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CIK Representation Concept and Related Ontology Concept

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Abbreviations

B2B	Business to Business
CI	Construction Industry
CIK	Construction Industry Knowledge
eCNM	Customer Needs Management
C&B	Construction and Building
e.g.	“exempli gratia” – for example
etc.	et cetera
EU	European Union
i.e.	“id est” – that is
IAG	Industrial Association/Grouping
IAI	International Association for Interoperability
ICT	Information Communication Technology
IFC	Industry Foundation Classes
IST	Information Society Technology
IT	Information Technology
KC	KNOW-CONSTRUCT
eKCS	Knowledge Community Support
KM	Knowledge Management
OO	Object Oriented
PC	Personal Computer
PDA	Personal Digital Assistant
RTD	Research and Technology Development
SME	Small & Medium Enterprises
SW	Software
UML	Unified Modelling Language
w.r.t.	With respect to

XML	Extensible Markup Language
XP	Extreme Programming Approach

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0 Executive Summary

Knowledge management intrinsically involves communication and information sharing, which can be strongly affected by the context in which it is viewed and interpreted. This situation gets worst when complex domains are considered, as it is the case of the Construction Industry domains. The development of ontologies to unify and to put into context the different concepts and terms of the sometimes rather traditional and locally colored construction industry domains is a necessary step to avoid misinterpretations and inefficient communication. As established, the KNOW-CONSTRUCT project decided, as an approach to this task, to re-use, as far as possible, existing ontologies, classification systems and other semantic resources in order to develop a system that may come to contribute to standards and to the integration, management and reuse of the area specific knowledge via a common knowledge base in order to consolidate and provide access to integrated knowledge, making community emergent knowledge a significant added value.

The starting point for the identification of sources was the Technical Annex of the KC proposal. All sources described there, as well as other, national and international, were accessed and analyzed, in what concerns their current state of development, usability and interest for the pre-defined areas of analysis and their suitability to the KC system. The difficulty of this task is well known, since the different sources are usually designed using different theoretical grounds and design principles. The identification of these sources leads to the conclusion that part of the existing information has some common principles and structures. 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.

Thus, after a careful process of selection, analysis and evaluation of a large amount of available resources and of the methodologies' description followed in their construction, a decision was taken about the sources to be used in the construction of the ontologies. After the analysis of the chosen sources, the end-user comments, of the user requirements analysis and after a review of the most frequently identified concepts, the team concluded that the core domains of a representative ontology for the Construction Industry were Processes, Resources and Results, along with Technical Topics. These domains were also chosen due to their potential for integrating other available semantic resources. In face of the complex nature of the construction industry, the CIK Ontology has been developed in an iterative fashion to make sure that the resulting ontology is both representative and easy to use and corresponds to the purposes of the project. The CIK ontology will be integrated in the upper level Enterprise Ontology.

Another decision taken was the need to construct not one, but more than one ontology, arisen from the perception that to deal with the very concrete reality of the Associations and SMEs of each country, KC system would need to have a local ontology that would answer the KC partners' particular professional and cultural needs. The development of this more specific ontology will be based on a larger, upper level ontology – the CIK ontology, where all the central concepts of the CI area are structured.

Therefore the solution proposed is to develop an inter-organizational KM system for Construction Industry Knowledge Communities which will be built upon distributed ontologies locally managed and centrally integrated. The central ontology will reflect standards and related classification schemes in the industry and the local ontologies will account for the individualised SME conceptual schemes, i.e. they will be strongly related to the consortium partners' needs. Two main concerns/challenges arise by choosing such methodology: 1) how to establish through the re-use and integration of existing ontologies (as far as possible) an adequate domain related ontology, as well as classification system for this sector applicable in SMEs environment, and 2) how to assure the continuous update/maintenance of both types of ontologies in order to enable a long life to the knowledge systems.

The KC knowledge management structure was, thus, defined according to the analysis of the pre-requisites results, the definition of the vision of the system and the analysis and evaluation of the available knowledge sources, taking into consideration the KC partners purposes, the project objectives and its professional and cultural context of use.

According to Annex I – “Description of Work”, the methodology for a creation of the SME Knowledge Communities in the construction sector will be elaborated with emphasis on knowledge representation and ontology issues, as well as cultural and trust issue. The methodology will include an overview of different models for knowledge communities, relevant for SMEs in the building sector stressing the roles of Associations in such communities. Based on these different models, we classified the CIK community as a hybrid of practice and interest. The main characteristics of CIK Community were then synthesized. Based on developments in internet technologies, we analysed and underlined the main trends in the development of online knowledge communities that will also be our main orientations in the development of CIK Community.

Business dynamics and changes in the operating environment often give rise to continuous changes to application requirements, which may be fulfilled only by changing the underlying ontologies. This is especially true for the WWW and Semantic Web applications that are based on heterogeneous and highly distributed information resources and therefore need efficient mechanisms to cope with changes in the environment. In the particular case of KC system, these

dynamics will also be an important issue. So, at the beginning we had to think about which would be the adequate strategy, research about available methods and tools in order to support the maintenance and evolution of CIK ontology and local ontologies. This level of ontology management is necessary not only for the initial development and maintenance of ontologies, but it is essential during deployment, when scalability, availability, reliability and performance are absolutely critical. Thus, we considered means for combining distributed and heterogeneous local ontologies using mappings. Additionally, because CIK ontology must reflect changes in system requirements, we will develop guidelines and an approach for managing the difficult and complex ontology-evolution process.

Based on the described and analysed characteristics for a CIK knowledge community, and adding these conclusions to the developed vision of the KC system and the user requirements elicited in the first phase, a general functional architecture for the Knowledge Community Support (eKCS) system was defined. KC will also rely on semantic web technologies for complex information retrieval, both internally and externally to the knowledge community. Compliance with the semantic web is one of the major success factors for KC. Particularly regarding the potential applications of the SW in business integration this project setup two demonstrators. The semantic blogging and semantic portals together illustrate some of the features of an information integration infrastructure. The semantic portal illustrates a process of aggregating RDF data from multiple sources and integrating it to provide a common browsable view.

1 Introduction

1.1 Know-Construct background

Facing the requirements of integral solution offers, increasingly tighter delivery times and ever-lower price margins the construction industry companies, and particularly SMEs, have to act quickly on redefining the ways for the achievement of their business objectives. A narrow technical specialisation must be replaced by significantly wider technical competence through integrated teams as knowledge communities, followed by on time, within budget works completion. The main challenge is to provide a cost-effective solution for the two main problems:

- (a) Construction industry (particularly SMEs) urgently needs radical improvements of communication with customers in order to provide better product support and services. The innovative forms of communications and relationships among SMEs and customers are increasingly important in order to improve the market share and/or survival chances in the "new economy era".
- (b) To respond to ever increasing customer requirements it is increasingly necessary to establish a closer co-operation (particularly among SMEs) within this sector, aiming at assembling alliances of SMEs into integrated teams that will genuinely align with challenging performance targets.

Taking into account these needs the consortium comprising Construction Industry Associations, SMEs from the same area and RTD organisations from four European countries initiated the research project with a main goal defined as development of an innovative solution of Internet Platform for Knowledge-based Customer Needs Management and for Support to Knowledge Communities of SMEs in Construction Industry. It was identified that the **professional associations** may represent an ideal environment to provide such a solution.

The goal of the project is to considerably contribute to the **competitiveness** of the European SMEs in construction sector by enabling them to increase the application level of the state-of-the-art, knowledge-based ICT solutions in their business relations to customer and mutual co-operation.

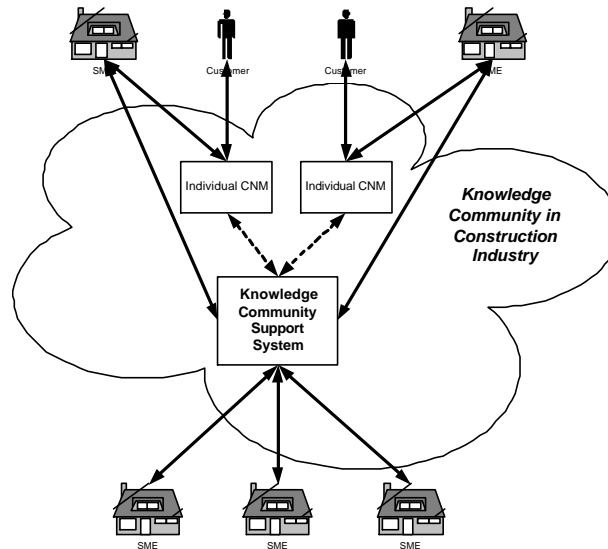


Figure 1: KNOW-CONSTRUCT basic concept

In order to successfully meet the challenges described above, the KNOW-CONSTRUCT project consortium has defined its main objective as the development of a common platform for knowledge based systems, which will provide a combination of two general functionalities (see Figure 1):

- (a) **Customer Needs Management (eeCNM) System** as an innovative decision making support system regarding the product characteristics, product applications and related consultancy services, and
- (b) **Knowledge Community Support (eeKCS) System** as a system to support an advanced and efficient formation of communities of SMEs in construction industry, through their specific knowledge integration, management and reuse via a common knowledge base.

The platform will be owned by associations, which will offer to their members possibility to establish individual eeCNM systems and take benefit of Knowledge Community Support System.

The **business objectives** can be summarised as:

- (a) Improved (innovative) technical support to product and service users (customers), and
- (b) Wider technical competence required to satisfy customer needs (e.g. for "turn-key" solutions delivery), through closer co-operation and knowledge exchange among SMEs within knowledge communities, including improved quality/price ratio and on time completion of increasingly complex tasks.

1.2 Purpose of this document

The objective of this deliverable is to present the results of the task *T1.4 Construction Industry Ontology and Knowledge Representation Concept*. In parallel with the requirements specification task a concept of the CIK representation was developed leading to a method and tools for

practicable management of knowledge. The ontology concept was confined (in this phase) to specific construction knowledge domain(s) related to user requirements from different sub-sectors, although including an high-level ontology with the purpose of supporting more general business requirements. Such wide coverage of construction industry sub-sectors was assured based on an involvement of the partners associations, and at least 4 additional associations, and a set of SMEs.

This document has the following structure:

Chapter 2 presents the results of the analysis of the available knowledge sources that contributed to the development of the CIK ontology. These knowledge sources were identified, classified and evaluated according to a set of criteria defined for the purpose of the Know-Construct ontology development.

Chapter 3 approaches the Knowledge Management Structures and Methods for Know-Construct. Models for knowledge communities are explored and the Know-Construct knowledge management structure is defined. The chapter finishes with the identification of the methods for the Know-Construct knowledge structure evolution. The general architecture for the Knowledge Community Support (eKCS) system is outlined and the technological perspectives for the construction of eKCS and KC are discussed.

2 Knowledge Sources for Know-Construct

The objective of this chapter is to present the results of the analysis of the available knowledge sources that may contribute to the development of the CIK ontology. As established, the KNOW-CONSTRUCT project will, as an approach to this task, re-use, as far as possible, existing ontologies and classification systems in order to develop a system that may come to contribute to standards. It will, thus, exploit the classification proposals in use in other European and international projects and the ontologies that resulted from projects in the construction area, in an attempt of harmonization with the current, well established proposals and as a way to oppose the unpredictable perennity of the stored data.

The difficulty of this task is well known, since the different sources are usually designed using different theoretical grounds and design principles. Also, 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 national and international classifications were identified, potentially just as important, which have not yet been used to the same degree, e.g. construction products and properties/characteristics.

The first step consisted in the identification and selection of existing, well established knowledge and semantic resources of multiple different international sources, in order to access subject field related information and develop the high-level ontology for the development of the internet platform for Knowledge-based Customer Needs Management and collaboration. In parallel other additional local/ national sources were identified, to provide knowledge for the development of other more specific ontologies, adapted to the local markets and communities.

The sources identified in the areas of interest for the project are of different typology:

- ontologies,
- terminologies,
- taxonomies,
- dictionaries,
- thesauri,
- national and international classifications,
- glossaries from the different specific subject fields,
- national and international standards, norms and regulations,
- associations' publications and documentation,
- SMEs internal documentation and possible databases,
- existing web portals with information regarding the CI area,
- other relevant scientific and technical documentation.

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. While the building and construction industry is mainly governed by the legally established standards, in the KM area (and ICT in general), as the main part of RTD activities in the project, there are still a large amount of de-facto standards.

This project will contribute to consolidate existing standards by using them whenever adequate. Nevertheless, KNOW-CONSTRUCT will also actively contribute and promote innovative approaches that can result in standardization initiatives. Customer Needs Management will develop ontologies 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 for CI (Construction Industry) standards, is the development of integrating ontologies both in the areas referred above and in inter-enterprise interoperability.

2.1 Identification and classification of Knowledge Sources

The starting point for the identification of sources was the Technical Annex of the KC proposal. All sources described there were accessed and analyzed, in what concerns their current state of development, usability and interest for the pre-defined areas of analysis. Other sources, national and international, were then analysed as a result from the direct contribution of the IC experts, the analysis of the public documents of other European projects in this area, the cross-reference present in the several project sites and the analysis of the CEN Workshop Agreements for the construction area.

Not all the resources are accounted here, as part of them are already identified and described in the state-of-art deliverable, namely the existing web portals. Besides CI online sites, the most relevant standards, ontologies, terminologies and classifications identified so far are:

- **ISO 12006-2** - *Building construction - Organization of information about construction works - Part 2: Framework for Classification of Information.*
 - The purpose of ISO12006-2 is to define a model for classification systems. It is not a classification system in itself. It sets out an approach whereby particular

classification systems that meet regional or national requirements can be developed according to a common international approach.

- The key concept in ISO 12006-2 is that: *Construction Resources* are used in *Construction Processes* that will result in *Construction Results*. Construction Resources are the things that are brought together so that construction can occur. Construction Processes are concerned with the act of construction using the resources provided. Construction Results are the results of processes being carried out using resources (see **Figure 2**).
- ISO 12006-2 does not contain any tables or parts. However, the class structure of the model recommends tables/parts that can be included within a conformant classification system. The aim of the standard is to support information use and exchange in areas such as computer aided design, specification provision and cost estimates.
 - This standard is intended to face the problem of the little international standardization of classifications for construction. The construction industries of individual countries, even adjacent countries, have tended to remain separate because of differences of culture and legislation, and each has developed its own methods of arranging information. National classifications can be difficult to change and there may seem insufficient reason to do so.
 - It also tries to bring together the most widely used classifications, which handle with work sections (mainly for specifications) and elements (mainly for cost analysis). These 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.
 - It aims at defining and structuring all these data and the relations between them in such a way that the stored information is consistent and reliable within and between the different applications.

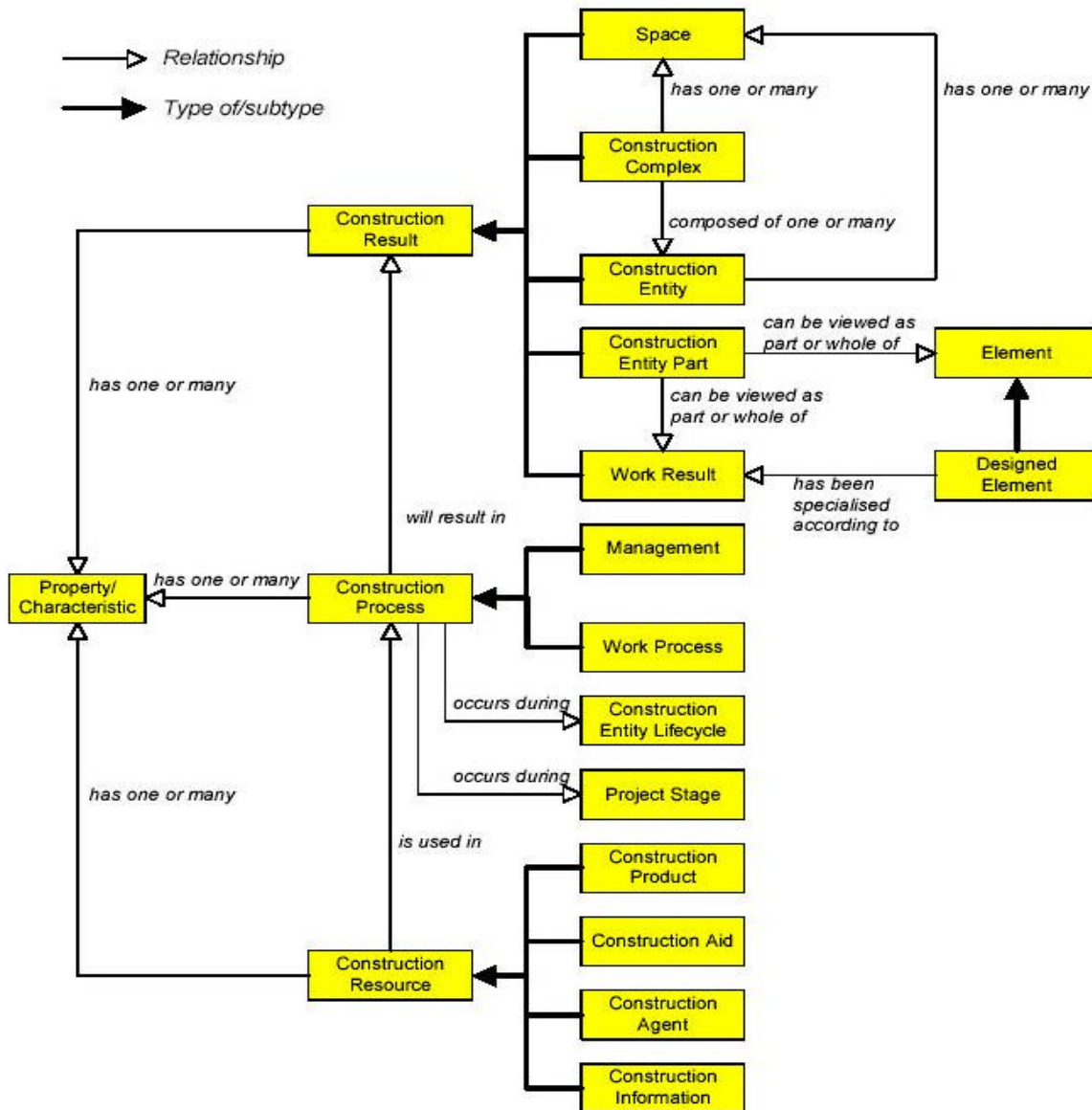


Figure 2 – Simplified view of ISO 12006-2 meta-schema.

- ISO 12006-3 - Building construction — Organization of information about construction works — Part 3: Framework for object-oriented information exchange.** The main part of ISO 12006-3 consists of the specification of a taxonomy model, which provides the ability to define concepts by means of properties, to group concepts, and to define relationships between concepts. Objects, collections and relationships are the basic entities of the model. The set of properties associated with an object provide the formal definition of the object as well as its typical behaviour. Properties have values, optionally expressed in units.

- The role that an object is intended to play can be designated through the model and this provides the capability to define the context within which the object is used.

Each object may have multiple names and this allows for its expression in terms of synonyms or in multiple languages. The language name of each object must always given in English (the default language). An object may also be named in terms of the language of the location in which it is determined or used. Objects may be related to formal classification systems through the provision of references.

- **e-cognos ontology** - *Methodology, tools and architectures for electronic consistent knowledge management across projects and between enterprises in the construction domain* - e-COGNOS has as one of the main results the development of an ontology for the construction industry domain. It aims at specify, deploy, implement and evaluate a web based infrastructure, including services allowing to create, capture, index, retrieve and disseminate knowledge.
 - This result would be used in KNOW-CONSTRUCT, taking into account the specifics of eCNM area and variety of the external system users - customers, which are not customised to standard ontologies.
- **e-Construct ontology** - *Electronic Communication in the Building and Construction Industry: Preparing for the New Internet* - Internet-based, commerce-oriented B2B/ B2C – e-Construct produced as the main result the bcXML (building and construction XML), using as the base ISO 12006-3 and the Dutch STABU Foundation’s Lexicon (for the taxonomy). The Lexicon uses three types of data: the Lexicon Data, the Product Data and the Business Data.
 - The first two have been addressed by e-Construct. The latter includes business knowledge and business rules related to construction activities that result in or modify objects, and will be an area to which the KNOW-CONSTRUCT will contribute.
- **EPIC** – European Product Information Co-Operation. EPIC is concentrated on the definition of a common set of construction product groups including notations in order to facilitate the transfer of data between computerised national and/or distributed databases and to harmonise search patterns
- **UNICLASS** – Unified Classification for the Construction Industry. Uniclass is a new classification scheme for the construction industry. It is intended for organising library materials and for structuring product literature and project information. It incorporates

both CAWS (Common Arrangement of Work Sections for building works) and EPIC (Electronic Product Information Co-operation), a new system for structuring product data and product literature.

- **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. It's of special relevance for industries dealing with heating systems, air conditioning, tubes. Dedicated to the dissemination of IT's for better EDI in Construction.
- **MASTERFORMAT** - Construction Specification Institute - MasterFormat is a master list of numbers and titles for organizing information about construction requirements, products, and activities into a standard sequence. It facilitates standard filing and retrieval schemes throughout the construction industry. MasterFormat is a uniform system for organizing information in project manuals, for organizing cost data, for filing product information and other technical data, for identifying drawing objects and for presenting construction market data.
- **IFC Model** – Industry Foundation Classes. The IFC Model Architecture has been developed using a set of principles governing its organisation and structure. These principles focus on basic requirements and can be summarised as:
 - provide a modular structure to the model;
 - provide a framework for sharing information between different disciplines within the AEC/FM industry;
 - ease the continued maintenance and development of the model;
 - enable information modellers to reuse model components;
 - enable software authors to reuse software components;
 - facilitate the provision of better upward compatibility between model releases.
- **ICIS LexiCon** – International Construction Information Society – The Lexicon uses three types of data: the Lexicon Data, the Product Data and the Business Data. The LexiCon is a vocabulary of terms of interest for the construction industry and as such an implementation of ISO DIS 12006-3. The languages currently available in the Lexicon are Dutch, English, French, German, Greek and Norwegian.

- The LexiCon is a structure for the storage of data in such a way that – within a certain context – the meaning of these data is assured. The LexiCon therefore can be regarded as a semantic system, defining the context for data explicitly and defining contexts within broader contexts.

Other sources with an interesting data potential are the terminologies (standardized or *de-facto*). Here we enumerate but a few of them:

- EN 12519 Windows and doors – terminology.
- UNE EN 12216 Blinds, inner & outer lattices – terminology, glossary and definitions.
- WI 33058 Iron fittings for buildings – terminology.
- UNE EN 12433-1 Doors: industrial, commercial, garage and large doors – Terminology – Part 1: Types of doors.
- UNE EN 12433-2 Doors: industrial, commercial, garage and large doors – Terminology – Part 2: Door components.
- PrEN 13119 Light Fronts – terminology.
- WI 129058 Glass for building – Terminology

Other known standards in the CI area that may be of use for the development of the ontology are:

1. ISO 1087-1990 Terminology & Vocabulary
2. ISO 10303-221 Functional Data and Schematics for Process Plants (draft ISO ballot scheduled for Fall 2003)
3. ISO 10303-227 Plant Spatial Configuration (1st Edition) (completed; awaiting commercial implementation)
4. ISO 10303-227 Plant Spatial Configuration (2nd Edition) (approved to be published as an ISO standard; demonstration implementations done in Spring 2003)
5. ISO 13584 Parts Library Structure (in development)
6. ISO 15926 Process Plant Data Warehouse (in development)
7. ISO 15926-2 EPISTLE Core Model (ECM) (completed)
8. ISO 15926-4 EPISTLE Reference Data Library (ERDL) (in development)
9. ISO CD 1457 - "Construction drawings - Designation systems".

10. ISO 6240 - "Performance standards in building - Contents and preparation"
11. ISO 6241 - "Performance standards in building - Principles for their preparation and factors to be considered"
12. ISO 8402 - Quality management and quality assurance - Vocabulary - 1994
13. ISO 10006 - Quality Management - Guidelines to quality in project management - 1997.
14. ISO TR 10127 - "Computer-Aided Design (CAD) Technique - Use of computers for the preparation of construction drawings".
15. ISO 10209-1 - "Construction documentation terminology - Terms relating to technical drawing"- 1992.
16. ISO 10209-2 - "Construction documentation terminology - Terms relating (to) projection methods"- 1993.
17. ISO CD 10209-3 - "Construction documentation terminology - Terms relating to construction documentation".
18. ISO DIS 10209-4 "Construction documentation terminology - Terms relating to construction documentation".
19. ISO WD 10303 - "Product data representation and exchange".
20. ISO TR 10623 - "Technical product documentation - Requirements for computer-aided design and draughting - Vocabulary".
21. ISO CD 13567 - "Construction documentation"

2.1.1 Country Specific Semantic Resources

Other well developed resources that may be useful for the CIK ontology definition and further development are the country specific semantic resources. These resources are highly developed and have been used in previous projects in the CI area and, in the majority of the cases presented here, they are the result of the work of several combined institutions and actors interested in developing the existing standards and classifications systems in the CI. A list of those resources, partly based on the FUNSIEC exploitation of the resources, is presented next.

Uniclass – UK

Uniclass is a construction information classification system (CICS) that covers information generated from all phases of a construction project. Differently from many other existing CICSs (i.e. CI/SfB), which focus on architectural projects, Uniclass focuses on both architectural and civil engineering works.

BS6100 – UK

The British Standard 6100, produced by the British Standard Institution (BSI), provides a glossary of the terminology used in the construction sector. The aim of BS6100 is to ensure co-ordination and consistency throughout the UK construction industry. Differently from previously published glossaries, which often mainly focused on specialist fields, BS6100 also covers generic construction terms, aiming to widen their usage throughout the industry.

Standard Dictionary for Construction (SDC) – France

The SDC intends to unify the vocabulary used along the supply chain within the sector and, as such, to become the dictionary of reference and a permanent source of description of technical characteristics of the construction products. The SDC is expected to be used as the referential within the sector in such a way that databases, classification systems, catalogues, and similar resources will be all based on the SDC vocabulary.

BARBi – Norway

This is a project initiated by the Norwegian construction industry to establish a reference data library with a complete collection of all concepts and objects from the building and construction industry with associated properties and relationships. The library will contain everything from complete constructions down to individual parts or products. BARBi links standards, classification systems and their definitions. Every object (concept) in BARBi has a global unique identifier. BARBi also provides multiple classification and specialization hierarchies for any concept.

BauNetz-Infolines – Germany

Virtual online reference covering the fields: building shell, interior, fittings, building services, planning. Provides basic knowledge, standards, news, services (planning aids, grants/subsidies, information centres, and experts), projects, literature, forums.

Structural Engineering Dictionary -Germany

Structural engineering online dictionary using Eurocode 2 - reinforced concrete and pre-stressed concrete construction. It is orientated about the vocabulary from the Eurocodes, which is becoming

the technical and linguistic standard in Europe. The work was developed at the Fachhochschule Konstanz in conjunction with the technical language education of civil engineering students.

CIC-Net

In what concerns the classification and codification of construction products area the Portuguese Construction Associations together with R&D institutes such as INESC Porto and IC have developed a new proposal based on EPIC, Uniclass and ISO 12006-2, having adopted a facet based classification structure associated with an Alphanumeric notation.

The following facets have been considered: **Function, Form and Constituent Material**. Classification tables were produced for each facet. The combination of a record from each of three facets determines a generic product. Each generic product has properties, which are inherited by a specific product placed in the generic product bag. With the objective to promote a unique classification for construction products along its lifecycle, criteria were defined as how to assign codes.

As for the classification and codification of construction activities, work has been made by the same entities mentioned above in coordination with Portuguese government and civil engineering branches such as LNEC (Civil Engineering National Laboratory).

The results presented above in the classification of building construction activities, materials and products, which resulted from national projects and constitute an innovative and integrated approach to these problems, will be used and disseminated by the partners of this project and presented as contributions to EC standards.

Non-European Sources

- Overall Construction Classification System (OCCS), (now OmniClassTM) *A Strategy for Classifying the Built Environment*. <http://www.occsnet.org/>
 - The OCCS is designed to comprehend and organize the entire universe of knowledge within the North American AEC Industry, throughout the full life cycle of the built environment, from conception to demolition, and encompassing all forms of construction. The OCCS is intended to be the basis for organizing, sorting, and retrieving information and deriving relational applications.
 - The OCCS is designed to comprehend the entire built environment, from completed structures, vast projects, and multi-structure complexes to individual products and component materials. It comprehends all forms of construction,

vertical and horizontal, industrial, commercial and residential. In a break from many of the systems that have preceded it, the OCCS also comprehends actions, people, tools, and information employed in the design, construction, and maintenance of these structures.

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 previously defined scenarios
- the objectives of the project

In the future development of the of the ontology, in order to integrate the knowledge of the specific markets and specific Customer Needs Management and Knowledge Community Systems, the knowledge sources will have to be defined according to the local market context, the SMEs and the Industrial Association/Grouping (IAG) concerns and needs and the documentation they usually produce.

2.2 Evaluation of Knowledge Sources

In order to choose the knowledge sources, a complex set of multi-criteria referring to different aspects were established. An analysis framework was elaborated in order to evaluate the analysed knowledge sources in what concerns to their suitability to the Know-Construct system and methodology.

The following table, inspired in the works of Pinto and Martins (2001) and Lelkin (2004), describes those criteria and their scope.

<i>Know-Construct - Knowledge sources evaluation criteria</i>		
<i>Type of source</i>	<i>Common Criteria</i>	<i>Description</i>
All	Origin	developer(s) type of entity (CEN, ISO, DIN, other)
	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
	Specific Criteria	
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
	Consistency	consistency of the application of the 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
	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

Table 1 - Criteria for the evaluation of Know-Construct knowledge sources

Other relevant sources - like associations' publications and documentation, SMEs internal documentation and possible databases, existing web portals with information regarding the CI area and other relevant scientific and technical documentation - will have a more contextualized approach.

After this process of identification, classification and evaluation, and taking in consideration 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 and for the development of Know-Construct high-level ontology are:

1. **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.
2. **bcBuildingDefinitions** taxonomy (from **e-Construct**), in the area of e-procurement, that provides a good starting point. It contains approximately 3000 concepts representing construction products. The *bcBuildingDefinitions* is the taxonomy developed by the eConstruct project in order to demonstrate the power of bcXML3, an XML-based language tailored to the representation of products/services in the construction sector. The bcXML meta-schema is the model of bcXML taxonomy. Additionally, it is supported by a software infrastructure freely available. Nevertheless, it is clear that this taxonomy has to be enriched since it has to represent a large spectrum of construction products commercialised within the supply chain.
3. **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 is compliant with the kernel of the IFC model;
 - It can be easily replaced by smaller ontologies, if required;
 - It is compliant with the Semantic Web recommended format;
 - It can easily be extended using a very simple mechanism based on bcXML;
 - Multilingual feature is part of the ontology;
 - It has been developed under open source license, which means that it is freely available to the sector.

The e-COGNOS ontology focuses on construction concepts related to the *consistent knowledge representation of (construction) knowledge items*. The e-COGNOS ontology comprises two taxonomies (concepts and relations). Those concepts and relations are grounded in the IFC entities, which form the highest level taxonomies.

4. **IFC model** - 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. Among others, the following features of the IFC model make it very useful:

- It provides a widely accepted backbone of concepts used in ICT tools for construction;
- IFC compliant data can be used to mine semantic content;
- It can provide a reference mechanism for smaller, more specialised ontologies;
- It can be linked to both e-COGNOS and eConstruct results.

The primary target of the IFC model is interoperability of software applications in the building and construction sector. IFC classes are therefore defined according to the scope and the abstraction level of software systems dealing with Construction specific content. The entities of the IFC model are grouped in layers where the kernel and core extension layers deal with general, abstract concepts whilst the shared elements and domain layers deal with specialised concepts of the real world.

5. **ISO 12006-3** - *Building construction — Organization of information about construction works — Part 3: Framework for object-oriented information exchange*. Is a Construction specific standard that defines a schema for a taxonomy model, which enables concepts to be defined by means of properties, the grouping of concepts and defining relationships between concepts? *Objects, collections* and *relationships* are the basic entities of the model. The role that an object should play can be designated through the model and this provides the capability to define the context in which the object is used.

6. **ISO 12006-2** - *Building construction - Organization of information about construction works - Part 2: Framework for Classification of Information*, whose purpose of is to define a model for classification systems, as described before, and that defines an approach whereby particular classification systems that meet regional or national requirements can be developed according to a common international approach.

3 Knowledge Management Structures and Methods for Know-Construct

3.1 Models for knowledge communities

According to Annex I – “Description of Work”, the methodology for a creation of the SME Knowledge Communities in the construction sector will be elaborated with emphasis on knowledge representation and ontology issues, as well as cultural and trust issue. The methodology will include:

- Overview of different models for knowledge communities, relevant for SMEs in the building sector stressing the roles of Associations in such communities. This will include guidelines for selecting of knowledge to be shared, and mechanisms to support sharing of knowledge among SMEs, i.e. mechanisms to effectively establish Knowledge Communities. The SME collaboration motivation will be specifically elaborated (e.g. schemes for assessment of clear business benefits of different types of collaboration).
- Guidelines for structuring of domain knowledge and knowledge representation, as well as ontology definition/update.
- Selection of approach and topics appropriate for e-eCNM and e-KMS and how to 'share' knowledge between these two functionalities, including methods for knowledge acquisition/capturing, presentation and maintenance.
- Guidelines for using set-up tools for a specific SME and/or Association and introduction of e-eCNM and e-KMS including definition of technical infrastructure (selection of appropriate technical means offered by the system) for setting Internet based platform.
- Manual for defining appropriate user interface for specific e-eCNM and e-KMS topics (to be applied based on the KNOW-CONSTRUCT system) - taking into account specific needs regarding trust etc.

The relationship between organizations and communities, including their implication in the organization structure, IT systems and business model, depends on the nature of the value derived of them. This area has not been sufficiently mapped before, but [Cornejo 2003] explores it very well starting with the nature of knowledge, the translation into value for individuals and organizations, the definition of community taxonomies and its influence on organizational drivers.

Defining “communities” as groups where knowledge and best practices in a given field are developed nurtured and transmitted through the social interaction of its members. In other words, a community is where members’ tacit knowledge is transmitted to other members, and where this know-how is occasionally codified and made explicit. IT has played a catalytic role in these communities, allowing not just the collaboration of thousands of geographically dispersed people but the formation of IT-mediated groups with the critical mass to establish a coherent community on almost any subject. As we know, the behavior of people is driven by the maximization of their own perceived utility. People act, or don’t act, in order to accrue the highest possible utility. Linking utility to knowledge, knowledge is defined as “the information required to satisfy a need”. The data and the context required for a person to perform a task: knowledge is such when it enables a person to do something. Even when that something is simply satisfying a personal curiosity, it is solving a need and effecting a change. If it is not good for anything but the person can understand it, it will simply be called “information”. If the person can’t make sense of it, it will be merely considered “data”. When knowledge is such, it enables the person to satisfy a need. This satisfaction can also be called “utility” (the capacity to satisfy a demand for a person). This is the link between knowledge and utility. The main road for knowledge-derived utility to accrue to an organization is through the enablement of the people that constitute it. In this scope, and also based on work of [Cornejo, 2003], we address different classifications of utility and define the main types of knowledge communities.

We distinguish utility for people from utility for organizations. Individual persons can derive two different types of utility from their participation in a community, defined by their effects on the person’s observed behavior:

(1) Objective utility - when the received utility can be compared with the utility derived from other productive factors used in the development of the person’s activity, or in other words, when the knowledge received can be directly applied to the improvement of the person’s economic situation or even in the execution of the person’s job. This area will cover such knowledge as methodologies, precedents, solutions to problems, professional growth tools.

(2) Subjective utility - this is provided by knowledge that can’t be directly related to the improvement of the economic situation or working abilities. In other words, it can be compared with the utility derived from economic factors. But it does exist, and encompasses knowledge that can state the person’s curiosity, or sustain the person’s need for a sense of belonging or appreciation. The means for attending the social and psychological needs of the individual.

We can also differentiate two types of utility that determine substantially different behaviour in organizations:

- (1) Direct utility - such as the organization can perceive and measure, and put in direct relationship with improvements in processes and operations. It will usually derive from the knowledge acquired by members of the organization.
- (2) Indirect utility - when the organization knows that it is benefiting from the acquired knowledge but can't identify the mechanism with clarity, and it therefore can't find a reliable way to measure and value it. Advertising is another classic source of this type of utility.

Based on this classification of utility, [Cornejo, 2003] built a basic predictive model that allow us to better understand the dynamics of the different types of communities, with particularly relevance for those that can generate some type of utility for someone (see Figure 3). This model will rest on a prediction of individual behaviours. Just as markets work by aggregation, the dynamics of communities will depend on the aggregations of the motivations of their users. Utility on the model is represented by degree in which it belongs to one or other type. To this quadrant was defined the following types of knowledge communities.

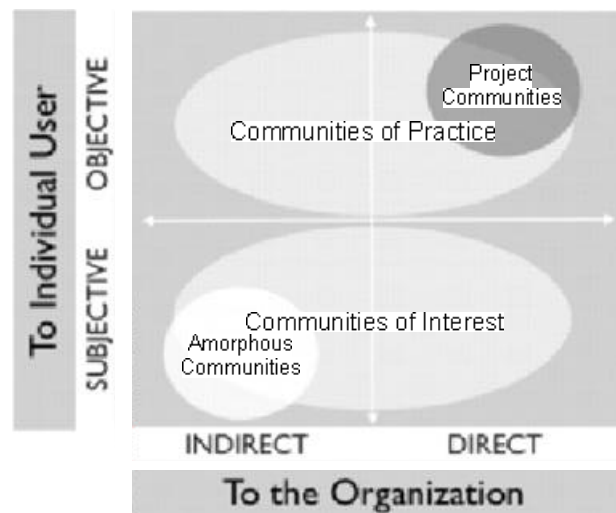


Figure 3 – Quadrant of Communities (based on [Cornejo 2003])

Communities of Practice - On the model, we can point them out as those in which the people (users) derive from the acquired knowledge a kind of utility due to the improvement of their productive and economic situation. These communities present the user with an “objective utility”. This Quadrant allows us to underscore something else important: the “practitioners” are individuals;

the Community of Practice need not belong to any particular organization for it to accrue benefits from the improvement of its members. When the organization is able to pinpoint the direct relationship between that knowledge and improvements in its processes and results, we will be talking about “direct utility”. When it is aware that somehow that knowledge reverts in some unquantifiable improvements to its situation, we will be talking about “indirect utility”.

Communities of Interest - This type of Community is defined by a different sort of utility: that derived from satisfying other needs such as curiosity, debate, belonging, recognition. In the model, we see that described as “subjective utility” for the individual. For the organization, the same division appears: a community of interest can generate either “direct” or “indirect” utility depending on how measurable that utility is.

Project Communities - A particular type of knowledge exchange environment which was traditionally hard to place is that made up of project-oriented teams and knowledge units. Typical examples include product development teams, project implementation teams, and customer pre-sales teams and so on. These are nothing more than the results of an extreme set of motivations... which are present in many other communities. This will help understand the place of communities inside the organization. Project Communities are those in which individuals derive an extremely “objective utility”, directly related to their jobs and their economic subsistence. Their attitude to the community is directly marked by this. On the other hand, organizations extract a clearly “direct utility” from their work, in as much as the project is related to the efficacy of its processes and the achievement of its aims. To put it in a nutshell, both parts of the deal regard this type of communities with the utmost seriousness and want the highest control on them.

Amorphous Communities - Reality shows many examples of environments in which knowledge is somehow exchanged, but the supposed virtues of communities are hard to find. We see fragmented environments, discontinuous participation, lack of stable funding mechanisms... and we even doubt that these things can be called a community. But it can. The reason for these apparently failed communities lies squarely in the motivations that are supposed to push it forward. When the individual users derive from them a purely “subjective utility”, with no translation into objective value (no cost and no benefit), and the organizations involved have a totally “indirect utility” such as that usually derived from marketing and promotional tools, we have those sorry, but frequent examples of “Amorphous Communities”. Users won’t be held to rules nor go out of their way to improve or maintain them. The organizations can’t justify serious investment in moderation or IT infrastructure. The community just drifts on, receiving disconnected bursts of activity.

According to the above, and in a simplifying way, we can say that the benefits of running a community for an organization or a group of organizations (such as a sectorial association in KC)

depend on the utility that the people get from it, both as individuals and as collective actors. Of course this is very much based on the individual and collective perceptions either. Some relevant issues that should be analyzed are:

- Organization - the way in which activities related to the community will be managed.
- Integration - the community's role in the organization (what will it be responsible for, what departments or structures is it related to, and how).
- Resources - allocation of the relevant means to the community.
- Intellectual property - treatment of knowledge assets used by, and generated through, the community.
- IT support required - integration in the IT infrastructure of the organization, and impact on its strategy and design.
- Value - identification of the value goals that the community should be measured against.
- Price formation - that value can be measured in money, and therefore charged to value recipients (be they consumers, partners, internal departments or other initiatives).

KC general objective is to improve the relationship of CI SME's 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 ICT tools, in particular tools that support the formation and operation of SME's knowledge communities, fostering an improved collaboration aimed at generating broader and more accurate knowledge to be used in satisfying customers.

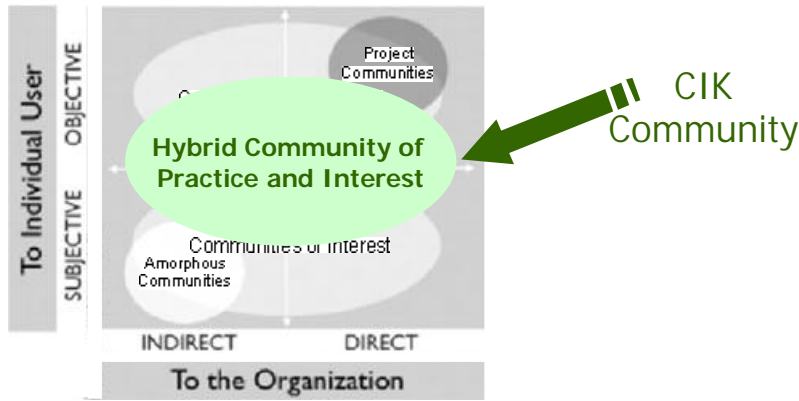


Figure 4 – CIK Community on Quadrant of Communities

The broader context of this development are the sectorial associations that provide, besides others, some sense of grouping to the participant SME's. According to the model of previous section, we can classify the CIK community as a hybrid of practice and interest (see Figure 4). From one side, company employees as individuals should see a direct utility to their particular jobs when participating in the CIK community. This direct utility comes into light when an employee (and consequently the company) realizes that, when solving a problem to an important customer (using the eCNM module), the information/knowledge used to reach the solution comes also from the contribution of the other community members. Nevertheless, not all the activities can be tracked to a causal benefit to the SME. For example, some chatting between two employees exchanging professional experiences or a report in a news or blog item by another employee of a concern regarding the performance of material, are activities that make sense in a community but cannot be assigned of a concrete immediate value for the organization.

Despite of CIK Community could be characterized as a Community of Interest, in this particular case it is our goal que this community should be supported by web technologies and theirs user can collaborate using a online meeting place. So, it is our objective to establish an online knowledge community that in your essence could be better defined as a stable, social aggregation based on communication – in this case, people will use the computer networks as their principal mean of interaction. In particularly case of KC, it has a specific mission that aggregates one or more groups of professionals and customers, and that will be related with construction area. This “place” has to be stable, simply stated, and easy to learn and to use. Also, an adequate culture of community is crucial for that will be successful.

Based on work of de Vries et al. 2004, we synthesize the following characteristics of CIK Community:

- The goal is to **develop and exploit knowledge** about construction area.
- There are **continuous interactions between participants** in order to meet these goals.
- Information and communication **processes are continuously made explicit**.
- It **adds value to the participants** (professionals and customers).
- The online meeting place is **usable**.
- The **culture focuses on the needs of the participants** as the route to high performance; involvement and participation create a sense of responsibility and ownership and, hence, greater commitment to the community.
- The context is highly complex and very unstable, and CIK Community will have to **continuously comply with the expectations** of its participants and their context of use.

Looking at the professional development as a process of continuing development of knowledge, skills and attitudes of professionals by means of formal and informal learning in the course of practice, the use of online knowledge communities for this implies that an online knowledge community has to support this process. As a member, a professional will have a place for continuing professional development that gives: individualised, flexible and easy access to a coherent and actual knowledge domain, a range of opportunities to interact with like-minded persons, and a range of opportunities to develop and exploit the knowledge domain. An example of this is: applying knowledge, learning from it, guiding others, disseminating ideas and results or doing research, embedded in a professional network. What do we expect from this use? Given the discussion so far, our premise is that the membership of professionals of an online knowledge community has positive effects on the continuing development of professionals, expressed in competences like knowledge, skills, experiences and attitude, but also, the development of organizational knowledge assets expressed in a growth and elaboration of the professional knowledge, applicability of knowledge, legitimacy of knowledge.

The main question here is how to implement and make use of online knowledge communities in order to meet these expectations. As an answer to this problem, we propose to adopt and adapt the reference model developed by [de Vries et al. 2004] that describes factors that affect the implementation and use of an online knowledge community as a type of networked organizational communication.

Based on this explanation, CIK Community will consist of three elements: professionals, on-line professional meeting place, and organizational context. We see the implementation of CIK

Community as a continuing communication process, a constant search for a fit between these three elements, as is shown in Figure 5.

- **Professionals** are all the professionals of the construction area and belonging to the associations of the project partnership.
- **On-line Professional Meeting Place** is the online place where the members of the community will take their discussions, debates, conversations, etc.
- **Organizational context** is related with the organizational goals, culture, technology, etc.



Figure 5 – Analytical model of CIK Community (adapted from [deVries et al. 2004])

Based on developments in internet technologies, it is important underline the main trends in the development of online knowledge communities that will also be our main orientations in the development of CIK Community. These are the following [de Vries et al. 2004]:

- **Integration of services** - an online meeting place will become more and more a portal that gives access to a wide number of continuous learning services from different organizations. The current development in internet technologies enables developers to integrate services more and more.

- **Practicality of use** - the online meeting place is expected to fit more and more in the common practice of professionals. It will become the networked desktop of professionals at home, at the workplace, at seminars, etc.
- **Personalization** - the online knowledge community as a networked professional portal is expected to adapt to the preferences and competences of the professional. The personal interface to an online knowledge community is expected to develop based on the development of the professional.

Online knowledge communities start as an information sharing facilities, but increasingly emulate more essential social processes. At the same time, it provokes more thoughts on the nature of human knowledge and how to share it. Complications in corporate learning seem to be quite different from learning in WWW-based communities. The latter relies on a broader spectrum of human interest. A pragmatic phrase is that we feel at home in a community once we broaden the topics of conversation. Pure knowledge is an abstraction. Persons need natural impulses before they give up possessive attitudes and enjoy the exposition of knowledge and expertise. It is the inherent hypothesis that the WWW will allow people to join expertise circuits for identity and feel more fulfilled.

3.2 Know-Construct knowledge management structure

Knowledge management intrinsically involves communication and information sharing, which can be strongly affected by the context in which it is viewed and interpreted. This situation gets worst when complex domains are considered, as it is the case of the Construction Industry domains. The development of ontologies to unify and to put into context the different concepts and terms of the sometimes rather traditional and locally coloured construction industry domains is a necessary step to avoid misinterpretations and inefficient communication.

The KC knowledge management structure was, thus, defined according to the analysis of the pre-requisites results, the definition of the vision of the system and the analysis and evaluation of the available knowledge sources, taking into consideration the KC partners purposes, the project objectives and its professional and cultural context of use.

According to KC vision the system should be based on the integration, management and reuse of the area specific knowledge via a common knowledge base in order to consolidate and provide access to integrated knowledge, making community emergent knowledge a significant added value.

3.2.1 Know-Construct ontologies structure

KC aims at developing methods for the 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 Associations will get a crucial role. This requires the elaboration of a structured approach to define/update/maintain knowledge which is shared among SMEs.

As it had been defined in the KC proposal, the methodology to be followed will mainly aim at identifying, evaluating and reusing existing semantic resources, like ontologies in the IC area, taxonomies, standards and terminologies. Thus, after a careful process of analysis and evaluation of a large amount of available resources and of the methodologies' description followed in their construction, a decision was taken about the sources to be used in the construction of the ontologies.

The need to construct not one, but more than one ontology came from the perception that to deal with the very concrete reality of the Associations and SMEs of each country, KC system would need to have a local ontology that would answer the KC partners' particular professional and cultural needs. The development of this more specific ontology will be based on a larger, upper level ontology – the CIK ontology, where all the central concepts of the CI area are structured.

This perception was reinforced by the reading of the CWA 15142 on *European eConstruction Ontology (EeO)*, where it is clearly stated that the e-COGNOS vision over the development of a big ontology was confronted with an unexpected reality. The end users actually showed their preferences to use their very specific, concise and precise taxonomies. They do not want to handle big ontologies; rather they are perfectly happy if their small resources are in place providing the results they are expecting. This fact has changed the concept of the e-COGNOS ontology: the big ontology is in place, but it is totally customisable in the sense that a small taxonomy with 100 concepts can replace the big one.

KC has decided to take this fact into account and look at this possibility as part of the standardised way to develop ontologies in the sector, but in such an away as to keep a common central ontological content (structure, attributes, relations, etc.) from where to derive the more specific ontologies.

Therefore the solution proposed is to develop an inter-organizational KM system for Construction Industry Knowledge Communities which will be built upon distributed ontologies locally managed and centrally integrated. The central ontology will reflect standards and related classification schemes in the industry and the local ontologies will account for the individualised SME conceptual schemes, i.e. they will be strongly related to the consortium partners' needs.

This methodology results in a need to develop the two types of ontologies in two different moments, as it is described in Figure 6.

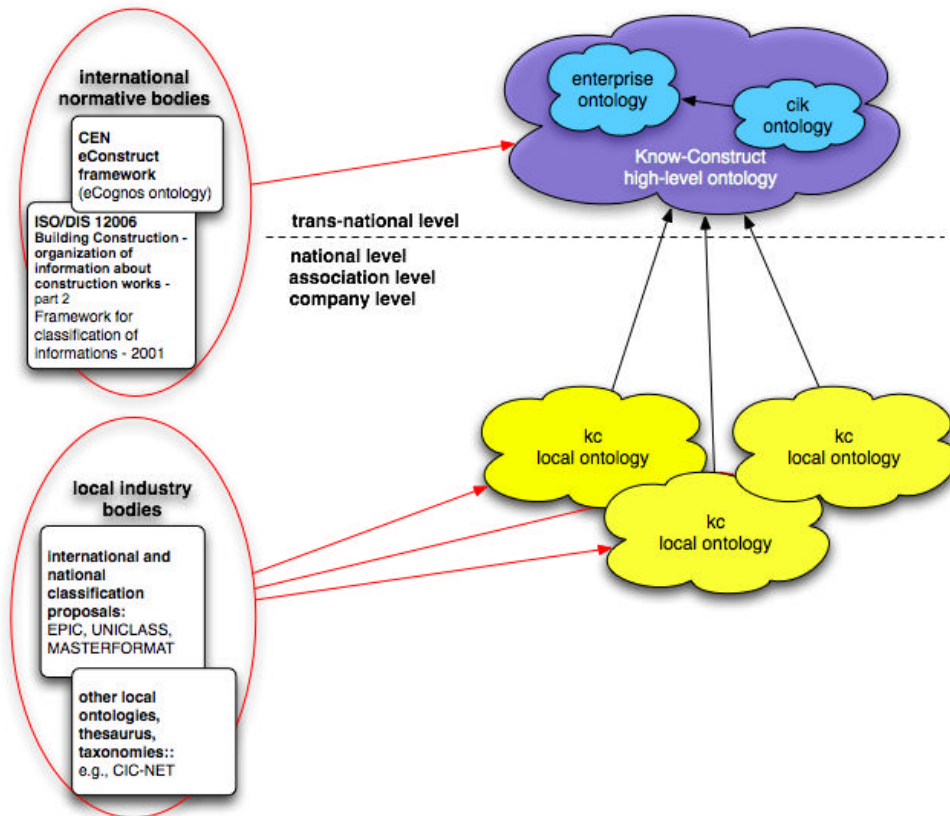


Figure 6 - High level structure of Know-Construct ontologies

Two main concerns/challenges arise by choosing such methodology are 1) how to establish through the re-use and integration of existing ontologies (as far as possible) an adequate domain related ontology, as well as classification system for this sector applicable in SMEs environment, and 2) how to assure the continuous update/maintenance of both types of ontologies in order to enable a long life to the knowledge systems.

KC, whenever possible, plans to reuse or extend ontologies that can be applied in its context. New developments made in the construction industry context or in any other will be submitted to the above listed representative type of ontologies.

KC will also use other practical classical methods for KM, specifically for acquisition of knowledge in the knowledge system development phase (i.e. collecting knowledge needed to set-up the knowledge system), which include the collecting of knowledge from experts (e.g. through interviews and user requirements analysis) and the gathering of knowledge from available information sources, as described.

KC considers that for future developments of the local ontologies, for the specific markets and specific Customer 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 a 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.

The process of analysis of all these sources must, at all time, be developed taking into consideration the domain experts 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.

An example - the Portuguese case:

In the Portuguese case, the association APCMC (among others) 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

knowledge sources available, should be representative enough to extract the type of knowledge necessary to populate the ontology and the eKCS.

Portuguese examples

- (Ex.: APCMC – Newsletter - Materiais de Construção; Obras & Materiais de Construção; Boletim Materiais de Construção; Anuário de Materiais de Construção; Catálogo Técnico Materiais de Construção)

3.2.2 Know-Construct CIK ontology

Ontologies represent shared knowledge between the parties, and result from a shared approach to a knowledge domain. In the case of KC, the decision to re-use and integrate available ontologies and classifications standards in the CI area, led to an even greater need to develop a Know-Construct high-level ontology that would allow the integration of these resources. In order to better answer the needs and purposes of the eCNM and eKCS systems, this ontology (named as CIK Ontology) is integrated in the Enterprise Ontology, as defined by the Enterprise Project by the Artificial Intelligence Applications Institute at the University of Edinburgh. (<http://www-ksl-svc.stanford.edu:5915/FRAME-EDITOR/UID-209&sid=ANONYMOUS&user-id=ALIEN>).

The following description respects only to the CIK Ontology that defines the domain of the CI which can be summarized in the following sentence:

The **Construction Industry** involves a set of resources (**Construction Resource**) that follow certain conditions (**Technical Topic**) which are used or required in a process (**Construction Process**) that leads to results (**Construction Result**).

As such, the proposed taxonomy includes four major domains to classify these major concepts:

- Construction Resource
- Construction Process
- Construction Result
- Technical Topic

As it can be seen the first three domains coincide with the major themes in the ISO 12006-2 standard. The other domain (Technical Topic) is the result of the integration of an e-COGNOS module, further developed so as to include issues related to the CI that are not covered by the e-COGNOS ontology and IFC model. Figure 7 shows the major concepts.

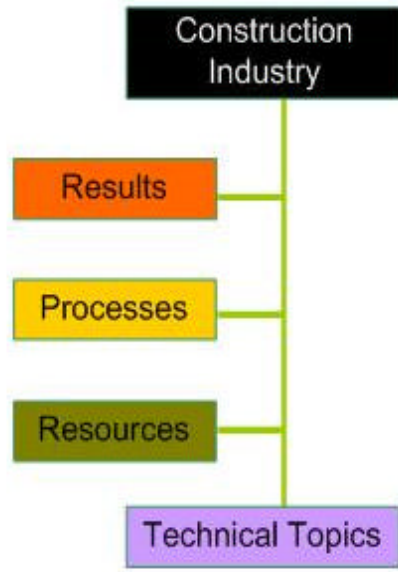


Figure 7 – Major domains in the CIK ontology

The following subsections describe the major elements of these four domains.

Construction Result

The notion of construction result should be understood as construction industry object which is formed or changed in state as the result of one or more construction processes using one or more construction resources. This domain includes four major subdomains: **Construction Complex**, **Construction Entity**, **Construction Entity Part** and **Work Result** (see Figure 8).

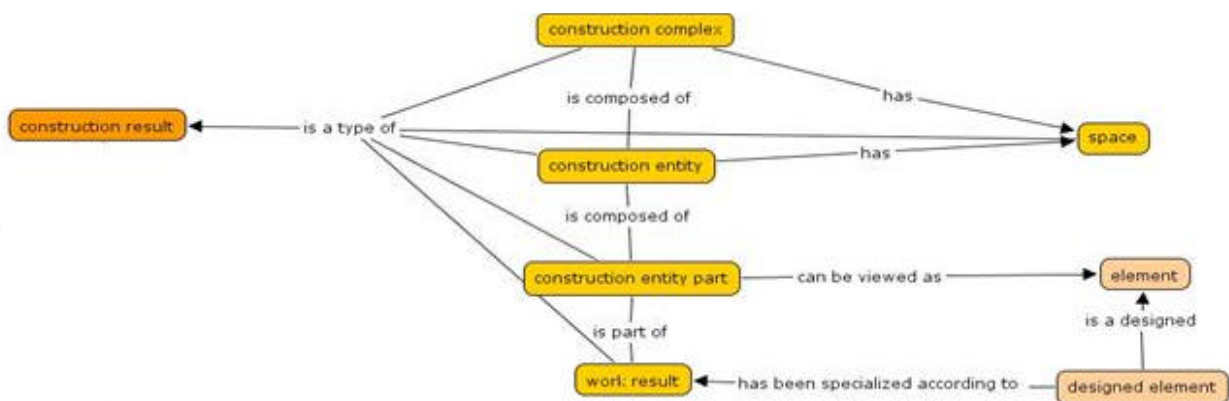


Figure 8 – Construction Result concept

Construction Process

This domain includes two major subdomains: **Management** and **Work Process** (see Figure 9). During the team discussions, it was realized that the process domain is a major component of any effective ontology that addresses construction knowledge management. In contrast to the wealth of classification systems dedicated to construction products, there is no consistent means to describe construction processes, understood here as a process which transforms construction resources into construction results. The team, therefore, spent a considerable time exploring best means to describe construction and management processes. The Management subdomain includes the following domains: **Knowledge**, **Organizational**, **Community**, and **Decision Making**. The Work Process subdomain includes the following major processes: **Administrative processes** and **Engineering processes**.

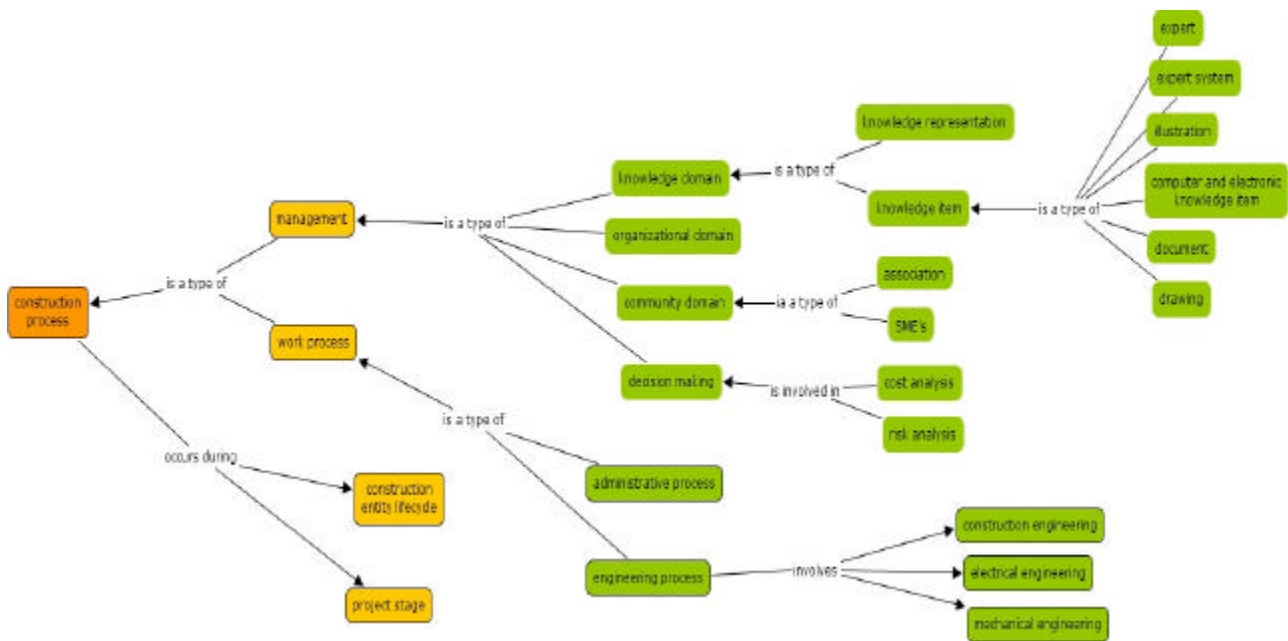


Figure 9 – Construction Result concept

Construction Resources

A construction resource is a construction object used in a construction process to achieve a construction result. This domain includes four major subdomains: **Construction Agent**, **Construction Aid**, **Construction Information**, and **Construction Product** (see Figure 10).



Figure 10 - Construction Resource concept

Technical Topics

This domain includes concepts related to issues like quality standard, design specification, productivity, cost and legislation. This domain follows the e-Cognos approach, whereby these topics present a softer domain of construction operations and present a kind of “*boundary conditions*” for the majority of work in construction. The concepts of this domain correspond to the needs and purposes of KC ontology and are related to a multitude of other concepts in other domains.

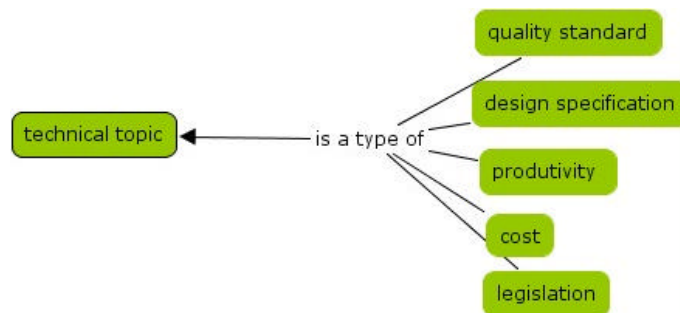


Figure 11 – Technical Topic concept

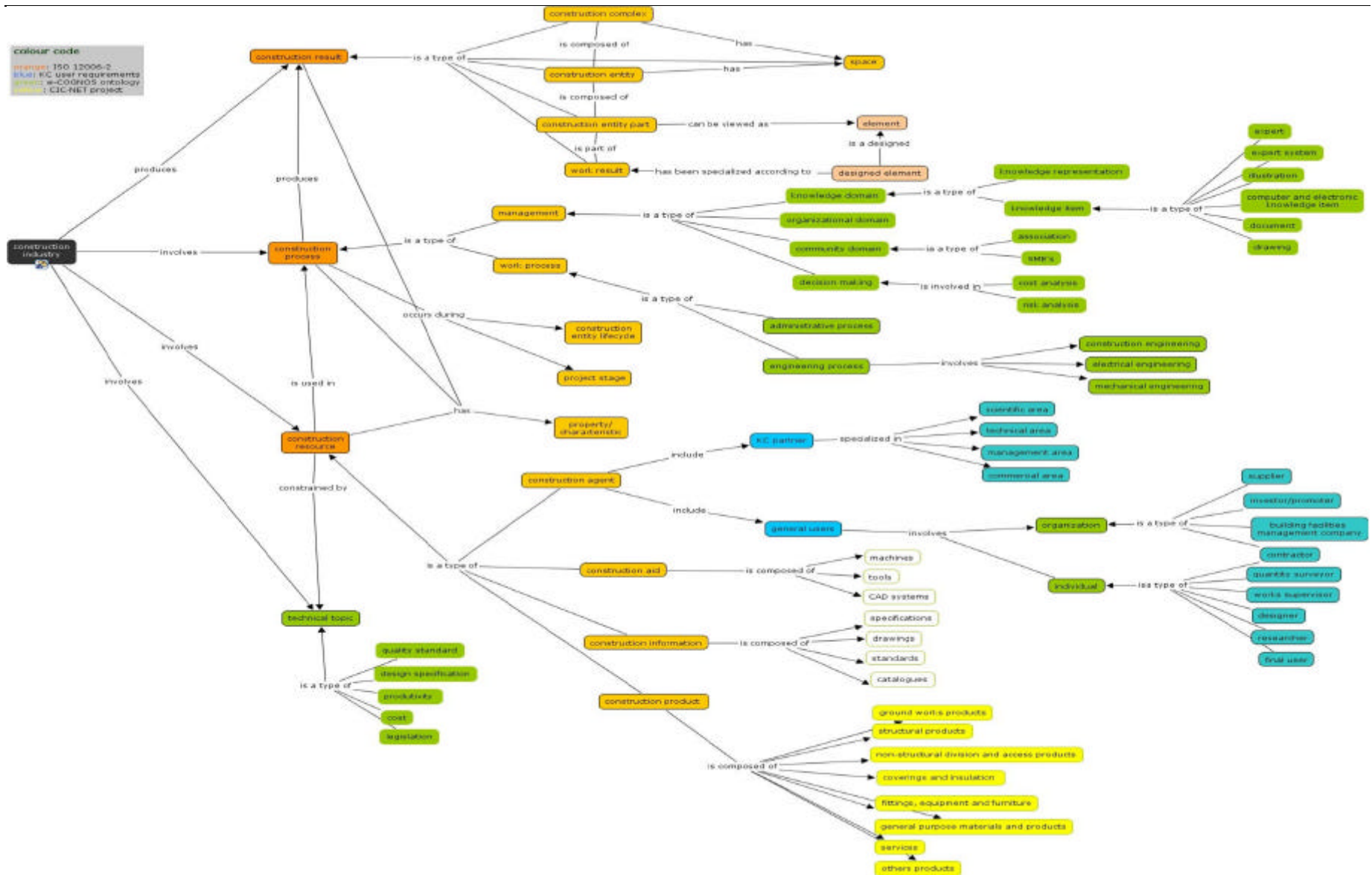


Figure 12 - CIK ontology

3.2.3 Know-Construct local semantic resources approach

In face of the complex nature of the construction industry, the CIK Ontology has been developed in an iterative fashion to make sure that the resulting ontology is both representative and easy to use and corresponds to the purposes of the project. The approach described in Figure 13 is an adaptation of the approach followed by the eCognos project – see eCognos 2002. Although the approach are named in almost the same way, the activities developed in each moment follow, most of the times, different approaches, as it is described below.

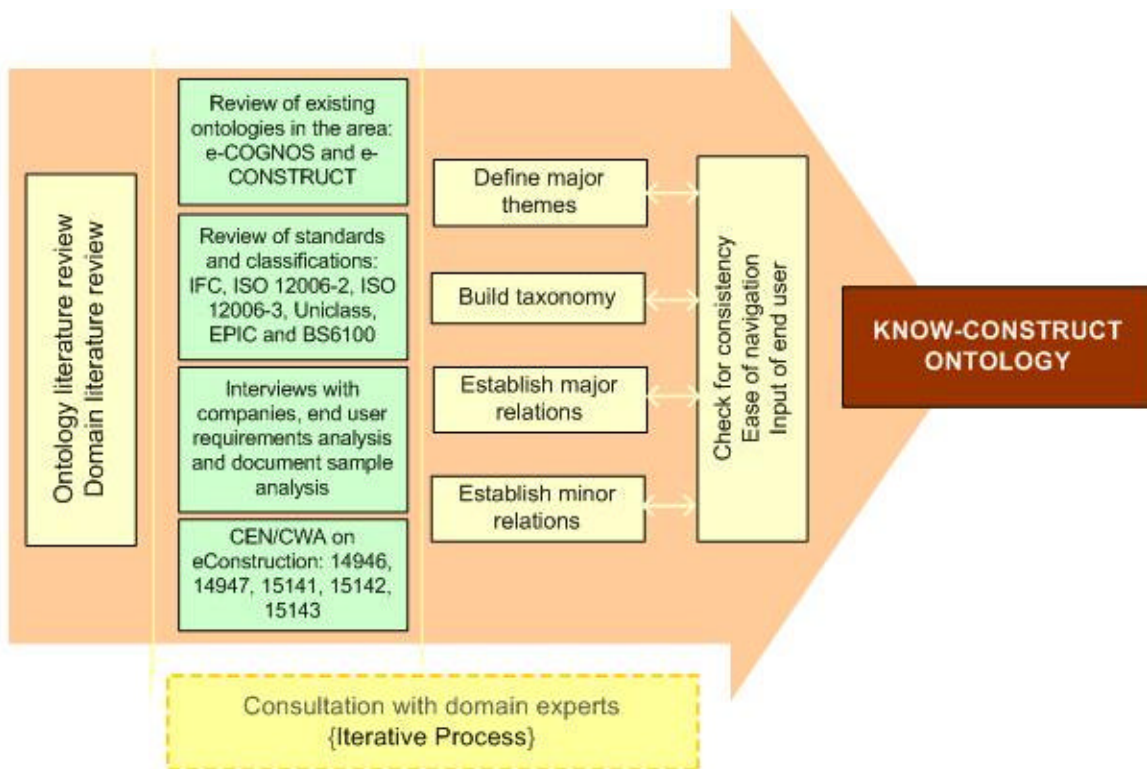


Figure 13 - KC local semantic resources approach

3.2.4 Ontology and Domain Literature Review

The team started by studying the rich literature available about ontologies development and previous attempts to create construction-related ontologies, such as the construction tailored ontologies from e-COGNOS, the ISO 12006-2 standard, the CIC-NET classification, the e-CONSTRUCT taxonomy. A special attention was dedicated to the analysis of re-use and integration descriptions, so as to recognize the major problems identified and the approaches followed in their resolution.

This process was complemented with the reading of the conclusions of the CEN / CWA on European eConstruction Framework (EeF) - Context and Scope for “eConstruction; European eConstruction Ontology (EeO); European eConstruction Meta-Schema (EeM) and European eConstruction Architecture (EeA).

Other literature related to the CI domain was also consulted, especially that dedicated to classification systems, in order to check for the semantic value and the consistency of use of some concepts.

3.2.5 Development of the Ontology

The next major step was a brainstorming by the team, complemented by interviews and a consultation with a sample of end user companies, about the major aims, themes and the overall structure of the ontology. This process was iteratively followed by a team of experts, whose role is to analyse and validate the conceptual and semantic structure of the ontology.

The development of this step took into consideration the need to be compliant with standards expressed by KC partners. Therefore, after a careful consideration of the existing standards and proposals for classifications in the CI area, a decision was made to use the classification presented by ISO 12006-2 - *Building construction - Organization of information about construction works - Part 2: Framework for Classification of Information* as the main standard/source to classify the information and to structure the ontology.

The next step focused on the analysis of the e-Cognos ontology and determination of the possibility of merge/integration of the modules in which it is structured into the KC CIK ontology. A careful analysis and some testing were made by accessing e-Coser, e-Cognos ontology server and studying the concepts distribution and the relations established under each module. This approach also took into consideration the widely used IFC standard, which was employed as the backbone structure of e-Cognos ontology and whose concepts/concept relationships were thus represented in the ontology.

This led to the conclusion that while a part could be merged into the high-level ontology, developed after the ISO 12006-2 (leading to the redefinition of the semantic value of some concepts and established relationships), other modules, like Technical Topics, would have to be integrated as one of the major domain concepts. The reason for this is that, just like with e-Cognos, this was considered a necessary domain to describe the environment where the other major domains exist. A few high-level concepts were added to this domain, while others suffered an evolution of their semantic value in order to answer KC purposes and needs, especially at the legislative level.

Parallel to these steps a careful analysis of classifications proposals like UniClass, EPIC and BS6100 was made and revealed, as it has been recognized by projects in this area, that previous taxonomies have developed a wealth of construction-related terms and classified them in one or another way. An analysis of these classification systems shows that they mix actors, products, and processes and some exogenous domains. In many cases, this is also done without a consistent approach, although much progress has been done in recent upgrades of some classifications.

These classifications were considered a significant semantic resource for the development of the ontology, as they could be mapped onto the CIK ontology skeleton and could also be used for the development of the more specific ontologies. Here, other, more particular (national) classifications will play a relevant role in the *localization* of the ontology, thus allowing the ontology to better cover KC partner's needs.

After a careful analysis of all the referred sources, end-user comments, of the user requirements analysis and after a review of the most frequently identified concepts, the team concluded that the core domains of a representative ontology for the Construction Industry were Processes, Resources and Results, along with Technical Topics. These domains were also chosen due to their potential for integrating other available semantic resources.

3.2.6 Development of the Basic Taxonomy

To establish the basic taxonomy, a sample of the major concepts defined in e-Cognos, IFC, EPIC, Uniclass and Cic-Net was chosen. These concepts reflect the existing industry standards and user needs and are a first step in the development of a product classification system.

After developing and validating this basic taxonomy, partly by referring to existing ontologies, partly through end-users input, the team will work on extending the ontology to include a substantial number of concepts from other ontologies, classifications and documentation sources and on the development of other ontologies, to provide better answers for the local markets and KC partners' needs.

3.2.7 Establishment of Relationships

This was the next step in our methodology. First the team established the relationships between high-level concepts. For that, part of the relationships were taken from the ISO 12006-2 schema, and part from e-Cognos.

Subsequent steps will establish relationships at lower levels within the ontology. This process is being validated by the domain experts that accompany the development of the ontology. The main relations used in CIK ontology are present below (see Figure 14).



Figure 14 – Know-Construct Relations

3.3 Methods for Know-Construct knowledge structure evolution

Business dynamics and changes in the operating environment often give rise to continuous changes to application requirements, which may be fulfilled only by changing the underlying ontologies. This is especially true for WWW and Semantic Web applications that are based on heterogeneous and highly distributed information resources and therefore need efficient mechanisms to cope with changes in the environment. In particular case of KC system, these dynamics will also be an important issue. So, at the beginning we had to think about which would be the adequate strategy, including methods and tools available, to support the maintenance and evolution of CIK ontology and local ontologies.

Ontology evolution is the timely adaptation of ontology to changed business requirements, to trends in ontology instances and patterns of usage of the ontology based application, as well as the consistent management/propagation of these changes to dependent elements. A modification in one part of the ontology may generate subtle inconsistencies in other parts of the same ontology, in the ontology-based instances as well as in depending ontologies and applications. This variety of causes and consequences of the ontology changes makes ontology evolution a very complex operation that should be considered as both, an organizational and a technical process [Staab et al. 2001]. It requires a careful analysis of the types of the ontology changes that can trigger evolution as well as the environment in which the whole ontology evolution process is realized.

Although evolution over time is an essential requirement for successful application of ontologies, methods and tools to support this complex task completely are missing. This level of ontology management is necessary not only for the initial development and maintenance of ontologies, but is essential during deployment, when scalability, availability, reliability and performance are absolutely critical. The ontology evolution is a problem clearly different of schemas evolution in the relational databases [Noy e Klein 2002].

Based on works of [Stojanovic et al. 2002] and [Maedche et al. 2002a, 2003], that have been developed an intensive work around the support of multiple ontologies and to manage the ontology evolution in enterprise-knowledge management environments, we consider means for combining distributed and heterogeneous local ontologies using mappings. Additionally, because CIK ontology must reflect changes in system requirements, we will develop guidelines and an approach for managing the difficult and complex ontology-evolution process.

3.3.1 Method for managing multiples KC local ontologies

In what concerns the management of multiple ontologies issues, because of the several local ontologies that will integrate the KC system will probably be based on different conceptual models, so to integrate them, we must solve the problem of semantic heterogeneity between these models. From the review on different approaches to support this task, we've decided to follow the ontology mapping approach that allows relating a portion of the source ontology to the target ontology's entities, transforming instances from the source ontology into instances in the target ontology. Ontology mapping approach allows transforming information but doesn't require the building of an integrated view. So, although it's more powerful than simple inclusion, it avoids the complexity and overhead of integrating multiple sources. Thus, to facilitate the process of managing and integration of KC local ontologies, we need to provide a set of mapping rules. After some discussion between the team, we decided to adopt the process defined by Maedche and their group of research from *Research Center for Information Technology, University of Karlsruhe*, in context of Ontologging project (see Figure 15).

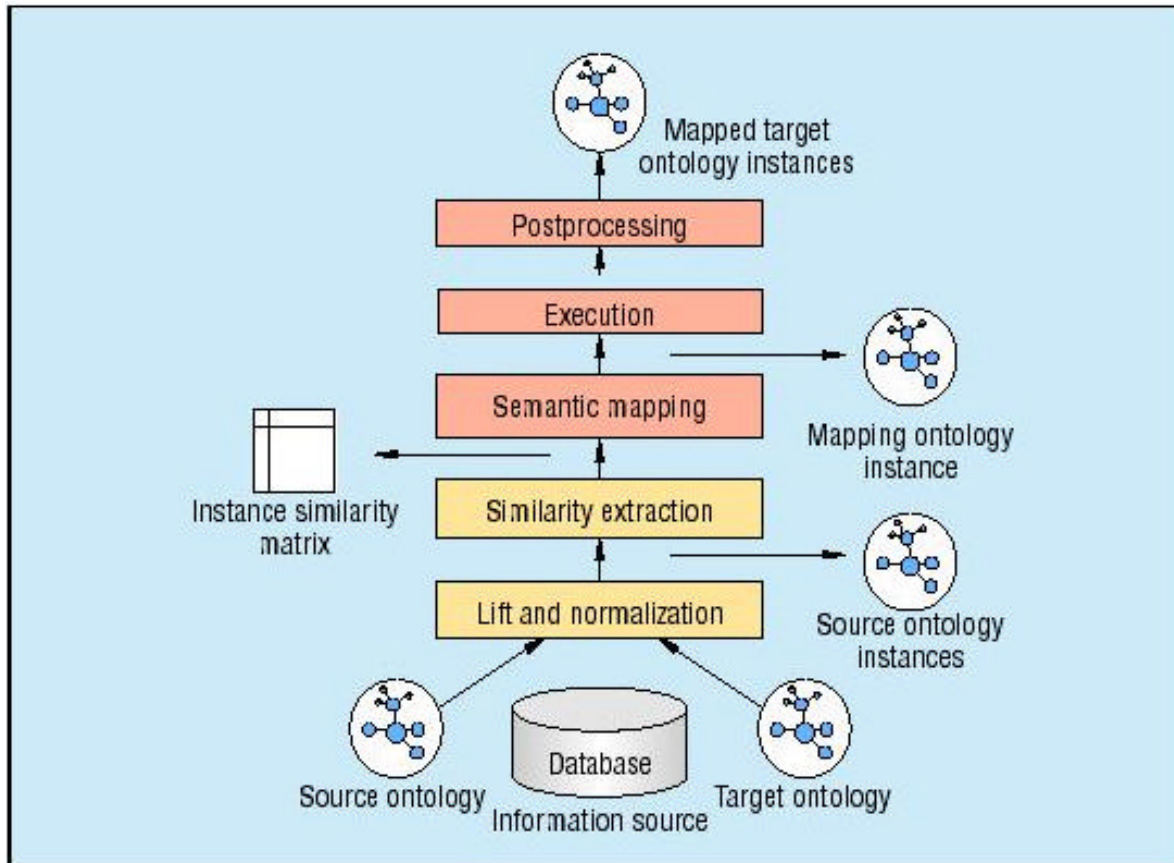


Figure 15 – The ontology-mapping process [Maedche et al. 2002a]

In this ontology-mapping process, **lift and normalization** phase has to do with bringing existing information to the ontology level. It extends the ontology-mapping problem somewhat to the problem of integrating existing information sources that are not ontology based. In addition, it must realize a wrapper for the information sources at hand, whose task is to transform the desired information source to the ontology level. If the source information is already ontology based, this phase is skipped. To help the user create more accurate ontology-mapping rules, the **similarity extraction** phase applies heuristic algorithms and machine learning techniques. It produces a similarity matrix reflecting the similarities between concepts and instances in ontologies being mapped. **Semantic mapping** phase creates the mappings that define how to transform source-ontology instances into target-ontology instances. These mappings are represented as instances of a mapping ontology, which defines all possible types of associations between ontology entities. It is possible to distinguish the mappings according to *type of related entities* (mapping rules can be established between concepts, attributes, and relations), *cardinality* (mapping rules can have 1:1, 1:n, or n:1 cardinality), *condition* (mapping rules can include conditions on the instances being transformed), *transformation function* (a mapping rule can include a transformation function that,

when applied to the source information in the source ontology, will produce the required information in the target ontology). **Execution** phase takes as input instances of the source ontology and the mapping ontology from the previous step and executes the mappings. Two execution modes are provided: static and virtual. The static-execution mode transforms the source ontology's instances once and then stores them in the associated knowledge management system - changes to instances in the source ontology are not visible in the mapped ontology. In the virtual-execution mode, the mapping-ontology instance transforms every query from the target ontology into a query over the source ontology. The system then executes the transformed query and transforms the obtained information back into the target ontology. With this approach, changes to the source ontology's instances are immediately visible in the target ontology. However, because the system performs a transformation at each request, performance is worse than in the static case. **Postprocessing** phase applies only to static execution, where the goal is to improve the results of the execution phase. For example, it deals with the problem of object identity (identifying, for example, "Construction Industry" and "CI" are the same object). For virtual execution, this phase is not applicable.

3.3.2 Method for managing KC ontologies evolution

In general, ad hoc management of the changes in knowledge management systems might work in the short term, but to avoid unnecessary complexity and failures in the long run, management must be interpreted at the conceptual level. So, we can distinguish two types of change generation in ontology-based knowledge management systems: (1) *top-down change generation*, where the knowledge officer or end user explicitly defines the requirements for ontology changes. These changes cover business strategy evolution, modification in the application domain, new user needs, additional functionality, and so forth and are captured in a variety of ways: direct discussion or interviews, customer specifications, surveys, or observations. Alternatively, some changes might be discovered by analyzing log files that track interaction of users with the system, which is known as (2) *bottom-up change generation* [Stojanovic et al. 2002].

Modifying one part of the ontology might generate subtle inconsistencies in other parts of the same ontology, in the instances, dependent ontologies, and applications. So, ontology evolution is a complex operation that should be realized as an organizational process. Based on works of [Stojanovic et al. 2002] and [Maedche et al. 2003], we will follow a process-oriented approach to analyze CIK ontology and local ontologies evolution requirements. The ontology evolution process will be thus defined as a synthesized way as a cyclic process of six steps involving three principal requirements (see Figure 16): (1) **resolving changes while keeping consistency** (this requirement

includes representation, semantics of change, propagation and implementation steps), (2) **user’s management of changes** (includes validation step), and (3) **continual improving** (includes discovery step). Basically, we can follow three distinct ways to discovery changes: structure-driven, data-driven, or usage-driven.

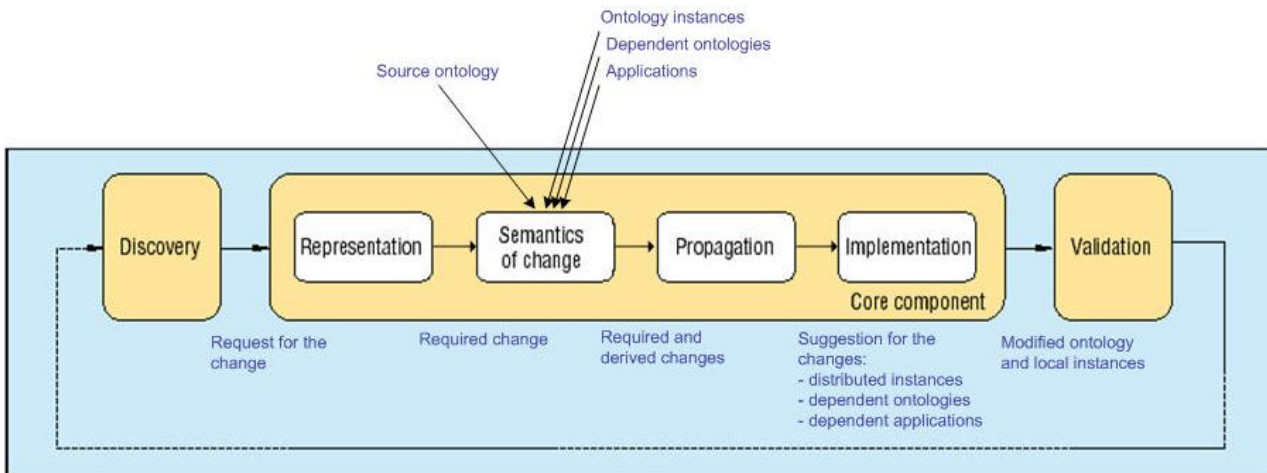


Figure 16 – The ontology-evolution process (based on [Stojanovic et al. 2002])

3.4 The generic architecture of the eKCS system

In 3.1 and 3.2 we selected two models to describe and analyse the desired characteristics for a CIK knowledge community. Adding these conclusions to the developed vision of the KC system and the user requirements elicited in the first phase, together with the concept developed in 3.3, we were able to define a general functional architecture for the Knowledge Community Support (eKCS) system. The full detailed functional architecture it is described in deliverable 1.4 - *IT system concept*.

3.4.1 The eKCS concept

KC has a very specific goal: to enable individual SME's to better solve the problems of their customers. Therefore, eKCS is focused on pursuing this goal in the first place. Although a knowledge community encompasses, as argued before, mechanisms that surpass this simple instrumental goal, the initial vision of eKCS is developed from this instrumentality. This means that eKCS supports CIK community building in a broad sense, but focused fundamentally in generating broader and deeper knowledge to be used in managing the SME's customers' relationship, particularly in problem solving.

The system (eKCS) will provide the following general functions (see Figure 17):

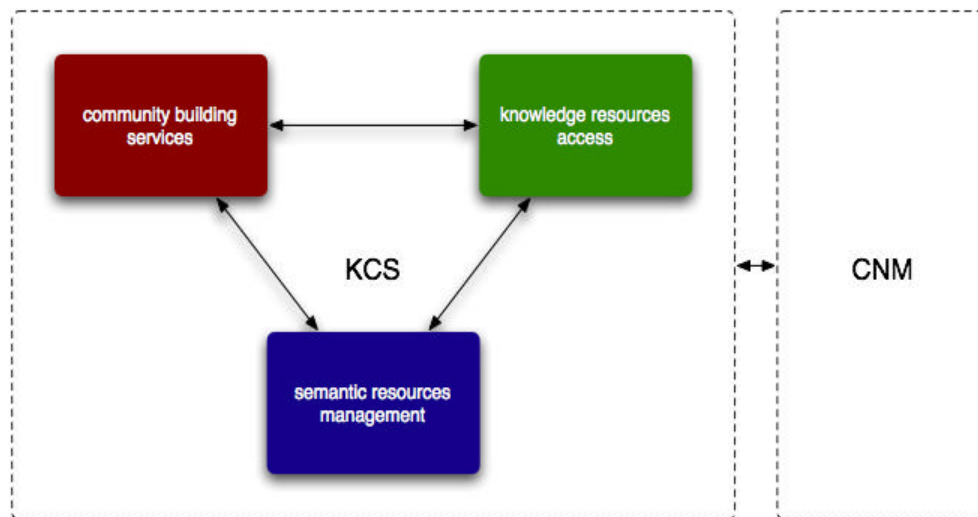


Figure 17 - eKCS general functional architecture

Community building tools: this part of eKCS supports the processes of community building by providing the instruments to foster professional interaction and socialization. Forums and weblogs are two of such instruments and will be tailored in eKCS to be strongly integrated with the semantic structure supporting knowledge management in KC. Other general communication and information dissemination tools will complement these services.

Semantic resources management: this is a set of infrastructural functionalities that will support information and knowledge acquisition, organization and storage in eKCS (and also eCNM). More specifically, it will enable the (i) management of classifications, thesauri and vocabulary, (ii) the acquisition of knowledge from digital content (including forums and weblogs entries, web pages, etc.) both internal to the CIK and from external sources, (iii) the maintenance of an ontology which is the base of knowledge representation, access and storage.

Knowledge resources access: creating, searching and updating knowledge resources will be a fundamental set of functionalities in eKCS. Although much of the community information/knowledge will be created in communication/interaction processes (forums, weblogs), there will be also the need to create/access knowledge in a more structured way. Digital content management and document management are the natural approaches regarding this issue.

3.4.2 Technological perspectives

Semantic web technologies are a fundamental option if eKCS is to provide complex information retrieval, both internally and externally to the knowledge community. We think that compliance with the semantic web is one of the major success factors for Know-Construct.

The opinion expressed by the CEN Workshop Agreement on European eConstruction Ontology (EeO) (CWA 15142, 2004) is that it is possible to rely on a standard "foundation" where complementary efforts can be combined in a harmonic and holistic way, especially regarding the developments related to the Semantic Web.

A strategic aspect then to be considered is the compliancy with the Semantic Web in the sense that the European Ontology for the construction sector has to be aware of the recommendations and developments promoted, mostly, by the W3C. The web, clearly the most important platform with which to be compatible today is the arena where business has been growing and promoted in a good pace.

This CWA works on two main axis, namely: (i) identification and analysis of the semantic resources (ontologies, taxonomies, product data libraries, and dictionaries); and (ii)

recommendations presented by the Semantic Web initiative, namely the use of OWL to represent the semantic resources. The combination of these two axis should lead us to propose the ontology(ies) – either as one entire resource or as a component to be reused in bigger ontologies – to be standardised and promoted within the construction sector. The Semantic Web is one of the most promising initiatives nowadays, when dealing with ontology-related matters.

One relevant European project that can provide important inputs for KC is SWAD-Europe. The SWAD-Europe project ran from May 2002 to October 2004, and aimed to support W3C's Semantic Web initiative in Europe, providing targeted research, demonstrations and outreach to ensure Semantic Web technologies move into the mainstream of networked computing. The project factsheet and objectives are available, and an overview of the project written for ERCIM news in September 2004.

Particularly regarding the potential applications of the SW in business integration, this project setup two demonstrators. The semantic blogging and semantic portals together illustrate some of the features of an information integration infrastructure. The semantic portal illustrates a process of aggregating RDF data from multiple sources and integrating it to provide a common browsable view. The semantic blogging demonstrator illustrates how small informal information items can be published by individuals in a lightweight way. The two demonstrators can be (and have been) combined for applications such as knowledge management where individuals can publish news items and small information snippets that integrate with structured data sources accessed via a common portal.

Another initiative that will have a big relevance in KC is the Simple Knowledge Organisation System (SKOS). SKOS is an area of work developing specifications and standards to support the use of knowledge organisation systems (KOS) such as thesauri, classification schemes, subject heading lists, taxonomies, terminologies, glossaries and other types of controlled vocabulary within the framework of the semantic web.

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