The Case-Based Reasoning System for Residual Value Risk in Public-Private Partnership Project

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ABSTRACT

Aiming to help Public-Private Partnership (PPP) project improve the performance, an approach to evaluate Residual Value Risk (RVR) for Public-Private Partnership (PPP) project was developed. When a Public-Private Partnership (PPP) project is transferred to the government, there emerges the question about the identification of value of the project, which is closely related to the Residual Value Risk (RVR). The methods of Case-based Reasoning (CBR), and a case-based residual value risk reasoning system of PPP projects (RVR-CBR System) is built with the help of myCBR3.0 workbench. This approach is mostly based on historical PPP experiences and knowledge. The findings can provide new methods and perspectives for researches on residual value risk of PPP projects, and has practical significance for PPP's application in infrastructure.

INTRODUCTION

Public–private partnerships (PPPs) are long-term cooperative relationships that are established between the public and private sectors for the purposes of planning, designing, financing, constructing, and managing projects that are traditionally within the realm of the public sector (Ho 2006). PPPs are important means by which governments deliver public services (Yang et al. 2013). In China, PPPs have been implemented for more than two decades. They increasingly have been recognized as effective mechanism for public service delivery (Wang 2013). However, the experience of the public sector with PPPs has not always been positive. Many PPP projects are either held up or early terminated (Kwak et al. 2009), and the RVR (Residual Value Risk) of PPP project has not been paid enough attention to, nor there are enough researches and effective assessment methods (Yuan et al. 2013). Thus the focus of this research is to establish RVR evaluating system based on Case-based Reasoning (CBR).

LITERATURE REVIEW

Residual Value Risk (RVR). The residual value (RV) of PPP projects refers to the market value that privately-operated party transfers to the government either on termination of the services contract, or during the course of delivery of the contractual arrangements, rather than the value in the end of the project life cycle. The RVR of PPP projects refers to the uncertainty caused by the residual value when it cannot reach the requirement of the concession agreement at the moment the project is transferred to the government (Demirag et al. 2010).

Authorities should also consider RVR when setting any capital expenditure contribution limits or liabilities. If residual value risk has been transferred then any Assets may need to be valued (HM Treasury of UK 2007). HAL (1998) suggested that the scale of the RVR for PPP projects depended on the value of project property at the end of the concession period. And whether the RVR was well controlled depended on whether the residual value of PPP project was mainly dominated by the contractor under the competitive market (HAL 1998). Yuan et al. (2013) develop a SEM (Structural Equation Modeling)-based risk assessment model on RVR in PPP project. The results indicate that this model could simply and clearly reflect the status of project's RVR (Yuan et al. 2013).

Nevertheless, the research work at present mainly includes the concept of RVR, sharing of RVR, and the formation process of RVR (Algarni et al. 2007; Jin 2010; Ke et al. 2010; Wei et al. 2011). Despite the fact that studies focused on RVR have been increasing, to date there appears to be a lack of attention paid to the method for evaluating RVR, few literatures about the PPP project risk management mentioned the evaluation method of the RVR, and the systematic research on RVR of PPP projects is in the blank stage.

Case-Based Reasoning (CBR). Case-Based Reasoning is a similar reasoning method. With reference to target case, the original case can be traced, in order to seek solution to new problems through the original case. The core of CBR includes case representation, organization, storage, retrieval, revision and retains. CBR, as a paradigm for building intelligent computer systems, CBR is an important reasoning method that solves a new problem by remembering previous similar situations and reusing information and knowledge from the solutions to these situations (Aamodt and Plaza 1994). At the highest level of generality, a general CBR cycle may be described by four processes: Retrieve, Reuse, Revise, and Retain (Mohammed 2013). Figure 1 shows the CBR Cycle (Aamodt and Plaza 1994).

Balducelli and Esposito (2000) developed a set of artificial intelligence methods, and they put forward a view that conducting fire risk management and planning based on case-based reasoning, genetic algorithm and numerical simulation. Mendes et al. (2003) used CBR method to study design risks in the near coast design. Goh and Chua (2009) and Goh and Chua (2010) proposed a case-based reasoning approach to construction hazard identification that facilitates systematic feedback of past knowledge in the form of incident cases and hazard identification. Besides, some scholars have made achievements for the CBR technology application in risk management (An et al. 2009; Zhiyun et al. 2010).

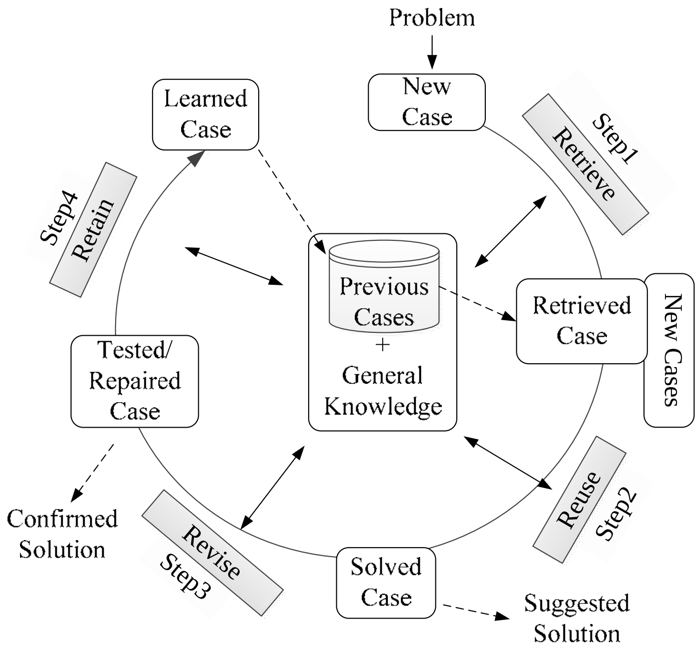

Figure 1.The CBR cycle.

It can be observed that CBR method has the potential to improve the efficiency and quality of risk analysis. However, it only remains in the phase of theoretical study, and hardly there are any practical implementation of the CBR technology in the of RVR evaluation.

With the rapid development of computer systems, and information technology, decision-making technology and artificial intelligence will be able to effectively combine the CBR technology, and makes impossible for design and application of the integrated RVR-CBR System.

ESTABLISHMENT OF THE RVR-CBR SYSTEM

In this paper, the methodology of RVR evaluation is based on CBR. This paper's contribution is to develop an innovative approach to evaluating the RVR of PPP projects based on the CBR method, combined with MyCBR which is one of the most popular CBR software platforms (Atanassov and Antonov 2012).

The building of the RVR-CBR System of PPP project includes four stages based on three assumption conditions.

Three assumption conditions. Firstly, the stages of reasoning in RVR-CBR System are based on cases, therefore a plenty of cases are necessary. Secondly, the information of PPP project is reliable and valid. Thirdly, the RVR value for all of the cases has been given in the case base (CB).

Four stages. (1) Step 1: Setting Attribute. Before conducting a case base (CB), the name, type and allowed values of each attribute must be set. Table 1 describes the most important features from a typical PPP project. These features are viewed as the attributes of each case in the CB. These important features have been selected from a wide selection used in the related literature and PPP projects database of UK, Australia, India, Canada and USA (see Figure 2).

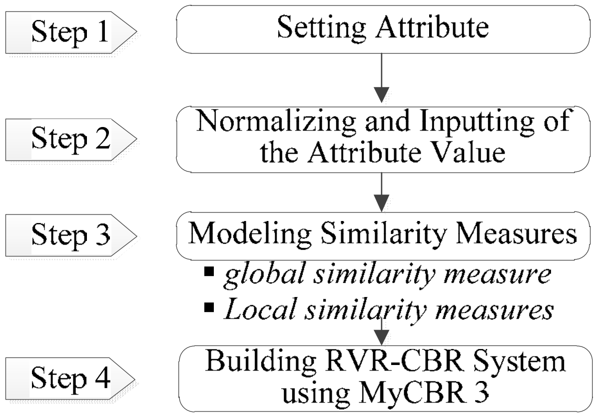

Figure 2.Four stages for building RVR-CBR system.

Table 1.Case Attributes of RVR-CBR System.

Attribute	Data type	Explanation	Description
Project ID	String	The unique identifier of each case	N/A
Name	String	Restored case name	N/A
Category	Symbol	Based on project type, PPP project is classified into twenty-four types, in which transport PPP project is classified into six types	Bridge; Light Rail; Metro; Road; Tunnel; Railway
PPP type	Symbol	Based on the procurement mode, PPP project is classified into twenty-seven types	BOT; BOOT; TOT;
Countries & areas	Symbol	The countries or areas of the PPP project	USA; UK; Australia; China; …
Size (km)	Float	The size of the PPP project	N/A
Contract Price ($m)	Float	The contract price of the PPP project	N/A
Contract award-method	Symbol	Contract award method is classified into two types	Competitive Tender; Direct Negotiation
Concession-period (Yrs)	Float	During the concession period the private company owns or operates the project	N/A
Project Status	Symbol	The four status of the PPP project	Construction; Operation; Transferred; End
RVR	Float	Residual value risk of the PPP project	N/A

Table 2 shows the CB sample of the transport PPP project for RVR-CBR System. There are eleven attributes of the CB including *Project ID*, *Name*, *Category*, *PPP Type*, *Countries* & *Areas*, *Size*, *Contract Price*, *Contract Award Method*, *Concession Period*, *Project Status*, and *RVR*, and three data types including *string*, *symbol*, and *float*.

Table 2.The CB Sample of PPP Project for RVR-CBR System.

Project ID	Name	Category	Countries & areas	Size (km)	Contract price ($m)	Contract award method	Concession	Project status	RVR
string	string	symbol	symbol	float	float	symbol	float	symbol	float
T0001									
T0002									
T0003									

(2) Step 2: Normalizing and Inputting of the Attribute Value. The value of 'Contract Price' attribute in the CB just reflects the contract price of the year when the contract was signed. Therefore, it is very important to normalize the contract price of each case in order to ensure the comparability between two given cases. The inflation rate is effective to solve the time value of finance. So we convert the contract price of each case into the new price in 2010 using the method of inflation rate, and convert the price into dollars according to the exchange rate in 2010. The new contract price is calculated by:

$$P = P'(1+ f_{a\sim b})^{n} \cdot r_e \quad (1)$$

$$f_{a\sim b} = \sqrt[(b\text{-}a)]{(1+ f_{a+1})(1+ f_{a+2})\cdots(1+ f_b)} \text{ -1} \quad (2)$$

Where P is the new contract price in 2010. P' is the contract price of the year when the contract was signed. $f_{a\sim b}$ is the average rate of inflation from the year a when the contract was signed to the current year b. r_e is the exchange rate in the current year b. Besides, the data of the inflation rate comes from national economic accounting of the World Bank and OECD, and the data of the exchange rate comes from the network.

For example, the contract price of one PPP project in Hong Kong in 1969 is 100 million HK$, and the exchange rate between Hong Kong dollar and US dollar is 0.1286 in 2010. The value of the contract price in 2010 is calculated in the following way (see Eq. (3) and (4)):

$$\begin{aligned} f_{1969\sim 2010} &= \sqrt[41]{(1+ f_{1970})(1+ f_{1971})\cdots(1+ f_{2010})} \text{ -1} \\ &= 5.16\% \end{aligned} \quad (3)$$

$$\begin{aligned} F &= F'(1+ f_{1969\sim 2010})^{41} \cdot r_e \\ &= 100(1+0.0516)^{41} \cdot 0.1286 \\ &= 101.13 m\$ \end{aligned} \quad (4)$$

Then, the normalized information of each PPP project can be input into the CB (see Table 3: the case base built in Microsoft Excel 2013).

(3) **S**tep 3: Modeling Similarity Measures. The CBR algorithm calculates the similarity between cases based on feature value pairs of the new and each historical case. A similarity measure has the following attributes (Mohammed 2013):

Table 3.The CB built in Microsoft Excel 2013

Project ID	Name	Category	PPP Type	Countries &Areas	Size (km)	Contract Price($m)	Contract Award Method	Concession Period (Yrs)	Project Status
T0001	A1(M) alconbury to peterborough	Road	DBFO	UK	21.0	371.78	Competitive Tender	30	operation
T0002	Alameda Corridor	Railway	(JV)	USA	32.0	3105.33	Competitive Tender	-	operation
T0003	Chengdu-Mianyang Highway	Road	BOT	China	92.7	370.14	Competitive Tender	30	operation
T0004	Chhatisgarh Maharastra Border Wainganga Bridge	Bridge	BOT	India	80.0	123.50	Competitive Tender	20	operation
T0005	Chicago Skyway	Road	OL	USA	12.6	2024.77	Competitive Tender	99	operation
T0006	Clem jones tunnel (north south Bypass Tunnel)	Tunnel	PPP	Australia	6.8	2347.47	Competitive Tender	45	operation
T0007	Cross City Tunnel	Tunnel	BOOT	Australia	2.1	923.94	Competitive Tender	33	operation
T0008	Cross-Harbour Tunnel	Tunnel	BOT	China	1.9	323.62	Competitive Tender	30	transferred
T0009	Dartford Bridge	Bridge	DBFO	UK	2.8	160.22	Competitive Tender	20	operation
T0010	Deep Tube Lines-Bakerloo, Central & Victoria Lines (BCV)	Metro	BOT	UK	-	11008.28	Competitive Tender	26	operation
T0011	Deep tube lines-jubilee, northern & piccadilly lines (JNP)	Metro	DBOT	UK	-	11304.92	Competitive Tender	30	operation
T0012	Dulles Greenway	Road	BOT	USA	20.2	197.36	Competitive Tender	43	operation
T0013	East yan an road Tunnel (south)	Tunnel	BOT	China	2.4	379.71	Competitive Tender	30	operation
T0014	Eastern Harbour Tunnel (EHT)	Tunnel	BOT	China	2.2	545.96	Competitive Tender	30	operation
T0015	EastLink	Road	PPP	Australia	39.0	3203.10	Competitive Tender	39	operation
T0016	Jingtong Expressway	Road	BOT	China	18.4	456.99	Competitive Tender	30	operation
T0017	Kaohsiung Rapid Transit System–the Red and Orange Lines Construction Project	Metro	BOT	China	-	367.17	Competitive Tender	36	operation
T0018	Lane Cove Tunnel	Tunnel	PPP	Australia	3.6	1455.31	Competitive Tender	33	operation
T0019	London Underground - Prestige	Metro	PFI	UK	-	436.63	Competitive Tender	-	operation
T0020	Lusoponte Concession	Bridge	PFI	Portugal	17.2	1985.43	Competitive Tender	32	operation

Table 3.(Continued).

Project ID	Name	Category	PPP Type	Countries &Areas	Size (km)	Contract Price($m)	Contract Award Method	Concession Period (Yrs)	Project Status
T0021	M2 Motorway	Road	BOOT	Australia	21.0	1033.53	Competitive Tender	45	operation
T0022	Melbourne City Link	Road	BOOT	Australia	22.0	2839.62	Competitive Tender	34	operation
T0023	Nanjing Yangtze river tunnel	Tunnel	BOT	China	6.0	652.95	Competitive Tender	34	operation
T0024	New southern railway (airport line)	Railway	PPP	Australia	10.0	1061.70	Competitive Tender	30	operation
T0025	Peninsula Link	Road	PPP	Australia	27.0	773.84	Competitive Tender	28	construction
T0026	Qionglai-Mingshan Highway	Road	BOT	China	52.7	357.99	Competitive Tender	28	operation
T0027	Route 3 Country Park Section	Road	BOT	China	10.1	861.57	Competitive Tender	30	operation
T0028	Second Stage Highway	Road	BOT	Thailand	156.0	116.09	Competitive Tender	30	operation
T0029	Skye Bridge	Bridge	PFI	UK	0.6	405.12	Competitive Tender	27	Transfer-red
T0030	State route 125 (south bay expressway)	Road	DBFO	USA	15.3	941.72	Competitive Tender	35	operation
T0031	Sub Surface Lines (SSL)-District, Circle, Metropolitan, East London & Hammersmith & City	Metro	BOT	UK	-	13680.05	Competitive Tender	26	operation
T0032	Sydney Harbour Tunnel	Tunnel	BOOT	Australia	2.3	860.03	Competitive Tender	30	operation
T0033	Taiwan High Speed Rail	Railway	BOT	China	345.0	23212.40	Competitive Tender	35	operation
T0034	Tate's Cairn Tunnel	Tunnel	BOT	China	3.9	416.22	Competitive Tender	30	operation
T0035	Western Harbour Tunnel (WHT)	Tunnel	BOT	China	2.0	922.26	Competitive Tender	30	operation
T0036	Westlink M7	Road	PPP	Australia	40.0	2037.44	Competitive Tender	34	operation
T0037	Yitzhak Rabin Trans-Israel Highway (Highway 6)	Road	DBFO	Israel	140.0	2001.43	Competitive Tender	30	operation
T0038	Yixian Road Skyway	Road	BOT	China	9.5	387.56	Competitive Tender	-	operation
T0039	Ningbo Changhong Tunnel	Tunnel	BOT	China	3.3	90.39	Competitive Tender	20	transfer-red

Reflective: a case always is similar to itself.

Symmetric: If *A* is similar to *B*, then *B* is similar to *A*

The main task for creating a CBR application is the definition of an appropriate similarity measure. RVR-CBR System follows the *local-global approach* which divides the similarity definition into a set of *local similarity measures* for each attribute, a set of *attribute weights*, and a *global similarity measure* for calculating the final similarity value (Stahl and Roth-Berghofer 2008). For an attribute-value based case representation consisting of n attributes, the similarity between a query *q* and a case *c* may be calculated as follows:

$$Sim(q,c) = \sum_{i=1}^{n} \omega_i sim_i(q_i, c_i) \tag{5}$$

Where, sim_i and w_i denote the local similarity measure and the weight of attribute *i*, and *Sim* represents the global similarity measure. There are *n* attributes in each case (*n*=8 in our research), and $\sum_{i=1}^{n} \omega_i = 1, \omega_i \in [0,1]; sim_i(q_i, c_i) \in [0,1]$.

The weight of attribute in the case base is confirmed by using the method of Expert Decision. The result is as shown in Table 4.

Table 4.Weight of Attribute.

Attribute	Weight	Attribute	Weight
Project ID	0	Contract Price($m)	7
Name	0	Contract Award Method	5
Category	9	Concession Period (Yrs)	7
PPPT ype	8	Project Status	6
Countries & Areas	6	RVR	0
Size (km)	8		

There are three types of the CB attributes: *string*， *symbol* and *float*. And, the attributes with the type of symbol and float should be modeled local similarity measures.

(i) Similarity Measure Modeling for Floating Attributes. For floating attributes, the similarity computation is typically based on a mapping between the distance of the two values to be compared and the similarity value is calculated by:

$$sim_i(q_i, c_i) = \frac{max - |d(q_i, c_i)|}{max - min}, min \leqslant d(q_i, c_i) < max \tag{6}$$

Where, *max* and *min* denote the maximum value and minimum value of attribute *i*. $d(q_i, c_i)$ is the absolute difference of the two values ($d(q_i, c_i) = c_i - q_i$).

(ii) Similarity Measures Modeling for Symbolic Attributes. For symbolic attributes, several possibilities to model the similarity are supported. The most general and flexible way is the definition of a similarity table where all pairwise value combinations together with their similarities are enumerated explicitly the similarity value is calculated by:

$$sim_i(q_i, c_i) = \begin{cases} 1 & (c_i = q_i) \\ 0 & (c_i \neq q_i) \end{cases} \tag{7}$$

(4) Step 4: Building RVR-CBR System using MyCBR 3. MyCBR is an open-source similarity-based retrieval tool and software development kit (SDK). With myCBR Workbench, highly sophisticated, knowledge-intensive similarity measures can be modeled and tested in a powerful GUI and can be easily integrated into the applications using the myCBR SDK. RVR-CBR System is developed using myCBR 3.0 workbench which is the latest version of myCBR. Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7 show the GUI of RVR-CBR System.

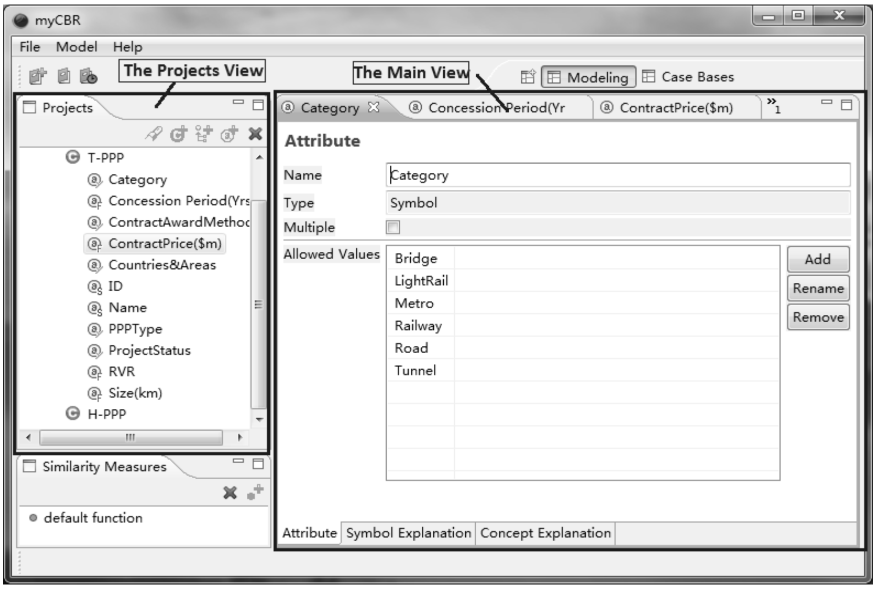

Figure 3.Create project, add concepts and attributes, assign the type and add the allowed value for each attribute.

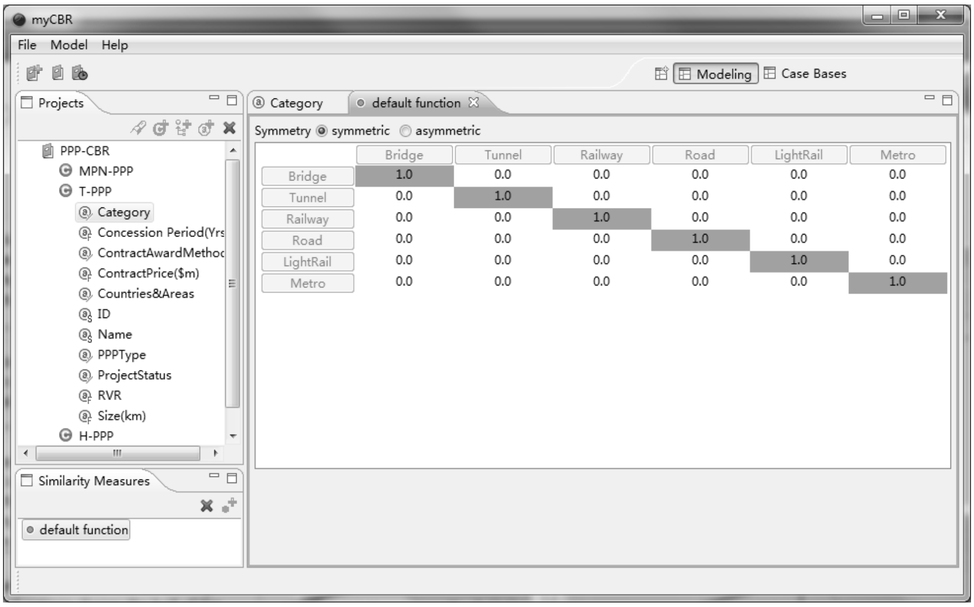

Figure 4.Similarity measure for category.

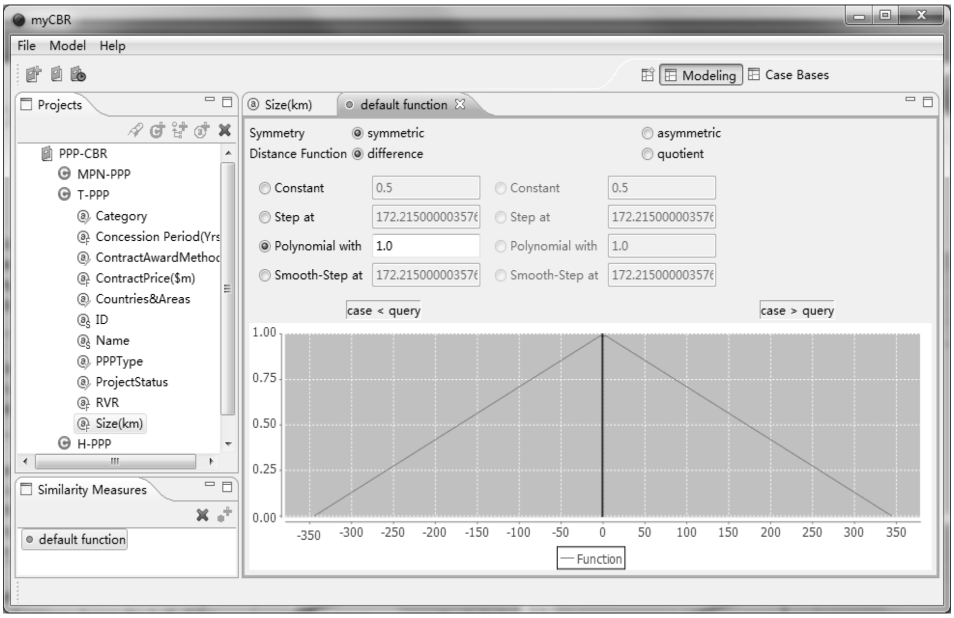

Figure 5.Similarity measure for size.

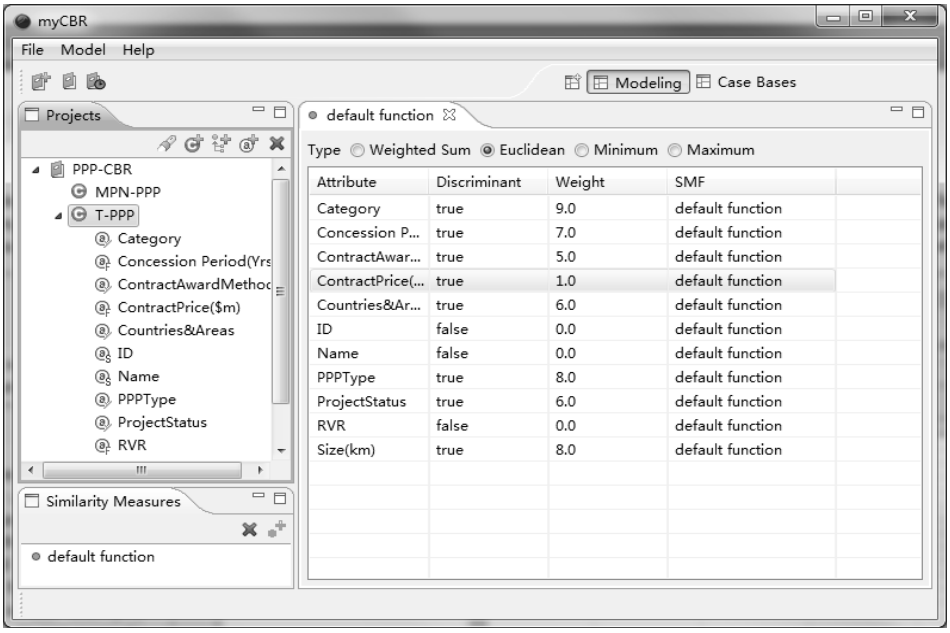

Figure 6.The global similarity measure.

(i) Firstly, we create a new project of PPP-CBR, add three concepts named MPN-PPP (Municipal Pipe Network PPP Projects), T-PPP (Transport PPP Projects), and H-PPP (Housing PPP Projects), and add attributes to each concept in the Projects View. Besides, we should assign the type and add the allowed value for each attribute in *the Main View* (see Figure 3).

(ii) Secondly, we should model the similarity measure to each attribute and the global similarity measure for the concept of T-PPP on the basis of Step 3, and input the weight of each attribute according to Table 3 (see Figure 4, Figure 5, Figure 6).

(iii) Finally, we add a case base in the Case Base view and import thirty-nine instances from *T-PPP* Case *Base.csv* created through "Step 2" (see Figure 7).

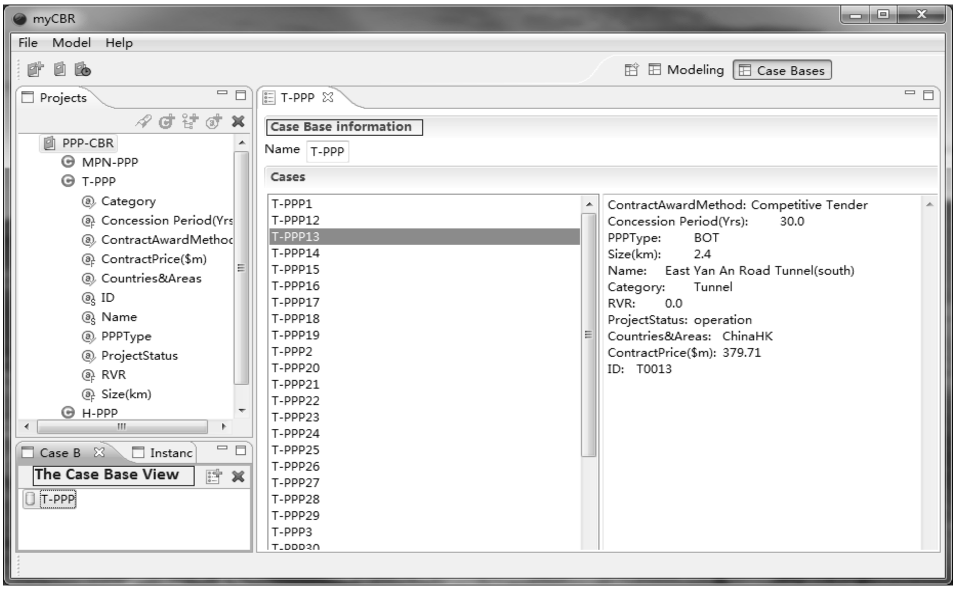

Figure 7.Add a case base and import instances.

CASE RETRIEVAL

The case retrieval is the most important process in RVR-CBR System design and also in the CBR component of the system. When a new PPP project comes, the RVR-CBR System retrieves, from a case base, previous cases that are similar to the new project situation.

For example, for a given project q = {Tunnel, 25Yrs, Competitive Tender, unknown, ChinaHK, BOT, transferred, 3.0km} information about previous project events similar to the current case retrieval. Firstly, select the concept T-PPP as the concept to start a retrieval for. Secondly, select the case base T-PPP from the available case bases within the project PPP-CBR. Thirdly, input the information of given project q= {Tunnel, 25Yrs, Competitive Tender, unknown, ChinaHK, BOT, transferred, 3.0km}, by specifying attribute values we formulate our query to the system. Finally, start the retrieval process on the selected case base with the specified query. Then, the result set of a retrieval is shown, and the overall similarity is shown and also used to sort the retrieved cases by their similarity to the case specified in the retrieval query.

Figure 8 shows that the case T-PPP 8 named Cross-Harbour Tunnel is the most similar to the given project, and the value of the similarity is 0.99, and the value of the case T-PPP35, T-PPP34, T-PPP14, T-PPP39, and T-PPP13 is 0.93. These cases are all very important for evaluating residual value risk of the given project. Therefore, we can evaluate the RVR of the given project by using some algorithms according to the RVR value of these retrieved cases.

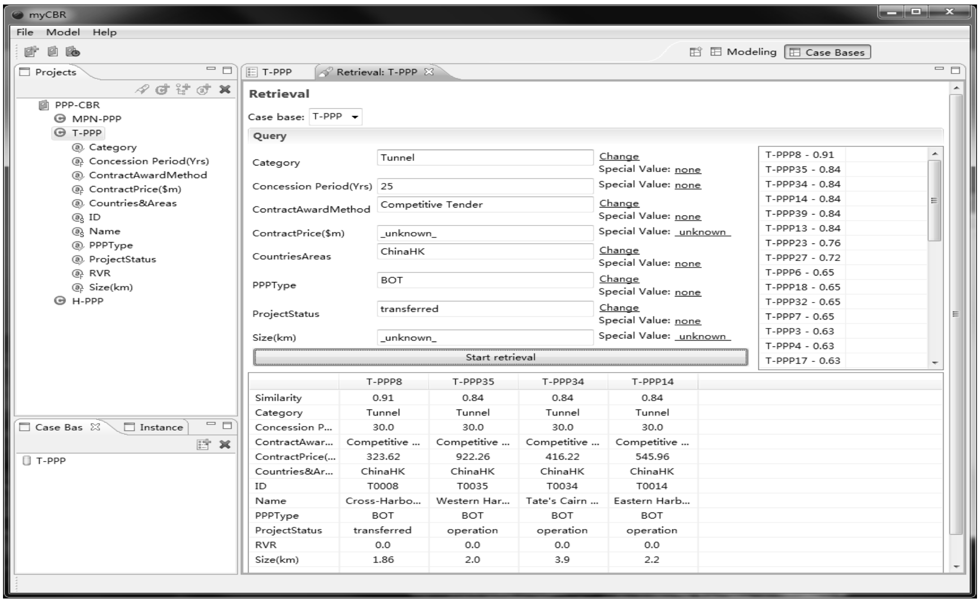

Figure 8.Case retrieval.

CONCLUSIONS

This paper proposes a case-based residual value risk reasoning system for Public-Private Partnership project (RVR-CBR System) with the help of myCBR 3.0 workbench. The RVR-CBR System is built through four stages based on three assumption conditions, with the capability to improve the efficiency of users in RVR evaluation. The RVR-CBR System can be used in our intelligent reasoning application of residual value risk for Public-Private Partnership project.

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