Application of BIM coding and example modelling for typical asphalt pavement diseases based on Omni Class

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Abstract. With the widespread application of BIM technology in highway engineering, the practice of coding asphalt pavement diseases and integrating it with BIM models in the highway management and maintenance stage can contribute to the clarity of data collection and source-tracing of the disease and strengthening the circulation of disease data in the whole life cycle of highway engineering. This paper compares the coding methods of construction and infrastructure coding at home and abroad, and identifies the disease of asphalt pavement according to existing norms and clarifies the rules for formulating disease coding in the aim of producing a unified coding method of asphalt pavement disease. At the same time, based on the establishment of the disease model, the coding information is integrated with the BIM model to fill in the gaps in the coding work in the management and maintenance of highway engineering to improve the circulation of code-integrated BIM disease model in the maintenance phase.

1. Introduction

With the vigorous development of China’s transportation infrastructure construction, highway construction has begun to transform from the previous extensive construction to the direction of scientific management. However, during the phase of road management, in order to ensure the healthy use of the road, the management department needs to obtain a large amount of road disease data in order to maintain the road in time. Due to the wide variety and a large amount of these data, it is necessary to scientifically carry out accurate sorting of these data and ensure that they can be effectively circulated among various departments, which can strengthen the collaboration capabilities of all parties and constitutes the core problem facing the management department.

Nowadays, with the wide application of BIM technology in the field of construction, the classification and coding of various structures and elements in buildings have become relatively mature. A coding system that complies with standards can effectively describe and classify engineering projects, bringing great convenience to engineering management, engineering cost and engineering maintenance.
and greatly improving the productivity of the construction industry. And BIM, which stands for building information model, has the capability of carrying engineering information and data per se, which can encapsulate the information contained in each link in the entire life cycle of the project and circulate it in the form of a three-dimensional visualized model. Therefore, the classification and coding of pavement diseases in the management phase of highway engineering and its integration with the BIM disease model can well realize the sharing and transmission of disease management data and information among various departments, which will facilitate the better understanding of the road surface, disease monitoring and its timely maintenance.

At present, the information classification and coding standards of the construction industry adopted in most countries are the ISO I2006 or ISO I2006-2 of the Omni Class and Uniclass classification methods. Despite the fact that the classification and coding of highway roads are covered in the ISO I2006-2 classification system [1], its content is very generic and the types of roads involved are different from those in China. China has made rapid progress in the study of highway engineering BIM coding this year. The local standard Highway Engineering Information Model Classification and Coding Rule DB32/T 3503-2019 promulgated by Jiangsu Province carried out detailed coding for all elements involved in each stage of the highway engineering life cycle, such as structure, personnel of all parts of the road and proposed detailed coding on various parts of the road structure, personnel and other elements in highway engineering, and put forward the classification and coding of information models suitable for each stage of the life cycle of highway engineering. The standard has made detailed coding of the personnel, machinery, materials, etc. involved in each link and process of highway construction from the aspects of results, process, resources and attributes; which can guide the transmission of information during the entire life cycle of highway projects. However, because the standard is only a local standard, it has not been widely promoted and applied. At the same time, the coding of the structure of the road by this standard does not involve the level of road disease and there are still many difficulties in the description of road disease information. Road diseases can be divided into many types according to different materials used on the road, different temperature and humidity environments, different occurrence locations and different forms of damage, etc. While this information can be formed between management departments in the form of text descriptions or markings, if it is built into three-dimensional visualization models and digitally managed and monitored, it will be difficult to correlate and match this information with the BIM model, which will hinder the digital management of these disease models by all parties. Therefore, a code specifically designed for road diseases is urgently needed to guide the work of road maintenance.

This paper proposes a coding method for asphalt pavement diseases, which, through the integration of road disease codes and BIM disease models, forms a three-dimensional visualized BIM digital coding model. It builds a bridge in the digital management of pavement diseases, so that BIM technology can be used for the reference of pavement maintenance application.

2. Relevant Work in the Field
The development of building informatization started early in developed countries such as Japan and the United States and has been quite mature in terms of infrastructure construction, industry norms, and data standards. As early as in the 1920s, Europe and America have begun to establish building information classification and coding systems suitable for their respective development stages in order to meet the needs of standardized design, project cost, project construction management, etc. However, due to the different tasks in various fields, the needs are different, so the classification system developed were quite different. In 1969, the Royal Institute of Chartered Estimates (RICS) promulgated the first classification standard for housing construction, and the European Union established the CEEC classification; the construction industry in the United States also attached great importance to the application of information technology to improve production efficiency and reduce construction costs. The United States gradually established relatively complete engineering project coding systems such as Uniformat II and Masterformat in the 1970s, which have had far-reaching influence in North America and achieved constant and a wide range of applications. Among them, the positioning of Uniformat II is for the full
cycle of engineering projects, and the coding structure is used for description, cost analysis and project management; Masterformat’s positioning is the organization and management of information and data in the implementation phase of a project, and at the same time provide detailed cost data of work results. In January 1997, the IAI (Industry Alliance for Interoperability) organization released the first complete version of the IFC (Industry Foundation Class) information model, which has been widely used and has now been accepted by the ISO. The Japanese construction industry began to take a series of measures to promote informatization (called CALS/EC in Japan) in 1995 [2], and planned to first implement informatization in national key projects in 2004. Its core connotation is: 1) Aiming at the entire life cycle of the project, all information is electronic; 2) The parties involved in the project use the Internet to submit and receive information; 3) All electronic information is stored in a database for easy sharing and utilization. At present, most of the information classification and coding standards of the construction industry around the world adopt the ISO I2006 "Organization of Construction Engineering Information" standard system of Omni Class and Uniclass classification methods.

China has also carried out some basic research work on the classification of building information. In 2017, China's third national BIM standard "Building Information Model Classification and Coding Standard GB/T51269-2017" was released. This standard directly draws upon the American OmniClass classification standard and makes localized adjustments according to domestic conditions. This standard is the coding work for the whole life cycle of the building and has made a detailed localized description of the specific information details of China's national projects. In 2019, Zhuo Pengfei from Shanghai Water Conservancy Engineering Design and Research Institute Co., Ltd. [3] compared different encoding types such as OmniClass and KKS, and proposed a mapping rule between OmniClass and KKS encoding. Through the investigation of various structures in water conservancy projects, classification standards in water conservancy projects are developed and extended to the BIM information classification of the whole life cycle of water conservancy projects. In terms of highway engineering coding, in order to facilitate machine learning to identify road diseases, Manfu Technology Co., Ltd. recognized and verified a large number of disease pictures. During this period, it also coded typical diseases of asphalt pavement, although such coding is only based on semantics. The marked coding cannot be associated with the BIM model and is difficult to circulate between the management departments. Nevertheless, it has given a lot of inspiration and reference for the coding of road diseases.

3. Research on Classification and Gradation of Asphalt Pavement Diseases

Nowadays, whenever road inspection work is carried out, the road management department’s inspection of a certain road will produce disease data of that contains disease types, complex reasons of cause, and different road levels. In order to achieve the correct sorting and classification of disease data, and to ensure that the type and degree of damage as well as the type of disease cause in the BIM software corresponds to the information and the requirements of the coding level classification, it is necessary to adjust the classification and gradation of asphalt pavement diseases on the basis of traditional norms. In the meanwhile, disease types not specified in the standard need to be eliminated in order to adapt to the application of BIM technology-based asphalt pavement disease coding in disease model.

In the classification of asphalt pavement diseases specified in the latest "Highway Technical Condition Evaluation Standard JTG 5210-2018", asphalt pavement damage can be classified into four categories: cracks, deformation, surface damage and repair marks, which can be further classified into 11 types of diseases. They are cracks, massive cracks, longitudinal cracks, transverse cracks, subsidence, rutting, wave crowding, potholes, looseness, oiling and repair marks.

In the standard, the classification of the damage degree of these 11 types of diseases and its criteria are clearly explained [4]. However, in the classification table for the diagnosis of the cause of the pavement disease in "Asphalt Pavement Maintenance Design Specification JTG 5421-2018", diseases that are not defined and graded in the "Highway Technical Condition Evaluation Standard JTG 5210-2018" appeared, such as pumping, shifting, and poor skid resistance. These diseases cannot correspond to those defined in the technical assessment standards. At the same time, due to the different degrees of
damage, the cause of the same kind of disease in the technical status assessment standard will be 2-3
types instead of just one single cause. And the pavement level involved in the same kind of disease is
also different because of the degree of damage. If the disease is coded according to the gradation given
in the evaluation standard, it will cause the overlapping of disease information, which hinders the
unification of coding [5], resulting in the confusion of the coding information. And it is also difficult to
ensure the accurate retrieval of disease models after it is linked to the BIM disease model, which brings
great inconvenience to disease code, making it impossible to complete the integration of disease
information.

Combining the definition, classification and grading of various diseases in "Highway Technical
Condition Evaluation Standard JTG 5210-2018" and "Asphalt Pavement Maintenance Design
Specification JTG 5421-2018" and based on the actual road surface disease to ensure the unification
of disease coding and the consistency of the definition of the disease in these two Codes, this paper
proposes the following adjustments to the type of disease and reason of cause:

(1) Eliminating the diseases that do not belong to the 11 main types of asphalt pavement diseases or
those that have unclear descriptions of the disease, such as: poor skid resistance, deformation, shifting,
pumping, etc. At the same time, wave crowding belongs to the 11 main diseases, but it is not included
in the corresponding classification. According to the reason for its formation, wave crowding is
classified into asphalt surface structure damage.

(2) In the damage of the asphalt surface layer structure and the base layer structure, there are block
cracks, horizontal cracks, longitudinal cracks, potholes, cracks and other types of diseases, but there is
no clear definition of the extent of these diseases, which is an important criterion for the
determination of the disease, so it should be fine-tuned. According to the research and comparison of the disease data,
the damage degree of the block cracks, transverse cracks, longitudinal cracks, pits and other diseases
generally only affects the surface structure of the asphalt pavement.

They will only affect the subgrade structure until the damage becomes severe. Therefore, mild block
cracks, transverse cracks, longitudinal cracks, potholes and other diseases are classified into the cause
types of the asphalt surface structure damage while severe ones of these diseases are classified into the
types of causes of damage to the base structure.

(3) Light and moderate cracks generally appear on the asphalt surface layer and do not reach the base
layer. They are hereby classified as structural damage to the asphalt surface layer, but due to the cracking
degree and large affected area, severe cracks are classified classify into the destruction of the basic
structure.

(4) Rutting appears in all three categories in the original table, namely, base structure damage, asphalt
surface layer structure damage, and asphalt surface layer performance degradation. In order to comply
with the rule of one single classification, minor rutting is classified as the cause type of asphalt surface
layer performance degradation while severe rutting is classified into the destruction of the basic structure.

(5) Based on the diagnosis table of pavement disease cause in the "Asphalt Pavement Maintenance
Design Specification JTG 5421-2018", other types of diseases with different damage levels are
reclassified in this paper, as shown in Table 1:

| No. | Type of disease cause | Typical type of disease |
|-----|-----------------------|-------------------------|
| 1   | Unstable Subgrade Structure | Subsidence; Severe Longitudinal Cracks; |
| 2   | Destruction of Base Structure | Cracks (Severe), Block Cracks (Severe); Transverse Cracks (Severe); Severe Rutting; Cracks (moderate and mild), Block Cracks (Mild); Transverse Cracks (Mild); Longitudinal Cracks (Mild); Potholes, Wave Congestion, etc.; |
| 3   | Destruction of Asphalt Surface Layer Structure: | Oil Flooding; Looseness; Mild Rutting; |
4. Research on coding of asphalt pavement disease

In the practice of detecting road diseases in highway engineering, the detection of road diseases is carried out in units of one kilometre. Within the range of the mileage pile, the diseases on the road are recorded in directions and the number, name, and degree of damage of the disease and at the corresponding road section is recorded in the disease detection report. However, in road disease inspection reports and patrol disease data table, it is necessary to describe the disease at each and every one of the road sections with sentences that are as accurate as possible, such as: the mileage of the disease, the name and type of the disease, the degree of damage, which direction the diseases is on, etc. This makes the statistical information of disease data lengthy and cumbersome and inconducive to the transferability of data among various departments. And it is also difficult to realize the inheritability and adaptability of disease data. Therefore, it is necessary to encode the disease of asphalt pavement and integrate it with the BIM model to achieve its digital management and to use the BIM model of the disease as the carrier [6] to realize the circulation of disease detection data among maintenance departments.

Based on the above requirements for the coding of asphalt pavement diseases above, the coding of the disease should not only consider the uniqueness of the description information, but also accurately describe the name, type, degree of damage, and type of damage cause [7], which will bring a great deal of help for data collection in road inspections, making the description of diseases concise and thereby saving data storage memory and enhancing data circulation.

The coding method and coding system of asphalt pavement disease classification gradation draws on GB7027-86 "Basic Principles and Methods of Information Classification and Coding" and the national "Building Engineering Design Information Model Classification and Coding Standard" [8], but in order to prevent the confusion of the first four levels and categories, corresponding adjustments are made in the coding form in order to meet the standards. The adjusted classification and coding rules for asphalt pavement diseases are as follows:

The code is composed of classification code and gradation code. The components are disease type code, disease name code, damage degree code, and cause type code. Among them, disease type code belongs to classification code, and the remaining four codes belong to gradation code. The disease type code is represented by 6 digits, the first 2 of which are the disease type code, which is the first-level category code of the asphalt pavement disease code, and the remaining 4 digits are complemented by 0; the disease name code is represented by 6 digits, the first two of which are the disease type code, the two digits in the middle are the disease name code, the remaining two digits are filled with 0; the disease damage degree code is also expressed by 6 digits, the first two of which are the disease type code, the two in the middle are the disease name code. Finally, the damage level is represented by the damage degree code; the reason type code is represented by an 8-digit number, which is obtained by adding 2 digits at the end of the damage level code to indicate the cause type of the disease.

(1) The connection between disease type code, disease name code, damage degree code and cause type code are all represented by ".", and the use of "—" will be discontinued, to so as to distinguish the new codes from the previous ones.

(2) Since the condition of the disease has been accurately described in the classification and gradation of the disease, it is only necessary to describe the disease step by step in one single direction according to the disease classification, without having to consider the cross-influencing factors, so the description of the disease type, name, degree, and cause type can be achieved in accordance with the code. The coding is shown in Table 2:
### Table 2. Asphalt Pavement Disease Coding

| No. | Category Code | Disease type | First-level category code | Disease name | Second level code | Third-level category code | Cause Type | Forth-level Code |
|-----|---------------|--------------|---------------------------|--------------|-------------------|---------------------------|------------|------------------|
| 1   | 10.01.03.20   | Massive cracks | 01 | light | 01 | Destruction of asphalt surface structure | 30 | |
| 1   | 10.02.03.10   | Longitudinal | 02 | light | 01 | Destruction of asphalt surface structure | 30 | |
| 1   | 10.02.01.30   | Crack Disease | 10 | Transverse crack | 03 | light | 01 | Destruction of asphalt surface structure | 30 | |
| 1   | 10.04.02.30   | Cracks | 04 | moderate | 02 | Destruction of asphalt surface structure | 30 | |
| 2   | 20.05.03.30   | Road Surface Disease | 20 | Potholes | 05 | light | 01 | Destruction of asphalt surface structure | 30 | |
| 2   | 20.06.03.40   | Friable | 06 | light | 01 | Performance degradation of asphalt surface | 40 | |
| 3   | 30.08.01.30   | Deformation Disease | 30 | Wave crowding | 08 | light | 01 | Destruction of asphalt surface structure | 30 | |
| 3   | 30.09.03.20   | Rut | 09 | light | 01 | Performance degradation of asphalt surface | 40 | |
| 4   | 40.11.04.40   | Oil flooding | 10 | Performance degradation of asphalt surface | 40 | |
| 4   | 40.11.04.40   | Repair marks | 11 | Performance degradation of asphalt surface | 40 | |

5. **Examples of application of typical disease model combined with BIM coding**
The BIM three-dimensional visualization model can encapsulate data and circulate it as an entity to in various links ensure the consistency and efficiency of data circulation. With disease coding and other completed disease data, it is possible to integrate all disease-related inspection data with the BIM disease model, and to synchronize this information with the BIM model when constructing a parameterized disease BIM model to achieve the fusion of data and model, whose nature is to use the BIM disease model.
model that integrates disease data as a link to realize the interconnection and retrieval of disease examination data among various departments.

The application of BIM technology in pavement disease model can make BIM technology more instructive in road maintenance work, and can visually express the semantics of pavement diseases and facilitate the study of the reasons of the development trend of disease and the different damage patterns and sorts out and integrates all the data and models, which is of great significance for guiding the road maintenance work. At the same time, a code describing the degree of damage to the disease is added, and the types and causes of the disease are sorted out to provide a basis for solving the problem of consistent information understanding and knowledge in the information exchange process of the project system.

The construction of the pavement disease model requires the extraction of the main attributive parameters that can abstract the description of the disease based on the description of the main parameters of the disease in the specification, such as: the depth of the pit, the peak and valley, difference of the wave swell, the size of the area, etc., and then use Dynamo to carry out the preparation of the parameterized model construction program. The prepared program can perform parameterized model of different types of diseases by reading the main control parameters of the diseases in the document. By sorting out the disease data obtained from actual disease detection, name, damage degree, and code information of the disease are organized into a document, and the disease information in the document is added to the disease model by manual input or Dynamo input, thus achieving the fusion of disease code and disease model, through the use of which, the current disease model can be obtained by the mere reading the disease data obtained from road inspections in the same way, and the development trend of the disease can be analysed by comparing the changes of the before and after disease models. At the same time, the detailed information of each disease is reflected in the project list, which brings convenience to the integration of disease information and the data circulation between various departments in the management stage. It also provides a foundation for the application of the BIM disease model in the collaborative platform in the future. See figure 1.
Based on the existing detection data, the constructed model can be stored in the form of a database and form a disease model library. The disease model library can be correlated with the Unity3d engine to realize the retrieval function of the model, and the use of the model can be extended to road section level or even the road network level by making use of the Unity 3D electronic sand table to visually analysed and retrieve the disease model. The information that can be retrieved includes the maintenance unit, name, code, and name of the disease. Information such as the degree of damage and the number of diseases can be used to expand the functions of the disease maintenance collaboration platform. See figure 2.

Figure 2. Display of disease model in the road section.

6. Conclusions and Future Work
Constructing a BIM-based asphalt pavement disease coding and parameterized disease model in the road engineering management link can uniformly coordinate the coding information and disease model information and fill the gap in the coding work in the pavement disease. The integrated BIM parameters disease coding model also brings extensive convenience to the circulation of disease data in the management department. At the same time, in the process of transportation construction project management, the BIM model that integrates coded information can also play a role in information consistency in the data circulation links of all parties. The BIM model can be used as an independent or as an interconnected entity to enhance the circulation of data information in the management department, thereby satisfying the needs of multi-business management.

Acknowledgement
The research was supported by the Open Fund of Key Laboratory of Transportation Industry (2019KFJJ-001), Natural Science Foundation of Inner Mongolia Autonomous Region (2020MS05056), and the Basal Research Fund of Central Public Research Institute of China (20212701).

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