RESEARCH AND PRACTICE OF DIGITAL MANAGEMENT AND DELIVERY IN METALLURGICAL ENGINEERING

BY

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SYNOPSIS:

The engineering digital service is one of the core competitiveness for metallurgical design enterprises in the coming future. From the perspective of project execution, digital services contain design delivery, engineering management, digital twin, asset maintenance, etc. A sophisticated and comprehensive digital management platform is the key tool to construct the digital environment. Based on the concept and objective of metallurgical engineering digitization, this paper proposes a framework for the digital platform, which is capable of the management and delivery of 3D models, attribute information, electronic documents, and other sources of data in the design phase. Designers use the add-in link between the design software and the platform to upload the model data. The interpretation, management, and processing of the data are realized by using the functions and data services provided in the platform. The end user can review the design through the data visualization function, and obtains data through the data interface to explore the potential application. Taking a renovation project of a blast furnace as an example, the specific content and implementation steps of digital management and delivery in the design phase are demonstrated. Through the above research and application, the routes to enhance the engineering data value are discussed.

Keywords: Digital Management, Digital Delivery, BIM, Data Interpretation, Data Visualization

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1. Introduction

To improve the implementation process and enhance the delivery quality of engineering projects, engineering digitalization is the only way for design companies. From the perspective of enterprise organization, digital development includes the digitalization of enterprise operations and engineering projects. As for the latter, the digital transformation of an engineering project is to convert all the physical entities, production factors, and project documents into the computer-readable data format and to realize the logicalization of all business processes by adopting the technologies of BIM, cloud service, big data, the Internet of things, etc. Supported by the basic functions of data acquisition, data storage, data association, and modeling analysis, the value of engineering data is deeply explored during the execution process of the project, to provide data-driven long-term forecasting and decision-making services for all participants. Currently, one of the core technologies of engineering digitization is the Building Information Model (BIM). Starting from the phase of project planning, BIM can integrate and provide the engineering information of each stage under the model-oriented principle, and help realize the digital management and operation of the whole project based on a unified digital platform.

The traditional management of engineering projects is mainly results-oriented. Phased inspections and acceptance checks are carried out to ensure the progress of the project. This kind of management mode needs massive input of human resources. Risks and hidden dangers cannot be detected on time. At present, the management of projects in large engineering enterprises is still carried out independently. It is difficult to carry out the refined management based on real-time collected data and to form an effective mechanism of centralized control. Digital management utilizes advanced computer-related technologies to achieve the datamation and networking of the management object, management content, and management method, for real-time quantitative control. The system includes the integration of four main parts: project process, project participant, project object, and project information. The project process generally refers to the activities that have been processed and well-accepted by all parties, such as project planning, project application, project design, etc. Life-cycle management is a widely discussed concept, aiming to standardize the organization and implementation of each project process with unified standards, improve the overall production efficiency, and achieve better economic benefits [1,2]. The project participants generally include the owner, design group, construction group, supplier, third-party supervision group, etc. By gathering all participants into a collaborative alliance that can coordinate resources and share information, a win-win situation of balanced rights, responsibilities and interests can be achieved. To this end, some scholars and enterprises have conducted the study and analysis of stakeholders [3]. The project object refers to the actual entity with specific function and geometric representation. The project information refers to the data or text generated in the project process that has certain values. Through the interconnection of BIM and the Project information Portal PIP [4], the participants can realize the whole-process management of project objects and project information.

Digital project delivery is to transfer the data and information within the scope of the project from the upstream producer to the downstream receiver according to the delivery strategy and standard by using digital technology, to realize the asset value of the project data. At present, the delivery methods at the project completion scenario are mainly based on the project central database, which contains the BIM model, 3D reality model, design drawing, etc. Receivers can browse and deepen the application of the delivery objects through different devices and terminals. It shall be noted that digital delivery does not simply mean an electronic integration and archiving of design documents, but shall also achieve the retrieval, extraction, association, processing, and visualization of all engineering data. At present, there is no systematic and standardized digital delivery strategy or template in the metallurgy field. The transfer and handover in the whole project process is still based on paper files, supplemented by electronic documents and scanned copies.

In this paper, a set of framework is proposed to realize the digital management and delivery of 3D models, attribute information, electronic documents, and other sources of data in the design stage. Section 2 puts forward the overall objectives of digital management and delivery in the design stage, and proposes the framework and main functions of the platform based on these objectives. Section 3 introduces a practical project with specific content and implementation steps of digital management and delivery in the design stage. Section 4 discusses the routes to enhance the value of engineering data. Section 5 conclude this paper.

2. Objectives and platform framework

The main objectives of digital engineering management include:

(1) Comprehensive management: to achieve refined and overall control of the project, through data collection, data production, data storage, and data query at all stages of the project;

(2) Systematic management: to achieve the associations of different engineering businesses and avoid isolated islands of information, by breaking the gap of different data structures;

(3) Real-time management: to realize overall intelligent decision-making through the timely update and analysis of data.

Moreover, a complete digital delivery system shall be able to achieve the following objectives:

(1) Data standardization: attributes are created and added according to unified rules to ensure convenient batch processing of the same type of data;

(2) Data correlation: data can be related to each other and used for invocation in various workflows based on encoding system;

(3) Data security: a set of safe and efficient data management systems is established to ensure data security and active control, based on the cloud platform deployment, data encryption, user permission management, and model version management;

(4) Data visualization: customized model visualization scheme can be provided.

To achieve the above goals, the digital management platform shall be embedded with a lightweight graphics engine, documentation engine, workflow engine, etc., to satisfy collaborative design, comprehensive review, file archiving, design delivery, and other application scenarios filled with various sources of data. The framework and main functions of the digital platform proposed in this paper are shown in Fig. 1. Based on the data processing flow, the platform is logically decomposed into four levels, which includes data production, data management, data service, and data visualization.

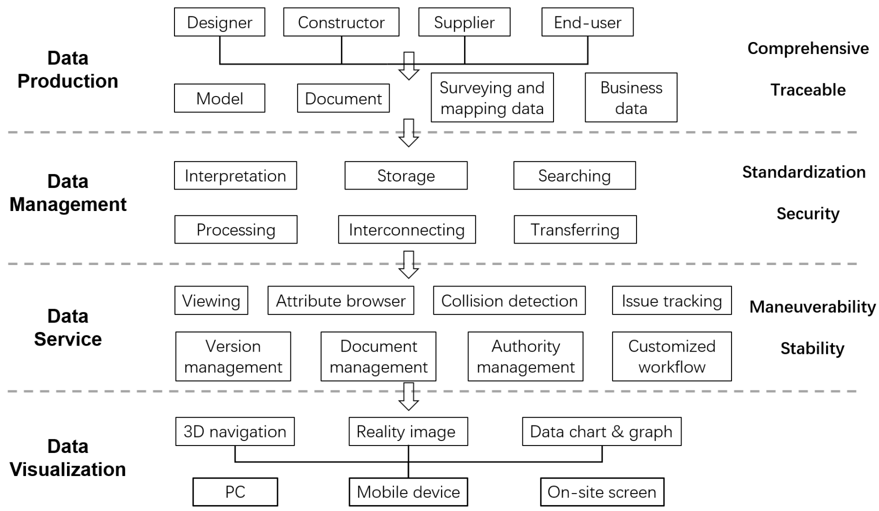


Figure 1 Framework and functions of the digital management platform

2.1 Data production

During the design period, the project data mainly include:

(1) Geometric model;

(2) Attribute information;

(3) Drawings and documents;

For digital delivery, data shall be strictly produced in accordance under rules of naming and encoding, to realize automatic data association. Before delivery, the data production is mainly completed by the design group. Data from the suppliers, construction group, owner, and other stakeholders can be collected by the BIM manager and uploaded to the platform. After the completion of phased delivery, customers can continue to process data through the interface provided by the platform according to the authority. For example, the construction group can further utilize the design model for the construction completion model. Operational data can be added to the equipment model for asset maintenance and reliability analysis.

2.2 Data management

The platform shall be able to interpret all sources of data according to certain data structure and stores them in the database. Structured data mainly include 3D model data, engineering data, user information, etc. Such types of data can be stored in general relational databases such as SQL Server and Oracle, or in NoSQL databases, which is more convenient for the deployment of cloud service. As for the unstructured data, such as documents, videos, and 2D drawings, they are usually directly stored in the project storage space in common formats. The data encryption, backup, and user-level permission setting are considered for the security issue.

2.3 Data service

The functions of data service are the core tools to create value for the project and stakeholders. The basic functions include:

(1) Version management

Version management enables users to record, update, withdraw, and delete data of different versions sorted by the upload time. For example, after professional review in the design software, the design model of a subsystem is uploaded to the management platform and assembled with other subsystems according to the unified spatial positioning. When the design content changes, the designer can modify the design in the professional design software and re-upload the model to the management platform. At this time, in the model browsing window of the platform, the old model will be replaced. But based on the storage mechanism, all versions can be backtracked according to the upload time or remarks.

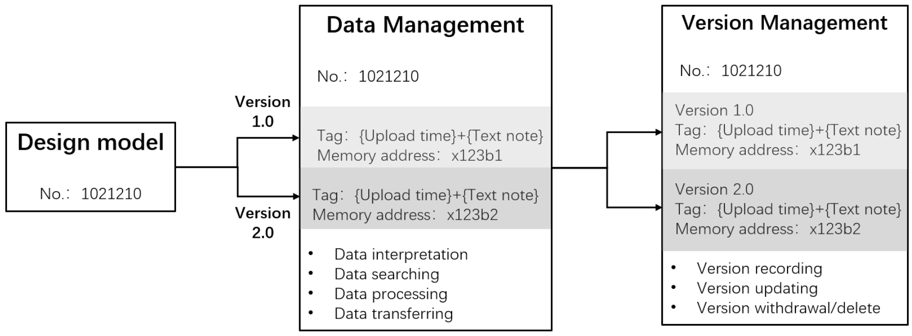


Figure 2 Version management

(2) Authority management

Authority management is one of the mechanisms to ensure data security. Based on the role allocations of users with different permissions to workflows and data, the rights and responsibilities of all parties are clarified. Roles can be set according to the type of organization they belong to, or directly authorized with certain access. The illustration of role allocation is shown in Fig. 3.

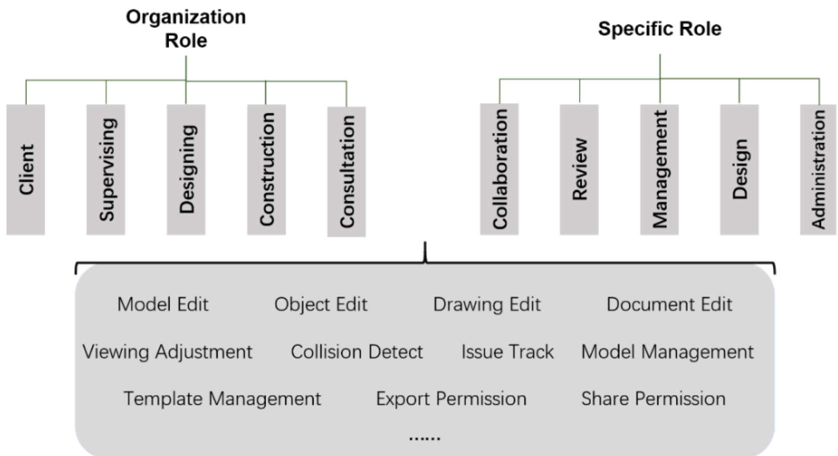


Figure 3 Role allocation

(3) Data visualization

After the interpretation of input data, the geometric model will be lightweight by the graphics engine embedded in the platform and stored in a new uniform format, which is free from the constraints of special design software. Various types of output data formats are provided for different application scenarios. The basic function of model browsing in the design stage shall ensure that all parties carry out the design review smoothly. The transformation of model data is illustrated in Fig. 4.

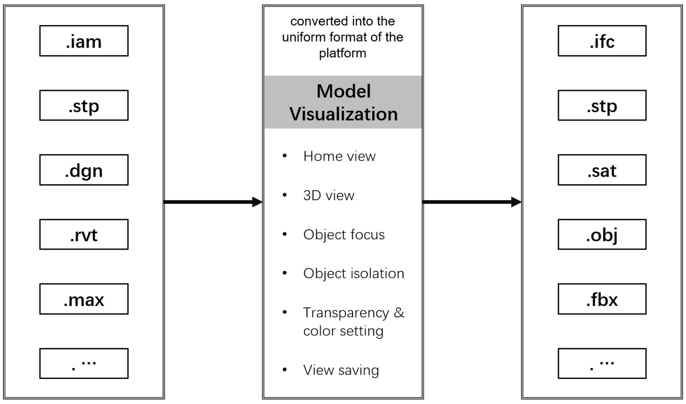


Figure 4 Transformation of model data

2.4 Data visualization

After processing, data can be visualized and presented in a user-customized pattern. The main tools include:

(1) Desktop client

A desktop client, which is compatible with the digital platform, is provided to the end users. The basic functions shall include the model and attribute browsing, data interface services, etc. The desktop client is mainly aimed at end-users who have potential demand for data maintenance and extensive application.

(2) Web browsing end

With the functions of model browsing and data maintenance, the web browsing end is more suitable for conferences, construction sites, and other occasions outside the office.

(3) Mobile device

Through the mobile APP, customers can access platform data more conveniently through tablet, mobile phones, and other online and offline ways.

3. Execution of digital management and delivery

This section introduces the process and key points of digital management and delivery of metallurgical engineering. The renovation project of a blast furnace is demonstrated as an example, which was firstly built in 2004 and put into operation in 2006. Under long-term operation, the aging of equipment and pipelines leads to high energy consumption and poor environmental protection effect. To further enhance the production capacity and help achieve the zero carbon target, the owner decided to transform the blast furnace into an advanced, reliable, and environmentally friendly ironmaking factory.

3.1 Digital management

A digital design management system is built based on the company-level cloud platform (Fig. 5), which can support the BIM implementation from feasibility research to design delivery. The participants mainly include the project manager, design group, construction group, owner, etc. The involved majors include iron making, mechanical equipment, architecture, structure, pipeline, electrical, etc. The main path of data transfer during the design phase is shown in Fig. 6. Designers of each specialty carry out model design and professional review in the professional design software (as shown in Fig. 7(a)-(d)), under the guidance of 3D design standards, to produce standardized model data. The content of 3D digital design standards mainly include the hierarchy of the model system, encoding and naming rules, model geometric depth, template of attribute information, etc. In addition to the design-related data, the original data of the tilting photographic model was collected by UAV for the real scene outside the casting house, and the original data of the point cloud model for the real scene inside the casting house was collected by the station-type laser point cloud equipment. The surveying and mapping data shall also meet the industry standards, which include the field collection range, collection method, setting of control point, data quality check, and model quality check.

After passing the professional review, the design models and documents are named and numbered according to the naming rules formulated by the project team, and then transferred to the project lifecycle management system (as shown in Fig. 8), which is responsible for the model assembling, design progress control, design information transfer, design archiving, etc. Moreover, for the participants outside the design group, design models and documents are packaged based on the project breakdown structure and uploaded to the data service platform for comprehensive review (as shown in Fig. 9(a)). Due to the large scale and complexity of the metallurgical engineering system, the space shortage problem is usually difficult to be clearly calculated in 2D drawings and has to be resolved according to the actual situation during site construction. The lightweight graphic engine can ensure smooth browsing of the model from the whole to the part, and help optimize the equipment size and pipeline arrangement in advance (Fig. 9(b)). Every single object can be searched by coding and objects of the same type can be searched by certain attributes. The cost engineer can use the geometric attributes and material data to conduct cost estimates and export the computation as an editable document format (Fig. 9(c)). Every participant can initiate design problems on 3D models and 2D drawings (as shown in Fig. 9(d)), and specify the responsible party for the issue rectification, as well as the deadline. Problems with labeling can be exported and edited for project summary and solution reference materials. For the complete digital system, data security is ensured by three layers of measures: private cloud storage, platform data encryption, and user access authorization. On the premise of data security and control, file backtracking can be performed through version management to avoid data loss caused by false deletion.

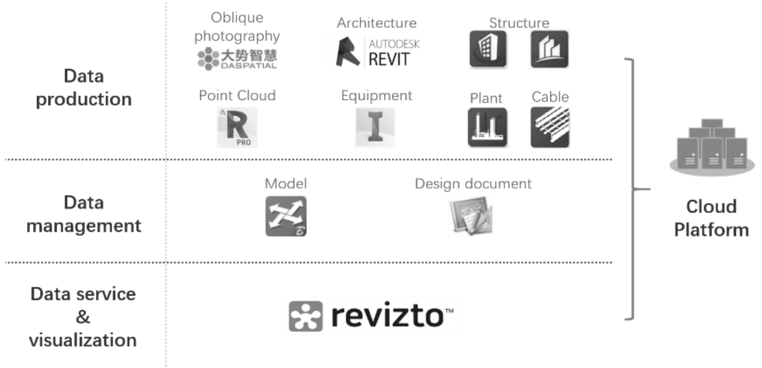


Figure 5 Design management system

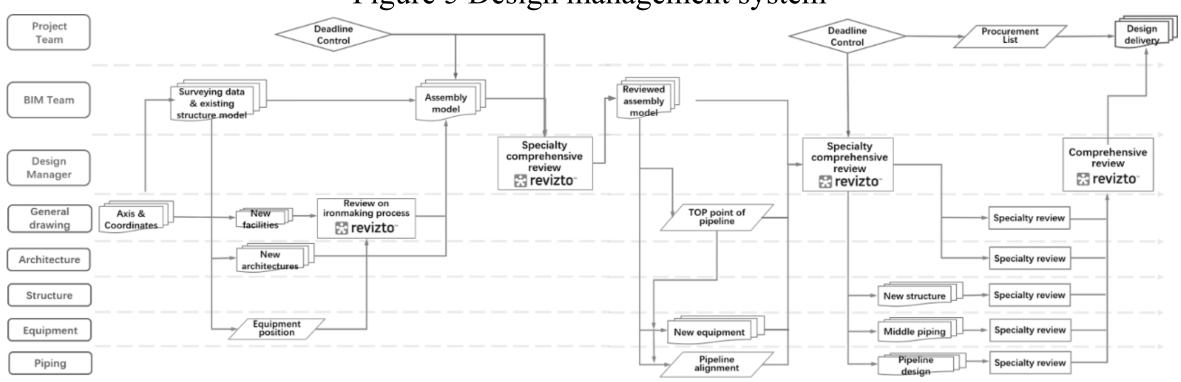
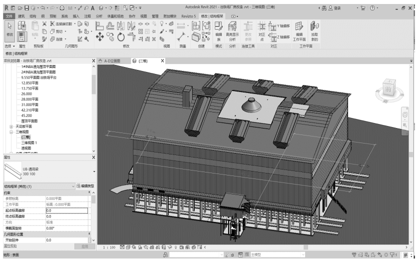
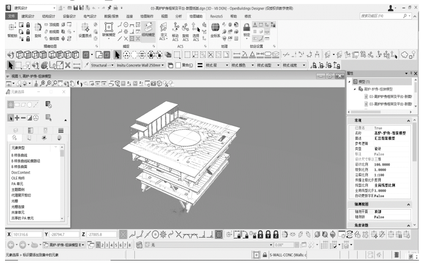


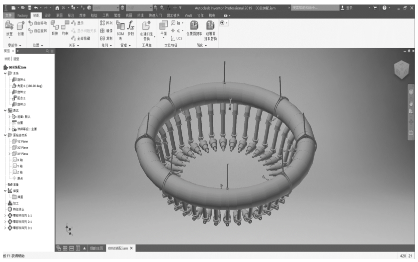
Figure 6 Data transferring in design phase



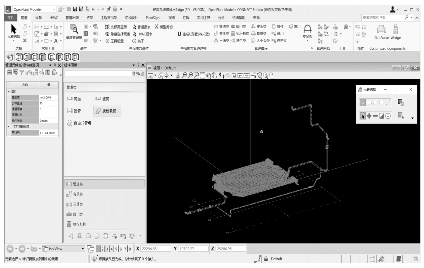
(a) Architecture model of casting house



(b) Structural frame of furnace body

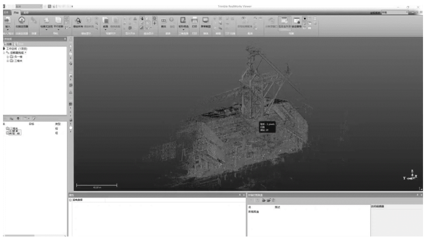


(c) Cooling equipment



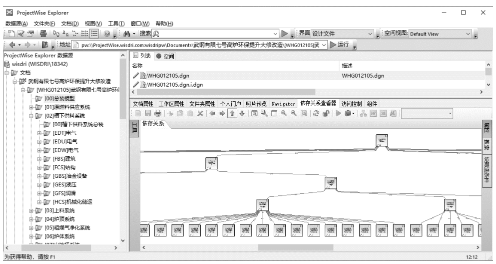
(d) Pipeline at the bottom of the furnace

(e) Tilting photographic



(f) Point cloud model

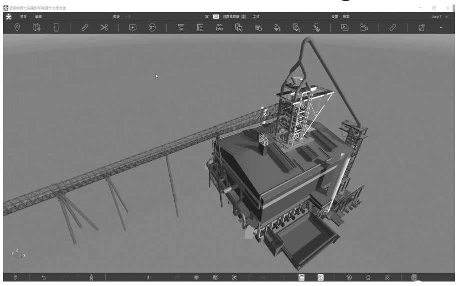
Figure 7 Data production



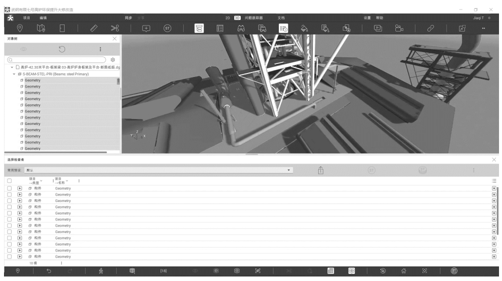
(a) Model management tree

(b) Document coding

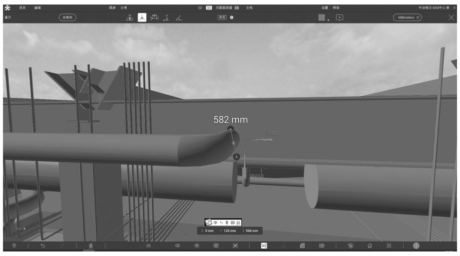
Figure 8 Model data management



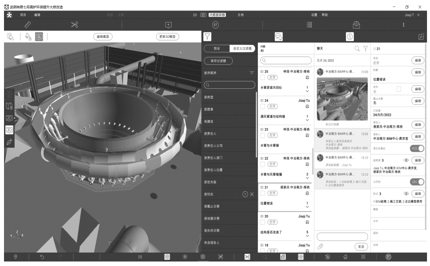
(a) Model viewing



(b) Attribute viewing



(c) Collision detecting



(d) Issue tracking

Figure 9 Data service

3.2 Digital delivery

Digital delivery in the design phase does not solely mean the handover of design content to the asset owner. All stakeholders shall be regarded as the beneficiaries of digital delivery. Through the transmission of valuable data, the management depth of the overall schedule, quality, and cost can be effectively controlled. To ensure the delivery quality, the scheme shall be determined at the project planning stage.

The planning content mainly includes:

(1) Delivery scope and standard

Delivery scope refers to the project subsystem and design specialties involved in the project. The overall delivery standard regulates the project hierarchy, design depth, delivery format, etc.

(2) Delivery data standard

For the standardization of the geometric model and attribute information, the attribute template of each object type shall be created according to project requirements (as shown in Fig. 10). Moreover, the encoding rules are formulated for every model object, to realize the life-cycle asset management.

(3) Document delivery standard

It generally consists of the document naming rule, numbering rule, and delivery list. The delivery list contains all the document directories to be delivered and the corresponding information, such as involved specialties, chief designer, etc.

(4) Data validation standard

The data validation shall be conducted before delivery. The content includes the model precision, integrity of attribute information, compliance with design specifications, and other review content that can be logicalized.

(5) Delivery platform configuration

The adaptation of the delivery platform to the hardware and operating system of the server shall be debugged. Moreover, the association of user roles with data access and platform functions, the maintenance mode of the platform and data, and other settings related to platform usage shall be planned and tested.

Attribute template of a type of tower

Number	Attribute	Delivery option	Source	Unit
1	Volume	REQ	DS	m^3
2	Working pressure	OPT	DS	Pa
3	Design pressure	REQ	DS	Pa
4	Working temperature	OPT	DS	℃
5	Inlet pipe size	REQ	DS	mm
6	Outlet pipe size	REQ	DS	mm
7	Material density	OPT	DS	kg/m^3

Note: the delivery options include the **Required** (REQ) and **Optional** (OPT);
the attribute sources include the **Designer** (DS), the **Owner** (OW), the **General Contractor** (GC), the **Sub-Contractor** (SC), the **Supplier** (SU), the **Software Supplier** (SW), etc.

Figure 10 Attribute template

Through the above services, the delivery of each professional design content has been completed. In the construction process of the renovation project, collisions among essential equipment, pipes, and structures have been significantly reduced compared with similar types of projects. The renovation construction has been completed on schedule with a lower cost of design change. The goal of ‘front-running management, timely coordination, and closed-loop problem-solving’ has been realized with technical support from the digital management platform.

4. Data value mining

Effective communication is one of the key elements to ensure the quality of digital implementation in metallurgical engineering. According to the above demonstration, it can be seen that digital platform can help improve the management mode of large metallurgical projects from phased result control to targeted process control and solve the problems such as irrelevant information interference and delayed progress control. In the process of engineering digitization, data is the engine. The accurate, timely, and comprehensive data acquisitions are the basis to ensure the circulation of value chain. The key to discover the value of data is the connection and algorithm among various sources of data. At present, in the process of project implementation, a large amount of data is put aside after collecting and archiving. The in-depth understanding and use of data are lacking. To improve the situation, the framework of a mature digital platform shall consider the requirements of all participants and the whole life-cycle business. The sole consideration of traditional business segmentation is difficult to improve the overall benefits of digital activities. The following aspects can be adopted for improvement.

(1) Strengthening of data governance ability: the logicalization of current industry norms and design principles; the capitalization of unstructured data; life-cycle application of encoding system; deep exploration of logical relationship between users, data, and processes, bringing more participants of engineering projects to be the data producers.

(2) Performance optimization of data visualization: lightweight rules and algorithms of the 3D model; 3D annotation and display of component attribute information with the same precision as the 2D blueprint.

(3) Improvement of collaborative working environment: embedding of the collaborative overall goals and sub-goals into the digital business and process; optimized allocation of digital resources on the platform.

5. Conclusion

The efficiency of labor production in the engineering industry increases slowly. To improve the situation, a digital management platform with data and workflow services is one of the effective solutions. At present, digital products on the market are difficult to meet the needs of metallurgical engineering. The advanced self-research digital management platform is one of the key content for design enterprises in the direction of digital development. This paper introduces the concept of digital management and delivery and proposes the framework of a digital platform based on digital objectives. The overall development of the platform is still in progress, and the functions have not been fully realized. There are still many difficulties to be overcome, including a large number of tedious data formats to be interpreted and transferred, the optimization of model lightweight performance, etc. These are also the interests of future research and development.

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