Authors:
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Further reference acknowledgements:


Abstract: Although data warehouse is very practical for decision making, its application in contract administration is rather limited due to the complicated legal issues and the voluminous data involved. This research attempts to bridge this gap in two ways. First, conceptual models of data warehouse are developed to explain the contents and overall features of the system which were verified by twelve experts in Malaysia. Second, a template, e-Dispute Resolution (e-DR), is prototyped using Microsoft Access based on the guidelines of contractual variations agreed by the experts. Subsequently, the prototype is evaluated by sixteen professional quantity surveyors from an established consulting firm. The prototype was organized based on a systematic breakdown of issues and incorporated a Boolean keyword search feature. The results show that the concept of data warehouse is applicable to contract administration and is well received by practitioners. Overall, this article renders significant theoretical and practical contributions where the resulting e-DR does not only lead toward a more informed decision making, but is also able to mitigate or prevent contractual disputes in the construction industry where such a phenomenon seems to be inevitable.

Keywords: Database application; Contract administration; Data warehouse; e-Dispute Resolution; Contractual variations; Construction industry.

INTRODUCTION

The construction industry is known to be fragmented and adversarial in nature (Cheung and Yiu 2007; Ajam et al. 2010). Every construction project is bound to have contractual conflicts or disputes due to high risk and degree of complexity of the project (Kim et al. 2008). Even though contract administration regulates contractual obligations and expectations between the contracting parties, contractual variations have been found to be among the most common cause of disputes in the industry (Charles and Bruce 1990; Semple et al. 1994; Zaneldin 2006; Perkins 2009; Serag et al. 2010). These variations or changes are unfavorable in construction projects in the context of contractual commitments and effective implementation of the project (Moselhi et al. 2005;
Anastasopoulos et al. 2010). This is particularly true with regards to issues concerning interpretation and understanding of construction contracts due to the illegibility of contract clauses and the use of legalese or complicated terms (Thomas et al. 1994; Broome and Hayes 1997; Shumway et al. 2004; Rameezdeen and Rajapakse 2007).

The problem is further compounded by the increasingly complicated legal issues, voluminous data involved, and contractual requirements of a construction project. Further, judgments from litigation cases create numerous legal views or positions into the practice of contract administration. The lack of understanding of the contract provisions and jurisdiction of legal cases is a common problem in the construction industry, as most of the users do not possess a legal background (Chong and Zin 2010). All these issues lead to contractual conflicts and disputes. Although previous studies have identified information technology (IT) as one of the possible measures of mitigating conflicts and disputes (Cheung et al. 2004; Nitithamyong and Skibniewski 2004; Chen 2008; Chong et al. 2011), the application of IT in contract administration in the construction industry is rather limited. This offers a fertile ground for research.

Data warehousing is a relatively new concept in the development of database and information systems domains (Hwang and Xu 2008; Inmon and Valente 2010). In fact, it is a collection of methods used to support users in conducting data analysis for the purpose of decision making and improving information resources (Inmon 2002; Rahman 2007). In the context of this paper, construction contracts are considered textual data in data warehouse. However, these data are yet to be effectively introduced in business decision making. This is simply because the basic database technology is designed for repetitive events and structured data such as transactions, whereas textual data are not repetitive and are unstructured (Russell et al. 2009). As pointed out by Inmon and Valente (2010), the greatest concern is the visceral mismatch between the structure of a database and the lack of textual structure. Nevertheless, the application of data warehousing should be able to perform data analysis, reporting, and query tools to help
the users swift through tonnes of data and extract valuable information from them (Gupta and Mumick 2005).

Due to this challenge, the development of data warehouse for contract administration (DWCA), particularly its contents and application features, needs to be well thought of. The objectives of the study are (a) to develop a conceptual process flow model for incorporating the data warehouse technology into the construction contract administration, and (b) to develop the e-Dispute Resolution (e-DR) prototype based on the resulting DWCA model depicting contractual variations.

Consequently, the outcome of this study will allow improved contract administration, which will possibly be adjusted and adopted in other countries, especially the Commonwealth countries which share similar common law system. Notwithstanding the limitations highlighted at the end of the paper, this research makes significant theoretical and practical contributions where it sets directions for future research and the possibility of replicating the same study in different countries with similar or diverse legal systems.

This paper is structured as follows. It first reviews the literature concerning data warehouse, followed by a description of the research approach used in this study. Next, the resulting DWCA model is explained. Subsequently the e-DR prototype development is illuminated. The following section presents the evaluation results of the prototype before its implications are discussed. The paper is then concluded.

DATA WAREHOUSE FOR CONTRACT ADMINISTRATION

Previous approaches

Previous studies concerning IT application in contract administration were analyzed and compared. Table 1 presents the details of nine related studies that were conducted between 1988 and 2011. Generally, it can be concluded that previous studies have dealt with both general
construction disputes and specific issues within contract administration. In addition, it can be observed that IT concepts and applications play a role in enhancing the usability and flexibility of a decision support system. However, the studies suffered from methodology weaknesses in one way or another such as the absence of verification by a panel of experts, contract forms, and historical/court cases. Such an overview renders a useful insight in terms of bridging the gaps available in the literature as well as practice. It is apparent that the development of DWCA from the decision-making perspective has not been thoroughly investigated, although data warehouse has been identified as a very practical tool in data application for organizations (Hwang and Xu 2008). The developed DWCA model therefore highlights a significant area of improvement for traditional contract administration (Chong et al. 2011). It motivates the development of e-DR prototype in this research.

Data warehouse: New breed of decision support systems in contract administration

Data warehouse is a read-only database created by combining data from multiple databases for purposes of analysis and decision making (Theodoratos and Sellis 1999). The contents of a data warehouse may be a reproduction of a part of some source data or the results of preprocessed queries or both (Chau et al. 2002). This approach of data storage provides a useful guide in making decisions. As a matter of fact, data warehouse has been recognized as a type of decision support systems. In this context, it is an analytical database that efficiently collects, organizes, and stores all relevant data in support of management decisions (Chau et al. 2002; Rujirayanyong and Shi 2006). It ensures that the users could access or retrieve the data for references and decision making at the appropriate time during the contract administration period. The characteristics of data warehouse technology thus motivate the need for a new breed of decision support systems in contract administration.
RESEARCH APPROACH

The research and development works consist of two main activities. The first activity comprises of the DWCA model development, and the second involves the development of e-DR prototype based on the most problematic issues of contractual variations. The prototype is named as e-DR following the terms (e-Dispute Resolution) for purposes of simplicity and easy to remember. Coincidently the acronym ‘DR’ appears in a way which denotes a medical doctor, which is aligned to the purpose of this study. These two main activities were simultaneously carried out with input sought from twelve experts using the mini Delphi approach to validate the model and agree on the guidelines on contractual variations for the contents of e-DR. The details of the experts are shown in Table 2. They were chosen based on profession and a wide range of expertise related to construction contract administration. All the experts have had more than 20 years of working experience. They are either directors or partners in their respective companies and hold significant roles in their respective professional bodies.

The Data Flow Diagram (DFD) method was selected for DWCA model development as this method focuses on the object perspective (Luo and Tung 1999). Specifically, two conceptual models of DWCA were developed to systematically describe the process flow involved in the development of e-DR prototype. These models were developed by referring to the requirements of data warehousing and literature related to construction contract administration. Subsequently, these models were verified and supported by the experts.

Meanwhile, the guidelines for contractual variations need to be assessed and commented by the experts for accuracy and completeness of its use for the local industry as the guidelines were derived based on a review of contract provisions from a local contract form, Pertubuhan Arkitek Malaysia (PAM) or Malaysian Institute of Architects 2006, and court cases. For this, two rounds of mini Delphi exercises were conducted and completed after obtaining consensus from the experts. The experts were asked for their degree of agreement using 11-point Likert scale for
the guidelines. This scale was chosen as it could detail out the levels of agreement. The score and definition for the agreements are modified from the related Delphi studies (Liang et al. 2006; Hsu et al. 2010), that is, 0= absolutely disagree; 1= strongly disagree; 2= highly disagree; 3= quite disagree; 4= slightly disagree; 5= neutral; 6= slightly agree; 7= quite agree; 8= highly agree; 9= strongly agree; and 10= absolutely agree.

Subsequently, the score changed from the points 0-10 to 1-11 to facilitate the analysis of geometric mean. The conversion is important to avoid calculation error that might have occurred when calculating zero score. The formula of geometric mean is the positive $n$th root of the twelve experts of a set of $n$ numbers (scores). This analysis is aimed to obtain an easy, comprehensible definite value based on the principle of Centroid method for the defuzzification and normalization process (Hsu et al. 2010). Then, a pre-determined threshold value was applied as selection criteria for the guidelines. The value was modified and classified into three categories (Kuo and Chen, 2008; Chong and Rosli 2010), such as:

- ‘Disagree’ = $1 \leq \text{geometric mean} < 4.75$
- ‘Undecided/Neutral’ = $4.75 \leq \text{geometric mean} < 7.25$
- ‘Agree’ = $7.25 \leq \text{geometric mean} \leq 11.00$

The guidelines were found to score more than the threshold value (7.25) and as such, they would serve as the contents of e-DR. The details of the contents (Part A) are shown in Appendix A. The rest of the parts (Part B, C, and D) serve as a reference to readers who wish to know the contractual variations in brief.

**DWCA MODEL**

A model is a valuable tool to communicate and manage a process requirement or information between entities (Chen et al. 2004; Chen et al. 2010). In this study, two conceptual models of
DWCA using the DFD method were developed. Generally, the models describe the process flow of the e-DR prototype development.

The first model (Level-0 DFD) (Figure 1) explains the sequence and processes involved in content development. It demonstrates how a clarified, organized, and reliable source of references regarding the contractual obligations and expectations required for contract administration are produced so as to help users produce better and more informed decision making.

As Figure 1 illustrates, the potential disputes or contractual issues form the basis of the Level-0 DFD model. The issues related to the disputes can be categorized into three main stages: (1) pre-contract stages; (2) construction or commencement of work stage; and (3) work completion stage, as shown in Table 3. The issues listed in the work stages are identified from the literature (Chong et al. 2011).

Besides, leading court cases, contract provisions, and literatures are important inputs in the DWCA in addressing contractual issues. It is imperative to first consider common law principles and legal positions related to the issues by referring to the court cases in order to enhance the information on contract provisions. Second, the contract clauses and sub-clauses related to the standard contract form are referred to in this study. A reference will be made to the main clause and its sub-clauses of the contract relevant to the contractual issues in addition to other related clauses. All the related clauses will be combined and cross-referenced in order to gain a wider view of the expressed contractual obligations and expectations. In addition, literature sources also contribute in terms of organizing and recognizing the characteristics of the contractual issues from different perspectives. Another consideration is the use of plain English guidelines to enhance contract clarity and to make them more accessible to non-lawyers.

Figure 2 shows the second conceptual model (Level-1 DFD) and its features as required by the DWCA. It is designed in such a way that it eases the users in searching for information and providing feedback. Eventually, the resulting e-DR aims at rendering self-examination and a
proactive approach in contract administration whereby the clarified references and/or guidelines are referred to and retrieved by the users.

The Level-1 DFD model consists of three main features such as keyword searching by using Boolean exact keyword search principle (Mitra and Chaudhuri 2000), dispute sub-categories (breakdown of issues), and a forum for comments or discussion. Accordingly, the contractual issues in the three work stages are kept in the database and classified according to the project particulars. The issues can be retrieved by using keyword searching or by selecting the concerned issue from the list of breakdown of issues. The project database is referred to in order to provide a list of choices based on the project features, that is, types of the project (building, road, etc.), contract–payment methods (lump sum contracts, cost reimbursement, etc.), procurement methods (traditional, design and build, etc.), and standard forms of contract [local such as the Public Works Department (PWD) 203A (Revised 10/83) form or international contract forms such as Joints Contract Tribunal, New Engineering Contract, etc.]. The specified particulars of the project will then be sorted out.

Subsequently, the targeted contractual issue will be further examined based on the characteristics of the issue in order to investigate and seek the root cause of the main issue. In this process, relevant references or guidelines stored in the database are selected. The database performs two functions. It provides the consensus data by the experts based on the issue’s root causes. The next function is to keep all the comments or discussions made by the construction practitioners regarding the particular issue or its sub-topics. It will serve as a forum of discussion for the practitioners in exchanging and sharing information.

The models were validated by twelve experts through the mini Delphi process. The experts commended on the extent of comprehensiveness of the models developed and their associated contents. Their involvement and the resulting output generated have greatly enhanced the validity of the models which facilitated the development of the e-DR prototype.
A prototype, namely e-DR was developed as a result of the developed DWCA models. The e-DR prototype is developed by using Microsoft Access 2007 Developer Extensions and Runtime due to its user-friendly functions and wide availability. The software was used to create a template to be evaluated by the practitioners. However, the prototype focuses only on one of the contractual issues identified in the construction or commencement of work stage, that is, contractual variations (Table 3). Nevertheless, all the relevant tables of the database such as project particulars, issues related to disputes in the three stages [pre-contract stage (pre-issues), construction or commencement of work stage (con-issues), and work completion stage (post-issues)] were developed. The tables and their relationships are illustrated in Figure 3. The One-to-One and One-to-Many relationships were set for the tables to ensure functionality of the data warehouse.

In this prototype, the dimension tables are main variations (MainVariations), sub variations (SubVariations), Content, and Forum, whereas the others are fact tables. In total, there are eight tables in DWCA. Project particulars describe the classification on the type of project, contract system, procurement method, and standard form used.

The main variations list the four main aspects of contractual variations such as issuance of variations, validity of variations, valuation rules of variations and additional expenses, and subsequent circumstances caused by variations. The sub-variations list the sub-issues from the four main aspects of contractual variations such as authorized persons and power, period of issuance, provisional sums, written instruction, definition/principle of variation, addition, omission, substitution, alteration of the kind or standard of materials or goods, removal of executed works, materials and goods, changes to the provisions in the contract, valuation rules of variations, Rule 1 of contract’s rates and prices, Rule 2 of fair adjustment, Rule 3 of fair market rates and prices, Rule 4 of day-work rates, Rule 5 of omitted work, Rule 6 of re-measurement on
actual quantities (provisional quantity), and additional expense and subsequent circumstances caused by variations. Content refers to the complete list of the generic guidelines/references on the contractual variations, whereas Forum is the platform for the end users to comment or provide feedback on the issue.

Subsequently, the database queries and forms were developed from the DWCA tables. The forms are an important feature in the e-DR database. The e-DR interface was developed based on the forms. The final e-DR database file was converted into an executable (exe) file in a template setting. As such, it serves as a read-only analytical database that is used as a foundation for decision making. The portion of the forum for comments or feedbacks is excluded from this, which is deliberately set in an unlocked mode. Overall, the interfaces of the prototype were described in the following sequence, such as:

- Front Page: It provides general information that the contents are derived from literature reviews, contract provisions of PAM 2006, legal cases, and the consensus views of experts. A disclaimer is also provided to explain the exclusion of liability.

- Main Menu: Subsequently, two options are made available in the main menu interface for retrieving the contents, that is, issues breakdown and keyword searching.

- Issues Breakdown: This interface consists of several database forms that were developed from the queries and tables of raw data. It is designed in such a way that users can easily locate the specific sub-issue to be referred to. Users can refer to the guidelines based on the sub-issue after clicking the “Click here for DETAILS” button. The users are able to comment or give their feedback (if any) after referring to the guidelines by clicking “GO to Forum/Comments” button.

- Keyword Searching: All the guidelines are allocated in the database. As such, the keyword searching feature would help users to locate the issue or guideline easily. The command
button “Find and Replace” is used to perform searching. Besides, users are also able to provide their comments in the interface by clicking “GO to Forum/Comments” button.

- Forum/Comments: This forum has been deliberately set unlocked with the command ‘Auto Number’ so that users can comment or discuss in the forum, and all the comments will be automatically stored and appeared here.

Data from contract provisions, legal cases, and literatures are organized and uploaded to the warehouse after receiving verification from the local experts. Apart from that, the interface to and from the data warehouse is operated in a batch mode (offline). Operating in an online mode is an appealing option but not very useful in this study (Inmon 2002). This is because the data warehouse needs to get full support or sanction from the local authority and professional bodies in order to publish legal information or contract provisions. This is also to prevent the conflict of interest (Chong et al. 2011). It would lock the database, and the users would not be able to edit the database, except for the feedback or comment section.

**TESTING AND EVALUATION**

The e-DR prototype is presented to sixteen professional quantity surveyors who are among the potential end users for testing and evaluation. They are required to rate their satisfaction based on the scores determined by the researchers, that is, 0 = extremely dissatisfied, 30% = dissatisfied, 50% = neither satisfied nor dissatisfied, 70% = satisfied, and 100% = extremely satisfied on five closed-ended questions. The questions were designed around the critical requirements of the DWCA and e-DR. An open question for comment and feedback was also included where the respondents were free to provide their responses. Table 4 shows the results of the prototype evaluation.
The overall score was 74.1%, thus indicating that the respondents were satisfied with the prototype. All the variables are above the neutral level (50%), thus confirming support for the overall score. The usefulness of clarity, practicality, and functionality of the prototype received positive feedback from the respondents. In addition, the respondents had little reservations regarding the coverage of the guidelines on contractual variations. This is evident from the comments posed by the respondents in the open-ended question where they would like to have more discussions and elaborations on the contractual variations issue. In addition, the respondents also suggested a checklist regarding contractual variations. A more detailed checklist and the checklist of contractual variations could be addressed in another area of computing applications or expert systems, which is purposely developed for that particular issue. This is beyond the scope of the research, whereby the DWCA or e-DR is designed to address more generalized contractual problems instead of individual case-based problems.

More importantly, many of the respondents felt that the prototype is able to mitigate contractual disputes and enhance their decision-making process compared with the conventional approach, in which the e-DR’s contents are well organized and facilitate better understanding.

DISCUSSION AND IMPLICATIONS

This research has successfully achieved its objective in terms of bridging the gap between IT application and contract administration, particularly for the construction industry. Specifically, the DWCA and the resulting e-DR prototype have provided evidence of how the data warehouse concept can be incorporated into contract administration to enhance the existing conventional approach whereby the users have to face voluminous and complicated legal documents in a manual way. Both the conceptual models and prototype have been verified and evaluated by reputed experts who further enhanced the functionality and validity of the proposed application. More importantly, the prototype has proved its ability to improve clarity of construction contracts.
that greatly influenced the understanding and interpretation of such contracts, especially among users who are without a legal background. Since such a system is non-existent to date, the efforts undertaken represent significant theoretical and practical contributions made in this study.

Judging from the evaluation results, it is thereby safe to posit that the e-DR application, when fully developed, could contribute to assisting users in making more informed decisions regarding contractual circumstances in a construction project and subsequently help in overcoming the various contractual issues highlighted in the article, if not all. These are among the two major value propositions of the system. Further, the application may not involve huge investment, as it was developed using Microsoft Access. The use of such a relatively inexpensive but yet user-friendly software is another attractive feature of the application. As such, there is a potential for the application to be shared and employed by various stakeholders such as construction companies, professional bodies, government agencies, and so on so that valuable information can be retrieved, exchanged, and stored in the data warehouse. To start with, the stakeholders first need to be informed of the value propositions of the application so as to garner their support. Besides, the stakeholders and their employees need to be trained on the features of the system. There is also a possibility that a user manual is developed to support the users as they use the application.

In addition, generalizing the e-DR application could be carried out, as the conceptual models render a generic approach toward contract administration. However, precaution should be noted when applying the application as certain adjustments are required especially for those countries that practice different legal systems. It is because the application follows Common Law jurisdiction. Nevertheless, the DWCA could serve as a useful reference in terms of its methodology and development, where the application can be modified and referred to suit the varying legal and cultural circumstances.

Notwithstanding the proactive approach proposed for the construction contract administration, two major limitations need to be considered. First, the keyword searching using
the Boolean method requires exact keywords or terms in order to effectively retrieve information. Further, the method does not do performance ranking for the retrieved information (Mitra and Chaudhuri 2000). As such, future development, particularly the use of plain English, is imperative so that the users can locate keywords or terms that they are familiar with instead of having to use legal jargons.

Second, although the validity of the conceptual models and e-DR application have been tested and proved to be valid, it is worth noting that the e-DR prototype evaluated in this study was confined to the disputes on contractual variations. There are many other issues plaguing the industry that were not captured in the application as well as other contractual forms. It is only by having a full suite of e-DR application that an effective evaluation of the features, contents, and characteristics of the system can be carried out. This includes the various characteristics of user acceptance on the IT application itself. Future research is warranted to address these limitations.

CONCLUDING REMARKS

This study provides a working example of how the DWCA conceptual models worked through the development and evaluation of the e-DR prototype. More importantly, the application is proven to help users make more informed decisions regarding contractual circumstances in construction projects. The findings show that the conceptual DWCA model explains a more clarified and accurate means of construction contract administration. The e-DR prototype, on the other hand, is proven to be user-friendly, reliable, and organized information to assist users or construction practitioners in Malaysia, particularly those without legal backgrounds, to analyze circumstances and make informed decisions compared to the conventional contract administration approach by which users are bogged down by the voluminous and complicated contract documents and provisions. It is hoped that future works are undertaken to develop a full suite of e-DR application. Since judgments from litigation cases create numerous legal views or positions
into the practice of contract administration, a research on the clauses to be taken into account by
contract drafters and experts is warranted. The resulting findings can be used as a basis to expand
the research to other countries with similar or different legal systems so that a unified application
can be developed. From the knowledge management (KM) perspective, the development of a KM
system that captures the input from different users is also possible in order to overcome the
contractual disputes and to learn from each other of how construction contracts can be better
administered. This will help avoid misunderstanding and interpretation of construction contracts
and ultimately lead to harmonious working relationships between the contracting parties.

Acknowledgment

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Manage.*, 136(8), 886-893.


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39-46.

outcomes of construction claims.” *Auto. in Constr.*, 16(5), 642-646.

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PART A: ISSUANCE OF VARIATIONS

- Authorized Person and Power
  - The right Person is the Professional Architect or other form of practice registered under Architect Act 1967 and named in the contract.
  - Architect issues variations or sanctions contractor’s variations provided that the variation will not vitiate the original contract.
  - Architect’s power is restricted, which he can’t omit a work and give it to another contractor.
  - If Architect issues variations that outside the scope of Contract and without expressed authority from the Employer, he may be liable to the Employer.

- Period of Issuance
  - Architect can issue variations at any time before issuance of the Certificate of Practical Completion (CPC).
  - But, after CPC period, the variations must be necessitated by obligations or compliance with the local authorities and service providers’ requirements towards the Work, or
  - Contractor shall conform to the local authorities and service providers’ requirements and proceed with the work if no AI in response for the inconsistencies with statutory requirements within 7 days of the given written notice.
  - AI to rectify Contractor’s default is not considered as a variation either before or after the CPC.

- Provisional Sums
  - There are two parts of ‘provisional’ items for variations, that is, Provisional Quantity and expenditure of Provisional Sums.
  - Provisional Quantity means the estimated quantities of work, materials or goods in the BQ which cannot be determined or detailed at the time.
    - Provisional Quantity describes as the tasks are with rates and prices for the pre-estimate quantity and it subject to re-measurement for the actual value.
  - Provisional Sums means Sums provided in the Contract and/or for Nominated Sub-Contract for work, materials or goods in the BQ which cannot be determined or detailed at the time.
    - Expenditure of Provisional Sums describes as the tasks but without detailed information for its quantity, and rates.
  - Provisional Quantity does not necessary require an AI for carrying out the work, like piling length in the Bill of Quantities (BQ).
  - AI is mandatory for expenditure of Prime Cost Sums or Provisional Sums.

PART B: VALIDITY OF VARIATIONS

- Written Instruction
- Definition/Principle of Variation
- Addition
- Omission
- Substitution
- Alteration of the Kind or Standard of Materials or Goods
- Removal of the Executed Works, Materials and Goods
- Changes to the provisions in the Contract

PART C: VALUATION RULES OF VARIATIONS

- Valuation Rules of Variations
- Rule 1 of Contract Rates and Prices
- Rule 2 of Fair Adjustment
- Rule 3 of Fair Market Rates and Prices
- Rule 4 of Daywork Rates
- Rule 5 of Omitted work
- Rule 6 of Re-measurement on Actual Quantities (Provisional Quantity)

PART D: OTHERS

- Additional Expenses and Subsequent Circumstances Caused by Variations
Table 1. Characteristics of previous studies in contract administration

<table>
<thead>
<tr>
<th>System/Name</th>
<th>Year</th>
<th>Method of decision making/process</th>
<th>Historical data/court case</th>
<th>Panel of expert</th>
<th>Reference of Standard Form</th>
<th>Targeted Issue</th>
<th>Use of IT tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCON (Kraiem 1988)</td>
<td>1988</td>
<td>Flow chart</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Differing site condition</td>
<td>No</td>
</tr>
<tr>
<td>Expert System For Construction Contract Interpretation (Robinson et al. 1991)</td>
<td>1991</td>
<td>Rule based</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Contract Interpretation</td>
<td>No</td>
</tr>
<tr>
<td>Prediction of Construction Disputes (Sim and Molnenaar 2000)</td>
<td>2000</td>
<td>Case-based reasoning</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Most severe contractual issues</td>
<td>No</td>
</tr>
<tr>
<td>Claim database management (Al-Sabah et al. 2003)</td>
<td>2003</td>
<td>Relational database</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>General disputes and claims</td>
<td>Yes</td>
</tr>
<tr>
<td>CoNegO (Cheung et al. 2004)</td>
<td>2004</td>
<td>Even Swaps</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Figure based disputes</td>
<td>Yes</td>
</tr>
<tr>
<td>PSO-based on Construction Claims (Chau 2007)</td>
<td>2004</td>
<td>PSO-based neural network</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Construction claims</td>
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<tr>
<td>Graph Model (Kassab et al. 2006)</td>
<td>2006</td>
<td>Prisoner’s dilemma strategy</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>General Dispute’s Problem</td>
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<td>FCBR (Cheng et al. 2009)</td>
<td>2009</td>
<td>Fuzzy case-based reasoning</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>General construction disputes</td>
<td>Yes</td>
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<tr>
<td>Model of data warehousing for contract administration (Chong et al. 2011)</td>
<td>2009</td>
<td>Data Flow Diagram (DFD)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>General contractual disputes</td>
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### Table 2. Background of the experts

<table>
<thead>
<tr>
<th>Group</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Registered arbitrator or legal professional</td>
</tr>
<tr>
<td>Legal</td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>√</td>
</tr>
<tr>
<td>L2</td>
<td>√</td>
</tr>
<tr>
<td>L3</td>
<td>√</td>
</tr>
<tr>
<td>Architect</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>√</td>
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<tr>
<td>A2</td>
<td>√</td>
</tr>
<tr>
<td>A3</td>
<td>√</td>
</tr>
<tr>
<td>Engineer</td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>√</td>
</tr>
<tr>
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</tr>
<tr>
<td>E3</td>
<td>√</td>
</tr>
<tr>
<td>Quantity Surveyor</td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>√</td>
</tr>
<tr>
<td>Q2</td>
<td>√</td>
</tr>
<tr>
<td>Q3</td>
<td>√</td>
</tr>
</tbody>
</table>
**Table 3. Contractual issues in the three work stages**

<table>
<thead>
<tr>
<th>Pre-contract award stage</th>
<th>Construction or commencement of work stage</th>
<th>Work completion stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEVEN areas:</td>
<td>TWENTY THREE areas:</td>
<td>NINE areas:</td>
</tr>
<tr>
<td>1. Estimating and pricing</td>
<td>1. Accessing to site</td>
<td>1. Defect liability period</td>
</tr>
<tr>
<td>2. Design information</td>
<td>2. Compensation/loss and expenses</td>
<td>2. Defects</td>
</tr>
<tr>
<td>submission</td>
<td></td>
<td>5. Final account and certificate</td>
</tr>
<tr>
<td></td>
<td>8. Interference/problem by professionals</td>
<td>8. Retention monies or fund</td>
</tr>
<tr>
<td></td>
<td>9. Interim payment</td>
<td>9. Unresolved variations</td>
</tr>
</tbody>
</table>
Table 4. Analysis of prototype evaluation

<table>
<thead>
<tr>
<th>No</th>
<th>Testing variables</th>
<th>Mean (%)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The usefulness of clarity aspects in contract administration for the references</td>
<td>75.6</td>
<td>Satisfying</td>
</tr>
<tr>
<td>2</td>
<td>The practicality of the e-DR to provide references and alertness to the users</td>
<td>74.4</td>
<td>Satisfying</td>
</tr>
<tr>
<td>3</td>
<td>The functionality of e-DR’s structure in terms of its features and interfaces</td>
<td>70</td>
<td>Satisfying</td>
</tr>
<tr>
<td>4</td>
<td>The coverage of the generic references concerning contractual variations</td>
<td>66.9</td>
<td>Slightly satisfying</td>
</tr>
<tr>
<td>5</td>
<td>Overall</td>
<td>74.1</td>
<td>Satisfying</td>
</tr>
</tbody>
</table>
Fig. 1. Level-0 DFD of e-DR’s contents
Fig. 2. Level-1 DFD of e-DR’s features
Fig. 3. Relationship between tables in e-DR database