspection warehouse, temporary repair warehouse, garbage washing garage, turning wheel warehouse, areas related to motor vehicle debugging | Closed Management of marked and controlled motor vehicle debugging service providers |
| 4             | Equipment room | Substation equipment room, signal equipment room, communication equipment room, equipment room related to motor vehicle debugging | Supervise and urge motor vehicle service providers to do a good job in the supervision and management of various specialties |

In the stage of motor vehicle debugging, the supervising unit formulates the supervising work program, carries out condition acceptance and strengthens process control according to the content of motor vehicle debugging service. Control and management of motor vehicle debugging project management, dispatching management, motor vehicle debugging preparation work, closed area management, electric bus and rail car unloading, nursing work, security work, logistics support work, etc. Thus, on the basis of ensuring the motor train debugging of vehicles and signals, the management system of dynamic adjustment is urged to provide a platform for the systems integration test and comprehensive adjustment, and to coordinate and cooperate with each professional debugging work.
5.2  Research on Key Points of Safety Supervision in Motor Vehicle Debugging

Through the analysis of the risk characteristics of the motor vehicle debugging stage and the summary of the experience of the motor vehicle debugging supervision, the key points of the safety supervision work are to organize the acceptance of good conditions, daily monitoring and dispatching management, risk identification and prevention, so as to guide the follow-up motor vehicle debugging supervision units to carry out safety with emphasis and pertinence work.

5.2.1  Organize and carry out conditional acceptance

The supervision should organize the conditional acceptance in the preparation stage of the debugging of the motor train, including the acceptance of starting conditions and cold and hot running conditions, checking the implementation of the preparatory work of motor vehicle debugging service providers, ensuring that the process control is in place, the preparatory work meets the requirements of on-site debugging of motor trains, and forms a conditional acceptance report, which is reported to the construction unit. The conditional acceptance report includes the following.

- Check the training of motor vehicle debugging service provider.
- Review of motor vehicle debugging organization scheme, project plan, motor vehicle debugging plan, cold and hot running test scheme, etc.
- Check the closeness of enclosed areas and the management of entrances and exits.
- Track and check the tunnel and track bed cleaning work of the motor vehicle debugging service provider.
- Check the quality of the limit test vehicle made by the motor vehicle debugging service provider.
- Inspection of temporary lighting and communication equipment and so on set up by motor vehicle debugging service providers.
- Check the finished product protection measures of the motor vehicle debugging service provider.
- Inspection of safe and civilized construction measures.
- Check the test preparation of the motor vehicle debugging service provider before cold and hot running.

5.2.2  Daily Target Control Scheduling Management

The dispatching departments of motor vehicle debugging shall be under the unified command of the chief dispatcher of motor vehicle debugging, and shall be responsible for the command and debugging, driving, emergency, rescue, emergency rescue and other related work during the period of motor vehicle debugging.

The traffic dispatching is responsible for the implementation of the driving, debugging and rescue work during the debugging of the motor train, including the dispatcher on the motor, the duty officer in the station comprehensive control room, the duty officer in the vehicle depot comprehensive control room, and so on.

Power dispatching is responsible for the stop / transmission of vehicle depot and main line, the compilation of protection scheme, emergency, emergency rescue, rescue and other work during the debugging of motor trains. There are station substation attendants and vehicle depot substation attendants.

The plan dispatching is responsible for the examination and approval of the commissioning and construction unit plan during the debugging of the motor train, participates in the coordination of the debugging plan of the motor train, compiles the weekly construction plan, and coordinates the work plan of the professional debugging unit and the construction unit of each bid section.

The security dispatch is responsible for the safety and security work of the motor vehicle debugging during the debugging of the motor train, ensuring the safety of vehicles and personnel during the debugging phase of the motor train, and setting up station security guards and vehicle depot security guards.

The dispatching management of the motor vehicle debugging service provider is the core link of the service, and it is the basis for the efficient, high-quality and safe completion of the service work. In
the daily marking and control, the supervision focuses on the formulation and implementation of various dispatching management measures, checks the overall arrangements for commissioning and construction in the closed area during the debugging of the motor train, and checks the power supply dispatching to carry out power outages and power transmission. Check the implementation and implementation of dispatching command, route management and electric bus on-line operation during the debugging of motor trains, and check the integrity of relevant records, such as stop and transmission records, route handling records, etc.

5.2.3 Risk identification and Prevention and Control
Like the safety management of any process, the core of safety management in the process of motor vehicle debugging is the identification and control of dangerous and harmful factors. The supervision unit should focus on supervising the motor vehicle debugging service provider to do a good job of safety risk identification and prevention and control from the two aspects of dispatching management and construction management in the safety management of the motor vehicle debugging process.

In the aspect of dispatching management, the main safety risks are analyzed on the basis of dispatching role, including the risk of train derailment, vehicle and object collision caused by interval operation, the risk of vehicle collision caused by system equipment failure, and so on. In power dispatching, there is the risk of electric shock caused by vehicle depot and main line power transmission, and the risk of being unable to send electricity due to the failure of system equipment. There is a risk of collision between people and vehicles caused by cross-operation between vehicles and construction personnel, and the risk of prolonging the construction period caused by the change of plan, and so on. There is a risk of human-vehicle collision caused by personnel breaking into the security dispatch, and the risk of personal injury caused by the closure of debugging area, and so on.

In the aspect of construction management, the main safety risks are analyzed from various professional perspectives, including the risk of collision between passengers and vehicles and the risk of electric shock accidents in the management of the debugging track area of motor trains. There are risks of derailment, damage of couplers, shedding of gearbox hanging device, non-rotation of wheel axle, bogie displacement, bogie damage, shaft cutting and car body tilt. Risk of Rail fracture and turnout failure in track specialty. There are some risks in signal specialty, such as interruption of signal cable, turnout of turnout, failure of electric switch machine, etc.

Supervising units should urge and supervise construction units to do a good job of risk identification, formulate preventive and control measures, and adopt preventive and control measures. When formulating preventive and control measures, we should not only prevent and control the identified conventional risks, but also formulate specific preventive and control measures according to the actual situation of specific line projects. For example, taking a Beijing rail transit line as an example, in view of the specific safety risks identified, the supervision unit urged the motor vehicle debugging service providers to formulate the following prevention and control measures.

Table 3 Key Prevention and Control measures for Motor vehicle debugging of a Beijing Rail Transit Line

| Serial number | Key Prevention and Control measures |
|---------------|-----------------------------------|
| 1             | Comprehensively sort out the risks and hidden dangers and the restrictive conditions of various specialties, form a negative list of risks, submit the information to the whole staff, and make a targeted assessment. |
| 2             | Confirm the key positions at the same time, such as train dispatching, electric power dispatching, security dispatching, driver, on-board dispatching etc, so that the responsibilities are clear. |
| 3             | In view of the characteristics of long braking distance on the line, three proximity warning signs are reset, and the driver adjusts triple protection with adjusting to ensure that there is no mistake. |
| 4             | In view of the fatigue risk of 24-hour debugging, the system of shifting shifts has been implemented, which increases the number of drivers and accompanying personnel. |
| 5             | In view of the risks of many construction projects, difficult clearance and repeated violation of restrictions, one is to control the card from the approval of the construction plan, the other is to increase clearance manpower. |
| Serial number | Key Prevention and Control measures |
|--------------|-----------------------------------|
| 6            | In view of the construction of joint sections and the risk of insufficient awareness and disobedience to management, highway constructors should strengthen communication and coordination with highway construction units and sign safety agreements. Secondly, security personnel should be added to joint sections under bridges and on highway bridges, one post per kilometer, and three shifts of 24-hour monitoring and patrol should be carried out. |
| 7            | Increase patrol vehicles, organize managers to supervise and focus on monitoring, closely guard crane pump trucks, one machine per person, closely monitor and control. |

The supervision unit has achieved good application results in the practice of the Beijing rail transit line project by urging the motor vehicle debugging service providers to comprehensively sort out the risks and hidden dangers, and marking and controlling the motor vehicle debugging service providers to implement prevention and control measures.

5.3 Motor vehicle debugging service evaluation

Through the above-mentioned condition acceptance, daily supervision and motor vehicle debugging service provider to cooperate with the supervision of accessing the safety monitoring system, after the motor vehicle debugging is finished, the motor vehicle debugging service situation is evaluated as a whole, and the motor vehicle debugging service report is issued.

6. Conclusion

Urban rail transit is a systematic project which integrates many advanced technologies, has intensive operation organization and high safety requirements. This paper analyses the joint debugging of mechanical and electrical equipment of the whole system, such as urban rail power system, signal system, vehicle system, environmental control system, FAS, escalator system, etc. On this basis, the methods and processes of system debugging are analyzed, summarized and summarized, and the joint debugging supervision mode is introduced. This paper organizes and coordinates the inter-system coordination, formulates the responsibilities and debugging contents of the participating units, participates in the formulation of inter-system coordination schemes and plans, and ensures the efficient, quality and orderly operation of the work during the inter-system coordination. By focusing on the analysis of motor vehicle commissioning links, identifying risk sources, researching the key points of supervision safety management, achieving quality control and risk prevention and control, and achieving dual insurance of management and control, it plays an important role in ensuring the safe and orderly development of motor vehicle commissioning and ensuring the safe operation of lines.

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