Study of a User-Centered CBR R5 Structure for Construction Dispute Resolution

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***Abstract*—Construction disputes are unique. Although traditional case-based reasoning (CBR) techniques can retrieve highly similar cases, they might be unsuitable for current cases because of preselected attributes and their predefined weights. A Latin maxim states that judgments shall be identical for like cases. Consequently, a dynamic and recursive system can solve construction disputes and avoid unfair judgments. Accordingly, this article proposes a CBR mechanism for resolving construction disputes. The proposed system strengthens the weaknesses associated with traditional CBR methodologies and successfully retrieves highly suitable reference cases. To ensure that the proposed system is customizable, a user-centered design (UCD) method and the corresponding International Standard Organization (ISO) standards are applied. Following the development of the UCBR, the proposed system is employed to predict the outcome of a dispute based on similarity.**

***Index Terms*—artificial intelligence, construction management, court decisions, dispute resolution, standards and codes, standardization**

I. Introduction

Resolving disputes based on the outcomes of previous cases is a characteristic of the English common law legal system, whereas resolving disputes according to laws and regulations is a characteristic of the Continental legal system. However, all legal systems share a common objective; they are applied to resolve disputes through laws and cases, such as rule-based reasoning and case-based reasoning (CBR). An integrated system can combine them to resolve disputes through laws or cases, for construction-related litigation, arbitration, mediation, or conciliation.

Most people tend to consider similar experiences when making decisions or solving everyday problems; thus, the CBR methodology offers a logical model that is similar to the behaviors that many people employ to resolve everyday problems.

Prentzas and Hatzilygeroudis asserted that the CBR methodology is weakened by four key factors (i.e., the inability to express general knowledge, knowledge acquisition problems, inference efficiency problems, and provision of explanations) [1]; however, it remains a user-centered design (UCD) method. This study proposes a UCBR model to strengthen some of these previous weaknesses and facilitate the efficient management of troublesome issues for construction professionals. The proposed model demonstrates practicable prediction and reasoning for resolving construction disputes, even under civil law jurisdictions. This support system is cost efficient and effective at mitigating construction disputes, improving the accuracy of retrieval cases, and reducing retrieval time. The proposed system is dynamic and recursive, and might substitute class action in managing large volumes of disputes within a short period.

The remainder of this paper is organized as follows. First, we address the concepts of professional responsibility and construction disputes. Second, general alternative dispute resolution (ADR) methods are introduced, followed by a review of the literature on CBR. Third, we detail the integration of the UCD concept and the International Standard Organization (ISO), and then discuss the development and testing of the proposed UCBR mechanism. Finally, the outcomes of the proposed system are presented, and our conclusion and findings are offered.

II. Literature Review

A. Dispute Resolution and Causation

Effectively resolving construction project disputes is critical for determining the overall project cost and ensuring the satisfaction of relevant parties. Dispute resolution generally involves four types (conciliation, mediation, arbitration, and litigation). ADR methods have proven helpful in various types of legal dispute in addition to formal court litigation. In the context of this study, arbitration, mediation, and conciliation are the major ADR methods relevant to the construction profession. Any ADR procedures can include a neutral party who can offer unbiased suggestions to the disputants. These methods are detailed as follows.

Conciliation and negotiation are dispute resolution methods involving well-established consent of both

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disputants. Mediation involves negotiating with the assistance of a fair third party (i.e., a mediator). Disputants may choose to agree on the offers of other parties or to respond with counter offers; however, the mediation outcomes are not enforceable under law. Similarly, arbitration involves negotiation with the assistance of arbitrators; however, arbitration is enforceable under law. Mini-trial, rent-a-judge, facilitation, and multidoor programs are also ADRs that are suitable for settling construction disputes, and they have proven effective in numerous cases.

Litigation is the traditional method for settling disputes in modern society. In the majority of countries with civil law systems, the types of litigation include civil, criminal, and state compensation cases. The majority of contract disputes are related to civil codes only. However, some construction disputes involve legal responsibilities among owners, project managers, architects, professional engineers, contractors, subcontractors, and their employees, exhibiting a type of chain reaction. Regardless of the type of dispute, the mechanism proposed in this study can assist in identifying solutions that maximize the benefits of decision makers.

In this study, we adopted the legal system of Taiwan—a civil law system—as an example to explain the responsibilities of construction professionals. First, regarding civil actions, Article 184 of the Civil Code proclaims the liability of torts as "A person who, intentionally or negligently, has wrongfully damaged the rights of another is bound to compensate him for any injury arising therefrom." Second, regarding criminal cases, Article 193 of the Criminal Code stipulates that "A contractor or an overseer who endangers public safety by violating an established rule of construction in erecting or demolishing a structure shall be sentenced to imprisonment for not more than 3 years, short-term imprisonment, or a fine of not more than 3000 yuan." Finally, regarding administrative concerns, article 3 of the State Compensation Law states that "The State shall be liable for damage to any person's life, body, or property resulting from a defect in the installation or management of any government-owned public facility. The compensating authority shall have the right to reimbursement from the said third person who is liable for the damage referred to in the preceding paragraph." These three types of liability are interactional, and the induced compensation and indemnity are related to the employees' liability in both public and private sectors.

Currently, researchers and practitioners are striving to determine the optimal method for resolving the aforementioned disputes. However, as mentioned by Udeaja et al., much of efforts on implementing knowledge management did not facilitate the collective learning of various participants involved in a project [2]. For that reason, the UCBR system combined with public litigation records may best fit the need of construction project team members.

B. CBR and Decision Support System

Recently, researchers and practitioners have utilized artificial intelligence (AI) technologies to develop different mechanisms for predicting judicial judgments [3]. These decision support systems are positive in assisting interested parties to predict and resolve disputes. Over the past decade, a series of innovative and improved methods has been developed to enhance the prediction and outcome of dispute resolutions. Chen (2003) developed a litigation prediction model (LPM) for predicting the trend of litigation caused by change disputes; the classification rate achieved 90% [4]. Subsequently, Chau indicated that the result of the CBR approach could predict 80% of the outcomes of construction claims [5]. El-adaway developed a logical induction-based decision support system for predicting the outcomes of construction claims and disputes [6]. The researcher also simulated legal discourse in construction disputes, thereby developing a multiagent system for construction dispute resolution (MAS-COR). Cheng et al. further enhanced the CBR model by combining it with fuzzy-set theory to establish a fuzzy (FCBR) model for use in a construction dispute settlement support system [7]. Subsequently, Pulket and Arditi proposed a universal prediction model (UPM) for construction litigation, demonstrating that the UPM offered a superior prediction rate to those obtained by previous studies [8]. By analyzing the legal factors of construction precedent cases, Mahfouz and Kandil employed support vector machines (SVM) and proposed an automated prediction model for construction litigations [9]. The support vector machine model was applied successfully to analyze the outcome of construction litigations, and the authors claimed that the accuracy reached 98%. El-Gohary and El-Diraby recommended an automated information extraction approach by utilizing syntactic and semantic features of the text to automatically extract regulatory information from building codes [10]. In 2011, the authors suggested further a deontic model (DM) which composed of a hierarchy of normative concepts, interconcept relations, and deontic axioms.

All of the aforementioned systems (Table I) have been developed to assist decision makers in efficiently resolving construction disputes. Recently, some hybrid or improved methods have been claimed to achieve even higher success rates. However, based on a review of relevant literature, we determined that few studies have discussed a comprehensive database system that integrates disputes and ADRs faced by the majority of construction decision makers from users' perspectives.

R5 Model: Researchers and practitioners are attempting to improve methods for resolving construction disputes. Based on Schank, Aamodt and Plaza proposed the 4R model (retrieve, reuse, revise, and retain), which is a process model based on the CBR cycle [11]. Subsequently, Finnie and Sun proposed the 5R CBR model by incorporating the repartition process as the initial step of the 4R process for building a case database [12]. The authors recommended that "The case base building is a form of similarity-based reasoning and can be improved using repartitioning of the possible world of problems and solutions." This recursive step can certainly improve the accuracy of the database. Because construction dispute resolution is considerably more complex than others types of resolution (because of its interdisciplinary characteristics), the 5R model is suitable for developing a CBR mechanism for resolving construction disputes. By employing the repartition process, old cases that are not in the case database can be added at any time.

TABLE I. LIST OF SYSTEMS HANDLING DISPUTES

System / Year	Model	Task	Researcher
1994	R4	Proposed R4 CBR model	Aamodt and Plaza
2003	R5	Proposed R5 CBR model	Finnie and Sun
2003	LPM	Predict probability of litigation	Chen
2003	CBR	Predict outcome of claims	Chau
2008	MAS-COR	Simulate legal discourse	El-adaway
2009	FCBR	Identify similar construction dispute cases	Cheng el al.
2009	UPM	Predict outcome of court cases	Pulket and Arditi
2010	SVM	Automated predict construction litigation	Mahfouz and Kandil
2010	IPM	Predict judicial results and reasoning	Arditi and Pulket

C. User-Centered ISO and R5 Model

Integration of the UCD concept and ISO: Human factors and ergonomics constitute a multidisciplinary expertise that entails integrating engineering, industrial and graphic design, statistics, operational research, psychology, and anthropometry. The involved concept is difficult and complex. Specifically, de similibus idem est judicium is a Latin maxim meaning that judgment shall be identical in similar cases. ISO 9241 provides directions on human-system interactions throughout the life cycle of interactive systems; thus, it is a powerful tool for ensuring that a design process remains human-centered.

ISO 9241-210:2010 defines a user experience as “a person’s perceptions and responses that result from the use or anticipated use of a product, system or service.” It also assists in managing the design processes of the software components of interactive systems. The most critical feature is that ISO 9241-210:2010 indicates that outputs and inputs of a human-centered design activity are interdependent on other activities. The proposed 5R-CBR model satisfies this standard. For ensuring that the system design is user centered, the applied guidelines of the ISO standards are described as follows:

- The users are relevant parties of dispute cases, and the task is intended to settle disputes among them.
- The system is not only designed to collect recommendations from literature and expert reviews but it also values the users’ perspectives.
- The entire user experience is considered throughout the system design process.
- The design can be applied and refined by users through the CBR revision function.
- It is an open and user-friendly system that can be used nearly every day; thus, users can be involved throughout the system design and development.
- The process can be iterative until the needs of the users are satisfied.

In the foundation research on UCD, Norman indicated that UCD is based on the users’ needs by omitting what they consider secondary issues [13]. The aforesaid ISO standards fulfill the UCD philosophy of a user-centered design process. ISO 9241-210:2010 can be employed during the CBR system design to facilitate the generation of new product ideas to create a UCBR model.

III. DEVELOPMENT OF UCBR MECHANISM

Human factors are among the concerns in developing an effective CBR mechanism. To incorporate a CBR procedure into a decision-support system, users must first carefully select and weight the attributes of the target case. Subsequently, the system identifies one or more similar cases. Because of its simplicity, even beginners of construction professional can operate the system effectively. Nevertheless, the main concern about this system is the accuracy and usefulness of case selection.

Because of the complexity of construction disputes, the 5R-CBR system (Fig. 1) can facilitate the dispute resolution by continually adding relevant cases. Because the usability is a key concern for system users, we employed a UCD method to develop the proposed CBR mechanism. The CBR methodology has been widely employed in the majority of professions. Moreover, the CBR method is a type of AI technology that solves new problems based on the solutions of similar previous cases, and UCD is a customized design that focuses primarily on the needs of end-users of a product. The combined CBR-UCD model assists decision makers and other disputants in learning the possible outcome of their disputes. It would help them to reach the meeting of minds efficiently. Consequently, the aforementioned interdependent design activities of ISO 9241-210 ensure that the CBR system is user-centered. Therefore, the UCBR model (Fig. 2) for dispute resolution appears to be beneficial for handling construction disputes.

IV. DESIGN OF UCBR PROTOTYPE MODEL

Regarding the proposed mechanism, a prototype UCBR system was developed using retrieval, input, and maintenance modules to obtain binding or unbinding decisions and agreements for the development of a CBR database management system. Next, a usability evaluation method was adopted to assess the usability of the prototype CBR database management system. Thus, the users’ satisfaction and needs regarding the prototype system can be observed. Moreover, the results from the evaluation can provide feedback and a reference for system designers to reapply the UCD methods to subsequently improve the system. Moreover, additional attributes may also be collected to enhance these modules. The novel UCBR mechanism can enhance human-system interactions by applying the interactive system components, thereby offering a reasoning prototype that is similar to the method people apply habitually in solving their daily problems. This cycle can be repeated until the optimal UCBR database management system is obtained.

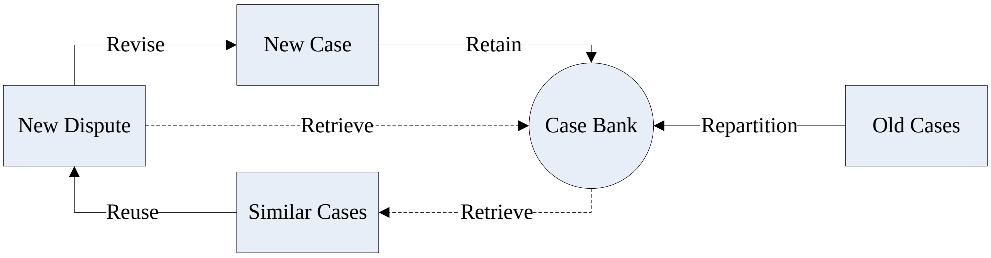

Figure 1. Model of R5-CBR.

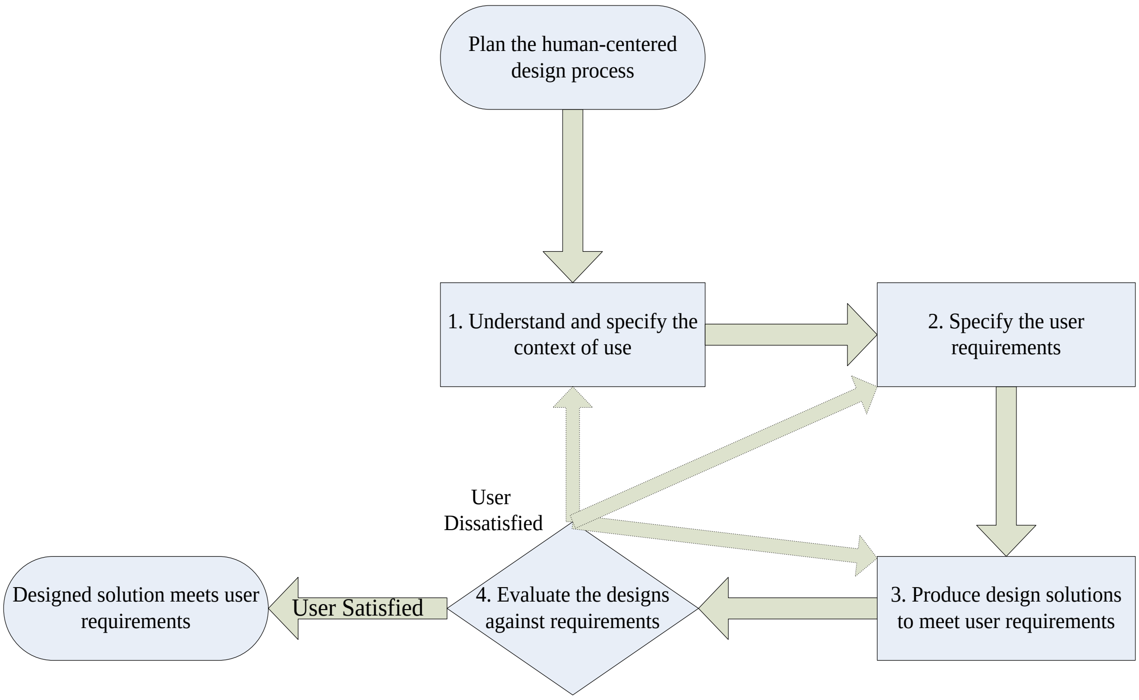

Figure 2. Human-centered design process.

The prototype model was designed based on the discussed UCBR mechanism. The design of the relational database model was initiated in accordance with external, conceptual, and physical architectural levels of a database. First, after obtaining all available dispute resolution cases, the design of the prototype system begins with a system analysis to ensure that the needs of end-users are met. At this external level, designers apply the UCD philosophy to organize a human-centered database system. Next, the database structure is defined at the conceptual level.

A. External and Conceptual Level

The system framework and flowchart (Fig. 3) are defined based on the needs of end-users. Subsequently, a logical data flow diagram (DFD), which is a structured analysis technique, is adopted to show how the data move and change in the database system. Next, the DFD and defined context diagram are created.

B. Physical Level of Design

After completing the conceptual and physical level (Fig. 4), the major steps of the physical level were conducted based on the following sequence: (1) distribute or input the collected data into tables; (2) develop the entity-relationship (E-R) model; (3) specify the primary keys for each data table; (4) establish the table relationships; and (5) normalize the database tables. Because the highest level of normalization is not always desirable, the three levels of normalization applied at this point involved deleting any repetitive data and establishing functional and transitive dependency. Following the table normalization, the tables were adjusted as necessary. Finally, we employed the database application Microsoft Access to develop the proposed system.

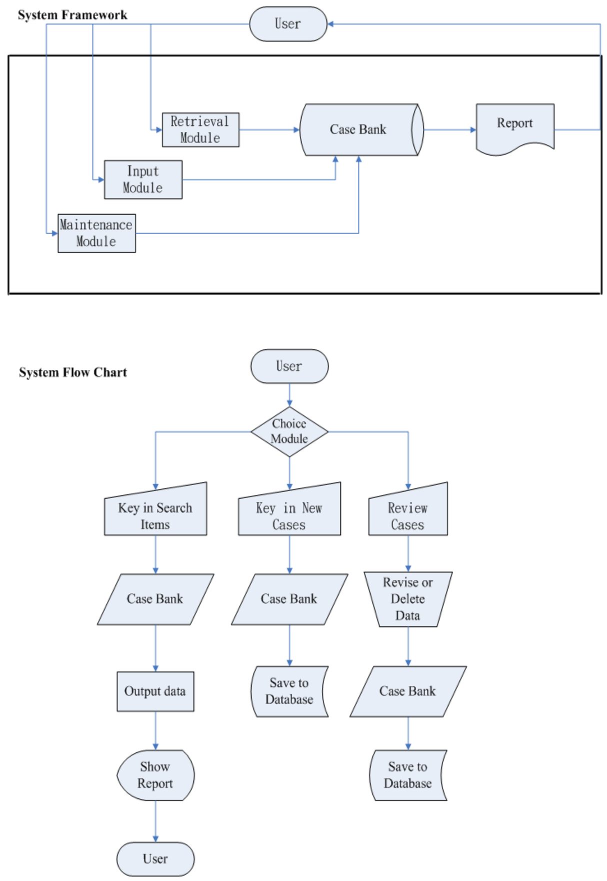

Figure 3. System framework and flow chart.

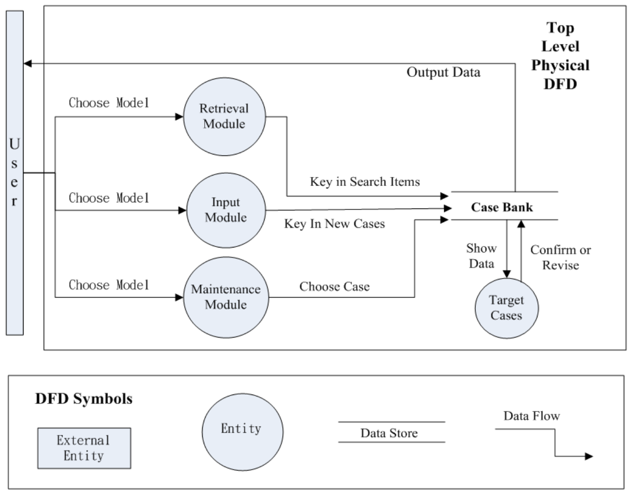

Figure 4. Top-level physical DFD.

Sources of Dispute Cases and Attributes: Local dispute cases were obtained from the database of the Judicial Yuan of the Republic of China to develop the prototype CBR database management system and to test the proposed UCBR model [14]. The case information and attributes recommended by experts and scholars were tabulated to build the E-R model. Subsequently, the table relationships were established and the tables were normalized. Moreover, any new cases were indexed and input into the database. Table II lists the categories of the 35 selected attributes of the proposed system.

TABLE II. CLASSIFICATION OF ATTRIBUTES

#	Classification	Attribute of Dispute
1	Decision Ground	Contract, Jurisprudence, Customs, Act, Arbitration, Mediation, Conciliation, Litigation, Other Means, Claimed Amount, Accommodation Amount, Insured or not.
2	Schedule Involved	CPM, Coordination, Concurrent Delay, Disaster.
3	Damage Measured	Cost Escalation, Advance Payment, Late Payment, Compensatory Liquidated Damage, Punitive Liquidated Damage, Appraised Lost Amount.
4	Quality Involved	Alternative Material, Supervision.
5	Change Order	Directed Change Order, Constructive Change Order, Scope.
6	Contract Type	Lump Sum, Unit Price, Cost plus Fee, Time Rate Pay, Percentage of Construction Expense.
7	Other Dis-agreement	Contract Interpretation, Unknown Site Condition, Misrepresentation of Site.

Weight of Attributes: For the proposed prototype UCBR system, 35 attributes were selected for predicting the outcome of similar dispute cases. They were recommended and defined after interviewing three construction and legal practitioners. The method for determining the weight of attributes for each case was identical to the method for establishing attributes. A 5-point Likert scale ranging from 1 (least important) to 5 (most important) was adopted to assign values to the attribute weights. These values can be subsequently adjusted dynamically to fit the particular needs of system users. This contrasts with traditional methods that involve employing fixed attribute weights. Additionally, it is more user-friendly because the attribute values can be binary (i.e., a case is either relevant to cases in the database or not); when there is no relevance between the dispute and the cases in database, the value is 0; otherwise, it is 1. The UCBR model manipulates only the 35 identified binary attributes to simplify the model (Table III).

Calculation of Similarity: To retrieve suitable referral case, the user must first determine whether an attribute is relevant and enter a value (0 or 1) for each of the 35 attributes. Next, the user may change the recommended attribute weights if necessary; thus, the system is dynamic according to the user's needs. Subsequently, the retrieval module reports the relevant cases after calculating the similarity between the target case and cases in the database.

TABLE III. SIMILARITY (S) OF THE TEST CASE BY ATTRIBUTE

#	Attribute	Target Case Scenario 1		Case 1	Case 2	Target Case Scenario 2		Case 3	Case 4
		User Defined Attribute	User Defined Weights (1~5)	Attribute	Attribute	User Defined Attribute	User Defined Weights (1~5)	Attribute	Attribute
1	Contract	1	4	1	0	1	4	1	0
2	Jurisprudence	1	3	1	1	1	3	0	1
3	Customs	0	0	0	0	0	0	0	0
4	Act	1	4	1	0	1	4	1	0
5	Arbitration	0	0	0	0	0	0	0	0
6	Mediation	0	0	0	0	0	0	0	0
7	Conciliation	0	0	0	0	0	0	0	0
8	Litigation	0	0	0	0	0	0	0	0
9	Other Means	0	0	0	0	0	0	0	0
10	Claimed Amount	0	0	0	0	0	0	0	0
11	Accommodation Amount	0	0	0	0	0	0	0	0
12	Insured or not	0	0	0	0	0	0	0	0
13	CPM	0	0	0	0	0	0	0	0
14	Coordination	0	0	0	0	0	0	0	0
15	Concurrent Delay	0	0	0	0	0	0	0	0
16	Disaster	0	0	0	0	0	0	0	0
17	Cost Escalation	0	0	0	0	1	4	1	0
18	Advance Payment	0	0	0	0	0	0	0	0
19	Late Payment	0	0	0	0	0	0	0	0
20	Compensatory Liquidated Damage	1	4	1	0	1	4	1	0
21	Punitive Liquidated Damage	0	0	0	0	0	0	0	0
22	Appraised Lost Amount	0	0	0	0	0	0	0	0
23	Alternative Material	0	0	0	0	0	0	0	0
24	Supervision	0	0	0	0	0	0	0	0
25	Directed Change Order	0	0	0	0	0	0	0	0
26	Constructive Change Order	0	0	0	0	0	0	0	0
27	Scope	0	0	0	0	0	0	0	0
28	Lump Sum	1	5	1	0	1	5	1	0
29	Unit Price	0	0	0	0	0	0	0	0
30	Cost plus Fee	0	0	0	0	0	0	0	0
31	Time Rate Pay	0	0	0	0	0	0	0	0
32	Percentage of Construction Expense	0	0	0	0	0	0	0	0
33	Contract Interpretation	1	4	1	0	1	4	1	0
34	Unknown Site Condition	0	0	0	0	0	0	0	0
35	Misrepresentation of Site	0	0	0	0	0	0	0	0
Similarity		Scenario 1		**100%**	**13%**	Scenario 2		**89%**	**11%**
Note: Calculation of Values		Denominator: 1*(4+3+4+4+5+4)+29*0=24, Numerator: Case 1 1*(4+3+4+4+5+4)+29*0=24, Case 2 1*3+33*0=3 Similarity: Case 1 24/24=100%, Case 2 3/24=13%				Denominator: 1*(4+3+4+4+4+5+4)+28*0=28, Numerator: Case 1 1*(4+0+4+4+4+5+4)+28*0=25, Case 2 1*3+34*0=3 Similarity: Case 1 25/28=89%, Case 2 3/28=11%			

The similarity between the queried dispute a in the case i in the database j is defined as the sum of the local resemblances of its integral attributes LSa multiplied by their relevance weights Wa and divided by the total of the relevance weights, as in (1).

$$\text{Similarity (i, j)} = \frac{\sum_{a=1}^{n} Wa \times LSa_{(i,j)}}{\sum_{a=1}^{n} Wa} \quad (1)$$

Equation variables:

Similarity$_{(i, j)}$: similarity between cases *i* and *j*.

Wa: weight of dispute *a*; user-defined (1 to 5).

LSa$_{(i,j)}$: similarity of attribute *a* between cases *i* and *j* (0 or 1).

n: number of attributes (35) or attribute types (7).

V. IMPLEMENTATION OF UCBR MODEL

A test case was selected to evaluate the proposed prototype UCBR model. The civil litigation case involved a delay lump-sum construction project. The key disputes of the litigation included punitive damage, contract explanation, jurisdiction, and the principle of good faith.

Among the 2323 construction litigation cases in the database, the UCBR model retrieved 1693 relevant cases LSa > 0. Five cases were 100% similar to the test case. The minor differences were trivial for this model; for example, the respondents had no effect on the result because they were not assigned attributes. However, some cases have little similarity (e.g., LSa≧13%). Table III shows the results of the similarity test for Scenario 1.

Compared with Scenario 1, which adopted six attributes (contract, jurisprudence, act, compensatory liquidated damage, lump sum, and contract interpretation); the proposed model was tested further by adding the cost escalation attribute. In this scenario, the model retrieved the same results with various similarity values. No case achieved 100% similarity with the test case (LSa maximum = 89%). However, some cases had much lower similarities than the results for Scenario 1, (e.g., LSa = 11%). Table III shows the similarity test results and calculations for Scenarios 1 and 2.

When we adopted the types of attributes (Scenario 3), only seven groups of them, and go through the same procedure, the results for the lowest similarity were 18% (Table IV). The similarities for Scenario 3 were markedly higher than those for Scenarios 1 or 2. In addition, more cases were retrieved from the database. Moreover, this implies that a deeper level of categorization certainly increases the accuracy of the model. The aforementioned scenarios demonstrate the benefits of the recursive and flexible function of the UCBR model.

After retrieving most similar judgments and reasoning of the historical dispute cases, the reasoning behind the case can also be employed to predict the possible outcomes of current cases. The predicted case results can then serve as a crucial reference for making decisions in future dispute resolution procedures. The implementation of the proposed prototype UCBR model demonstrates its usability with fair prediction capability. This database is a useful tool to pursue claimants, and it is an efficient support system for decision makers.

VI. Conclusion and Recommendation

A. Conclusion

This article proposes a user-friendly CBR system for resolving similar dispute cases. The proposed system strengthens the weaknesses associated with traditional CBR methodologies and successfully retrieves highly suitable reference cases. We developed a convenient approach for systematically managing construction-related disputes. Because a CBR system must consider the principle of stare decisis in common law systems, the proposed UCBR mechanism can assist decision makers in efficiently identifying the most appropriate cases based on accumulated judicial judgments from the databases such as LexisNexis and Westlaw International, two frequently used commercial law retrieval databases in Anglo-American jurisdictions. Finally, the proposed mechanism can enhance the knowledge of users in mitigating contractual disputes, and the dynamic user-centered design can suit the needs of end users in a timely manner.

B. Recommendation

The proposed UCBR mechanism can assist decision makers in efficiently assessing historical cases during the process of resolving disputes. However, the attribute selection process plays a crucial role in improving the accuracy of retrieved cases. In practice, employing a fair third party, such as a town mediation committee, to operate the system is essential for convincing plaintiffs that the system is fair. Likewise, the assessment of losses can be appraised through the help of this fair third party. These improvements certainly contribute to resolving a high percentage of disputes [15]. Moreover, a more comprehensive structured or unstructured construction litigation databases on evidence, standards, and appraisals may advance the efficiency of the system [16]. Furthermore, sensitivity analysis and statistical screening techniques may be utilized to evaluate the impact of the litigation issues and judgments [17]. The aforesaid issues are all worth to study further for facilitating the efficient assessment of valuable historical cases.

TABLE IV. Similarity (S) of the Test Case by Type

#	Type of Attribute	Target Case (Scenario 3)		Case 5	Case 6
		User Defined Attribute	User Defined Weights (1 to 5)	Attribute	Attribute
1	Decision Ground	1	5	1	0
2	Schedule Involved	0	0	0	0
3	Damage Measured	1	2	1	1
4	Quality Involved	0	0	0	0
5	Change Order	0	0	0	0
6	Contract Type	1	2	1	0
7	Other Disagreement	1	2	1	0
Similarity		Target Case (Scenario 3)		**100%**	**2/11=18%**
Note: Calculation of Values		Denominator: 1*(5+2+2+2)+3*0=11, Numerator: 1*2+6*0=2 Similarity: 2/11=18%			

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