Knowledge based community management in the Construction Industry

Knowledge based community management in the Construction Industry

MANUEL MOREIRA DA SILVA
INESC Porto / ISCAP-IPP
mdasilva@iscap.ipp.pt

ANTÓNIO LUCAS SOARES
INESC Porto / FEUP
als@fe.up.pt

DORA SIMÕES
INESC Porto / ISCA-UA
dora.simoes@isca.ua.pt

RUTE COSTA
CLUNL – UNL
m.rutecosta@mail.telepac.pt

1. Introduction

Building and construction companies have to continuously renew their working habits in order to face an increasing competitive environment where flexibility and adaptability to change are the obliged route to success. As Ceton (2000) states, the increasingly widespread use of computers only serves, as it is generally recognized, to highlight the fragmented way that building projects are commenced, designs created and realized, construction carried through to completion, and buildings maintained, renovated, and ultimately demolished. All too often lost information and miscommunication complicate these operations.

According to ISO 12006-2 at present there is little international standardization of classifications for construction. Indeed, the construction industries of individual countries have tended to remain separate because of differences of culture and legislation, and each has developed its own methods of arranging information (ISO 12006-2, 2001). National classifications can be difficult to change and there may seem insufficient reason to do so.

The application of Information and Communication Technologies (ICT) in the construction industry sector gives rise to a great amount of complexity. There exists an enormous amount of relevant international, European and national initiatives all having their own view on the topic with an even greater number of results.

In the ISO standard it is also recognized that the ICT innovation life cycle in the Construction industry sector is typically as fragmented as the industry itself (ISO 12006-2, 2001). This is not necessarily a problem (since fragmentation is often related to flexibility) but it often results in a lot of misconception and miscommunication among the different stakeholders and their supporting ICT systems involved, all having their own understanding and view on activities, results and mechanisms in construction processes, as it has been acknowledge by different organizations dwelling with standardization and harmonization processes.

2. Know-Construct – KM in the Construction Industry

2.1 Vision and Objectives

The KNOW-CONSTRUCT project (www.know-construct.com) appears in this context and is currently in the process of identifying, choosing and integrating existing knowledge sources and semantic resources of multiple different sources in order to support the development of an *Internet Platform for Knowledge-based Customer Needs Management and Collaboration among SMEs in the Construction Industry (CI),* whose main objective is consistent knowledge representation of construction knowledge items.

The Know-Construct (KC) platform can be described as a common internet-based platform for SMEs from the construction sector that will try to provide an effective combination of two general functionalities:

a) *Customer Needs Management (CNM) System*: a decision making support system regarding the products characteristics, applications and other consultancy services for SMEs customers applying the "web enabled dialogue", and
b) *Knowledge Communities Support (KCS) System*: a system for SMEs to support a form of co-operation through the creation of Knowledge Communities of SMEs in Construction Industry (CI).

The system should support the integration, management and reuse of the area specific knowledge via a common knowledge base.

2.2 KC Implementation and risks

The platform will be owned by associations, offering to members an area to establish individual CNM systems and take benefit of KCS System. The system will be used within the associations to collect and exchange the business area specific knowledge among the members (SMEs) in a form of essential expertise, reachable anywhere, at any time. Such system will satisfy SMEs' urgent need for a radical improvement of communication with customers and it will offer an effective knowledge sharing with other SMEs as a base for further implementation of new co-operation forms.

During the conception stage of this project three main type of risks were identified:

1. Risks related to acceptance by SMEs and Associations in construction sector: There is a certain risk that the highly innovative approach of the KNOW-CONSTRUCT project will not be accepted by traditional SMEs and Associations in this sector, specifically taking into account the education level and reluctance against the e-

technologies and knowledge sharing, which are the key issues of the project. The consortium is therefore carefully composed to include Associations and SMEs highly committed to the project's approach. On the other hand, considerable efforts in the project will be dedicated to the methodology to solve these cultural aspects and to develop an appropriate training approach.

2. Risks related to solving RTD problems such as efficient knowledge management in SMEs, representation of the knowledge from specific domains defined in the requirements analysis phase (including the ontology adaptation) and particularly to the representation of the experienced-based knowledge.
3. Risks related to time needed for development and initial knowledge acquisition; a proposed approach which includes early prototype development is likely to be an effective approach to manage this risk and guaranteeing an early end-users' feedback on the system concept and development.

In this article and for the purpose of this workshop we will refer mainly to the 2nd type of risks and to the methodology developed to overcome them, as well as to the process of choice of the knowledge sources and definition of the high-level ontology and domains ontologies.

3. Identification and selection of knowledge sources

The development of the project led to the establishment of a multidisciplinary S&T approach combining research activities in different areas, such as KM, particularly creation of the adequate ontology, effective forms of on-line interaction among customers and SMEs, as well as a product classification system for this sector, new forms for a representation of the CI knowledge (e.g. experience-based), investigation of efficient approaches for training, etc.

The first step was the identification and selection of existing knowledge and semantic resources of multiple different sources like:

- terminologies,
- ontologies,
- international classifications,
- standards, norms and regulations,
- national classifications – to adapt the more specific ontologies to the local markets and communities,
- associations/SMEs internal publications and documents,
- other relevant scientific and technical documentation

for the development of an internet platform for Knowledge-based Customer Needs Management and collaboration. The difficulty of this task

is well known, since the different sources are usually designed using different theoretical grounds and design principles.

In this sense, terminology and terminology management techniques, together with KM techniques, play a part in this project, especially in what concerns the development of initial domain models, the identification of knowledge sources for detailed CI knowledge ontology development, the selection of methods and techniques for continuous knowledge capture, ontology development and validation and in the development of the multilingual taxonomies and ontologies.

One of the first tasks of this project was, then, to identify the existing knowledge sources to access subject field related information and develop the high-level ontology and other more specific ontologies. According to ISO 12006-2 (ISO, 2001) the most widely used classifications are work sections (mainly for specifications) and elements (mainly for cost analysis). They are also the most widely varied, not only in their itemization and structure but also in the range of other purposes to which they are put. As a result of our research, several other classifications were identified, potentially just as important, which have not yet been used to the same degree, e.g. construction products and properties/characteristics.

KNOW-CONSTRUCT will, along with the necessary development of classifications and taxonomies that answer the project's needs, re-use/integrate as far as possible existing ontologies, classification systems and terminologies in order to develop a system that may, in the future, contribute to standards. The initial interaction of the Know-Construct project with standards issues will be to assure full compliance of the developed solution components with the current legal and de-facto standards in the targeted building sector and in relevant ICT domains.

It will also actively contribute and promote innovative approaches that can result in standardization initiatives. The ontologies will be developed in the areas of product characteristics, product applications and related consultancy services. These ontologies will be crucial for the decision making support system but also to create uniform models for customer's access. Standard or integrating ontologies do not exist in these areas. Furthermore, another essential innovation, potentially contributing to CI (Construction Industry) standards, is the development of integrating ontologies both in the areas referred above and in inter-enterprise inter-operability.

It will thus exploit proposals used or in use in other European and international projects, in an attempt of harmonization with the current well established standards, also as a way to oppose the unpredictable perennity of the stored data. Besides CI online sites and other sources, the most relevant ontologies and classifications identified so far are:

- e-Cognos ontology - Methodology, tools and architectures for electronic consistent knowledge management across projects and between enterprises in the construction domain.
- e-Construct ontology - Electronic Communication in the Building and Construction Industry.
- EPIC – European Product Information Co-Operation.
- UNICLASS – Unified Classification for the Construction Industry.
- BATIBASE - The major operational classification used at national level in France, used as reference for construction products.
- EDIBATEC - is a classification standard for the construction industries of special relevance for industries dealing with heating systems, air conditioning and tubes.
- MASTERFORMAT - Construction Specification Institute - master list of numbers and titles for organizing information about construction requirements, products, and activities into a standard sequence.
- IFC Model – Industry Foundation Classes.
- ICIS LexiCon – International Construction Information Society

3.1 Criteria for the selection and integration of sources

According to the general view expressed in the CWA 15142 – *European eConstruction Ontology* (EeO), from the available sources, those which, at the moment, present the best solutions for the purpose of reuse and integration of information are:

- The LexiCon, from STABU, which is a very rich semantic source, that stands as a good example of taxonomy-equivalent resources for the construction sector when using the ISO DIS 12006-3.
- From e-Construct, the bcBuildingDefinitions taxonomy, in the area of e-procurement, that provides a good starting point.
- The e-COGNOS ontology, in the area of Knowledge Management, that represents a good option ready to be used, with very useful features:
    - It contains 15 000 concepts covering different domains,
    - It can be easily replaced by smaller ontologies, if required,
    - It is compliant with the Semantic Web recommended format,
    - It can easily be extended,
    - Multilingual feature is part of the ontology.
- In the area of general design, engineering, construction and maintenance, the IFC model represents good overall backbone

> taxonomy of concepts used by today's ICT tools. It provides a widely accepted backbone of concepts used in ICT tools for construction and IFC compliant data can be used to mine semantic content. Finally it can be linked to both e-COGNOS and eConstruct results. (CEN, 2004)

The identification of these sources leads to the conclusion that part of the existing information has some common principles and structures, mostly because they result from European or governmental projects which also aim to contribute to harmonization and standardization. But, its diversity, nevertheless, puts us before the problem of how to adapt the selected resources according to the KC consortium purposes and scope and the industry consortium predefined needs, taking also into consideration:

- the specific cultural and professional context of the ontology's development and use
- the target-audience(s)
- the objectives of the project

For future developments of the ontology (specific markets and specific Costumer Needs Management and Knowledge Community Systems) the sources have to be defined according to the local market context, the SMEs and the Industrial Association/Grouping (IAG) concerns and needs.

Therefore the sources must be an integrant part of the local market information resources, the SMEs internal documentation and catalogues, internal documents and databases (contacts, material properties, specifications, standards, prices), and the diverse publications in the area of the CI, especially those edited by the Associations or available in the internet (portals, individual sites, online libraries, newsgroups, etc.)

Thus, on the second stage of the ontology definition and management – the establishment of the local more specific ontologies - other more detailed local specifications/structures will have to be considered and developed taking into account the local/national sources of knowledge and of knowledge dissemination.

In the Portuguese case, the association publishes several editions of newsletters, magazines and other annual publications which constitute eligible knowledge sources, as they contain technical information concerning the different issues and subject fields of the Portuguese CI. The conjugation of the information contained in all publications, along with other Ksources available, should be representative enough to extract the type of knowledge necessary to populate the ontology and the KCS.

3.1.1 Evaluation of Knowledge Sources

In order to evaluate and choose the knowledge sources, a complex set of multi-criteria referring to different aspects were established. The following table, inspired in the works of Pinto and Martins (2001) and Lelkin (2004), describes those criteria and their scope.

Table 1

Know-Construct - Knowledge sources evaluation criteria		
Type of source	*Common Criteria*	*Description*
All	Origin	developer(s)
	Relevance	for the pre-defined areas of analysis for specific cultural and professional context(s)
	Adequacy	from the domain expert point of view from the ontologist point of view
	Completeness	explicit in-depth coverage
	Comprehensiveness	domains addressed in the area
	Ease of data acquisition	possibility of access and reuse (merge/integrate)
	Language	language(s) in which it is available multilingual features language independence
	Current status	finished, work in progress, in revision
Type of source	*Specific Criteria*	*Description*
Ontologies	Conceptual framework/model	ontology assumptions and ontological commitment and their relation to KC objectives
	Type of concept	identification of generic concepts and relationships identification of domain concepts and relationships
	Design principles	internal structure
	Knowledge acquisition	quality of knowledge sources adequacy of knowledge acquisition practices
	Supported applications	applications supporting the ontology codification language
	Documentation available	Type of documentation available and accessibility
	Relations consistency	consistency of the semantics of the relations type of relations
	Modularity	which concepts are represented in which modules
Terminologies	Terminology purpose and scope	operational terms – functions the terminology is intended to serve
	Standardized/non-standardized	implemented as standard other type
	Granularity	level of complexity of the available data
	Quality of the definitions	do they follow unified patterns, are simple, clear, concise, etc.
	Interconnectivity	to what extent is the terminology mappable to coding systems or terminologies
	Precision and recall	retrieval effectiveness
	Normalization	of content and semantics
	Equivalence	quality of the equivalents

	Responsiveness	frequency of update
Classifications	Classification purposes	classification purposes and their relation to KC objectives
	Conceptual framework	classification assumptions and their relation to KC objectives
	Classification scope	domain(s)
	Type of concepts	degree of abstraction/specificity
	Previous use	use in ontology projects and outcome analysis

Other relevant sources will have a more contextualized approach. The process of analysis of all these sources is developed taking into consideration the domain expert point of view, who will, on the one hand, deal with the interconnection between specific and high-level ontologies (to guarantee the right conceptualization/structuring of the concepts and of the information flux in the platform) and, on the other hand, deal with highly fragmented knowledge and questions like language variation, regional/local specificities/usage of terms, and introduction of new terms not always accepted or preferred. In this stage the implementation of the principles of terminology management will strongly contribute to minor miscommunication or poorer development of the ontologies.

4. Construction Industry Knowledge (CIK) ontology structure and definition

The selected methodology will undergo three main tasks: (1) interviews with associations and companies and current practice analysis in the initial conceptualisation phase and in the refinement of the ontologies obtained in the previous phases; (2) document processing to retrieve and integrate information from a variety of sources – the document types to be used in this knowledge acquisition process will be extracted per construction company and per association; and (3) manual and semi-automatic processing to build the ontology in two-layered representation, that takes, as a basis, the relevant concepts obtained in the previous tasks.

In the formalization stage, the goal is that the system, making use of the Description Logics language, tries to automatically formalize the new portion of the knowledge. The domain and top-level ontologies will be formalized using OWL language and supported in the Protégé editor. The development of this knowledge process will be a cyclical one between conceptualisation and formalization stages. Special attention will also be given to the continuous update and maintenance of the resulting ontologies and technology platform.

4.1 KC Functionalities

KC general objective is to improve the relationship of C&B SMEs with their customers by providing the later an innovative support regarding information and knowledge about products, processes and associated issues. This is achieved through specifically developed ITC tools, in particular tools that support the formation and operation of SME's knowledge communities, fostering an improved collaboration towards customers satisfaction.

KC functionalities are clustered in two modules: *CNM* and *KCS*.

CNM - Customer Needs Management

CNM module is the front-end of KC for the customers of the SME community. KC will help users through CNM to solve problems and get support in the following areas:

- materials/products/components
- processes/procedures
- services
- construction context/domain
- resources

Typical roles of the CNM system users are: designer (architect, engineer ...), work supervisor, contractor, investor/promoter, product and services providers and the final customer.

From the *customers' point of view*, KC-CNM will provide the following main functionalities in terms of customer services:

1. Information search
   - General browsing;
   - Browsing community resources;
   - Searching materials/products/components/procedures (facilities to search information and knowledge related to materials);
   - Searching services/domain/context (facilities to search information and knowledge related to services).
2. Consultancy services
   - Interactive, web-based consultancy (tools to help customers to solve problems and get advice).

CNM also features a portal service, providing the customers with access to individual community members e-commerce/e-business systems, integrated with information search and consultancy functionalities.

From the *community members' point of view*, CNM will provide customer relationship management functionalities in terms of:

- collecting and organizing feedback and knowledge from customers;
- managing consultancy services.

KCS - Knowledge Community Support

KCS module is the platform that supports the community of SMEs. Its goal is to manage information and knowledge within the community and to integrate relevant external knowledge: a system for SMEs to support an advanced and efficient formation of communities of SMEs in construction industry, through their specific knowledge integration, management and reuse. It has two main functionalities:

1. Knowledge community manager
    - Knowledge sharing (tools to collect, disseminate and search experiences, problems, opinions within the community).
    - Knowledge community building (tools to create and share knowledge through collaboration).
    - Content management (tools to classify, organize and search documents and other types of electronic content).
    - Knowledge structure management (tools to manage ontologies and classifications schemes).
    - Setup and configuration tools.
2. Knowledge community integrator
    - Information collector (collection and organization of information from external sites and portals).
    - External search manager (complement searches in the community knowledge with searches in external sites, portals, databases).

Each knowledge community (in this case – SME's gathered around a sector's association) has a set of knowledge which needs to be integrated into the ontology in order to answer its needs and its associate's requests/queries. But, each of these communities is at a different stage of development and uses/disseminates knowledge according to different principles, means and for purposes that are only relevant for a very specific target.

On the other hand, each knowledge community is structured in a different way – they aim at different targets, have different policies and embrace several different types of participants (initial and predicted). All these social and technical idiosyncrasies have to be considered in the conceptualization stage and in the definition of the methodology of the project.

Thus, methods for creation of Knowledge Communities of SMEs in construction industry which will specifically address cultural issues in construction industry as well as new ways of developing trust between SMEs in this sector, where the IAGs will get a crucial role. This requires elaborating a structured approach to define/update/maintain knowledge which is shared among SMEs.

4.1 Methods for knowledge acquisition and representation

IT-supported KM solutions are built around some kind of organizational memory that integrates informal, semi-formal and formal knowledge in order to facilitate its access, sharing and reuse by members of the organization(s) to solve their individual or collective tasks. In such a context, knowledge has to be modeled, appropriately structured and interlinked to support its flexible integration and its personalized presentation to the consumer.

Ontologies have shown to be the right answer to these structuring and modeling problems by providing a formal conceptualization of a particular domain that is shared by a group of people in an organization. The ontologies development process in the area of the Construction Industry is not a straightforward activity. Previous projects, like e-COGNOS, were confronted with an unexpected reality: the end users actually showed their preferences to use their very specific, concise and precise taxonomies (CEN, 2004).

Know-Construct has taken this into account and keeps this possibility as part of the standardised way to develop ontologies in the sector. In KC we have decided to follow the CommonKADS methodology because it has been the must successful methodology in the development of knowledge management systems and it has been used in several projects to support the ontology-based knowledge management in semantic web portal.

The Know-Construct will address both types of knowledge relevant for CNM and KCS:

- the experience based knowledge
- the formalised knowledge related to specific topic

The methods for acquisition of such knowledge will be developed taking into account the available knowledge, the user demands regarding the knowledge to be gathered and stored, the way knowledge can be gathered (systematic approach, specifications for a system to be developed), etc. Knowledge harvesting approaches (extracting knowledge of person-to-person interaction and its integration in the knowledge repository) applicable in industrial environment will be incorporated.

5. Conclusion

It is our view that the high-level ontology of Know-Construct will reflect the standards and related classification schemes in the industry, on the one hand, and, on the other, the local more specific ontologies will account for the individualised SME conceptual schemes, i.e. they will be strongly

related to consortium partners' needs, as identified in the analysis of business case scenarios and in the users requirement definitions. The implemented method aims at developing a methodology of common Construction Industry Knowledge representation applicable for large sets of SMEs in the construction industry as a basis for the establishment of a knowledge community.

Bibliography

CEN - European Committee for Standardization; *CWA 15142:2004 E - European eConstruction Ontology (EeO).* Brussels, 2004.

Ceton, Greg; *Background of the Overall Construction Classification System (OCCS)*. Construction Specification Institute (CSI), 2000.

Cornejo, M.; *Utility, value and Knowledge Communities.* Knowledge Communities (to be published), 2003.

Debras, Philippe; et al.; The Construction Pilot in GENIAL: Implementing the GEN Vision in the Construction domain. *CIB-W78 Conference, Information Technology in Construction,* Stockholm, 1998.

De Vries, S.; P. Kommers; Online knowledge communities: future trends and research issues. *International Journal of Web Based Communities* 1(1): 115 – 123, 2004.

Gómez-Gauchía, H.; B. Díaz-Agudo; et al.; *Two-layered approach to knowledge representation using conceptual maps and description logics.* First Int. Conference on Concept Mapping, Pamplona, Spain, 2004.

eConstruct Public Deliverables, available at http://www.bcxml.org/

e-COGNOS Public Deliverables, available at http://www.e-cognos.org/

Lelkin, Peter L.; *Terminology standards and implementation*. Standards Australia, Committee for Information Technology IT-014, 2004.

Know-Construct: Internet Platform for Knowledge-based Customer Needs Management and Collaboration among SMEs in Construction Industry. Division of Work (DOW), 2004.

Martinez, D.; Mira, J.; Taboada, M.; Knowledge base development *Lect. Not. in Artificial Intelligence*, 2774, 1373-80, 2003.

Pinto, Helena S.; and Martins, João P.; Ontology Integration: How to perform the Process. *Proceedings of the international conference on Knowledge capture*. Victoria, British Columbia, Canada, 2001.

ISO 12006-2 Building construction — Organization of information about construction works - *Framework for classification of information,* DIS version 2001.

Taboada, M. et al.; Modelling knowledge bases by reusing generic ontologies and unified terminology servers, *International Journal of Knowledge-Based Intelligent Engineering Systems* , 7 (4): 190-197, 2003.