Information System of Quality Control in Construction Process of Highway Mechanical and Electrical System

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Abstract. In order to improve the quality in construction process of Highway Mechanical and Electrical System (HMES), the construction process of HMES in China is firstly introduced, and subsequently the quality problems and its causing factors are analysed. Based on the analysis results, the function of Information System of Quality Control in Construction Process of HMES (ISQCCP-HMES) is designed and the framework of ISQCCP-HMES which includes the access layer, display layer, application layer, support layer and basic layer is proposed. The application of the proposed ISQCCP-HMES shows that the quality control efficiency of HMES is improved and the quality control burden of HMES is also reduced.

1. Introduction

In the background of high-quality development in the transportation industry in China, the adaptation of internet and information technology to monitor and control the quality in highway construction process and to solve the quality control problem of highway construction process has become a hot research field. Ye Huixian [1] provided the construction process quality information remote control system of asphalt pavement and established the control system of raw material production, mixture production and mixture compaction process based on the wireless transmission technology and applied in the reconstruction and expansion project of Huishen highway. Chen Shenbo [2] proposed an information management platform architecture which integrated the operation mode of the whole highway construction quality and the network video monitoring technology, GPS technology, and GIS technology. Yang Xianzhen [3] established the information system platform of quality supervision and collaborated the quality supervision, engineering supervision, construction and other party of highway construction. Zhang Yan et al [4] put forward the framework of road information system in highway construction and applied it in the construction process of Jiqi highway. The above researches mainly focus on the quality control information system of the highway pavement, the highway engineering, the construction monitoring and management, and so on. However, as the key system affecting the highway operation and management service level [5], the Information System of Quality Control in Construction Process in Highway Mechanical and Electrical System (ISQCCP-HMES) has not been involved.

In this paper, the construction process of HMES in China is firstly introduced, and subsequently the problems in the construction process quality control of HMES are analysed, and at last the function design and the framework of ISQCCP-HMES is presented.
2. Quality problems in the construction process of HMES

2.1. The construction process of HMES

As illustrated in Figure 1, the construction process of HMES in China can be divided into five stages:

2.1.1. The design stage of HMES. In this stage, according to the design specifications and related data such as the predicted traffic volume, the system framework and scale of HMES are determined, the composition of devices and subsystem are defined, and the construction budget is evaluated.

In general, there are three steps in the design stage of HMES:

1) preliminary design: in this step, the preliminary scale, position and main devices are determined based on the highway design requirements and the survey data, the preliminary project quantity data and design budget are evaluated and so on.

2) construction drawing design: this step is the deepening of the preliminary design. In this step, the management and maintenance system are determined, the devices and its installation position, data communication mode and path, power supply mode etc. are defined, and the detailed budget is fixed, and so on.

3) joint design: in this step, the construction parties are organized by construct owner to evaluate the construction drawing design, and some modification and optimization advices is proposed according to the realization of HMES.

2.1.2. Construction of HMES. In this stage, the construction of HMES is carried out according to the design documents and related construction specifications. The main construction process can be given as follows:

1) construction organization design and approval: in this step, according to the overall design and construction plan, the construction objectives such as quality objectives, safety objectives, construction period objectives are firstly defined, and subsequently the construction organization and personnel division are determined, the overall construction plan and main construction schedule are planned, the quality assurance system and measures, accident emergency plan are determined in turn.

2) construction management and implementation: in this step, the construction people, materials and machinery are organized to realize the design of HMES according to the organization design documents and related construction standards.

3) system test and supervision: in the construction of HMES, the test and supervision should be executed according to the test and supervision specifications, such as Quality Inspection and Evaluation Standards for Highway Engineering Section 2 Electrical and Mechanical Engineering (JTG F80/2-2004) and Supervision Specifications for Construction of Highway Engineering (JTG G10-2006).

2.1.3. The trial operation of HMES. In this stage, the realization degree of system functions defined by the design documents of HMES is evaluated, the operation stability and reliability of its system and device are determined, and the problems existing in the system trial operation stage are corrected. The trial operation period of HMES is usually three to six months. And the trial operation results of HMES can provide support for the subsequent handover acceptance and formal operation stages.

2.1.4. The handover of HMES. In this stage, the operation data of HMES and the function indicators of related specifications are verified to evaluate the compliance of system design function, system performance, and construction management process. And also in this stage, the quality level of HMES is defined according to the test results.

2.1.5. The formal operation of HMES. In this stage, the devices and subsystems of HMES are running according to the management and operation rules of related construction owner, and all the functions are realized and opened to their users.
The design stage of HMES

Preliminary design
Construction drawing design
Joint design
Construction organization design and approval
Construction management and implementation
System test and supervision

2.2. The quality problems of HMES construction process

According to the problems found in the inspection and supervision of HMES construction process, the quality problems in the HMES construction process are given in Figure 2.

In figure 2, the quality problems can be classified into the following types:

1) the debug problems in construction process: the debug problems in construction process mainly include the incomplete debug, the debug process without test, etc. As shown in Figure 2, the debug problems account for 36% of total quality problems.

2) the material and devices quality problems: the main material and devices quality problems are the inconformity with the function and performance indicators of related nation or industrial standards. In figure 2, the ratio of the material and devices quality problems is 28%.

3) the construction process quality problems: the construction process quality problems which account for 18% of total quality problems in figure 2, mainly include the installation process problems, the reserved and embedded construction process problems, the cable process problems, and so on.

4) the inconsistent design function: the inconsistent design function is the disagree between the design and realization of HMES, such as the lack of design function, the weakness of design function. In figure 2, the ratio of the inconsistent design function is 14%.

5) the interference of construction interface: the interference of construction interface which account for 5% of the total quality problems in figure 2, mainly includes the interference of reserved and embedded of HMES and the debug process in the construction process.

Furthermore, in order to improve the quality of HMES, the causing factors of quality problems are analysed in this paper from the human, machine, material, regulation, environment and inspection aspects. In Figure 3, the human factor which leads to the quality problem accounts for 37% of the total factors, the ratio of machine factor is 3%, the ratio of material factor is 14%, the ratio of regulation factor is 10%, the ratio of environment factor is 4%, and the ratio of inspection factor is 32%.
Based on the above quality problems and the causing factors analysis results, the quality control of HMES construction process should focus on the mentioned elements, which is also the focus of the construction information system mentioned in this paper.

![Figure 3. The causing analysis of quality problems in HMES construction process](image)

3. Functional design of the proposed ISQCCP-HMES
On the basis of the mentioned quality problems and causing analysis of HMES construction process, in order to improve the quality in the construction process of HMES, this paper propose the ISQCCP-HMES which employ the internet and information technology.

In the proposed ISQCCP-HMES, the function is design as follows:

1) the process quality control function
   There are three sub functions in this function: quality assurance documents review function, device quality control function, and key process quality control function. In quality assurance documents review function, the quality assurance documents in each stages is reviewed according to the related specification to ensure the authenticity, integrity, completeness and effectiveness of HMES construction process quality assurance documents. In the device quality control function, the quality control forms and requirements of device are generated automatically. In the key process quality control function, the key process in HMES construction process is involved such as the process handover, process control, unit commissioning, process self-inspection.

2) the construction process control and display function
   In this function, the key construction process is controlled and the progress information is displayed. In the key construction process control function, the quality of devices and materials are controlled in the following stages: front sequence handover, concealed foundation construction, column construction, cable construction, unit commissioning, and quality inspection. In the progress information display function, the real-time construction progress is display in the graph mode in the ISQCCP-HMES.

3) the construction process quality evaluation function
   In this function, the evaluation plan which includes the material and device quality evaluation, process quality evaluation and overall quality evaluation, is automatically generated and the evaluation results are created.

4) the generation function of construction process documents
   In this function, the construction process documents including the prepare document, devices and material quality assurance document, process control and inspection assurance documents, etc., are generated in ISQCCP-HMES.

In summary, the functions of the proposed ISQCCP-HMES are illustrated in Figure 4.
To realize the above functional design, this paper provides the framework of the proposed ISQCCP-HMES based on the B/S and App architecture (Figure 5).

As illustrated in Figure 5, there are five layers in the proposed ISQCCP-HMES:

1) Access Layer: Web mode which access this system in the computer web front end and App mode which access this system in the mobile phone or other handheld device.

2) Display Layer: the interface of the proposed system which is defined in the portal site.
3) Application Layer: the application determined in the functional design of the proposed system, which usually includes the process quality control application, construction progress control and display application, construction quality evaluation application, and the generation of construction process documents application.

4) Support Layer: the support module of this system, which includes the work flow module, metadata management module, electronic form module, parameter management module, standards and specifications database, and so on.

5) Basic Layer: the basic support devices and software, which mainly include the network system, cloud storage platform, security devices and etc.

Moreover, besides these five layers, there are also three auxiliary system in the proposed ISQCCP-HMES, which are the operation management system, security system and technical support system.

On the basis of the proposed framework, the ISQCCP-HMES is developed and adapted in the HMES construct process to effectively improve the quality control efficiency and reduce the burden of quality management of HMES construction process.

4. Conclusion
In this work, the construction process of HMES in China is firstly introduced. In the construction process of HMES, the design, construction, trial operation, handover and formal operation stages are given, and in each stage, the quality problems are collected according to the test and supervision data and operating data. In order to solve these quality problems, the causing factors are analysed from the human, machine, material, regulation, environment and test aspects.

Based on the analysis results, ISQCCP-HMES is considered as the effectively tool to solve these quality problems and the function requirements are designed, and the framework of ISQCCP-HMES which includes the access layer, display layer, application layer, support layer and basic layer is proposed. The application of the proposed ISQCCP-HMES shows that the quality control efficiency of HMES is improved and the quality control burden of HMES is also reduced.

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