Research Article

Intelligent Generation and Analysis of the Municipal Road Construction Scheme Based on the KNN Algorithm

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The construction of municipal road engineering is a complex system engineering, and its internal components are interconnected and mutually restricted, and the relationship is intricate. The quality of its construction plan directly affects the realization of the project’s quality, safety, environment, progress, cost, and other goals, and the project construction plan occupies an important position in the construction of the project. The selection of construction plans for municipal road projects involves a wide range of areas. According to the characteristics of specific municipal road engineering projects, it is very important to establish a scientific construction scheme intelligent generation model and select the optimal construction scheme suitable for the project from many feasible construction schemes, which has very important theoretical research value and practical application value. After analyzing the knowledge characteristics of road construction technology and the content of road construction schemes, this study decomposes the knowledge of road construction schemes into two parts: case characteristics and solutions. Then, according to the needs of case retrieval technology, the data storage form of each subdivision index is proposed and the value range is explained, and a complete structure form of the road construction scheme case database is formed. Combined with actual engineering cases, the feasibility and applicability of the intelligent generation method of the road construction scheme based on the KNN algorithm is confirmed, which provides a new idea for the automation of road construction scheme preparation and the improvement of the scheme application effect.

1. Introduction

With the progress of science and technology and the rapid development of social economy, the construction organization method of modern construction projects has become a complicated activity. A slight mistake in the decision-making in modern construction will cause immeasurable consequences, mainly because a large part of the construction decision-making is unique, and the requirements for its success rate are relatively high. In recent years, my country's construction engineering quality, safety, and environmental protection accidents have occurred frequently, and “short-lived projects” and “short-lived buildings” have frequently appeared. The main reason for the problem is that in the process of optimizing the construction plan of the construction organization design, the organization and planning of the plan objectives such as cost, construction period, quality, safety, and environmental protection are unreasonable, and the control of the objectives during the implementation of the construction plan is not enough. In order to realize the optimization of the construction plan, it is only to save costs and improve the
progress of the construction, without forming a balance of indicators such as construction period, quality, environmental protection, safety, and cost; blindly pursue the construction period and cost, so that the quality, safety, and environmental protection of the project fail to pass. When comparing and selecting construction plans, it is not possible to track a single target or several targets, but to think about the goals of construction period, quality, cost, safety, and environmental protection in a balanced manner, because the enterprise obtains the project through the optimization of the construction plan of the project. Profit maximization is a vital part of engineering construction organization [1–5].

To sum up, with the continuous and rapid growth of traffic flow, there is still a demand in the field of road construction in my country. Considering the current problems of increasing traffic pressure and the need to optimize the road structure, my country should carefully carry out road planning and design, improve the road structure, focus on greening, informatization, and intelligence in the process of road construction and strive to become a traffic power. In addition, in the 70 years after the birth of the computer, the related science and technology has developed rapidly, and it has been widely used in various fields of human social production and has produced great results. Compared with other industries, the application of computer technology in the field of road engineering construction is not mature, especially in engineering information transmission, engineering planning, and engineering construction guidance. [6–8] Combining computer technology to develop a related engineering information system is a feasible and practical way to explore the development of road engineering construction. Among them, BIM (Building Information Modeling) and other technologies are often used as the supporting technology of various engineering information systems to provide great help for industrial upgrading due to their advantages of massive engineering information, scheme integration, and 3D visualization viewing mode. For more than ten years, the civil engineering industry has been rapidly informatized through information and communication technology in just a few years and finally realized the digital delivery and life-cycle information sharing system from design, construction to operation, and maintenance stages. As the road construction plan is an indispensable guiding document for each road project, its traditional preparation method has a large room for transformation. In line with national policies and industry development trends, this paper studies intelligent technology for generating road construction plans based on the principles of traditional experience programming.

2. Related Work

A series of studies on the intelligentization of construction schemes were carried out earlier in foreign countries. In 1983, Janet Kolodner et al. developed the first case-based reasoning system CYRUS with the “Dynamic Memory” model proposed by Schank. It marks the breakthrough of purely theoretical research on intelligence and has gradually become a technology that can solve practical problems and has been applied in many fields. On the basis of the CYRUS system, researchers have developed a number of well-known case-based reasoning systems in the fields of law, medicine, and cooking, realizing some simple applications of case reasoning, such as MEDIATOR developed by Kolodner and Janet in 1989. System, one of the first case-based problem-solving programs, uses case-based reasoning to solve 10 different tasks involved in its problem. The term “Case-based Reasoning” was first used by Kolodner et al. in 1985, which laid the foundation for the establishment of an intelligent conceptual system of construction plans. Subsequently, the concept of the intelligent construction scheme has received extensive attention, and some international conferences on the theme of an intelligent construction scheme have been held for many years. At this time, scholars in Eurasia and other regions have gradually carried out intelligent research and applied it to a wider field. Kahn developed a case-based system, ProtolsIS, that correctly classified 84% of medical imaging examination requirements, successfully applying a case-based reasoning system to selected areas of diagnostic imaging procedures. At the same time, uncertainty theory and many artificial intelligence methods have also been widely used in the research of intelligent concept of construction plan, and the technology of intelligent concept of construction plan has been further developed and matured and has been used more for solving practical problems. Fathi–Torbaghan proposes a fuzzy logic-based diagnostic decision support expert system (MEDUSA) to handle the representation of uncertain and imprecise knowledge through fuzzy sets and fuzzy relations in target case reasoning. Reategui proposes an approach to integrate case-based reasoning and neural networks (NNs) in diagnostic systems. The neural network is used to predict the target, and the intelligent concept module of the construction plan is used to find the historical cases that are closest to the prediction results. The NN-intelligent model has been used to develop a congenital heart disease (CHD) diagnosis system, and a relatively accurate calculation value has been obtained. In 1997, Kraslawski proposed an adaptive method based on rough sets and applied it to the field of non-numerical parameter determination in equipment design. Applying rough sets to case matching is the most difficult and an important step to successfully use intelligent systems. In 1999, Bartlmoe proposed an integrated framework for data mining and knowledge management, using the method of case base reasoning to improve the knowledge-intensive and weakly structured process of data mining and showed how knowledge management can complement data mining. Babbar–Sebens proposed a new case-based micro-interactive genetic algorithm interactive optimization algorithm that uses case-based storage and case-based reasoning to manage the effects of nonstationarity in decision-maker preferences during the search process, and does not affect the performance of the search algorithm. Kwon developed a model based on case reasoning and genetic algorithms to predict the management and maintenance costs of aging buildings. Experiments were carried out on 20 validation datasets, and the model was validated with an average absolute error rate of about 18% for simulation-adjusted costs.
with 90% as the similarity criterion. It can be seen from the above research that the current construction scheme intelligent technology has been widely used in all walks of life, and the practical application of construction scheme intelligent technology is often combined with computing technology to build a complete information system. In the field of engineering, construction plan intelligence is often used in cost calculation, risk judgment, etc., but it is rarely used in the preparation of construction plans. This paper intends to build a road construction plan generation system based on case-based reasoning research [9–15].

3. Construction of Case Library of the Municipal Road Construction Scheme

The construction of a case library is a prerequisite for the operation of an intelligent system of construction schemes. A clear and concise structure of the case library is also an important direction to improve the efficiency of scheme generation and ensure quality. According to the meaning of program knowledge, each case in the road construction program case library can be divided into two parts: case feature attributes and solutions. The selection of case feature attributes directly affects the efficiency of case retrieval and the reasonableness of the output results. The standardized solution structure can standardize the expression of output knowledge and use the storage and reuse of solutions. In this chapter, through the analysis of the road construction method and the content of the construction plan, combined with the actual relevant norms and clauses, the relevant factors of the plan preparation are listed through the principle of the analytic hierarchy process, and the characteristic attributes of multiple cases are selected and the corresponding value range is found. Finally, according to the data characteristics of the road construction scheme, it is proposed to use the binary method to represent and store a single case and complete the theoretical construction of the road construction scheme case library.

3.1. Municipal Road Construction Technology and Program Content

3.1.1. Municipal Road Construction Technology. The general structure of the road is shown in Figure 1. From top to bottom, it mainly includes the following parts, including surface layer, base layer, cushion layer, and roadbed.

Surface layer: as the surface of the road, the surface layer directly contacts the traffic and is greatly affected by precipitation and temperature. In order to ensure the normal use function, it must have good stability and durability, including an anti-wear surface layer and 1 to 2 layers of main surface layers to maintain strength.

Base layer: the force transmission layer under the surface layer and above the cushion layer is less affected by the seepage of the surface layer and groundwater.

Cushion: the transition layer between the base layer and the subgrade is in terms of temperature and water insulation. This layer should be installed when the soil subgrade is in a bad state such as dampness and frost heave.

Subgrade: Subgrade is the foundation supporting the rest of the road structure. It also requires greater strength, stability, and durability and is greatly affected by natural conditions such as groundwater, climate, and temperature. The amount of roadbed engineering is large, and its scope of operation involves the road along the road, which consumes a lot of labor and capital, and the quality of the roadbed directly affects the normal construction, follow-up maintenance cost, and use effect of the roadbed project. In road construction, the main tasks with large amount of works, strong technicality, and difficult construction are roadbed
and pavement construction. This section summarizes the commonly used construction techniques of the two as follows:

1. Excavation and filling scheme for soil subgrade.

   In the selection of earthwork excavation and the filling scheme, in addition to considering natural conditions and construction machinery, it is also necessary to fully consider the utilization efficiency of excavation and filling earthwork to reduce the amount of engineering. The commonly used methods are shown in Table 1.

| Method name          | Construction methods                                                                 | Features                                                                 |
|----------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Soil subgrade        | Layered filling                                                                      | The required compaction and stability can be obtained separately for each layer of soil. It is suitable for filling deep valleys, steep slopes and ponds with large height and small horizontal area. |
| filling              | Vertical filling method                                                              |                                                                          |
|                      | Mixed fill method                                                                    |                                                                          |
| Lateral full-width   | After the subsoil is filled vertically, the upper soil is filled horizontally in layers. |                                                                          |
| excavation method    |                                                                                      |                                                                          |
| Soil cutting         | Vertical excavation                                                                  |                                                                          |
| excavation           |                                                                                      |                                                                          |
|                     | Mixed method                                                                          |                                                                          |

2. Blasting plan for stone subgrade

   Excavation of stone subgrade for mountain roads is usually the main engineering quantity of the project. Using the blasting method can quickly improve the construction efficiency and save costs and labor. At the same time, the blasting method is also suitable for the excavation of special roadbeds such as frozen soil and swamps. Common excavation methods are shown in Table 2 [17].

In addition, the excavation and filling of the roadbed involves various conditions including earthwork, dirt,
masonry, and their combinations, and the abovementioned construction methods are often used in combination.

3.1.2. Contents of the Road Construction Plan. The road construction plan includes the project overview, the construction method of sub-projects, the resource allocation plan, the project progress plan, and other guidance information required for the entire project from the start of the project to the acceptance. The specific process is shown in Figure 2.

Road construction plans contain information on many different structural features. The relevant content in the project overview is structured information, and the corresponding labels can be found directly; it includes semi-structured information including construction methods, progress plans, mechanical demand plans, labor demand plans, and production facility plans; unstructured information includes construction plans, the schematic diagram of each construction method, and other information. In the process of building a case base, information with a higher degree of structure is easier to store, semi-structured information should be decomposed as much as possible, and unstructured information can only be stored as a whole.

3.2. Research on the Construction of the Municipal Road Case Database. The construction of the municipal road case library should consider the actual structure of the road construction scheme and the use requirements of the intelligent generation system of the construction scheme. A complete intelligent system of the construction plan should have modules such as human-computer interaction interface, case library, case correction, case retrieval, and case maintenance, as shown in Figure 3 [18].

In the whole process of case reasoning, the output construction plan results come directly from the knowledge of the case database or the correction results based on it. According to the characteristics of road construction schemes, finding an appropriate scheme structure decomposition method and reasonably describing case information is of great significance for the subsequent case retrieval efficiency and output scheme quality. The construction of the case library should consider the following two factors. Identification and entry of target case information. The information required for case retrieval is difficult to identify from large paragraphs of the text. The case database should select the representative and practical information of the case and give it a label that is easy to retrieve. The first step of case reasoning is to divide the whole road construction scheme into case feature information and case scheme information and further extract the effective information of the case storage of case information. The cases in the library store the construction method, mechanical and manual configuration, schedule, and other contents. In order to meet the basic functions of information storage, reading, output, and maintenance of the case database, the semi-structured information should be decomposed and stored as much as possible, and the unstructured information should be retained as a whole to maximize the convenience of information use.
3.2.1. Selection of Characteristic Factors of Municipal Road Case Library. The preparation of the program uses various methods in accordance with local conditions and comprehensively according to a variety of practical factors. These related factors are the main components of the case feature information. This section lists a number of factors that can represent the case characteristics of road projects and their corresponding value ranges. Extract the project overview information in the complete construction plan and use the principle of AHP to decompose the main influencing factors of plan preparation into four secondary subsystem factors of project nature, construction conditions, engineering quantity, and construction period according to the actual engineering practice experience and further analyze the factors. Each second-level subsystem constructs three-level specific indicators, and the final subdivided influencing factors are shown in Figure 4 [19].
(1) Engineering Properties. The related factors and values of engineering properties are shown in Figure 5 below.

Road types and road grades refer to our country’s regulations, and according to the requirements of road width, cross-sectional composition, design speed, number of one-way motor vehicle lanes, width of each functional belt, total road width, and partition setting, urban roads are divided into four grades. The highway can be divided into five grades according to the traffic volume and usage task requirements. In the relevant construction technical specifications and quality acceptance specifications of highways and urban roads, the control standards in many aspects are different according to different road types and grades, including properties of subgrade fillers, setting of drainage works, division of borrow and spoil areas, acceptance criteria for subgrade construction quality, strength standards for pavement materials, acceptance criteria for pavement construction quality, and special subgrade treatment plans. Road grades and types are factors that must be considered in the preparation of construction plans.

Design information includes road design speed, lanes, sidewalks, support structures, and other related information. Design information depends on actual needs such as design traffic volume and traffic composition, and it is limited by site conditions and has little impact on the selection of construction methods. This item is suitable for assisting in comparing the similarity between cases.

(2) Construction Conditions. Natural zoning: during the construction process, rainfall and temperature will cause changes in the degree of dryness and wetness of the soil and uneven expansion and special response plans need to be formulated for extreme weather. The dryness and wetness of the same type of subgrade soil are closely related to the difficulty of excavation, strength, and stability after completion. Therefore, the humidity of the subgrade soil and the local climatic conditions have a great influence on the method of excavation, filling, and compaction of the subgrade. The index of natural zoning uses geographic location to distinguish the climatic conditions and humidity conditions in various parts of the country and better represents the above two types of factors at the same time. Using this indicator also reduces the number of case feature attributes and improves retrieval efficiency. According to the “Highway Natural Zoning Standard JTJ 003–86,” the national highway natural areas are divided into three levels, including 7 first-level natural areas, 52 second-level natural areas, and third-level natural areas determined by each province.

Engineering geological conditions: According to Platts classification, soil quality can be divided into 16 grades according to its hardness. The hardness of the soil directly affects the construction method. The soft sand and humus can be excavated with sharp shovels and picks, while the excavation of large rocks is often carried out by blasting. Different grades of soil will have certain differences in parameters such as bulk density and tightening coefficient under natural humidity, and the power of the construction machinery used should also be adjusted accordingly. In addition, the soil along the project is often layered, and various types of soil are often mixed together, which will cause uneven changes in the excavation resistance. Therefore, when constructing the case database, both the hardness of the soil and the complexity of the layering of the soil should be considered at the same time to evaluate the geological conditions of the project [20].

Topography: Topography reflects the construction site conditions that can be provided. The five basic types are shown in Table 3 below. It represents the undulating shape of the construction site surface.

(3) Engineering Volume. The engineering quantity reflects the scale of the engineering project, and the engineering quantity directly affects the choice of the construction method. The engineering quantity information to be considered in the preparation of the road construction plan includes: excavation and filling volume, excavation and filling rock volume, road starting and ending stakes, bridges, tunnels, and box culvert information. Except for the construction of bridges, tunnels, and box culverts, the excavation and filling of earthwork and stonework often occupy the largest engineering volume in road engineering. According to the three types of factors including the starting
and ending stakes of the road, the amount of excavation and filling in the whole section, and the topography and landforms, the degree of concentration of the distribution of excavation and filling works can be inferred, and the excavation and filling method can be basically determined. Due to topographical constraints, bridges, tunnels, box culverts, and other projects often divide roads into multiple sections, thereby changing the division of road construction sections and changing the distribution of engineering volumes, so this type of project starts and ends.

(4) Construction Period. The construction period is an important indicator that affects the profitability of construction enterprises. The indicator that can more accurately reflect the construction time is the number of effective working days, which is also one of the data for calculating the mechanical configuration plan. In addition, more detailed influencing factors such as groundwater level conditions and local precipitation can still be found. Since such influencing factors are partially included in the factors listed above or have little influence on the formulation of the plan, considering such factors in the feature attributes will lead to a decrease in the efficiency of case retrieval [21].

### 3.2.2. Structure of Municipal Road Cases

In view of the characteristics of various types of information and strong ambiguity required for the compilation of road construction plans, the structure of the case database should follow the principles of practicability, abstraction, and simplicity.

Practicality, the content of the engineering construction method part in the road construction scheme case library is directly applied to the target project, so the case library should be completely based on real historical cases and store the actual construction method content, number of machine models, etc.

Abstract: The preparation of road construction plans is affected by many fuzzy factors such as engineering geological conditions, soil quality, climate, topography, and landforms where the project is located. Such factors are often recorded in popular descriptive texts in the construction plan. Applicability, in the case database, it needs to be stored in an abstract way as data that is accurate and can fully represent the original text description to ensure the accuracy of case retrieval;

Simplification, the accumulation of the amount of information stored in the case library gradually increases over time, which puts forward higher requirements for the hardware facilities of the case library. At the same time, a large amount of textual information in the original scheme often contains a lot of redundant information, which occupies the space of the case library and the actual utilization rate is small. Therefore, the relevant texts should be simplified as much as possible to extract valuable information.

In the two parts of the complete case, the multiple characteristic attributes of the case determine its own nature. As the source of the similarity calculation data between cases in the construction plan intelligent technology, its value forms are various. When the data storage method is a numerical value or a fixed text, it is most conducive to the calculation of similarity between cases. After the case solution is revised and put into use, in order to facilitate practical use, its data storage method should be standardized into the process and construction method of sub-item projects, and the construction method is mainly in the form of a long text. According to the above two types of requirements, combined with the characteristics of road construction scheme information, the following structured representation method is proposed. The feature attributes, construction methods, and corresponding procedures in a complete case are represented in the form of a two-tuple: case=({features, program}), and the entire case library is simply denoted as $C=\{F, P\}$.

#### (1) Case: The set of all cases in the entire case base is expressed as $C=\{C_0, C_1, C_2, C_n, \ldots, C_m\}$, $i \in (0, n)$, where $n$ is the number of all original cases. $C_i$ represents the $i$th existing case, and each case contains two elements of $F$ and $P$. Among them, $C_0$ represents the target case, and its construction method $P$ is empty before the case retrieval. After the final plan is completed according to the intelligent reasoning in this paper, the overall copy of $C_0$ is recorded as $C_{n+1}$ and all data in $C_0$ is cleared. [22].

#### (2) Features: $F=\{F_1, F_2, F_3, F_n, \ldots, F_m\}$, $i \in (1, m)$, $m$ is the number of all feature attribute categories, representing the set of all feature attributes for a single case. $F_i$ represents the $i$th type of feature attribute. Considering the hierarchical nature of the feature attribute, a certain type of feature attribute contains multiple specific attribute values, then $F_i=\{F_{i1}, F_{i2}, F_{i3}, F_{ip}, \ldots, F_{ig}\}$, $j \in (1, g)$, $g$ is the number of specific attributes included in a certain type of attribute. The form of the value of a specific attribute in $F_i$ can includes: clear symbols, clear numbers, interval numbers, fuzzy linguistic variables, random variables, and texts. The relevant attributes in the road construction scheme case library are generally

| Basic terrain | Feature |
|--------------|---------|
| Mountain     | Above 500 meters above sea level, deep valleys and steep slopes |
| Plain        | Below 200 meters above sea level, flat and broad |
| Plateau      | Above 1000 meters above sea level, the undulations are not large, and the edges are steep |
| Hills        | The altitude is above 200 meters and below 500 meters, the slope is gentle, and the terrain height difference is generally less than 200 meters |
| Basin        | Low in the middle, high around |

Table 3: Five basic topographic features.
recorded in the form of text paragraphs or numerical values.

(3) Program: \( P = \{ P_1, P_2, P_3, \ldots, P_h \}, i \in (1, h), h \) is the number of sub-projects, safety and environmental protection scheme, and mechanical configuration of the entire construction scheme. The sum of the number of sections such as the plan and the number of construction sections. \( P_i \) stores the \( i \)th sub-project, mechanical configuration plan, progress plan, and other related content. When representing the construction method of sub-projects, since \( P_i \) contains a variety of process steps, then \( P_i = \{ P_{i1}, P_{i2}, P_{i3}, P_{ij}, \ldots, P_{io} \}, j \in (1, o) \), \( o \) is the corresponding chapter include the number of specific process steps. \( P_{ij} \) represents the name of each process step and stores the descriptive text of the specific operation. When representing the mechanical configuration plan, \( o \) is the total number of required mechanical types, \( P_{ij} \) represents each mechanical model, and the specific required number is stored. In particular, when expressing a schedule, \( P_i \) is in the form of a tuple. The name of the tuple represents the number of each construction section. In the value of the tuple, the starting and ending stakes of the section, the starting and ending dates of the section, and the total amount of excavation and filling works (m³) of the section are stored in a fixed order at the same time, separated by fixed symbols, such as "K11 + 100-K21 + 500, 2010/1/1-2010/4/1, 12345," if the engineering quantity information in this section is missing, it will be replaced by a space. \( o \) is the number of processes in the construction section, \( P_o \) represents the name of a process, and the start and end dates of the process are stored in the form of strings [23].

According to the above structure, a single historical case can be structured and stored in the following way, as shown in Table 4.

Most of the solutions of the case are semi-structured information, and it is necessary to further deepen the process splitting of each sub-item project. The intelligent technology generation scheme of the construction scheme has a great dependence on the quality of the cases in the case database. In order to achieve a better retrieval effect, ideally, the selected original cases should meet the requirements of various grades of roads and projects of various scales. Most of the various situations in which conditions such as secondary divisions are combined with each other, it is recommended that various construction companies collect 85 completed typical cases in the past 5 years, so that they cover large, medium, and small-scale highway projects in the target project province and nearby provinces and ensure that the basic chapters of each plan are complete, so as to build road construction plan cases library.

### 4. Intelligent Generation Model of the Road Construction Scheme Based on the KNN Algorithm

While using the common KNN algorithm to obtain the construction method of the target project, it also uses the influence of the fuzziness of the feature attributes to obtain better retrieval results. Then, based on the retrieval results to supplement the schedule plan and the generation method of the mechanical configuration plan, a relatively complete intelligent generation model of the road construction scheme is proposed.

#### 4.1. Most Liked Case Retrieval Model Based on the KNN Algorithm

**4.1.1. Case Similarity Calculation Research.** After constructing the initial case database, the characteristic value of the target problem is input into the intelligent system, and the solution to the target problem is obtained through the main steps of case retrieval, case reuse, case correction, and case storage according to the characteristic. Case retrieval determines the main content of the solution, which is the basis for subsequent revisions to determine the final solution. The step of case retrieval is based on the idea of “similar problems have similar solutions,” so the key issue of case retrieval is the calculation of “similarity” between cases. The KNN algorithm is one of the most widely applicable methods in the calculation of similarity. KNN classification algorithm is one of the classic algorithms in the field of machine learning. It was originally proposed by Fix and Hodges in the 1950s as a nonparametric statistical learning method based on sample instances. The principle of the algorithm is to calculate the \( k \) adjacent cases with the highest similarity to the problem in the case base according to the characteristics of the target problem, as shown in Figure 6, for example, for a two-dimensional case set containing only 2 feature attributes, \( k = 3 \), and by finding the 3 cases in the case library with the closest distance to the features of the new problem (green square in the figure), we can obtain by finding the three points in the circle, it can be determined that the problem is closer to a class of problems represented by triangles, and a solution to the new problem is formulated based on the historical solutions of these three points.

The main calculation steps of the KNN algorithm are as follows: (1) Construct a sample set: \( D = \{(x_{ij}, y_i), i = 1, 2, \ldots, \)
m; j = 1, 2, . . . , n}; where D is n. The sample point set in the dimensional space \( R^d \); the sample \( x_i \) is represented as a feature vector \( x_i = [x_{i1}, x_{i2}, \ldots, x_{im}, y_i] \), and \( x_{ij} \) can represent the \( j \)th feature value of the sample \( x_i \). Divide the samples into training set \( D \) and test set \( D_1 \); (2) Preliminarily determine the initial value of the number of adjacent cases \( k \); (3) Select a distance function (here is Euclidean distance), the similarity calculation function is as the following formula:

\[
\begin{align*}
    d(x_{pj}, x_{qj}) &= \sqrt{(x_{pj} - x_{qj})^2}, \\
    d(x_p, x_q) &= \sum_{j=1}^{m} w_j \times d(x_{pj}, x_{qj}), \quad (1) \\
    \text{sim}_{pq} &= 1 - d(x_{pj}, x_{qj}).
\end{align*}
\]

In formula (1), \( d(x_{pj}, x_{qj}) \), \( d(x_p, x_q) \) are two samples \( x_p, x_q \) and the \( j \)th eigenvalue distance and inter-case distance of \( x_q \), respectively; \( w \) is the attribute \( j \) weight, satisfying \( \sum w_j = 1 \); 
(4) Use the training set data to optimize the number of adjacent cases \( k \). When the label value in the sample set is a discrete variable, its function is \( F: R^n \rightarrow v_i, V = \{ v_1, \ldots, v_s \}, v_i \in V \); for the case where the label value in the sample set is continuous and discrete. When the category (value) of the sample \( x_i \) to be judged is shown in the following formulas (2) and (3):

\[
F(x_i) = \begin{cases} 
\arg\max_{k} \sum_{i=1}^{k} \delta(v, f(x_i), \text{sim}_{sk} > \lambda \land \text{Numsim}_{sk} \leq k), \\
\sum_{i=1}^{k} w_i \times \text{sim}_{sk} > \lambda \land \text{Numsim}_{sk} \leq k),
\end{cases}
\]

\[
Q = \min |y_i - F(x_i)|. \quad (2)
\]

In formula (2), \( w_i \) is the weight of sample \( i \), which indicates the degree of influence of the case on the target case; \( \delta(a, b) \) is the generic judgment function, when \( a = b \), \( \delta(a, b) = 1 \); otherwise, \( \delta(a, b) = 0 \); \( w_i \) is the weight of the retrieval case, satisfying \( \sum w_i = 1 \). Using the multi-fold cross-validation method, the optimal retrieval model of the minimum difference between the predicted value and the sample value is obtained. \( \text{sim}_{sk} \) is the similarity value calculated based on the similarity function or distance function, \( \lambda \) is the threshold of similarity, and \( k \) is the set value of the number of adjacent cases. (5) Determine the predicted value of the sample to be classified according to the sample value of the adjacent case \( k \). After a new sample to be judged \( x_q \) is given, \( x_0 \)

\[
x_t = \{ x_j | \text{rank(\text{sim}_{ij})}, t = 1, 2, \ldots, k \}. \quad (4)
\]
According to formula (4), the predicted value $F(xq)'k$ of the sample to be classified can be calculated. After obtaining the $k$ most similar cases of the target project according to the above process, you can screen and modify the final construction method based on this basis and continue to pass the process, construction method, and other information to the subsequent schedule generation module and mechanical configuration calculation. Modules generate complete solutions.

The principle of the KNN algorithm is relatively simple and easy to understand and easy to operate, and it is widely applicable to the solution of multi-feature problems. The calculation steps for solving problems with more feature attribute dimensions are the same as before, only the number of calculations is increased. When solving new problems with characteristic attribute values that are quite different from all historical cases, multiple sets of different solutions can be obtained under the premise of making full use of historical knowledge, and the solutions to the relatively independent problems can be obtained through manual correction. Therefore, the method also has good learning ability.

4.1.2. Weight Optimization Algorithm Based on 2D Cloud Reasoning Different feature attributes have different influences on the compilation of road construction plans and assigning corresponding weights according to their different degrees of influence will make the calculation results close to the actual needs. Table 5 shows the common feature attribute weight calculation methods and characteristics in domestic and foreign research.

| Method category                              | Calculation                                                                 | Advantages and disadvantages                                                                 | Example                                                                 |
|----------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Subjective empowerment method                | The weights are obtained by industry experts through analysis and processing based on experience. | Relying on subjective experience, the relative size of the weights is less likely to be wrong, but it cannot obtain high numerical accuracy. | Expert scoring method, analytic hierarchy process, etc.                |
| Objective empowerment                        | According to the relationship and characteristics contained in a large amount of data in the case database, the weight is calculated from the actual value. | The weights with finer precision can be obtained without relying on human subjective experience, but the quality requirements of the original data are high, and the relative size of the weights cannot be guaranteed to be correct. | Rough set theory method, weight method, dispersion method, etc.        |
| Combination of subjective and objective      | Combining the results of the subjective and objective weighting methods in a certain proportion or modifying the results of a single subjective or objective method by another. | While ensuring the relative size of the weights is correct, the influence of subjective factors is weakened to a certain extent. A more reasonable fusion method needs to be further explored. | —                                                                      |
| Artificial intelligence method               | According to the characteristics of the characteristic attributes, use various intelligent algorithms that imitate the way of human thinking or the algorithms obtained by modeling and summarizing certain types of practical problems to calculate the attribute weights. | The weight calculation model is further complicated, and the diversified artificial intelligence technology also provides a more suitable calculation model for the weight calculation in various fields, making the calculation results more objective and accurate. | Genetic algorithm, neural network, ant colony algorithm, particle swarm algorithm, etc. |

According to formula (4), the predicted value $F(xq)'k$ of the sample to be classified can be calculated. After obtaining the $k$ most similar cases of the target project according to the above process, you can screen and modify the final construction method based on this basis and continue to pass the process, construction method, and other information to the subsequent schedule generation module and mechanical configuration calculation. Modules generate complete solutions.

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In the initial construction of the case database of road engineering construction plans, a small number of typical cases are often entered into the database. The small number of cases cannot support the requirements of the objective weighting method, and the subjective weighting method is a relatively better choice. However, in the calculation process of the traditional subjective weighting method, the ambiguity of the attribute input value is also ignored. The fuzzy attributes such as “engineering geological conditions,” “natural divisions,” and "topography" in the feature attributes of the case in this paper can be quantified into specific values by compiling standard evaluation rules, but it is difficult to avoid subjective judgments. Error results in a greater risk of error in this type of fuzzy attribute value. According to general engineering experience, this type of attribute happens to be the main factor affecting the formulation of the plan, and it occupies a large weight in the similarity calculation. In addition, there are certain errors in the characteristic attribute values such as the amount of cut and fill of earthwork and road length, resulting in a certain ambiguity in the input values of the characteristic attributes involved in this paper. In order to weaken the influence of the potential error of attribute value on the calculation of the similarity of the case, this paper adopts the subjective weighting method in the calculation of the similarity of the road construction scheme and proposes a weight optimization algorithm based on two-dimensional cloud reasoning to solve this kind of problem, that is, the final weight of each feature attribute $= f$ (the fuzzy degree of the input value, the original weight).

4.2. Case Analysis

4.2.1. Project Overview

(1) Project overview: There are 29 special subgrade treatments and 12 retaining walls along the whole
(1) Determination of characteristic attribute values: According to the basic information of the project and various survey reports, complete the scoring of the engineering geological conditions of the project according to Table 7 and take the average value. The specific results are shown in Table 6 below.

### Table 6: Specific overview of the expressway project.

| Serial number | Basic information                  | Value       |
|---------------|------------------------------------|-------------|
| 1             | Construction period                | 24 months   |
| 2             | Road type                          | Highway     |
| 3             | Road class                         | Level I     |
| 4             | Project budget                     | 302 million yuan |
| 5             | Start and end station number       | K32 + 200-K41 + 500 |
| 6             | Design width range (m)             | 12.25-24.5  |
| 7             | Number of lanes                    |             |
| 8             | One-way or two-way                 | Two-way     |
| 9             | Quantity of earthwork excavation (10,000 m³) | 143.5 |
| 10            | Quantity of earth-filling and stonework (10,000 m³) | 135.4 |
| 11            | Design life                        | 100         |
| 12            | Pavement type                      | Asphalt road|

### Table 7: The value of the characteristic attribute of the expressway.

| Feature attribute categories | Body type | Storage form | Value       |
|------------------------------|-----------|--------------|-------------|
| Engineering properties (F)   | Road class | Character shin | “Tier 1”    |
| Introduction to road design  |           | Character shin | ...         |
| Start and end station number | Character shin | K32 + 200-K41 + 500 |
| Multi-segment bridge starting and ending stakes | K34 + 300-K35 + 890; K39 + 200-K40 + 790 |
| Multi-segment tunnel start and end stakes | String | — |
| Multi-section box culvert starting and ending stakes | String | — |
| Cut volume (m³) | Floating point | 1435000 |
| Excavation volume (m³) | Floating point | — |
| Filling volume (m³) | Floating point | 13.54 |
| Filling volume (m²) | Floating point | — |
| Work volume (F)               |           |              |             |
| Construction conditions (F)   | Topography | Fu Shen     | Mountain    |
| Natural division              | String    | V1_         |             |
| Engineering geology           | Floating point | 0.1         |             |
| Duration (F)                  | Project plan start and end dates | Integer | March 10, 2017–March 10, 2019 |
| Effective working days per month | Integer | 26         |             |

The subgrade filling and excavation section is about 6.3 km, and the design speed is 80 km/h. The specific basic overview is shown in Table 6 below, including two bridges with station numbers K34 + 300-K35 + 890 and K39 + 200-K40 + 790.

(2) Topography: The terrain in this study is a transitional section from mountains to hills. The terrain conditions are complex, and it belongs to the type of tectonic erosion landform. The water network is developed, and the entire terrain decreases gradually from the northeast to the southwest in an inverted shingle pattern.

(3) Engineering geology: The exposed bedrock in the project area is mainly sandstone and mudstone. The geological structure of this contract section is simple, the integrity of the rock mass is good, but the rock quality is poor. The main adverse geological phenomena in the contract section are small slumps and splintering. The special subgrade along the line is mainly a weak subgrade formed by silty clay deposited on the slope. The maximum thickness of the soft subgrade is about 9.8 m, generally 3–6 m.

(4) Hydrometeorology: This contract section belongs to the subtropical monsoon climate type, with an annual rainfall of about 1100 mm, concentrated in July to September. Strong winds often occur in the alternate stages of spring, summer, autumn, and winter, with an average wind speed of 1.2–1.5 m/s for many years. Frost occurs throughout the year, generally 60 days. This contract section belongs to the Jialing river water system, there are many streams in the project, and the secondary water network is densely covered.

4.2.2. Construction Plan Generation Based on KNN
### Table 8: Comparison of characteristic parameters of similar road projects.

| Related information               | This project | No. 26     | No. 20     | No. 7     |
|-----------------------------------|-------------|------------|------------|-----------|
| Case name                         | —           | —          | —          | —         |
| Similarity                        | —           | 0.919      | 0.814      | 0.771     |
| Road class                        | High speed  | High speed | High speed | High speed|
| Road length (km)                  | 6.12        | 6.126      | 9.51       | 5.802     |
| Bridge length (km)                | 3.18        | 5.041      | 1.2        | 2.515     |
| Tunnel length (km)                | 0           | 0          | 0          | 1.319     |
| Box culvert length (km)           | 0           | 0.528      | 0.856      | 1.03      |
| Total excavation volume (10,000 m³) | 143.5    | 144.27     | 55.78      | 82.229    |
| Total fill volume (10,000 m³)     | —           | —          | 113.109    | 73.204    |
| Total volume of rock fill (10,000 m³) | —      | —          | 88.843     | 64.876    |
| Topography                        | Mountain    | Mountain   | Mountain   | Hills     |
| Natural division                  | V1          | V1         | V2         | V2        |
| Engineering geology               | 0.35        | 0.45       | 0.55       | 0.5       |
| Total valid working days (days)   | 450         | 600        | 500        | 600       |

### Table 9: Intelligent generation scheme construction method part.

| Sub-project, mechanical configuration plan name | Process, machine name, etc. Pₗ | Content                                                                                                                                 |
|------------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Construction preparations (P1)                  | Preparation of construction technical documents | (1) Drawing review. (2) Management requirements. (3) Technical disclosure. Setting requirements for project department, mixing station, steel bar processing plant, construction access road, etc. |
|                                                 | Engineering measurement        |                                                                                                                                 |
|                                                 | Construction site layout       |                                                                                                                                 |
| Process test (P2)                               | Test monitoring indicators     | (1) Test items. (2) Measurement data requirements. (3) Measurement method.                                                        |
|                                                 | Construction of the test section| (1) Filling test construction. (2) Earth-rock filling test construction. (3) Compaction quality inspection. Earthwork: (1) Compaction quality inspection. (2) Compaction settlement difference detection method. |
| Subgrade filling (P3)                           | Substrate treatment            | (1) Removal of base vegetation and backfilling of potholes. (2) Loosening and rolling of base soil. (3) Base test.                  |
|                                                 | Layered paving                 | Earthwork: (1) Fully vertical and horizontal layered filling. (2) Construction standards for inclined filling. Earth and stonework: Horizontal filling layer-by-layer. |
|                                                 | Leveling                       | The pusher is used for initial leveling, and the leveling is manually coordinated with the grader. The moisture content is controlled to 2%. Filling: (1) Rolling parameters are according to the requirements of the test section. |
|                                                 | Rolling                        | Earthwork: (1) Inspection of packing. (2) Layered compaction. (3) Compaction quality inspection. Earthwork: (1) Compaction quality inspection. (2) Compaction settlement difference detection method. |
|                                                 | Compaction and fill level      | Inspection.                                                                                                                                 |
|                                                 | inspection                     |                                                                                                                                 |
| Subgrade excavation (P4)                       | Construction lofting           | (1) Check the geological conditions. (2) Stake out the boundary of the excavation.                                             |
|                                                 | Layered excavation             | Earthwork: (1) Excavation from top to bottom, requirements for deep excavation sections. (2) Requirements for zero-filled sections. |
|                                                 | Loading and transportation     | Stonework: (1) Excavate mechanically as much as possible and use smooth blasting and small charge for the rest controlled blasting. (2) Blasting method process and requirements. |
|                                                 | Clear the bottom and brush the slope | That meets the requirements of subgrade filling shall be transported to the fill, and the rest shall be transported to the spoil site. After mechanically brushing the slope, the square grid method is manually used to control the flatness. |
| Shallow excavation of roadbed (P5)              | Replacement with 1.2 m thick sand and gravel. | When it is shallow, excavate it directly and replace it with gravel soil or pebble gravel soil. |
|                                                  | Soft base                      | Laying the sheds and set up ramps during construction. (2) Grade 5 frame anchor protection for the slope subgrade. |
| Special roadbed treatment                       | High fill embankment           | Set up a transition section not less than 10m.                                                                                     |
|                                                  | Deep digging                   |                                                                                                                                 |
|                                                  | Fill and cut junction          |                                                                                                                                     |
been improved. The quality and the level of detail have also been greatly improved, and the method selection, construction organization, and quality control indicators have been greatly improved, and the times. Based on the original scheme, the construction scheme is based on the updated and more abundant cases of pavement engineering construction methods. The difficulty of management, and the increasing complexity of various management information, the increasing difficulty of management, and the increasing complexity of corresponding construction plans. This study starts from the principle that road construction scheme preparation relies on knowledge reuse, accumulates experience in packaging engineering by building a structured road construction scheme case library and uses the KNN algorithm as a case retrieval model to quickly output the construction scheme of the target project and obtain more reasonable results. Case similarity meter is then used in order to make the output scheme get a better application effect and add new knowledge to the case base.

Data Availability

The dataset is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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5. Conclusion

Urban roads are an important part of the city. The management of urban roads is managed and maintained by the city administration, including road ancillary facilities such as roadways, sidewalks, bridges, tunnels, and footpath boards. Municipal roads are the pulse of the city and the foundation of the city’s foundation. The construction of municipal roads in a city is one of the most important factors in evaluating the development of a city. The rapid development of modern urban construction, the continuous expansion, reconstruction, and new construction of urban roads, the continuous expansion and expansion of the road network scale and various management information, the increasing difficulty of management, and the increasing complexity of corresponding construction plans. This study starts from the principle that road construction scheme preparation relies on knowledge reuse, accumulates experience in packaging engineering by building a structured road construction scheme case library and uses the KNN algorithm as a case retrieval model to quickly output the construction scheme of the target project and obtain more reasonable results. Case similarity meter is then used in order to make the output

| Sub-project, mechanical configuration plan name | Process, machine name, etc. $P_{ij}$ | Content |
|-------------------------------------------------|-------------------------------------|---------|
| Hot hammer asphalt pavement (P6)                | Construction preparation            | Site cleaning and construction lofting. |
|                                                 | Asphalt mixture mixing              | Factory mixing method and heating temperature requirements. |
|                                                 | Transportation                      | Shipping time and unloading requirements. |
|                                                 | Paving                              | Two paving machines on the lower layer are paving at the same time. A single machine on the upper layer is paving. |
|                                                 | Compaction                          | Initial pressure is light, the recompression is heavy, and the final pressure is light. |
|                                                 | Seam treatment                      | Horizontal seams with flat seams and longitudinal with thermal seams. |

(2) Construction plan output: The initial case database is constructed by collecting more than 40 cases of classic road construction plans. The initial case database is smaller and $k = 3$, and several similar cases are obtained. The comparison of their characteristic parameters is shown in Table 8 below.

With reference to the 3 cases output by the intelligent system and based on the most similar cases, the engineer can prepare the target case plan. The content of the entire construction method is shown in Table 9. Among them, the subgrade construction scheme mainly relies on intelligent technology to obtain and then modify it, and the natural conditions have relatively little influence on the selection of pavement engineering construction methods. The construction method of the intelligently obtained scheme is based on the updated and more abundant cases of the times. Based on the original scheme, the construction method selection, construction organization, and quality control indicators have been greatly improved, and the safety, engineering and other aspects of the new scheme have been improved. The quality and the level of detail have also increased.
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