Research on the Digital Construction and Application Standard System of Highway Engineering

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Abstract. With the proposal of digital highways, the digitization and high-quality development of highway engineering are the trend. Currently, the construction and application of digital highways are in the exploratory stage. This article conducts research on existing international, national, and industry standards, and analyzes the current standard system. It coordinates the cross-stage data flow and application methods, proposes the architecture of the standard system for digital highway construction and application, which includes four parts: basic standards, data standards, supporting standards, and application standards. It plans the standard content from aspects such as data foundation theory, tool development, and lifelong application methods. Finally, it researches and proposes the application methods of the standard system, constructs an information flow method with information production and transmission as the core, and helps realize the high-quality construction and application of digital highways.

Keywords: Highway engineering, Digital, Standard, System, Whole life cycle.

1 Introduction

Transportation infrastructure is a critical component to a nation's economy, security, and well being[1].In 2023, the Ministry of Transport of the People's Republic of China issued the "Opinions on Promoting the Digital Transformation of Highways and Accelerating the Development of Smart Highway Construction"(Document No. Jiaogonglufa [2023] No. 131), which proposed to establish and improve the digital standard system for highways and accelerate the revision of relevant standards such as digital highways and data governance, and improve the digital content of existing standards. Currently, there are numerous levels of digital standards for highway engineering, with group standards and local standards usually following the overall framework of national and industry BIM standards. Most of them are compiled around classification coding, data storage, and application in various stages. However, in the practical application process, the digitization of standards needs to be addressed first, and this consideration is rarely mentioned in the current standard system and content, resulting in significant barriers to the implementation of many standards.

Digital standards are still independently formulated with the aim of design, construction, and operation and maintenance stages, which do not fully consider the characteristics of the whole life cycle of digital technology. Although at the current stage, relatively independent work is still needed in terms of management mechanisms and processes, the lack of overall coordination and systematic consideration in terms of standards is also a major problem. To

address issues such as cross-stage data transmission and low data utilization, these need to be resolved in the research process of the digital highway standard system.

The majority of domestic digital standard systems and concepts are based on the further extension of the international BSI organization and ISO standard system. However, when it comes to the process of digitizing standards, there is a lack of research on how to carry out standard applications, application processes, and the positioning and role of each standard in the application methods.

Currently, the construction and application of digital highways are in the exploratory stage, and there are three main issues in terms of the standard system. Firstly, both domestic and international standard systems are mostly generic or tailored to the housing construction industry, lacking research on standard systems specifically for highway engineering digitization. Secondly, insufficient consideration is given to the coordination and consistency of standard digitization and the entire lifecycle in the framework design process. Thirdly, the standard system lacks an elaboration of the interrelation of standards and lacks a systematic approach to application methods.

In order to solve the above problems, based on the existing standard system, the demand and industry characteristics of highway engineering will be deeply analyzed, and the standard system framework for digital construction and application of highway engineering will be constructed, and the application process of standard system will be put forward, and the standard digital application mechanism and method will be constructed.

2 Analysis of the existing standard system

2.1 Basic theoretical framework analysis of the standard system

The underlying standards of data in the BIM field have been centered around semantics, storage, and processing, First proposed by BuildingSMART, the international BIM specialisation, And adopted by ISO and other international organizations such as Standardization, Three basic technical standards have been gradually formed, They are IFC(Industry Foundation Classes), IDM(Information Delivery Manual), IFD(International Framework for Dictionaries), To guide the storage and exchange of information[2].

IFC/IFD/IDM are all key standards in the BIM field on an international scale. As an open, neutral data model and file format, IFC provides specifications for describing information on building and infrastructure projects, facilitating data exchange and sharing between different software and systems. With the increasing requirements of information delivery for construction engineering, IFD and IDM serve as guidance documents to provide project teams and owners with ways to define and manage the delivery of BIM project information[3].

In conclusion, through unified data formats and delivery requirements, IFC/IFD/IDM reduce errors and inconsistencies in information exchange, and improve collaboration and coordination capabilities. They are widely adopted around the world, providing a common language and framework for construction engineering, promoting the circulation, cooperation and sharing of information, and driving the innovation and development of engineering, The relationship diagram is shown in Figure 1.
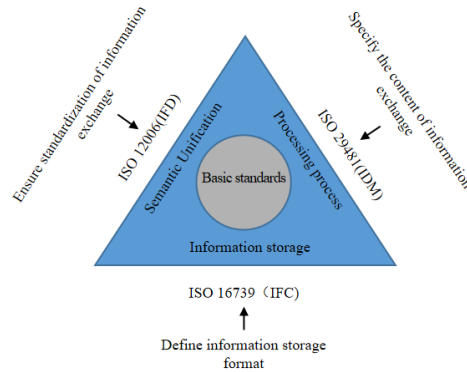
Fig. 1. Relationship diagram of IFC/IDM/IFD).

2.2 Analysis of international standard system

ISO / TC59 / SC13, in the Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM), issued 21 standards, analysis and summary for the standard structure, given in Table 1.

Table 1. Summary of the 21 published standards by ISO/TC 59/SC 13.

Type	standard number	Brief description
IFC	ISO 16739-1	Objected description of the engineering information
IDM	ISO 29481-1, ISO 29481-2, ISO 29481-3	Specifies a methodology and format
IFD	ISO 12006-2, ISO 12006-3	Specifies a language-independent information model
Data template	ISO 23387	Sets out the principles and structure for data templates
Data dictionary	ISO 16757-1, ISO 16757-2, ISO 16354, ISO 23386	distinguish categories of knowledge libraries and to lay the foundation,the provision of data structures for electronic product catalogues,establishes the rules for defining properties
Information container	ISO 21597-1, ISO 21597-2	defines an open and stable container format to exchange files of a heterogeneous nature
Information exchange	ISO 12911, ISO 23262, ISO 19650-4	identifies a structured approach, investigates barriers and proposes measures to improve interoperability between geospatial and BIM domains,provides the detailed process and criteria for the decision points when executing an information exchange
Information management	ISO 19650-1, ISO 19650-2, ISO 19650-3, ISO 19650-5, ISO 22263	Outlines the concepts and principles for information management, specifies a framework for the organization of project information

Generally speaking, the ISO international standard system in the Organization and digitization of information about buildings and civil engineering works based on the three IFC/IDM/IFD

basic standards, and more from data standards such as data dictionary, data template, information exchange and information container.[4].

2.3 Analysis of the national and highway engineering standard system

In 2011,Research of Chinese Building Information Modeling Standard Framework, edited by the BIM research group of Tsinghua University, was nominally issued. The CBIMS is mainly divided into two categories: technical standards for software developers and application standards for construction implementers, as shown in figure 2[5].
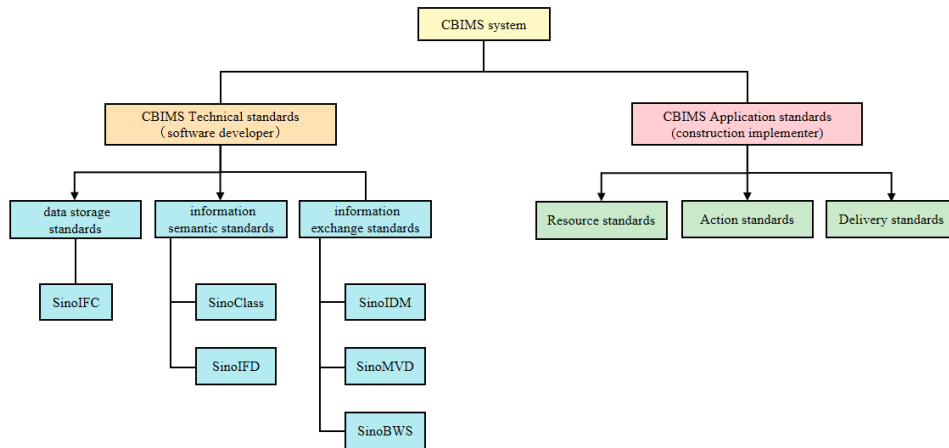

Fig. 2. Standard system of CBIMS.

Under the guidance of CBIMS, the Ministry of Housing and Urban-Rural Development has formulated the national BIM standard and proposed China's national BIM standard system, which is divided into four levels: unified standard, basic data standard, implementation standard and application standard as shown in figure 3.
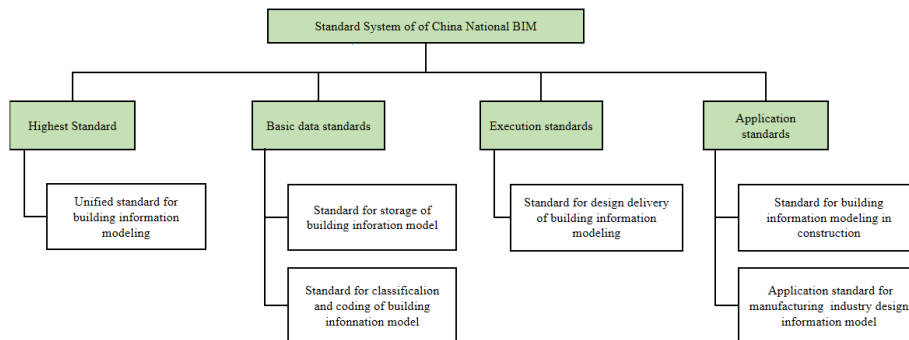

Fig. 3. Standard system of national BIM.

In 2021, the Ministry of Transport of PRC successively issued three industry standards, among which JTG/T 2420-2021 is the basic standard, clarified the framework of highway engineering information model, established the classification coding system and data storage structure.

JTG/T 2421-2021 and JTG/T 2422-2021 respectively standardized the requirements for the application of BIM technology in the design and construction period of highway engineering. The Standard system of BIM in highway engineering is shown in figure 4[6].
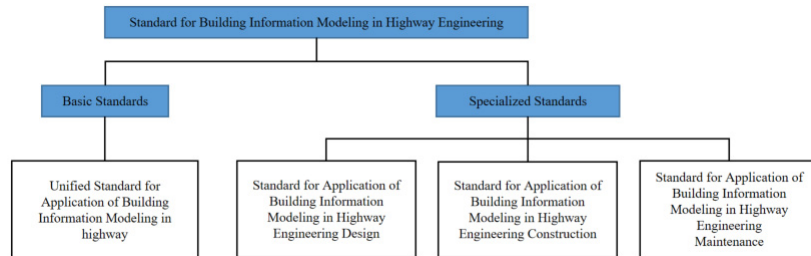

Fig. 4. Standard system of BIM in highway engineering.

Generally speaking, the published standards in China can be divided into two categories, the first category is basic data standards, which usually include data storage, classification and exchange formats; The second category is the implementation of application standards, including model level, project delivery, model application and so on.

2.4 Conclusion of the standard system analysis

Through the analysis of the international, national and highway industry standard system, it is summarized as follows:

1) In the organization and digitization of information about buildings and civil engineering works, international standards provide a series of methodologies for IFC, IFD, IDM, data dictionary, data template, information exchange, information management, etc.

2) Under the unified standard, the national standard sets up three categories of standards: data standards, implementation standards and application standards, mainly focusing on the construction industry, while the related content of the highway industry is less.

3) The three BIM technical basic standards of the highway engineering have defined the principle requirements of model architecture, classification, storage and application delivery in each stage, but the guidance for the digital construction and application of highway engineering is still insufficient.

4) On the basis of the above analysis and summary, focusing on highway engineering, through the relationship between IFC / IDM / IFD three basic standards, standardize highway engineering from three aspects: semantics, data and process,semantics include data dictionary, data classification and data template, The data includes language expression, data model and data architecture, and the process includes information exchange requirements, model view definition, delivery process, Reflect the standard relationship of highway engineering data through entities, attributes and relationships, as shown in figure 5.
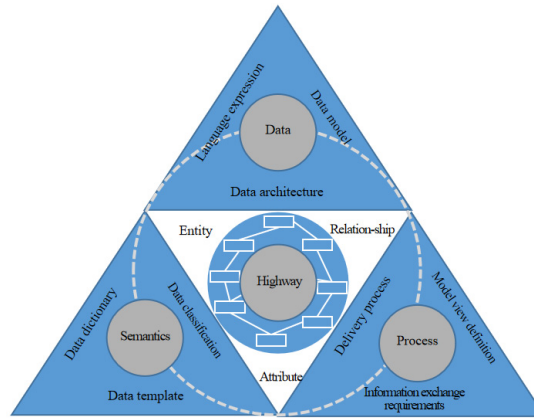
Fig. 5. Relationship diagram of highway Engineering data standards.

3 Research on standard system structure

Standard system is an important support to promote the digital construction of highway engineering and application quality and efficiency, At present, the domestic and foreign standard system is basically limited to the BIM standard of the construction industry, failing to cover the highway engineering. Highway is a typical ribbon project, which has the characteristics of "wide area and close combination with the surrounding environment", The construction of digital construction and application standard system of highway engineering will have key guiding significance for the implementation of digital highway projects, realize data circulation, co-construction and sharing, and improve the level of digital construction and application standardization of highway engineering.

Based on the characteristics of highway engineering and the analysis and summary of the existing standard system, it is proposed that the digital construction and application standard system architecture of highway engineering is composed of four parts: basic standard, data standard, supporting standard and application standard.

The basic standards are standardized from three aspects: data storage, information semantics and information transmission, Clarify the common requirements of model classification, storage and delivery in each stage, so that the different data of digital highway construction projects from survey, design, construction, maintenance and operation can be transmitted in a unified, lossless and efficient way to the maximum extent.

The data standards include data dictionary, data template, data exchange, decomposition structure and information container, which is a further refinement on the basic standard. Its main goal is standardization, consistency and standardization of data in the whole life cycle of highway engineering, facilitating data interoperability, storage and data exchange, and realizing data sharing and data reuse based on different majors, stages and platforms of highway engineering.

The supporting standards include application resource standards, general data environment construction and digital base platform construction, which solidify the data standards and provide technical support for the digitalization of standards.

The application standards are used to standardize the application of digital highway construction projects in the whole life cycle, as well as in various stages of investigation, design, construction, maintenance and operation, so as to realize the effective sharing, inheritance and transmission of models and information.

Under the guidance of the above ideas, the standard system of digital construction and application of highway engineering is shown in the figure. is shown in figure 6.
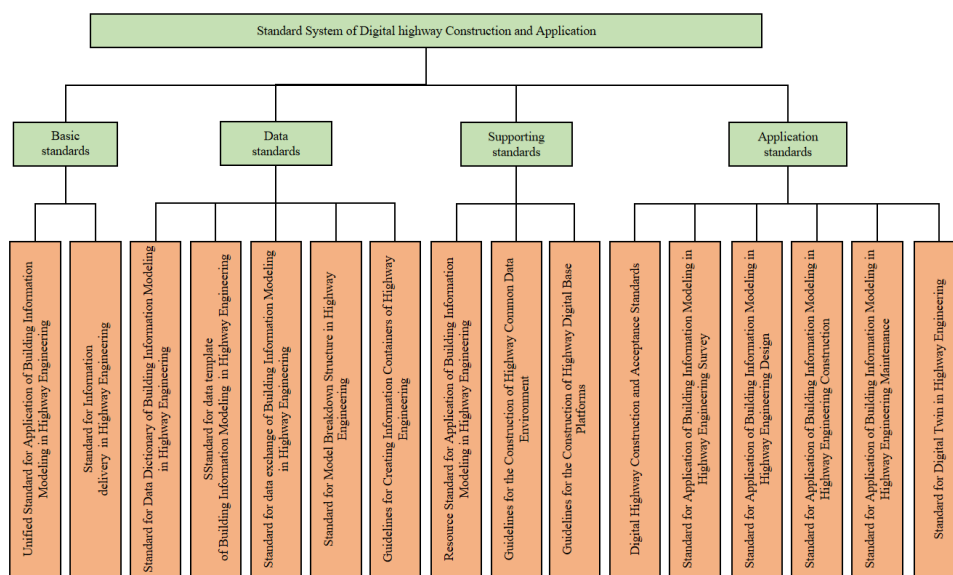

Fig. 6. Standard system of digital construction and application of highway engineering.

4 Application research of the standard system

Digital construction and application of highway engineering, Should by the "Standard for Information delivery in Highway Engineering" of the information delivery guide combining "Digital Highway Construction and Acceptance Standards""Standard for Application of Building Information Modeling in Highway Engineering Survey""Standard for Application of Building Information Modeling in Highway Engineering Design""Standard for Application of Building Information Modeling in Highway Engineering Construction""Standard for Application of Building Information Modeling in Highway Engineering Maintenance""Standard for Digital Twin in Highway Engineering" conducting demand analysis, Generate the data template specified in the "Standard for data template of Building Information Modeling in Highway Engineering", Complete the creation of MVD rules that meet the requirements of the " Standard for data exchange of Building Information Modeling in Highway Engineering"; The concept and attribute definition of the model unit represented

by MVD rules should be quoted from the classification coding, data dictionary and model decomposition structure that meet the requirements of "Unified Standard for Application of Building Information Modeling in Highway Engineering""Standard for Data Dictionary of Building Information Modeling in Highway Engineering" and "Standard for Model Breakdown Structure in Highway Engineering"; Data after conformity inspection shall be stored in the Common data environment, The data storage shall comply with the "Unified Standard for Application of Building Information Modeling in Highway Engineering", The data environment shall comply with the "Guidelines for the Construction of Highway Common Data Environment", Data application and construction delivery were carried out in combination with the "Resource Standard for Application of Building Information Modeling in Highway Engineering""Guidelines for the Construction of Highway Digital Base Platforms" and "Guidelines for Creating Information Containers of Highway Engineering".The framework for the application of the standard system is shown in figure 7.
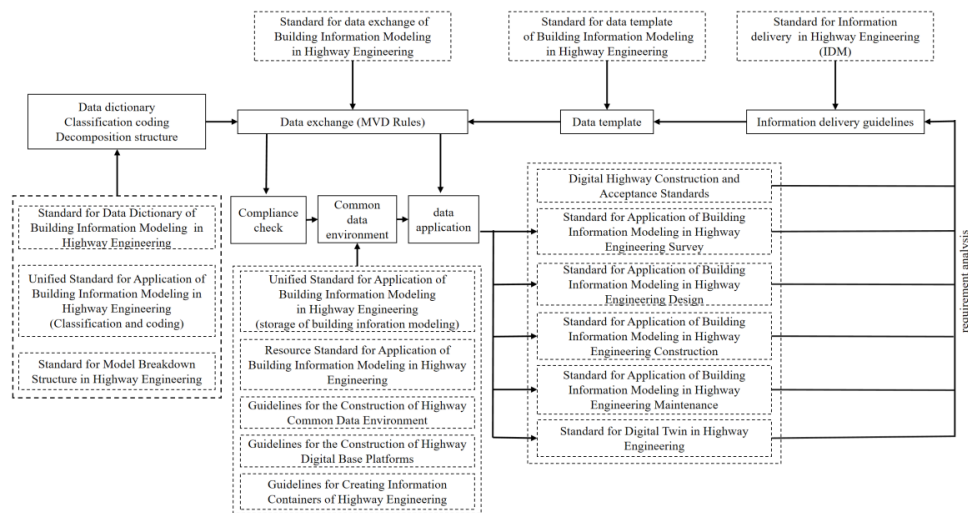

Fig. 7. Framework for the application of the standard system.

5 Conclusions

1) Through the analysis of the international, national and highway engineering BIM standard system, in the international standards for IFC, IFD, IDM, data dictionary, data template, exchange, information, information management and a series of methodology, on the basis of considering national standards mainly focus on the construction industry, and highway industry issued for highway engineering BIM technology standards, combined with the characteristics of highway engineering, put forward the standard system of highway engineering digital construction and application ,which is composed of basic standard, data standard, supporting standard and application standard.

2) In the standard system, the basic standard is standardized from three aspects: data storage, information semantic and information transmission; the data standard is further refined on the basic standard, facilitating data exchange, storage and data exchange, and realizing data

sharing and data reuse based on different specialties, stages and platforms of highway engineering. The supporting standard is the solidification of data standard to provide technical support for the realization of standard digitalization. The application standard is used to standardize the application of digital highway construction projects in the whole life period and in various stages of survey, design, construction, maintenance and operation, so as to realize the effective sharing, inheritance and transmission of models and information.

3) For the proposed highway engineering digital construction and application standard system, put forward the standard system application method, combined with the information transfer requirements from the five application standards for full life highway engineering digital construction and application demand analysis, generate data standard data template, to meet the data exchange requirements, create to meet the classification code and data dictionary and the relevant provisions of the model model structure, relevant data into the general data environment storage, and final data application and construction delivery. This application method provides a solid foundation for the digital construction and application of highway engineering, and promotes the digital transformation process of highway construction in China.

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