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The Use of Weighted Euclidean Distance to Provide Assistance in the Selection of Safety Risk Prevention and Control Strategies for Major Railway Projects

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Abstract: A major railway project is a complex, giant system with multi-party participation, one characterized by complex geological conditions, long construction periods and large scale, which leads to an increased likelihood of safety risk events during construction. In order to solve the problem of scientific selection and formulation of safety risk prevention and control strategies for major railway projects, an auxiliary selection method of safety risk prevention and control strategies for major railway projects based on weighted Euclidean distance (WED) is proposed. The relevant ontology is used to conceptualize and formalize the knowledge of safety risks of major railroad projects, and combine the characteristics of major railroad projects; it refers to the prevention and control measures of historical safety risk events associated with major railroad projects, and then constructs the knowledge structure and case base around safety risks of major railroad projects and the circumstances of the case. In determining the comprehensive weights, the G1 method is used to determine the subjective weights, the anti-entropy weight method is used to determine the objective weights and game theory combines the subjective and objective weights. In comparing the array of safety risk prevention and control cases associated with major railway projects, the weighted Euclidean distance is used to calculate the similarity between these cases and the target case, which in turn assists project managers in determining the safety risk prevention and control strategies appropriate for major railway projects. This study takes Landslide No. 1 in the Tunnel A inlet planning area as an example. It utilizes the WED method to assist in selecting safety risk prevention and control strategies for major railway projects, which verifies the method's feasibility. The proposed method enriches the method of the assisted selection of safety risk prevention and control strategies for major railway projects, makes strategy formulation more scientific, has specific reference significance for the formulation of safety risk prevention and control strategies for major railway projects, and promotes the improvement of safety risk prevention and risk control for participating units.

Keywords: major railway project; weighted Euclidean distance (WED); security risk; ontology; game theory

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1. Introduction

Major railway engineering projects generally refer to complex, giant systems with a large scale, complex technology and many participants. Meanwhile, compared with traditional railway projects, major railway projects have the characteristics of complex geological conditions, frequent natural disasters, extra-long construction periods, and a large number of participants [1–4], which makes it challenging to choose and avoid safety risks when they occur quickly, and reduce the impact of risk events. How to efficiently and scientifically select safety risk prevention and control measures has become a considerable challenge for the safe construction of major railway projects. Therefore, in terms of the selection of security risk prevention and control strategies, Yan first used ontology to represent the knowledge of EPC as to general contracting projects and established the corresponding EPC general contracting project risk case database; then, the fuzzy subset was used with the proximity method to reason about the cases [5]. This method introduces the assisted decision-making idea of "normalization of completed project cases—comparison of case proximity—selection and formulation of risk control methods", which innovates the risk control strategy formulation method. He and Li used assisted decision-making for the first time in the formulation of landslide control measures for a slope, and established an assisted decision-making model for slope landslide control measures based on case-based reasoning, thereby using historical slope landslide management cases in the decision-making associated with slope landslide control measures for the Sichuan–Tibet Railway [6]. Shen used BIM technology to establish an intelligent management system for prefabricated buildings to improve the accuracy and scientific nature of safety risk prevention and control strategies in construction [7]. Michalak used a CTR decision support system based on the AHP method for risk management related to railway transport hazards [8]. Jiang proposed a construction safety risk management decision-making method based on ontology and the CBR method which integrated similarity and correlation algorithms to improve the reasoning process. The method is demonstrated with a subway construction project as an example [9], which lays the foundation for the present article to use ontology and weighted Euclidean distance for the auxiliary selection of safety risk prevention and control strategies for major railway projects. Su used the CBR method to establish a case reasoning model for safety accident pre-control and decision-making in the construction industry, provide safety solutions for safety accidents in construction, timely control the impact scope of safety risks, and help safety managers make decisions on preventive measures more effectively [10].

At the same time, due to the lack of geological, meteorological, and hydrological data from periods of construction and the difficulty of obtaining information on some major railway projects, it is necessary to rely on historical engineering data for decision support and guidance after the occurrence of safety risk events [11,12]. If one were to ignore the guiding significance of historical cases and formulate safety risk prevention and control strategies for major railway projects based on experience, it would inevitably lead to the unnecessary waste of resources and the lack of applicability and rationality of the prevention and control measures [6].

In general, the existing studies mainly focus on safety risk management decision-making in housing construction and railway transportation. However, there are a few studies on safety risk prevention and control decision-making in major railway projects, although there is a lack of more objective and scientific quantitative decision-making analysis. Therefore, this article proposes an auxiliary selection study of safety risk prevention and control strategies for major railway projects based on the weighted Euclidean distance (WED) method, which is commonly used in similarity analysis of two elements, with the main focus on the development of prevention and control strategies after the occurrence of safety risks. This method provides a guiding basis for participating units in the formulation of safety risk prevention and control strategies, improves the scientific rationality of selecting safety risk prevention and control strategies for major railway projects, and is significant for the safe construction of major railway projects.

2. Literature Review

2.1. Prevention and Control of Safety Risks in Major Railway Projects

In the field of railway projects, the major railway project is a complex system with multi-party participation, which has the additional characteristics of difficult geological conditions, complex cultural backgrounds, challenging construction environments, a large number of participants, a large scale of the project, a long construction period and a complex engineering structure [4,13,14], which makes the safety risks in the construction process complex and changeable. China has constructed and participated in major railway projects, such as the Haramain High-Speed Railway, Qinghai–Tibet Railway, Yunnan–Tibet Railway, and Lalin Railway. Most of these railway projects have encountered construction safety risks, such as earthquakes, landslides, avalanches, mudslides, and other construction safety risks [15–18]. Some major railway projects cannot be quickly controlled because of the safety risks in the construction of the railway, resulting in severe delays in the construction period, injuries and deaths, a well as other serious consequences.

At the same time, the construction of major railway projects supports the development of the national economy. It establishes a hub for economic and cultural exchanges, so it has become one of the overall goals of major railway engineering construction to ensure safety during the construction of major railway projects, strengthen the early warning of safety risks, reduce the safety risks that occur in the construction, and formulate scientific and reasonable safety risk prevention and control strategies. Zhang constructed an index system for early warning of the construction safety risks of major railway projects in difficult and dangerous mountainous areas from the perspective of the "man–machine–pipe–environment" and established an early warning model for railway construction risk in difficult and dangerous mountainous areas based on extensibility theory to provide early warning of safety risks in major railway engineering construction [19]. Wang proposed a method for the identification of safety risks in major railway projects in complex and challenging areas, one which uses WBS, RBS, and grid management to form a safety risk identification matrix which can intuitively discover the spatial and temporal distribution of safety risk factors, which is helpful in the study of the interaction between risk factors and provides guidance for specifying safety risk prevention and control measures [20]. Based on the identification of four types of disaster risk factors in the construction of the Sichuan–Tibet Railway and the analysis of the impact of risk factors on the engineering structure, Lu finally evaluated the construction safety risks of different types of disasters in the Sichuan–Tibet Railway engineering structure, and proposed management methods including "integration of survey and design", "integration of construction and management", "integration of disaster monitoring", and corresponding risk management and control technical measures [2].

At present, the research on safety risk prevention and control for major railway projects is mainly centered on the identification and analysis of safety risk factors, as well as safety risk prevention and control based on the results of safety risk evaluation associated with the major railway project safety risk prevention and control strategy. The present work seeks to develop this under-researched area, given the need to strengthen the research in this area, and to assist managers in developing safety risk prevention and control strategies.

2.2. Application of the Ontology

Ontology comes from philosophy; it systematically describes the nature of objective things in the world. In other words, ontology is a conceptualized and formalized description of objective things, and its application provides a unified understanding for all parties to the communication. The domain of ontology supports the conceptualization of a certain domain of knowledge, and the efficiency of searching, accumulating, and sharing knowledge will thereby be significantly improved, promoting knowledge sharing [9,21]. In recent years, ontology has been widely used in academia, usually in fields such as architecture [22,23], artificial intelligence (AI) [24,25], and biomedicine [26,27], and with functions such as decision-making [28–30] and knowledge management [31,32].

With the advent of the high-speed development of China's railways and the guidance of the "Transportation Power" strategy, ontology has gradually become used in railway construction [33–35]. In the field of construction safety, ontology is usually used for the sharing, communication, and management of safety knowledge. In this article, an ontology is used to establish a safety risk knowledge structure for major railway projects, a construct which is to be used in the field of safety risk management of major railway projects, to conceptualize further and formalize the domain of knowledge in this field, and to give full play to its knowledge management and decision-making functions. It seeks to assist project managers of railway construction in the formulation of safety risk prevention and control measures. Cao constructed an accident risk ontology and a context ontology, analyzing an accident report based on railway domain knowledge, and established an ensemble evolution model of scenario–risk–accident chain ontology (SRAC), which was applied to risk management and accident response in the field of railway engineering to ensure risk detection and prevention in the construction process [34].

2.3. Weighted Euclidean Distance (WED) Method

The traditional Euclidean distance method is a method used to measure the spatial distance between two vectors [36,37]. The magnitude of its value reflects the degree of similarity between two vectors [38], i.e., the smaller the value of the Euclidean distance, the more similar the two vectors are. In this article, we add weights to the traditional Euclidean distance equation to form the WED method, which can calculate closeness more scientifically and accurately than can the traditional Euclidean distance method [39], improves the accuracy of measuring the spatial distance between two vectors in the structure of the multi-dimensional data space [40], and more accurately reflects the degree of similarity between two vectors. WED is widely used in the fields of data mining, cluster analysis, information point comparison, risk evaluation, and decision making [36,37,41–45]. Tan based an analysis on WED, using it to compare and analyze the salient features of the target for target re-identification [42]. Zhu innovated the use of WED for cluster analysis of information data to improve the probability of cluster analysis success [43]. This article uses this method in the auxiliary selection of safety risk prevention and control measures for major railway projects to determine a more reasonable guiding basis for developing safety risk prevention and control strategies.

The WED method calculates the similarity of feature vectors, and the weight values of different elements depend on the closeness between the corresponding elements; the closer the closeness and the more significant the contribution to the final WED, the greater the weight value [46]. The expression of WED is shown in Equation (1):

$$dist(X,Y) = \sqrt{\sum_{h=1}^{z} \frac{d_h}{D}(x_h - y_h)^2} \quad (1)$$

In Equation (1), $d_h = \frac{\partial}{2}|x_h - y_h|^2$, ∂ is the moderating factor, with a value range of [0, 1]; and $D = \sum_{h=1}^{z} d_h$. It is assumed that x_h represents the row vector of the safety risk event's characteristic attribute matrix and the accident background characteristic attribute vector for the calculated case, and y_h represents the row vector of the safety risk event's characteristic attribute matrix or the target case's accident background characteristic attribute vector.

3. Methods

3.1. Building a Knowledge Structure of Safety Risks in Major Railway Projects

3.1.1. Knowledge Structure of Safety Risks in Major Railway Projects

The project was begun through searching and analyzing in CNKI and Web of Science using Python, examining the aspects of safety risk management of major railway projects, the safety risk accidents of railway projects, the safety risk accident handling measures of railway projects, and so on. It was found that, at present, there are diverse forms involved in the descriptions of safety risk and accident handling measures, and other related contents of the major railway projects do not form a unified mode or terminology, either. The forms are diversified, which affects the sharing and dissemination of safety risk management knowledge and the inability to quickly and accurately provide an empirical basis for preventing and controlling safety risks. At the same time, compared with the traditional railway project, major railway project construction has a long construction period, many participants, a complex construction environment, and other characteristics, and some project managers have a lack of management experience and poor awareness of safety hazards and other issues [47], so the construction of major railway projects is prone to challenges in facing the environment, people, things, management style and other causative factors associated with severe security risk events, in addition to other causal factors [9,20,48,49]. Therefore, there is an urgent need to quickly and accurately propose appropriate safety risk prevention and control measures to control the scope and extent of safety risks [50]. To solve this fundamental problem, it is necessary to conceptualize and formalize the safety risk knowledge associated with major railway projects and form a safety risk knowledge structure by combining the characteristics of major railway projects [9].

This article uses ontology to conceptualize and standardize the knowledge in the field of safety risks associated with major railway projects. It constructs a knowledge structure model of safety risk for major railway projects, which provides a model basis for the subsequent research. The knowledge of the model is divided into explicit knowledge and tacit knowledge, in which the explicit knowledge comes from the "Technical Code for Risk Management of Railway Construction Engineering" [51], safety risk management regulations and policies, and guidelines for major railway projects, in addition to the investigation reports of safety risk accidents associated with major railway projects. The tacit knowledge comes from the experience of construction participants, as well as from experts. After analyzing and combing through the explicit and implicit knowledge relevant to major railway project safety risks, as well as the content needed for the establishment of a knowledge vector and knowledge matrix in the auxiliary selection of safety risk prevention and control strategies for major railway projects, it is found that most of the major railroad project safety risk events are more obviously characterized by the attribute of the "accident background", and the change of the accident background affects the degree of occurrence and the treatment measures taken. The change in the accident's background affects the degree to which risk events occur, and the measures taken to prevent them. Therefore, to subsequently utilize the WED method to carry out the auxiliary selection of safety risk prevention and control strategies for major railroad projects, this article constructs a knowledge structure model for major railway project safety risks from the three elements of "accident background", "risk events", and "prevention and control measures". Moreover, "prevention and control measures" are elements of building a major railway project safety risk knowledge structure model. In the model, the "accident background" element is used to construct the "accident background characteristic attribute" vector; the "risk event" element is used to build the "construction links—safety risk event characteristics and attributes" matrix; through the "prevention and control measures" element the major railway project safety risk prevention and control measures can be developed on a primary basis. Figure 1 shows a knowledge structure for safety risks associated with major railway projects, drawn using Visio2019.

Based on the formation of a knowledge structure for safety risks associated with major railway projects, to rationalize and standardize the content of the structure and meet the requirements of logical conditions, construction site conditions, and ontology, it is necessary to carry out a rationality and standardization test of the knowledge structure [9]. Therefore, this article makes use of the relevant rules and technical specifications of safety risk management and the prevention and control strategies of major railway projects to test it, and after the evaluation and optimization by experts aiming to make the structure more perfect, which is in line with the actual situation of the research on the selection of safety risk prevention and control strategies for railway projects, finally, according to the major railway project safety risk knowledge structure, refining it to form a major railway project safety risk case database.

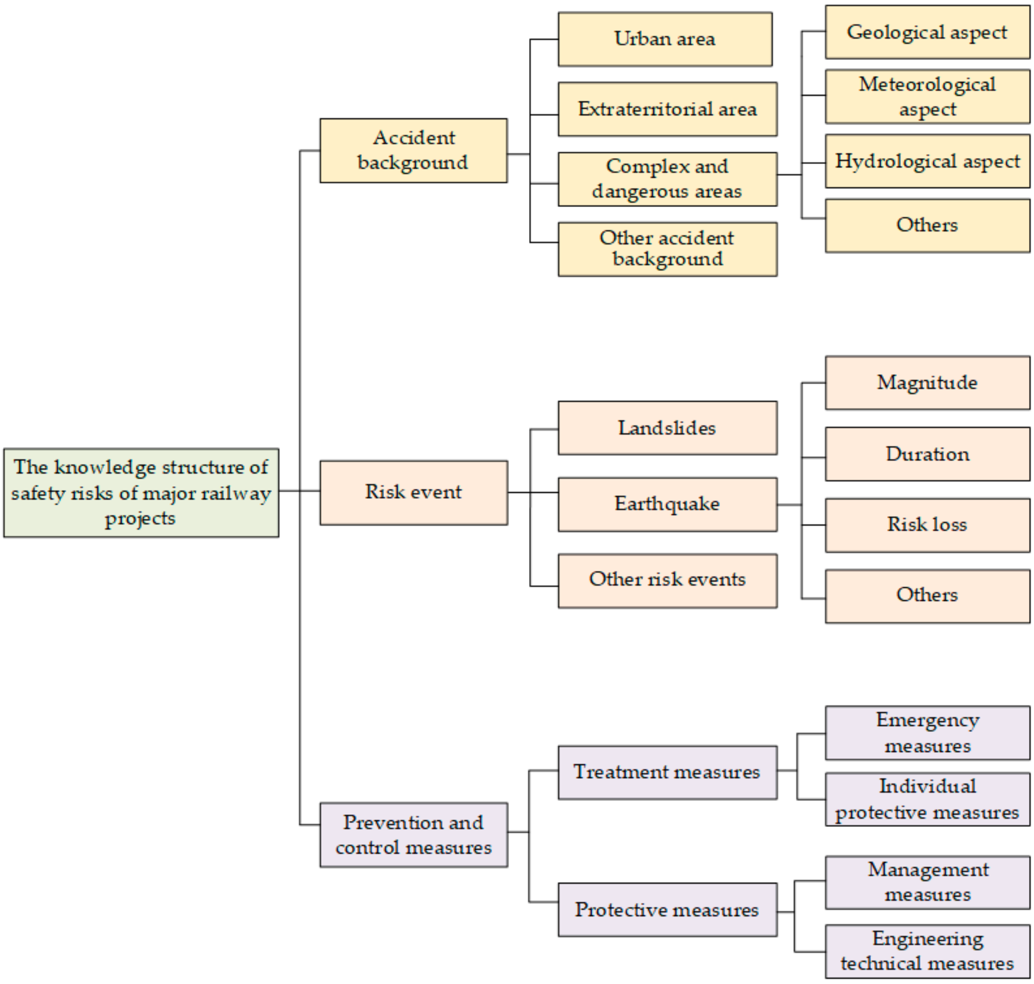

Figure 1. Knowledge structure for safety risks in major railway projects.

3.1.2. Knowledge Vectors and Matrix Creation

Based on the knowledge structure model for safety risks associated with major railway projects, the vector of "accident background characteristic attributes" and the matrix of "construction link—safety risk event characteristic attributes" are formed. The degree of occurrence of characteristic attributes is assigned based on expert opinions.

The "accident background characteristic attributes" vector refers to the vector consisting of the characteristics of geological conditions, meteorological conditions, hydrological conditions, and other characteristics of the accident background of a major railway engineering safety risk event. For the vector of "accident background characteristic attributes" of the safety risk event, suppose the set of accident background characteristic attributes of the safety risk of the railway project is $M = \{m_1, m_2, \cdots m_j\}$. The "accident background characteristic attributes" vector is written as $(m_1, m_2, \cdots m_j)$.

The "construction links—safety risk event characteristics attributes" matrix refers to the construction phases of major railway projects and different types of safety risk events in the construction phases of links, as well as different types of safety risk events in major railway projects relevant to the selection of safety risk prevention and control strategies which might have a more significant impact on the characteristics of the event attributes, which are composed of vectors. Take major railway project landslide safety risk events as an example, in which the matrix of the interactions of landslide probability and risk of loss, the duration of landslide, and the time required to return to standard construction time as characteristic attributes, while also considering the matrix columns composed of the over-support, excavation, initial support, second masonry and other construction links.

For the "construction link—safety risk event characteristic attributes" matrix of safety risk events, according to the technical specifications and given that the main focus of this article is on the construction stage, assuming that the construction links of the major railway project safety risk events are t, and the characteristic attributes of the safety risk events are q, then the "construction link—safety risk event characteristic attributes" matrix is of the order of $t \times q$, which is denoted as

$$B = \begin{pmatrix} b_{11} & \cdots & b_{1q} \\ \vdots & \ddots & \vdots \\ b_{t1} & \cdots & b_{tq} \end{pmatrix} \tag{2}$$

Referring to the method of Yan Wenzhou [5], and drawing on the five-level Likert scale, several experts were engaged who have been engaged in the railway engineering industry for a long time, and who have rich experience in the construction of major railway projects as well as the prevention and control of safety risks; they understand the requirements for the development of the national emergency response plan, and know the situations associated with the construction of the major railway projects. These experts were asked to assign values to the vector of the "accident background characteristics and attributes" and the matrix of the "construction links—characteristics of the safety risk event attributes", ultimately determining the values of the vectors and the matrix by the plurality principle of the number of the final assignments. The degree of occurrence of the feature attributes is assigned according to Table 1, and the feature attributes are divided into non-measurable and measurable feature attributes; because the measurability of the accident background feature attributes is poor, all the feature attributes of the accident background are attributed to non-measurable feature attributes.

Table 1. Assignment table for the degree of occurrence of characteristic attributes.

Title	Feature Attribute Category	Whether or Not the Attribute	Assign a Value	ε_j or ε_q Assignment
Accident background characterization attributes	Non-measurable	Yes	$m_j = 1$	To assign values according to the degree of "very good, good, good, poor, poor, very poor" according to 1, 2, 3, 4, 5, and 6, respectively.
		No	$m_j = 0$	0
Safety risk event characterization attributes	Non-measurable	Yes	$z_q = 1$	To assign values according to the degree of "very small, small, small, large, large, very large" according to 1, 2, 3, 4, 5, and 6, respectively.
		No	$z_q = 0$	0
	Measurable	Yes	$z_q = 1$	The expert measures the degree of occurrence of the qth feature attribute within the corresponding process. To be in the same order of magnitude as the value of the non-measurable feature attribute, the measurement rule is defined as (actual occurrence degree value—planned occurrence degree value)/planned value × 6
		No	$z_q = 0$	0

In Table 1, ε_j is the degree of occurrence of the characteristic attribute of accident background; ε_q is the degree of occurrence of the qth safety risk event characterization attribute in a construction process. After the introduction of characterization attributes ε_j and ε_q, order $m_j^* = m_j \cdot \varepsilon_j$ and $z_q^* = z_q \cdot \varepsilon_q$. The "accident background characterization attributes" vector is W; the "safety risk event characterization attributes" is $Z^* = \left\{z_1^*, z_2^*, \cdots z_q^*\right\}$.

3.2. Game Theory to Determine the Combined Weights

Currently, in this research field, the single assignment of subjective or objective assignment is mainly used [52–54], and fewer researchers use the method of comprehensive assignment.

This article uses the G1 method to determine the subjective weights, the anti-entropy weight method to determine the objective weights, and the Nash equilibrium theory from game theory to determine the comprehensive weights. Among them, the G1 method can reflect the expert's empirical consciousness, which is more subjective; the anti-entropy weight method can utilize objective data to determine the weights, which are more objective. The Nash equilibrium theory, taken from game theory, determines the comprehensive weights, which can combine the expert's empirical consciousness and objective data to align the final weights with some reality and minimize the deviation between the comprehensive weights and the subjective and objective weights [55].

3.2.1. G1 Method of Subjective Weight Determination

The G1 method avoids the steps of determining weights according to expert opinions and consistency tests in subjective weight determination methods such as AHP and ANP and simplifies the steps of weight determination. Therefore, this article chooses to use the G1 method to determine the subjective weight, reflecting the subjective consciousness of experts.

Let the evaluated object be F. Based on the rational judgment of experts on the importance of evaluation indices, if the order of importance of the set of evaluation indices $X_m = \{x_1, x_2, \cdots x_m\}$ is $x_1^* > x_2^* > \cdots > x_m^*$ and $r_k = \frac{\omega_{k-1}}{\omega_k}$ satisfies $r_{k-1} > \frac{1}{r_k}$, where $k \in [2, m]$ [56], r_k takes the value shown in Table 2.

Table 2. Table of values for r_k.

Value of r_k	Value Meaning
1.0	x_{k-1}^* and x_k^* are equally important
1.1	x_{k-1}^* and x_k^* are between equally and slightly unequally important
1.2	x_{k-1}^* is slightly more important than x_k^*
1.3	x_{k-1}^* is between slightly more important and significantly more important than x_k^*
1.4	x_{k-1}^* is significantly more important than x_k^*
1.5	x_{k-1}^* is somewhere between clearly more important and strongly more important than x_k^*
1.6	x_{k-1}^* is strongly more important than x_k^*
1.7	x_{k-1}^* is between strongly more important and extremely more important than x_k^*
1.8	x_{k-1}^* is extremely more important than x_k^*

Then, the indicators' weights are shown in Equations (3) and (4).

$$\omega_k = \left(1 + \sum_{k=2}^{m} \prod_{a=k}^{m} r_a\right)^{-1} \quad (3)$$

In Equation (3), ω_k is the weighting factor of x_m^*, $\prod_{a=k}^{m} r_a = \frac{\omega_{k-1}^*}{\omega_m^*}$.

$$\omega_{k-1} = r_k \times \omega_k \quad (4)$$

In Equation (4), ω_{k-1} is the weighting factor of x_{m-1}^*.

3.2.2. An Anti-Entropy Weighting Method of Objective Weight Determination

The anti-entropy weight method is an improvement and refinement of the entropy weight method, one which overcomes the problem of the traditional entropy weight method having a high sensitivity to the weight difference of the evaluation indices, which leads to the absence of some indices [57]. The method utilizes objective data to determine the weights, a technique which is strongly objective. This article uses the anti-entropy weight method to determine the objective weights.

Suppose there are S evaluation objects, the set of evaluation indicators is $X_m = \{x_1, x_2, \cdots x_m\}$, and the standardized matrix formed is

$$C = (c_{ij})_{s\times m} = \begin{pmatrix} c_{11} & \cdots & c_{1m} \\ \vdots & \ddots & \vdots \\ c_{s1} & \cdots & c_{sm} \end{pmatrix} \tag{5}$$

Then, the anti-entropy value of the jth indicator is as in Equation (6).

$$E_j = -\sum_{i=1}^{s} P_{ij} \ln(1 - P_{ij}) \tag{6}$$

In Equation (6), $P_{ij} = c_{ij} / \sum_{i=1}^{s} c_{ij}$.

The weight of the jth indicator is as in Equation (7).

$$\omega_j = \frac{E_j}{\sum_{j=1}^{s} E_j} \tag{7}$$

In Equation (7), $j \in [1, m]$.

3.2.3. Game Theory of Composite Weight Determination

The Nash equilibrium theory for game theory combines the subjective weights determined by the G1 method with the objective weights determined by the anti-entropy weight method to form the comprehensive weights and minimize the deviation between the weights to achieve optimality [58]. Therefore, in this article, we choose game theory to determine the comprehensive weights, and the specific steps are as follows:

(1) Construct basic weight sets and feasible weight sets

In this article, we use the G1 method to determine the subjective weights and the anti-entropy weight method to determine the objective weights, thus constructing a basic weight set $U = \{u_1, u_2\}$, containing two attribute vectors and noting that any linear combination of two weight vectors is given by Equation (8).

$$u = \sum_{k=1}^{2} \alpha_k \cdot u_k^T \qquad (k = 1, 2) \tag{8}$$

In Equation (8), u is the set of feasible weights and α_k denotes the linear combination coefficients.

(2) Formation of countermeasure models using Nash equilibrium theory

Nash equilibrium theory is a non-cooperative game equilibrium, so based on the Nash theory the subjective weights and objective weights are adjusted to find the balance point which minimizes the deviation between the linear combination of weights and the basic weights, that is, the formation of a countermeasure model, as in Equation (9).

$$Min \left\| \sum_{j=1}^{2} \alpha_j \cdot u_j^T - u_j^T \right\|_2 \tag{9}$$

According to the differential nature of matrices, the first-order derivative condition for the optimization of Equation (9) is

$$\begin{pmatrix} u_1 \cdot u_1^T & u_1 \cdot u_2^T \\ u_2 \cdot u_1^T & u_2 \cdot u_2^T \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} = \begin{pmatrix} u_1 \cdot u_1^T \\ u_2 \cdot u_2^T \end{pmatrix} \quad (10)$$

(3) Normalization of composite weights

(α_1, α_2) is obtained from Equation (10) and normalized using Equation (11).

$$u^* = \sum_{k=1}^{2} \alpha_k^* \cdot u_k^T \quad (11)$$

3.3. Auxiliary Selection Steps for Defense and Control Strategies

Based on the above analysis, the steps taken to assist in selecting safety risk control strategies for major railway projects are shown in Figure 2, which was drawn by Visio 2019.

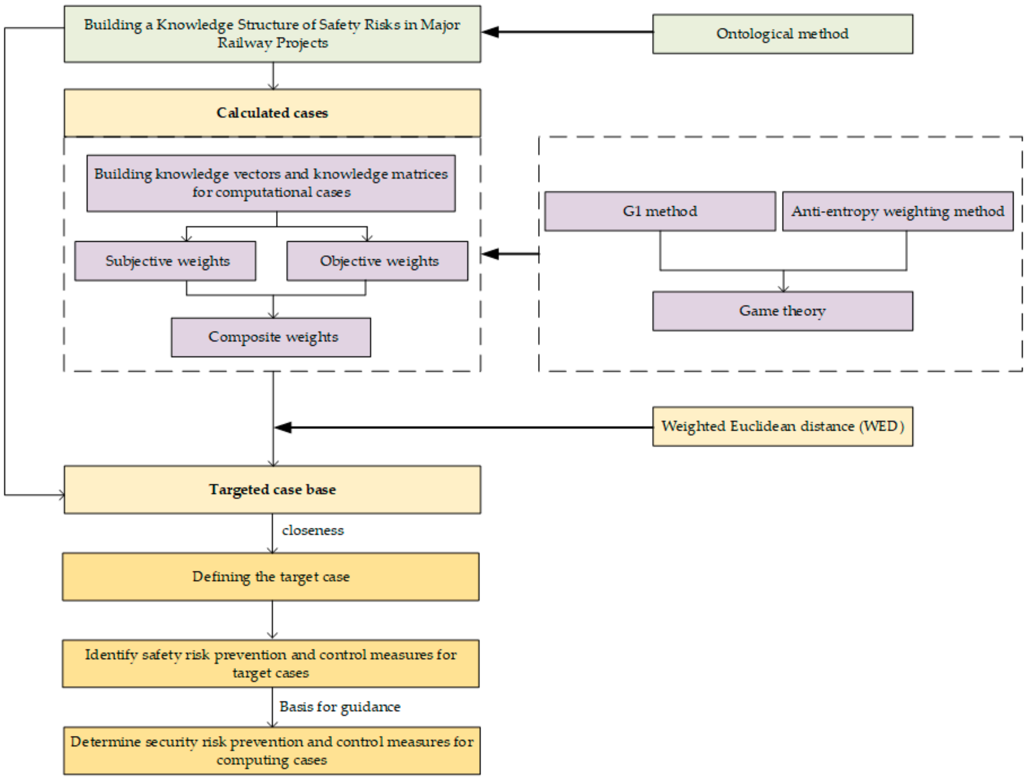

Figure 2. Technology roadmap for auxiliary selection of prevention and control strategies.

The first task is to establish the knowledge structure for major railway project safety risks. In this stage, the expert interview method and literature research method are used to collect and study various explicit and implicit elements of knowledge, combine them with the characteristics of major railway engineering construction, and clarify the "accident background", "risk events", and "treatment measures" of the safety risks of major railway project construction that have occurred in the past. The ontology is then used to conceptualize, abstract, and share the knowledge of major railway project safety risks and form the knowledge structure for major railway project safety risks. The construction of a major railway project safety risk knowledge structure provides the basis for forming feature attribute matrices and vectors of computational cases and refining a major railway project safety risk management case database.

Second, the matrices and vectors of the characteristic attributes are formed. At this stage, the vector of "accident background attributes" and the matrix of "construction link—

safety risk event attributes" of safety risk events are formed, and the vectors and matrices are assigned values. Experts in the related fields of major railway projects, on-site management, and construction personnel are invited to assign values to the vector and matrix according to the "Assignment Table of the Occurrence Degree of Characteristic Attributes" proposed in Table 1. At the same time, this article defines the event of formulating safety risk prevention and control strategies as a "calculated case" and the event in the safety risk management case database of major railway projects as a "target case", which facilitates the comparison of closeness using the WED method.

Third, the composite weights are calculated. This part utilizes three methods, the G1 method, anti-entropy weighting method, and game theory, to derive the importance levels u_1^* and u_2^* of the accident context and safety risk events.

Fourth, WED is utilized to calculate the degree of proximity of the calculated case to the target case. In this stage, the composite weights and WED are utilized to determine the degree of proximity between the calculated case and the target case in terms of the "Accident Background Characteristics" vector and the "Construction Link-Safety Risk Event Characteristics" matrix to quantify the similarity between the calculated case and the target case. The target case is derived from the historical cases in the case database that are similar to the calculated case in terms of background, events, and other basic elements. It is also important to note that when performing the weighted Euclidean distance weight calculation, the calculated case is given a larger weight when it has high similarity with the feature attributes corresponding to the target case, and the opposite outcome is given a smaller weight.

Fifth, determine the target case and its safety risk prevention and control strategy. In this stage, the weighted average method combines the "accident background characteristic attributes" vector and the "construction link—safety risk event characteristic attributes" matrix proximity to determine the combined proximity of the final calculated and target cases. The resulting equation, Equation (12), is as follows:

$$dist(X,Y)' = u_1^* dist(X,Y)_1 + u_2^* dist(X,Y)_2 \quad (12)$$

In Equation (12), $dist(X,Y)'$ denotes the comprehensive closeness; $dist(X,Y)_1$ and $dist(X,Y)_2$ denote the closeness of the calculated case to the target case's "Accident Background Characteristic Attributes" vector and "Construction Link—Safety Risk Event Characteristic Attributes" matrix, respectively.

Then, comparing the comprehensive closeness between the calculated cases and the target cases, and taking "the smallest value of comprehensive closeness" as the criterion, the target cases are selected as the main reference bases for determining the formulation of safety risk management, prevention, and control strategies, in order to realize the purpose of assisting the selection of safety risk prevention and control strategies for major railway projects by the WED method.

Sixth, determine the calculated case's safety risk prevention and control strategy. In this stage, the safety risk prevention and control strategy of the major railway project of the target case can be taken as the main basis. At the same time, the characteristics of the construction of the major railway project, the experience of the personnel and experts at the construction site, and the safety risk prevention and control system, in addition to policies, norms, and so on, are taken into consideration to formulate the safety risk prevention and control strategy for the calculated case.

4. Application and Results

4.1. Project Background

The No.1 landslide in Tunnel A is located within its inlet planning area. Tunnel A's No.1 landslide, in the geological aspect, has a tongue-shaped, profile form which is similar to the linear type that is associated with the extra-large high level of rocky landslides. As for the meteorological aspect, it is located in a study area where the rainfall is sufficient, the sunshine time is long, the winter is relatively dry, and the summer is humid and with no high temperatures. In the hydrological aspect, its area is part of the Yarlung Zangbo River Basin. It has the characteristics of an alpine valley geomorphology. As for the seismic aspect, its location in the southern part of the Tibet region of the Lhasa Massif, which was formed as a result of continuous plate collision, this has led to a strong horizontal tectonic movement linked its characteristic seismic activity.

As for the tunnel construction, it is proposed to adopt the construction program of a drilling and blasting method, so, taking the key construction links of the drilling and blasting method as an example, assume that the main construction process comprises the four links of advance support, excavation, initial support, and secondary masonry [59,60], which are represented by t_1, t_2, t_3, and t_4. To reduce the impact of the No.1 landslide on the excavation of Tunnel A and control the safety risk it generates, safety risk prevention and control measures need to be formulated for this purpose.

4.2. Security Risk Prevention and Control Strategy Selection Steps

(1) Construct the knowledge vector and knowledge matrix. According to the knowledge structure of major railway project safety risk, it can be determined that there are four kinds of characteristic attributes in the accident background: geological conditions, climatic conditions, hydrological conditions, and seismic conditions. These are respectively expressed by m_1, m_2, m_3, and m_4. There are four kinds of characteristic attributes of safety risk events: the probability of landslide occurrence, the risk loss caused by a landslide, the duration of a landslide, and the time needed to resume normal construction after a landslide. These are represented by q_1, q_2, q_3 and q_4.

At the same time, the expert scoring method is adopted. Eight experts are invited to assign values to the vector of "Accident Background Characteristic Attributes" and the vector of "Construction link—Safety Risk Event Characteristic Attributes" according to Table 1. The scoring results of the experts are processed by taking the plurality of the number of the scores to form the corresponding knowledge vectors and knowledge matrices, as shown in Equations (13) and (14):

$$M = \{5, 2, 3, 5\} \tag{13}$$

$$B = \begin{pmatrix} 4 & 3 & 2 & 1 \\ 5 & 4 & 2 & 3 \\ 4 & 5 & 3 & 2 \\ 3 & 2 & 3 & 4 \end{pmatrix} \tag{14}$$

(2) Determine the composite weights. According to the game theory method of determining the composite weights and the weights required by the WED method, combined with the information on the No. 1 landslide in Tunnel A, the importance values for the vector of "accident background characteristic attributes" and the matrix of "construction link—safety risk event characteristic attributes" are determined to be $u_1^* = 0.534$ and $u_2^* = 0.466$.

(3) WED method of proximity calculation and target case determination. According to the major railway project safety risk knowledge structure formed by the target case database, assuming that the WED method and the weighted average method of the "accident background characteristics attributes" vector and "construction links—safety risk event characteristics attributes" matrix possess a proximity to the calculation and formation of a comprehensive proximity, the case of the D_0 is analyzed relative to the target case; this is compared to the cases of some of the cases. The results of the comparisons are shown in Table 3.

Table 3. Partial table of comparative case results.

Number	Target Case Name	Comprehensive Closeness
D_1	Desha landslide	1.132
D_2	K4114 landslide	1.352
D_3	A landslide at one of the tunnels' exits on the Lan Yu Railway	1.631
D_4	Landslide on the right side of the line of Qinghai–Tibet Railway, section k1154+900-980	1.962
D_5	Kazira Mountains #1 landslide	0.856

According to the results of the analysis in Table 3, it can be seen that the closeness value between the calculated case and the target case of the Kazira Mountains #1 landslide is the smallest, so the prevention and control strategy associated with the Kazira Mountains #1 landslide is selected as the main basis for the development of a safety risk prevention and control strategy for the Tunnel A No.1 landslide.

4.3. Security Risk Prevention and Control Strategy Development

Taking the prevention and control strategy of the Kazira Mountain #1 landslide as the main basis, combined with the construction characteristics of Tunnel A, the experience of the construction site personnel and experts, and the existing content of the safety risk prevention and control systems, policies, and norms, the safety risk prevention and control strategy for Tunnel A's No.1 landslide is formulated to include optimization of the line design, reduction of construction excavation disturbances to the slopes, and the addition of anti-slip piles, etc. Therefore, the WED method can assist decision-making relative to the safety risk prevention and control strategy for major railway projects.

5. Discussion

In the previous research on safety risk prevention and the control of major railway projects, the main research directions have included the identification of safety risk factors of major railway projects using WBS, RBS, and other methods, the evaluation of safety risk factors, and the proposal of risk prevention and control measures for major railway projects using the AHP method, fuzzy comprehensive evaluation method, decision tree method, and so on [61], in addition to providing an early warning of the safety risk associated with major railway projects, which is presently lacking. Research on the auxiliary selection of safety risk prevention and control strategies for major railway projects is necessary to strengthen the research to enhance the safety risk prevention and control associated with major railway projects. Therefore, based on the major railway project safety risk knowledge structure formed by the major railway project safety risk case database, i.e., the history of the major railway project safety risk events and their solution measures, is statistically organized. In the development of major railway project safety risk prevention and control measures to assist in the selection, the subjective recommendations of experts and the risk data obtained from the case database of empirical cases are combined to help the site construction management personnel to quickly and accurately make decisions. Meanwhile, the WED is usually used to measure the similarity between the two, and the weights are increased, rather than the method used in the traditional Euclidean distance, a change which reflects the similarity more scientifically. In this article, the ontology and the WED are utilized. The advantage of this method is that the selection of safety risk prevention and control strategies is quantified. It is more scientific in assisting project managers in developing safety risk prevention and control strategies.

Conceptualization and formalization of major railway project safety risk domain knowledge using an ontology is the basis of this assisted selection research method. Researchers have rarely conceptualized and formalized domain knowledge in previous studies before researching safety risk prevention and control. The conceptualized and formalized knowledge relevant to major railway project safety risks can help knowledge management and dissemination. The formation of a major railway project safety risk case database can, with the help of WED, help in the conducting of a comparative analysis of the characteristics and attributes of the calculated case and the target case, which can assist in selecting the guiding basis for the formulation of safety risk prevention and control strategies for major railway projects.

In previous studies, some researchers have preferred to use subjective weights or objective weights, without being able to use subjective and objective weights in combination, which reduced the scientific nature of weight determination [58]. Based on previous research results, in this paper, the Nash equilibrium theory used in game theory to determine the comprehensive weights will be used in the context of the experts' experienced counsel and objective data, to realize a combination of qualitative analysis and quantitative analysis. In the field of safety risk prevention and control for major railway projects, firstly, experts in the relevant fields put forward subjective weights according to their own experience and cognition as to the complexity of safety risk prevention and control and the difficulty of the prevention and control tasks. Secondly, experts formed objective weights based on actual data. Finally, the subjective weights formed qualitatively are combined with the objective weights formed quantitatively, so that the final comprehensive weights are formed from multiple perspectives, which makes the final weights more in line with reality and minimizes the deviation between the comprehensive weights and the subjective and objective weights. At the same time, the comprehensive weights are used to calculate the comprehensive proximity of the case to the target case.

Based on the use of the WED method in previous studies, this paper sets forth the method as a means for analyzing the major railway project safety risk prevention and control strategies. The selection of the WED method in this field permits full reference to the historical cases, and significantly improves the rationality of the safety risk prevention and control strategies. As far as possible, it avoids the lack of existing information caused by the fact that a project cannot scientifically formulate preventive and control measures given the complexity of the problem. And long-term practice relative to the safety risk prevention and control policies of major railway projects has formed a large number of engineering examples; these examples contain much experience and knowledge, so one can use the WED method to select a more similar historical engineering example. Then, it is more scientific, allowing the construction site management personnel to provide a reference basis for the development of risk prevention and control strategies. Compared with the traditional Euclidean distance method, the WED method adds weight to determine the weight value of different elements through the closeness between the corresponding elements, which in turn improves the accuracy of measuring the spatial distance of two vectors in the multi-dimensional data space structure, which makes the results more scientific and reasonable, and can more scientifically provide the management personnel at the engineering site with a reference basis for the development of safety risk prevention and control strategies for major railway projects. In this paper, the WED method is compared and analyzed with the traditional Euclidean distance method in Table 4 to highlight the advantages of the WED method in assisting the selection of safety risk prevention and control strategies for major railroad projects.

Table 4. Comparison table for the traditional Euclidean distance method and the WED method.

Name of Method	Advantages	Disadvantages	Comparison Analysis
Traditional Euclidean distance	The calculation process is simple and is commonly used in similarity calculations.	Simply representing the cumulative difference between two spatial vectors and ignoring the effect of the difference between the corresponding individual elements leads to biased results and a large error in accuracy.	Although the WED method is more complicated in the calculation process, it is superior to the traditional Euclidean distance in terms of the accuracy of the calculation results, which can make the calculation results more accurate.
WED	Taking into account the effect of differences between corresponding individual elements in vectors improves the accuracy of the calculation results and is commonly used in space vector similarity calculations.	The calculation process is more complex and requires the weights to be calculated first.	

Overall, the use of the WED method for major railway project safety risk prevention and control strategy has assisted decision-making. First, it can help decision-makers faced with a lack of engineering data, and it can refer to historical engineering data to develop the prevention and control strategy of major railway project safety risk events; second, the use of a quantitative and qualitative combination of assisted decision-making methods can improve the scientific nature and rationality of the development of the prevention and control strategy; third, the weighted Euclidean distance is a relatively simple and intuitive method of similarity determination, one which is easy to popularize and apply in the context of safety risk prevention and control policies of major railway projects, thereby achieving the purpose of assisted decision-making for the prevention and control strategies associated with major railway project safety risks [62,63].

However, this method should be used flexibly in major railway projects, and more in-depth research is still needed, so several suggestions are put forward. (1) When using this method to assist in the selection of safety risk prevention and control strategies for major railway projects in actual projects, it is necessary to take into account the suggestions made by the experts on the safety risk prevention and control strategies for actual projects, as well as the prevention and control strategies of the historical cases in the case database, so as to combine the subjective suggestions with the objective reality and select a more scientific risk prevention and control strategy. (2) The construction unit needs to constantly supplement and enrich the case database of safety risk prevention and control strategies of major railway projects, so as to provide more information for the next selection of safety risk prevention and control strategies for major railway projects. (3) To make decisions more quickly, it is also necessary to combine the method with artificial intelligence in future research to improve the speed and accuracy of the development of prevention and control strategies. (4) To ensure the long-term effectiveness of the WED method in the selection of safety risk prevention and control strategies for major railway projects, it needs to be flexibly applied according to the environment and conditions of the actual project. For example, given a lack of historical data, one needs to reduce the dependence on the WED method, and combine this with the experience of field experts, in order to determine the risk prevention and control strategy; if the historical data is more abundant, one needs to increase the dependence on WED method, and use the WED method to assist in the selection of the historical cases relevant to the risk prevention and control strategy, operating as the main reference basis for the actual project risk prevention and control strategy development.

6. Conclusions

Compared with traditional railway projects, the safety risks of major railway projects are more frequently encountered. There is a lack of key materials, resulting in a greater need for historical information on safety risk prevention and control measures for major railway projects to assist managers in developing safety risk prevention and control measures when the safety risks of major railway projects are present. This article uses the safety risk prevention and control strategy of major railway projects as the research object, establishes a major railway project safety risk knowledge structure using an ontology, and determines the guiding basis for formulating prevention and control strategies using WED. There are three main conclusions.

(1) This article uses ontology to structure, conceptualize, and share knowledge about safety risks in major railway projects. At the same time, the "accident background", "risk events", and "treatment measures" of major railway project safety risk events are refined to form a major railway project safety risk knowledge structure and case database, one which can be used for major railway project safety management. The knowledge structure of major railway project safety risks is thereby formed, and the case database is used in the auxiliary selection of major railway project safety risk prevention and control strategies.

(2) Game theory is used to combine the subjective weights determined by the G1 method and the objective weights determined by the anti-entropy weight method into the

comprehensive weights. This not only guarantees that the comprehensive weights reflect the subjective consciousness and experience of experts, but also embodies an objective actuality and ensures that the combination of weights is scientifically reasonable. In turn, it realizes the weight calculation required in WED, making the weight value closer to reality.

(3) After the No. 1 landslide in tunnel A case analysis, the use of the WED method in its safety risk control strategy to assist decision-making has a certain degree of feasibility. At the same time, the use of WED on the major railway project safety risk control strategy can serve to assist in the selection of research, enrich the theoretical approach to the selection of a safety risk prevention and control strategy, improve the scientific development of the strategy for the selection of safety risk prevention and control strategy for the major railway project, and provide a favorable decision-making basis, as well as enhance the participating units' ability to ensure effective safety risk prevention and control.

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