ONTOLOGY-BASED CONSTRUCTION CLAIM DOCUMENTS FRAMEWORK

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ABSTRACT

The traditional way of construction project claim document production suffers from tediousness and inefficiency. The manual assembly of claim event history leads to poor reliability of the claim report, due to the claim knowledge gap between experts and clerks. Sharing the team's comprehensive and formal claim knowledge with all of the participants in the claim work flow would result in a more effective way of producing claim documents. This study proposes a system for the ontology-based automatic generation of construction claim documents. The system will extract claim knowledge from all the potential sources into ontology. Software agents supported by the ontology will then complete each part of the claim events history data collection and generation process. The system will also support other functions such as information retrieval, natural language processing and database management. Such a system would efficiently facilitate the claim documents work and become an effective assistant to claim experts.

Keywords: Ontology, construction project claim, document production

1. INTRODUCTION

Currently, in practice, due to the claim knowledge gap between the expert/lawyer and the clerk, the traditional way of claim document production work flow suffers from serious drawbacks: inconsistency and unreliability of the claim event history, and tedious and inefficient manual work. Those drawbacks seriously undermine the robustness of the claim argument.

To solve this problem, besides the automation of the documents processing work to improve the efficiency, this paper takes the strategy of sharing the comprehensive and formal claim knowledge with all the participants within the claim work flow. To be specific, equipped with the machine-interpretable representation of the claim knowledge, a computer could much better do the clerk's manual claim work. In this paper, following that strategy, an ontology-based construction claim production framework is proposed to address the problem. With a brief literature review on the principle and application of ontology, as well as the research development on construction claim documents management, the feasibility and applicability of the proposed framework are analyzed. Then, the structure and the mechanisms of the framework are illustrated, and a demonstrative case is given. Finally, the significance of the framework's implementation and the needed future work are also discussed.

2. LITERATURE REVIEW

2.1 Ontologies in construction

The most widely accepted definition of ontology is "An ontology is a formal, explicit specification of a shared conceptualization."(Studer et al. 1998). An ontology is represented as a set of concepts within a domain and the description of the relationships between the concepts (Akinci et al. 2008). So, through a well-defined structure, ontologies could serve as a formal representation about a specific body of knowledge in a domain, and this kind of formal representation can be interpreted by computers. That kind of formal representation works as a good methodology for sharing knowledge among certain people and/or computers. Sharing a common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies(Gruber 1993; Musen 1992).

To be specific, as a kind of knowledge representation, the languages for describing ontologies varies, but with the development of Web technology, the Web-based languages for ontologies which include RDF (Resource Description Framework), and OWL(Ontology Web Language) developed by W3C become more and more popular. Facilitated by the web, those languages fit better in describing ontologies much better in terms of sharing.

In the construction area, research on ontologies application mainly focuses on the following issues: laying a comprehensive foundation for knowledge management, build the industry-wide ontologies for construction, like e-CKMI (e-COGNOS Knowledge Management Infrastructure) (El-Diraby et al. 2005; Lima et al. 2003); Knowledge extraction and representation, for example, domain knowledge extraction from handbooks (Lin et al. 2009), and space representation in construction (Akinci et al. 2002); Interoperability facilitated by ontologies, like the interoperability of process-related application in the Architecture, Engineering and Construction (AEC) sector (Tesfagaber et al. 2003)and the "ontology integrator (Onto-Integrator)" for facilitating ontology interoperability (El-Gohary and El-Diraby 2009). All of these studies indicate that ontologies have a great applicability in the construction realm.

2.2 Construction claim documents management

Due to the fact that claims do not arise in every single project, there is no separate role for managing claims in the way that there are estimators, planners and accountants. In practice, the personnel given this role are in most cases decided in an ad-hoc manner (Vidogah and Ndekugri 1998). Therefore, it is very common that the claim clerk always have deficient knowledge and intuition for finding, collecting, and summarizing relevant documents necessary to make up a solid claim argument. Thus, the knowledge gap mentioned above between clerks and claim experts is the main reason for the inconsistency and unreliability of claim event histories. To solve this problem, a number of expert systems were developed to undertake the legal analysis for certain scenarios: analyzing changes claims (Diekmann and Kim 1992), and analyzing the impact of delays on the contractor's progress (Alkass et al. 1993). Further, on a more general level, the claims-related provisions of AIA (American Institute of Architects) A201 General Conditions document were incorporated into a knowledge-based system that provides specific advice to a contractor for the evaluation and processing of a construction claim (Cooper 1994). However, none of those systems address the issue of accessing and collecting contemporary records of event in order to establish the archive and generate the brief history for events.

To solve the problem of relevant documents omissions in the preparation of claim arguments, some researchers adopted the strategy that it is essential for all project groups to be part of the same document exchange framework, and to enlist or register all their documents within a central web based repository. This framework operates as a document-clearing house for all project groups (Hammad and Alkass 2000). This strategy only puts all the potential candidate documents together to prevent physical loss, but it still does not take the claim body of knowledge into consideration to process that bulk of documents and the sharing of records across the different stakeholders may raise potential risk issue in term of proprietary information considerations.

3. FRAMEWORK FOR ONTOLOGY-BASED CONSTRUCTION CLAIM DOCUMENTS PRODUCTION

The proposed framework uses the knowledge in the ontology to support the intelligent agents' decision and processing. So, before discussing the structure of the framework, it is necessary to understand how the ontology represents the desired claim body of knowledge.

3.1 Strategy for re-structuring claim knowledge

The first step in building this framework is to obtain the desired claim knowledge body from certain sources, then re-structure it in order to fit into an ontology structure. Here we assume that the desired knowledge is already in hand. The strategy of how to re-structure the claim knowledge is the concern discussed here.

On one hand, to build an ontology, it has to go through the following procedure: defining classes in the ontology; arranging the classes in a taxonomic (subclass-superclass) hierarchy; defining slots and describing allowed values for these slots; filling in the values for slots for instances (Noy and McGuinness 2002). On the other hand, in this case, one important function of this framework is, based on the claim knowledge collected, to identify the facts which could incur a potential claim event. Thus, concerning both the pre-defined structure of ontology and the target function, a strategy to re-structure the claim knowledge was proposed. Under this strategy, as an illustration, the knowledge about identifying claim incurring facts could be re-structured as shown in Figure 1.

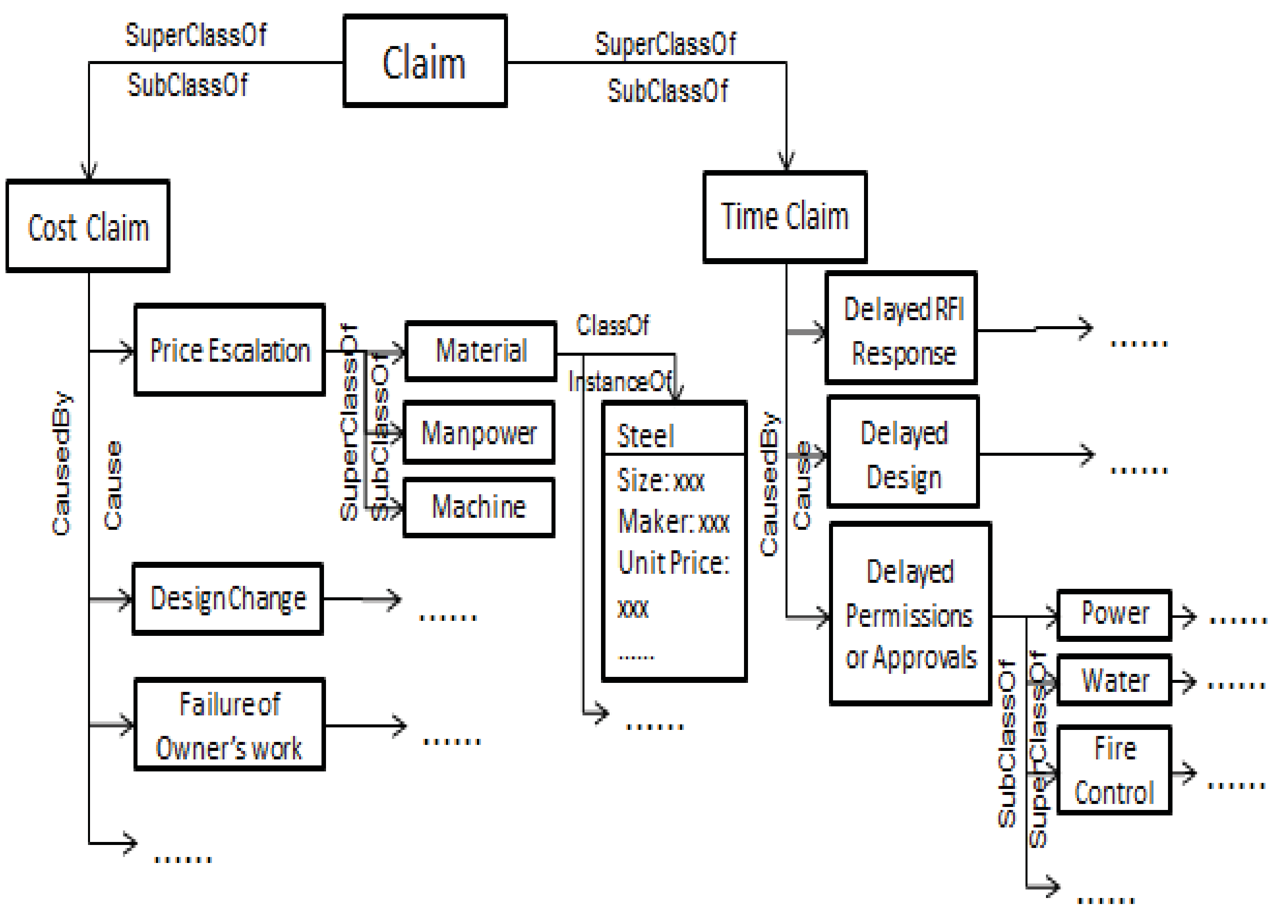

Figure 1: Illustration of the Strategy for Re-structuring Claim Knowledge

According to the Noy and McGuinness' (2002) theory about the structure of ontology, the strategy could be understood in the following order:

Classes: particularly, in Figure 1, the rectangular boxes represent classes, like the classes of "Claim", "Cost Claim", "Time Claim" and so on;

Instances: the boxes with name and slots inside represent the instances originate from a certain class. For example, the "Steel" instance of the class "Material" is represented by a box with compartments inside. The name of the instance is on the top, and the slots with particular values are listed under the name, like "size: 16mm", "Maker: XX factory", "Unit Price: $XX per Ton" and so on. Thus, a particular construction material used in the project can be presented in a systematic manner for further use;

Relationships: arrow lines represent the relationships between classes or between classes and instances, and the names of the relationships are marked on the either side of an arrow line. For instance, class "Claim" is the super class of classes "Cost Claim" and "Time Claim", and in reverse, "Cost Claim" and "Time Claim" are the sub-classes of "Claim". Further, "Cost Claim" could be caused by the classes of "Price Escalation", "Design Change" and so on, and in reverse, those classes could cause "Cost Claim". That is the initiative or passive representations for a certain relationship in terms of the object we talked about. The same thing happens on the relationship between classes and instances.

Thus, by this strategy, the desired knowledge body could be re-structured into a proper form which fits into ontology's structure.

3.2 Language for representing the ontology

With the re-structured body of knowledge, the next step is to describe it by an ontology language. Actually, the ontology language serves to convert the knowledge structure into text material. In this framework, Ontology Web Language will be used. To clearly illustrate the principle of the ontology language, Description Logic and OWL were put together here to map the semantic concepts in the claim knowledge body, as shown in Table 1.

For example, claim cases could be categorized into time claim and cost claim. These two kinds of claims are the subcategories of claim cases, but are disjoint with each other. So, OWL could represent this situation by manipulating the syntax words of "SubClassOf" to represent a piece of knowledge that "Time (or Cost) claim is a kind of claim", also by "disjointWith" to represent that "Time claim and Cost claim are disjoint with each other".

By using the above-mentioned strategy to re-structure the desired body of knowledge into the ontology and representing it by OWL, the foundation for the framework could be laid.

Table 1: Mapping between OWL and Concepts

OWL Syntax	Description Logic Syntax	Example
intersectionOf	$C_1 \cap \ldots \cap C_n$	Cost Claim $\equiv$ Cost $\cap$ Claim
oneOf	$\{x_1, \ldots, x_n\}$	Material $\equiv$ {Steel, Concrete, …}
SubClassOf	$C_1 \subseteq C_2$	Time Claim $\subseteq$ Claim
disjointWith	$C_1 \sqcup C_2$	Time Claim $\sqcup$ Cost Claim
……	……	……

3.3 Framework Mechanism

Based on the varied natures of claim document production work on different periods of a construction project, the mechanism of the proposed framework could be divided into two stages.

The First Stage: supported by the ontology mapping the desired claim knowledge, the first stage of the framework attempts to simulate the work flow of the traditional claim document management work, mainly including identifying claim documents and filing them according to each claim event. The mechanism of this stage would be as shown in Figure 2.

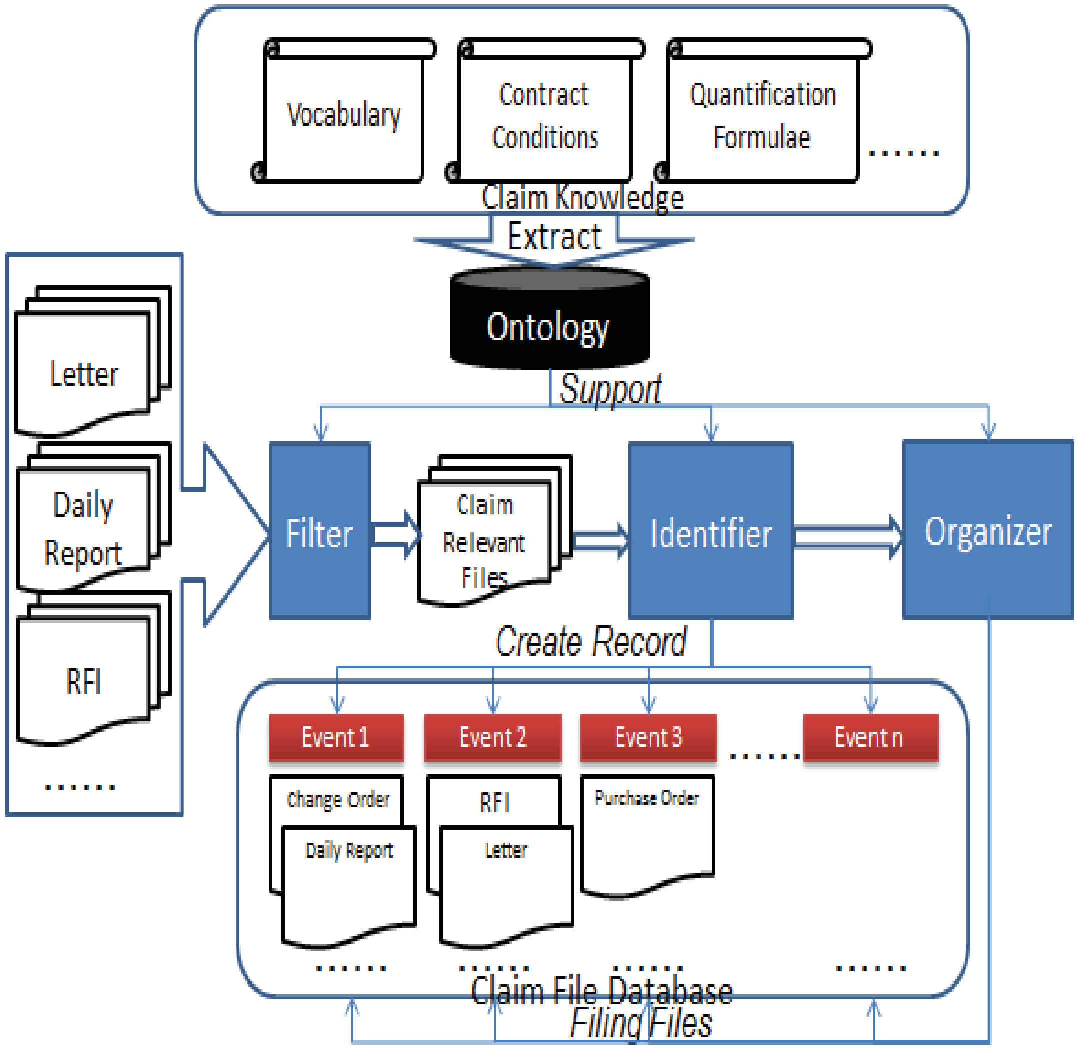

Figure 2: Mechanism of the Claim Document Identifying and Filing Framework

This stage of the framework starts from the beginning of the project toward the closing out point. It should cover the period, in which the facts that could incur any claim events are possibly happening, e.g., this is the development stage of all the claim history. Under this framework, the incoming and outgoing documents on a project are read by the "filter", which is one of the intelligent agents in this framework, and then it filters out the irrelevant files and only keeps the claim relevant files. Then those relevant files are passed to the "Identifier" to parse the claim relevant documents into two classes. One class will contain the files which are possibly incurring a claim event while the other contains those which are part of the developing history of an already created event. After that, the "Organizer" will do the corresponding filing work for each class in a certain database: a new claim event will be created based on the first class files and the files will be stored as the first record of that newly created event; meanwhile the files in the second class will be put under the already created event to which the files are associated. All of the decisions made by those agents in this work flow are supported by the knowledge in the ontology. With this work flow running on a daily basis, the project claim record-keeping work is automatically updated while the project is progressing.

The Second Stage: The second stage of the framework should be adopted when the project is going to end and meanwhile all the claim history is basically finalized. The framework's mechanism of this stage is shown in Figure 3. In this stage, in the claim document database, all of the claim relevant documents have been organized by the claim events. To each one of those events, the "Briefer" will generate the history description in a concise manner and the "Calculator" will do the quantification work for the cost and/or time claimed for. Also, those works cannot be bone without the knowledge from the ontology. After that, the history for each claim event is finished, and it is ready to submit the claim history to the expert for further optimization work.

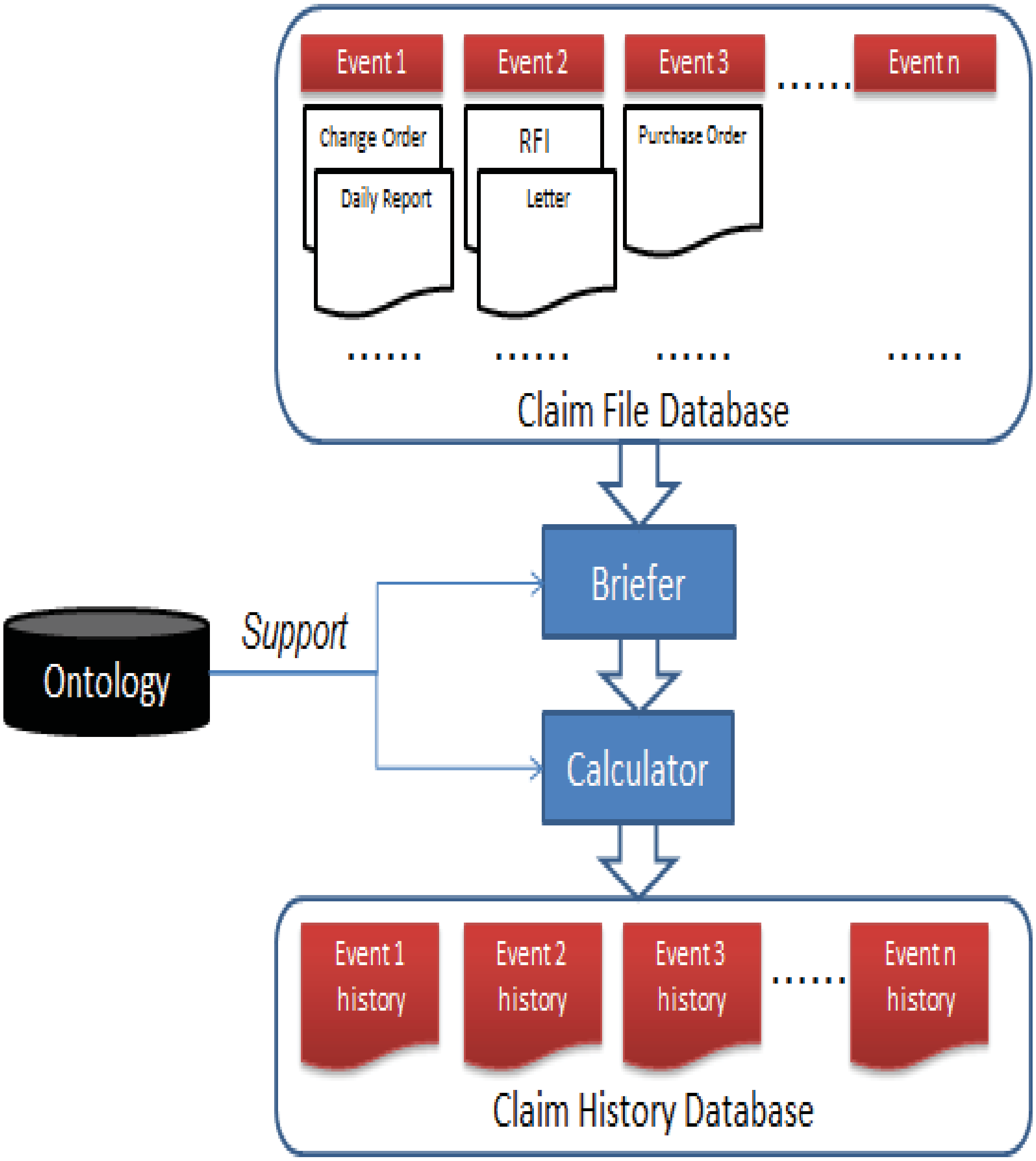

Figure 3: Framework of the Claim Events History Generation

4. CASE EXAMPLE

To illustrate how the proposed system works, here one condition of FIDIC 1987 contract document is taken as a piece of claim knowledge to conduct the demonstration. The condition of "12.2 Not Foreseeable Physical Obstructions or Conditions" basically regulates that in construction process, the Contractor encounters a negative physical obstruction or condition, which is not reasonably foreseen by an experienced contractor, and the part of incurred expense which exceeds the budget should be reimbursed by the Employer. The knowledge of this condition involved in this system could be briefly represented in claim knowledge ontology as shown in Figure 4.

To be specific, take the function of agent "filter" for example. The essential elements for the definition of this condition include: 1. Unforeseeable by an experienced contractor; 2. Physical; 3. Incurred over-budget expense or over-schedule time happened. If an event satisfies all of these three points, it could be identified as a potential claim event related to this piece of condition. In another word, as far as this condition concerned, the three points become to the key words to be searched for by the "filter" agent over all the documents' content, in order to identify and keep the relevant claim documents. Any documents containing some or all of those key words or equivalents will be recorded. And those documents which are cited or mentioned in them should also be involved.

However, by this case it could be identified that the main challenges in the development of this system contain but are not limited to the following:

The quantitative representation of claim knowledge. It is common that some terms or concepts in contract documents are not exactly specified. For example, like the word "reasonable promptness" regarding project participants' response time limit appears quite a few times in the general condition of AIA A201 (1997 edition) contract document. However, this word lacks a quantitative definition to specify a particular number of days. Thus, those qualitative terms or concepts like "reasonable promptness" do not work with this system.

1. To address this issue, proper quantification approaches should be developed depending on specific situations. Following the case of "reasonable promptness", its situation varies in different provisions. In 4.2.11 about Architect's interpretation and decision, it could be defined as refer to the "agreed time limits" or "15 days if no agreement is made", which is an easy case to quantify; but in 3.12.5 about Contractor's review and submittals and 4.2.7 about Architect's response to Contractor's submittals, instead of a specific number of days, a principle is applied here as "cause no delay in the Work or in the activities of the Owner or of separate contractors".
   In this situation, it is better to specify the principle through the reference to the critical path in the schedule to determine a "due date" as the quantification of the "reasonable promptness"; and, in 2.2.4 about the information and services required of the owner, there is neither a specific number not an applicable principle. In this situation, the quantification approach could use the precedent cases regarding this term as a reference to quantify it. So, the approaches to solve the issue of quantifying a qualitative term or concept could be; 1, specifying the applicable principle or 2, referring to the precedent cases.
2. A well-structured document formatting system is needed. Since a significant part of the system depends on the interpretation of the content of documents, poorly structured contents of documents would undermine the validity and feasibility of the system. To address this challenge, a couple of Semantic Web developing techniques, XML (eXtensible Markup Language) and RDF (Resource Description Framework), can be employed. Generally speaking, XML is a meta-language that allows users to define markup for their documents using tags. Nesting of tags introduces structure. The structure of documents can be enforced using schemas. Meaning can be expressed by RDF, which encodes it in sets of triples, each triple being rather like the subject, verb and object of an elementary sentence. These triples can be written using XML tags (Berners-Lee et al. 2001). In RDF, assertions are made in a document that particu-

lar things (e.g., Owner) have properties (e.g., issue) with certain values (e.g., change order). With the support from these techniques, the documents' structure could be better defined, based on which the reading function of the agents could be reasonably achieved.

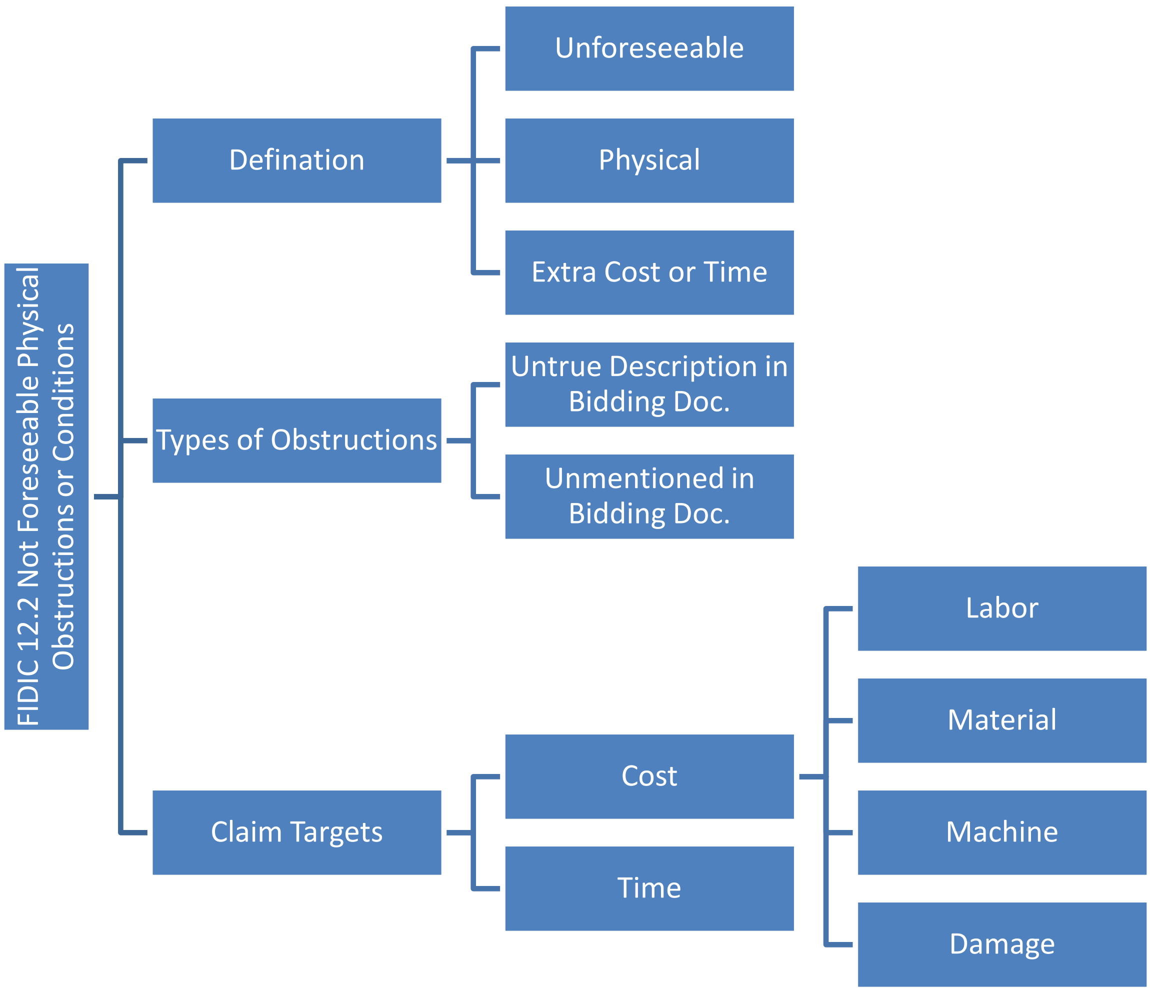

Figure 4: Chart for FIDIC 12.2
"Not Foreseeable Physical Obstructions or Conditions"

5. SIGNIFICANCE AND FUTURE WORK

By sharing claim knowledge using the claim work flow, this proposed framework would effectively prevent the inconsistency and unreliability of the claim document production that would occur in the traditional way of work. Furthermore, the automation of the document processing activity would efficiently substitute for the manual work, which would save considerable time and improve the accuracy of the product. Thus, the drawbacks of the traditional work flow would be avoided. Moreover, if this framework is implemented correctly, it will become a good assistant to the claim experts/lawyers, as well as to the project managers.

However, in order to implement and validate this proposed framework, there are a lot of other issues that should be worked out. For example, the implementation of some important functions which should be done by some of those agents, like identifying the content of the documents, generating the brief for each claim event history, still needs further research. The technologies involved would include, but are not limited to information retrieval, natural language processing, database management, and object-oriented programming.

Another issue that needs much work is, how to define and obtain the needed claim knowledge bodies. To do this job, the characteristics of the target claim knowledge should undergo a thorough analysis and discussion. Initially, the potential sources of that knowledge could be contract documents (For instance, AIA documents), precedent law cases, and the experts' personal understanding and experience. Also, it is worthy to point out that, to prevent the risk of the proprietary violation to the project participants, currently this framework is assumed only works within the environment of one single project stakeholder. For example, claim knowledge sharing only happens in the work flow of the general contractor. Knowledge sharing across the different project stakeholders is not an assumption adopted in this research.

REFERENCES

Akinci, B., Fischer, M., Kunz, J., and Levitt, R. (2002). "Representing Work Spaces Generically in Construction Method Models." *Journal of Construction Engineering and Management*, 128(4), 296-305.

Akinci, B., Karimi, H., Pradhan, A., Wu, C.-C., and Fichtl, G. (2008). "CAD and GIS interoperability through semantic web services." *Journal of Information Technology in Construction*, 13, 39-55.

Alkass, S., Mazerolle, M., and Harris, F. C. (1993). "An integrated system to minimise the costs of analysing construction claims." *Computer System Engineering*, 4(2-3), 271-288.

Berners-Lee, T., Hendler, J., and Lassila, O. (2001) "The Semantic Web." *Scientific American*, 284(5), 34.

Cooper, T. E. (1994). "A knowledge-based construction claims advisor for the A.I.A. A201 general conditions document." Auburn University. *ProQuest Dissertations and Theses*, 446 p.

Diekmann, J. E., and Kim, M. P. (1992). "Supercharge: expert system for analysis of changes claims." *Journal of Construction Engineering and Management*, 118(2), 399-410.

El-Diraby, T. A., Lima, C., and Feis, B. (2005). "Domain Taxonomy for Construction Concepts: Toward a Formal Ontology for Construction Knowledge." *Journal of Computing in Civil Engineering*, 19(4), 394-406.

El-Gohary, N., and El-Diraby, T. (2009). "Merging Architectural, Engineering and Construction (AEC) Ontologies." *Journal of Computing in Civil Engineering*, 1(1), 24.

Gruber, T. R. (1993). "A Translation Approach to Portable Ontology Specification." *Knowledge Acquisition*, 5, 199-220.

Hammad, M. M., and Alkass, S. T. "A Web-Based Construction Project Document Information Center in Support of Claims Preparation." *Proc., Eighth International Conference on Computing in Civil and Building Engineering*, ASCE, 279, 110.

Lima, C., Diraby, T. E., Fies, B., Zarli, A., and Ferneley, E. "The E-COGNOS Project: Current Status and Future Directions of an Ontology-Enabled IT Solution Infrastructure Supporting Knowledge Management in Construction." *Proc., Construction Research Congress 2003*, ASCE, 120, 103.

Lin, H.-T., Hsieh, S.-H., Chou, K.-W., and Lin, K.-Y. "Construction of Engineering Domain Ontology through Extraction of Knowledge from Domain Handbooks." *Proc., 2009 ASCE International Workshop on Computing in Civil Engineering*, ASCE, 346, 21.

Musen, M. A. (1992). "Dimensions of knowledge sharing and reuse." *Computers and Biomedical Research*, 25, 435-467.

Noy, N. F., and McGuinness, D. L. (2002). "Ontology Development 101: A Guide to Creating Your First Ontology." Knowledge System Laboratory, Stanford, CA.

Studer, R., Benjamins, V. R., and Fensel, D. (1998). "Knowledge engineering: Principles and methods." *Data & Knowledge Engineering*, 25(1-2), 161-197.

Tesfagaber, G., Bouchlaghem, N. M., Baldwin, A. N., Cutting-Decelle, A. F., and Khalfan, M. M. A. "Ontology Modeling of IDEF3 Process Description for AEC Applications Interoperability." *Proc., Construction Research Congress 2003*, ASCE, 120, 105.

Vidogah, W., and Ndekugri, I. (1998). "A review of the role of information technology in construction claims management." *Computers in Industry*, 35(1), 77-85.