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2 Project Objectives

The MACE project works on changing how learning technology is used for architecture in Europe. It connects digital repositories and integrates the contents created in previous European projects and by existing architectural design communities. Some members of the consortium are content providers themselves or are associated with architects and universities dealing with architecture and design, while others have a background in computer science or learning research.

MACE will provide a framework for community based services such as finding, acquiring, using and discussing learning contents that were previously available only to small user groups. Close integration of universities as well as professionals ensures that demands from the user side are recognized and that fitting solutions are created. Since users are distributed across Europe, the project addresses multicultural and multilingual issues and creates working solutions for sharing contents across borders. The project addresses five major objectives:

Objective 1: Integration of multiple sources of architectural content

MACE integrates multiple sources of architectural content, from academia as well as from professional sources. Existing repositories are integrated into a common infrastructure and a common interface is developed to be able to query all available data. Project partners also work together with other projects to get access to contents used there.

This objective also includes the adoption of a common metadata standard for all contents and a set of methods for converting existing metadata from other standards or translating user queries from and to other standards. The creation of a MACE Application Profile based on the LOM (Learning Objects Metadata) standard in the first year is a huge step towards this objective.

Objective 2: Enriching a critical mass of digital high quality content with metadata

In the project, the consortium develops and uses several types of metadata for enriching contents: traditional content metadata and ontologies, contextual metadata, competence metadata and learning process and learning design metadata (IMS-LD http://www.imsglobal.org/learningdesign/), usage related metadata and metadata acquired through social interaction like recommendations by peer users or blog entries. These metadata are collected and structured in the aforementioned MACE application profile.

Objective 3: New Forms of Multilingual & Multicultural Content

A result of the work for objective 2 will be a large mass of enriched content becoming available in full. Chances are that there will be several single content blocks describing the same concept or topic and existing either in different languages (Italian / Spanish) or in different media types (text / image). We want to create a system that can handle multilingual contents and make them searchable through a common user interface. Work on this has been started on a conceptual level but no tangible results are available yet.

Objective 4: Improve knowledge access and discovery by interactive visualization

The integration of multiple content sources and the variety of available metadata need new and sophisticated methods to allow access to contents for people. In order to ease access to and navigation in a plethora of potentially interesting content items, interactive visualizations can reduce cognitive load and make the relevant information available in a pro-active way.

4
We will develop domain-specific visualizations in order to provide optimal access to the available data and thus foster knowledge discovery.

**Objective 5: Building a sustainable architecture and design content community**

Several universities of design and architecture are included in the MACE consortium. Together they will work as core distributors of the project results. Second, EAAE (via the partner Department of Architecture at K.U. Leuven) will be a multiplicator among a large number of universities across Europe. Moreover, there are several partners with connections to industry and professional users in the consortium whose main task is to make MACE known and used in the professional communities through Europe. Additionally, MACE is linked to several other initiatives, networks and projects, such as PROLEARN, ARIADNE, DYNAMO and TenCompetence. This helps in building user communities and disseminating project results. By adding more contents from architectural and learning repositories, the project reaches a critical mass of digital content and will have a significant impact in the EU on learning about architecture and cultural heritage. We hope that it will become a base for further community activities in these domains.

3 **Consortium**

3.1 **Fraunhofer Gesellschaft**

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society. Customers are industry, the service sector and public administration.

From Fraunhofer, two institutes take part in MACE: the Information Centre for Planning and Building (IRB²) and the Institute for Applied Information Technology (FIT³). The IRB provides several of their content repositories as bases for enrichment in the project. FIT creates technical means for enriching these contents (and more) with contextual metadata in a fast and semi-automated way. FIT also hosts the project website and some of the middle layer services that allow applications and databases to work together easily. In addition to working in the project on a technical and content-wise level, Fraunhofer also is project coordinator, responsible for directing the project and ensure cooperation with the European Commission.

3.2 **Katholieke Universiteit Leuven**

From the Katholieke Universiteit Leuven, two departments take part in MACE: the Department of Computer Science and the Department of Architecture.

3.2.1 **Department of Computer Science**

The Computer Science department⁴ has a long history of building e-learning solutions, notably in the area of sharing and reusing of learning objects. One result of this is the ARIADNE foundation that grew out of two European research projects in the period 1996-2000 and focuses on sharing and reusing learning objects. It brings to MACE capabilities for collecting and storing metadata in distributed environments. A distributed network of learning object repositories (called the "Knowledge Pool System") with associated metadata generation and query tools has been developed.

² http://www.irb.fraunhofer.de/?lang=en
³ http://www.fit.fraunhofer.de/index_en.html
⁴ http://www.cs.kuleuven.be/~hmdb
The ARIADNE foundation has been deeply involved since more than 5 years in global standardization activities in this field, in bodies such as the IEEE LTSC and the CEN/ISSS LTWS. The Foundation is widely recognised as an important actor in the field and it entertains collaborative relationships with many other organisations across the world and thus will have an impact when promoting the MACE project to fellow researchers and users.

### 3.2.2 Department of Architecture

The Department of Architecture, Urban Design and Regional Planning⁵ is connected to the European Association for Architectural Education (EAAE⁶) by the person of Prof. Neuckermans. Founded in 1975, the EAAE fulfils an essential role in providing a European perspective for the work of architectural educationalists as well as concerned governmental agencies. The EAAE counts more than 100 Active Member Schools in Europe from the Canary Islands to the Urals, representing almost 5,000 tenured faculty members and more than 100,000 students. Together with the Department of Architecture, a lot of contacts and interested parties are available to MACE, both for providing digital contents as well as using the works created in the project. Through the department, the project consortium gets access to DYNAMO⁷, a large collection of design projects, useful for students and professional architects.

### 3.3 Open University of the Netherlands

Open University of the Netherlands is very active in the field of learning technology and the facilitation of learning in ill-structured, self-organising, networked learning communities. Their focus is on creating an approach for enriching contents and users with competence and learning process metadata, which will provide a better learning experience. Through Open University, the project consortium also gets access to other current projects and networks of e-learning, such as TenCompetence⁸ and PROLEARN⁹.

### 3.4 University of Applied Sciences Potsdam

The Interface Design programme and the Interaction Design Lab at Potsdam work on the extension and adaptation of existing tools and e-learning platforms in order to provide easy access to contents. In the first year, they already have created some impressive interfaces and are responsible for the overall look and feel of the project in presentations and publications. They are also experimenting with new visualizations targeted at objective 4 of the project: Improve knowledge access and discovery by interactive visualization.

### 3.5 Nautes s.r.l.

Nautes¹⁰ operates in the Information Technology field and specialises in collaborative work and knowledge management. Nautes has participated in the WINDS project, deals with web-based training for professionals (a set of e-learning courses to train architects, commercial trailers and all people interested in the subject of lighting) as well as web-based training for egovernment projects aimed to citizens, employees, and consultants in lifelong learning. Nautes works closely together with the Universita' Politecnica Delle Marche, providing technical support for collecting performance indicators of the project and for data repository integration activities.

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⁸ [http://www.tencompetence.org](http://www.tencompetence.org)
⁹ [http://www.prolearn-project.org/](http://www.prolearn-project.org/)
3.6 Universita' Politecnica Delle Marche

The Dipartimento Di Architettura Costruzioni E Strutture at Universita’ Politecnica Delle Marche\(^{11}\) is committed to promote research and development activities in the field of innovative architecture technology. It has deep knowledge of both architecture design and construction issues and information technology models. The WINDS\(^{12}\) project (IST-1999-10253) was coordinated by this group and is now evolving into a technology-enhanced learning community in Architecture and Civil Engineering, involving more than 20 universities across Europe. Contents from the WINDS database form one of the base repositories in MACE.

The department has been coordinating the requirements analysis work in MACE and delivered an extensive overview of metadata deemed useful by architects. This information has been transformed into an application profile by several partners and will now be used for collecting metadata.

3.7 Technical University of Catalonia

The Division of Industrial Construction in the Department of Construction Engineering at Technical University of Catalonia\(^{13}\) specialises in the fields of architecture and engineering. The research groups work on Structural Technology, Building Materials and Industrial Constructions, Construction Management and Innovation of Construction Processes. They are also in charge of coursework for engineering schools in Barcelona and Terrassa within the programs of Civil Engineering, Industrial Engineering, Geological Engineering and Public Works Engineering and as such played a leading role in the aforementioned WINDS project.

The department brings in professional expertise and has helped to create the extensive overview of metadata useful for architects, among other things.

3.8 Università IUAV di Venezia

The University IUAV\(^{14}\) of Venice is well known as an important centre of architectural and planning sciences in Europe and worldwide. Research activities of the involved research group focus on the construction of a learning system based on the idea of a “virtual atelier”. The virtual atelier is both a didactic environment (virtual class) and a group of teacher-student dialogue tools able to check designs developed by the students in the didactic courses and design laboratories. They also were one of the key partners in the WINDS project as coordinators of the WINDS’ Department of Architectural Design.

The university brings in architects experts in: architectural design, e-learning and architectural knowledge management. They have been very active in requirements analysis and story development for the project.

3.9 Humance AG

Humance AG\(^{15}\) provides consulting regarding analysis, transfer and delivery of information in electronic form. This applies to training but also to the efficient distribution of product specifications, company strategies and information. In the context of the WINDS project, they have developed an online platform for creating, sharing and using digital e-learning contents. This tool suite is also used within MACE to enrich some of contents directly. Later in the project, we will provide a plug-in mechanism to allow searching and using of all contents available in MACE. In addition to that, Humane also makes the MACE project known throughout its partner network and helps in dissemination in professional communities.

\(^{11}\) http://portal3.univpm.it/english_ver/index.htm
\(^{12}\) http://winds.fit.fraunhofer.de
\(^{13}\) http://www.upc.edu/eng
\(^{14}\) http://www.iuav.it/homepage/
\(^{15}\) http://www.humance.de/
3.10 Politecnico di Milano
The University of Milano\textsuperscript{16} offers courses in Engineering, Architecture, and Industrial Design and has approximately 42,000 students enrolled. They were also one of the key partners in the WINDS project. In the person of Prof. Ezio Arlati, Politecnico di Milano will bring in expertise in hypermedia design process development and technical information & regulations about building products, especially in regard to the Industry Foundation Classes (IFC), a standard for facilitating interoperability in the building industry.

3.11 Collaboratio snc
Meaning “Laboratory for Collaboration”, Collaboratorio is a company located at VEGA (Venice Gateway for Science and Technology, a scientific park for the promotion of innovative business enterprises), with headquarters in Venice, Marghera. The company focuses on new trends in architecture. Since 2000 it has operated in the field of training, communication, and construction. It has exhibited projects and installations at the “Biennale di Architettura di Venezia” in 2000, 2002 and 2006, and has organized international symposiums, trips, and training courses. Collaboratorio also produces the www.architecture.it Internet\textsuperscript{17} portal.

3.12 Deutsches Forschungszentrum für Künstliche Intelligenz
The German Research Center for Artificial Intelligence (DFKI\textsuperscript{18}) today is one of the largest non-profit contract research institutes in the field of innovative software technology based on Artificial Intelligence (AI) methods. DFKI focuses on the complete cycle of innovation, from world-class basic research and technology development through prototypes to product commercialisation. Based in Kaiserslautern, Saarbrücken, and Bremen, the DFKI is one of the important "Centres of Excellence" worldwide. Important in DFKI's mission is to move innovations as quickly as possible from the lab into the marketplace. Only by maintaining research projects at the forefront of science, DFKI has the strength to meet its technology transfer goals. R&D is carried out in several research labs, including Knowledge Management (Prof. Dengel), Intelligent User Interfaces (Prof. Wahlster), and Language Technology (Prof. Uszkoreit). DFKI has close ties to the Universities of Kaiserslautern, Saarbrücken, and Bremen, which all have outstanding reputations in Computer Science.

4 Project Results/Achievements
This section briefly outlines the results of the MACE project. While we present a brief overview here, the interested reader is referred to two major publications describing the MACE system in detail:


\textsuperscript{16}http://www.polimi.it/english/
\textsuperscript{17}www.architecture.it
\textsuperscript{18}http://www.dfki.de/web/welcome?set_language=en&cl=en
4.1 MACE Portal

The MACE portal (Figure 1) is the single access point to the vast universe of MACE. It offers a wide variety of features related to architecture learning material, geared towards ease of use and highly successful methods to find appropriate learning resources about architecture. In addition, the MACE community features are available through the portal. The easiest way to get to know MACE is to start exploring it at:

http://www.mace-project.eu

4.1.1 MACE Finding results

The portal offers several means to access the contents in MACE, e.g., users can “Search by Keywords”, “Browse by Classification”, “Browse by Location”, “Browse by Competence” conduct a “Social Search” or a “Filtered Search”.

Figure 1: MACE Portal at www.mace-project.eu
Search by keyword allows users to retrieve results based on a simple keyword search as known from Google. In addition, the user can graphically browse the underlying architectural classification of learning resources or search on a geographical map. Furthermore, the user can search appropriate learning resources that are used to improve certain competences/skills as well as use community features to find interesting learning material. Here, we will briefly explain the filtered search method as one of the more often used MACE search tools.

Figure 2: Screenshot of MACE Filter Search looking for “paris”

Figure 2 shows the filtered search portal of the MACE system. Here, the user is able to qualify the keyword search with several additional facets: the repositories in which to search, the language of the results, the resource media type, the resource classification, and the associated competency. When choosing a respective facet, the interface is dynamically changing, providing the numbers of results for each facet that match the selected criteria.
The results of a submitted query are displayed at the bottom of the page. A small overview for each result is presented, containing information such as the resource title, a short description, and the repository where it was found. The user can decide to either immediately get to the result, or to view more metadata about the resource on the respective MACE detail page. An example of such a detail page is presented in Figure 3.

**Figure 3: Screenshot of a MACE detail page**

The results of a submitted query are displayed at the bottom of the page. A small overview for each result is presented, containing information such as the resource title, a short description, and the repository where it was found. The user can decide to either immediately get to the result, or to view more metadata about the resource on the respective MACE detail page. An example of such a detail page is presented in Figure 3.

**MACE Community tools**

MACE not only focuses on architectural content, but also on the users that are interested in the provided contents. Therefore, we aim to attract users, and we want to encourage these users to contribute information. Such contributions can be tags, comments, and ratings, but also new resources (by using the MACE bookmarklet) as well as formal classifications for MACE resources. Furthermore, the building of communities around MACE and MACE
contents is a key for our sustainability efforts. Therefore, the provision of social media functionalities that allow end users to contribute had to be realized.

Figure 4: Screenshot of MACE social search for "Tensegrity"

We integrate the ALOE project into MACE that helps enable social community features needed to stimulate and maintain communities using MACE. ALOE is a web-based social media sharing platform that allows contributing, share and access arbitrary types of digital resources such as text documents, music or video files. Figure 4 shows the MACE social search interface, basically a tag cloud. In addition to social search, the MACE system provides information on the latest and the most active users to stimulate community contribution. For each user, a small summary of the recent activities is given.

Users are able to either upload resources (using the system as a repository) or by referencing a URL (using the system as a referatory; called bookmarking). Users can tag, rate, and comment on resources, they can create collections of resources, join and initiate groups etc. The respective functionality is offered through the MACE detailed page showing the metadata of the learning resource, visible in Figure 3. Furthermore, arbitrary additional metadata can be associated with resources.

http://aloe-project.de
4.2 MACE Architecture

The MACE Architecture includes the application- and the data-server-tier. The application-tier includes the business logic that enables the functionality of the MACE system necessary for front-end applications and widgets. This tier offers, for example, filtered search, communication and user management services. The ALOE system is integrated at this level.

The data-server-tier comprises all stores that are used in MACE. As the goal of MACE is the provision of simplified access to architectural learning resources, the system deals with the metadata describing the learning resources and their usage. This is also clearly visible in Figure 2 that shows the filtered search front-end. Figure 3 shows a screenshot of a detail page thereby describing the various employed metadata used in the search to describe the respective learning resource.

The complete MACE service architecture is shown in Figure 5. Based on a modular service oriented architecture, the various MACE services are clustered according to their main functionality like online services for user management, usage analysis and real-world objects, competence services, metadata stores and ALOE, as well as example project integration.

The following chapters only briefly summarize the key features of the architecture to give an overview of the complex architecture. At the heart of the MACE system, the metadata stores provide the basis on which all functionality is realized. Together with the competence services, they create the backend on which all services operate. The logic of MACE, aka its finding, ranking and (metadata and user) management methods are implemented in the logic or middle layer, while the frontend provides the human computer interface as described in the previous section. The interested reader is referred to some reflections on the MACE backend architecture and its implementation in Wolpers et.al., Bridging repositories to form the MACE experience, to be published in the journal “New Review of Information Networking”, Leslie Carr (ed.), Taylor&Francis, to appear.
4.2.1 MACE domain metadata store

As consequence of the focus on metadata, the MACE system relies heavily on the metadata descriptions of the learning resources provided by the various associated repositories. The learning resource metadata is harvested into the central MACE domain metadata store using the OAI-PMH\(^{20}\) protocol. The MACE store contains all relevant learning resource metadata including for example the title, the abstract, the location of the learning resource, but also information about the classification of the learning resource within the MACE classification, relations with other learning objects or competences associated with the learning resource.


4.2.2 MACE usage metadata store

In addition to the MACE domain metadata store, the MACE system also stores how the users have interacted with the system. The observations, captured as usage metadata, include search and access as well as communication activities. Usage metadata is stored in the contextualized attention metadata (CAM) format. We use usage metadata for a variety of purposes, including support for self-regulated learning, context learning path elicitation.

For self-regulated learning approaches, one main tool is the reflection of learning activities to the learner (and possibly the learning resource author as well.) Within MACE and using usage metadata, we provide a simple time-based overview of activities to enable the support of reflection on the learning path. The learner is able to analyze which learning resources she accessed when, how she found them and which topics have been relevant to her and when. These reflective information can then be used to make learning paths more explicit, e.g. to modify and control them to make learning activities better targeted to the respective learning goals.

4.2.3 Competence Service

The problem of meta-tagging resources with competences has been discussed extensively from educational, technical, and domain driven perspective.

1. MACE has gained first insights in applying standards for representing competences as IMS-RCDEO, HR-XML, and unification frameworks as European Qualification Framework. Whilst different granularity of competences can be modelled with the standards as such there is often a difficulty in using the created taxonomies for meta-tagging resources. MACE has evaluated different approaches for creating competence taxonomies. As one extreme the approach of sticking to high level competences (11 high level competences are defined from the EU directive) has had limited success in the acceptance of end users as often the competences have been defined so broad that educators and learners had the problem of the contextualisation and interpretation of the competences. On the other hand, experimenting with approaches from previous projects as WINDS has shown that the very detailed taxonomy with hierarchical relations can lead to comparable problems, while with detailed taxonomies the problem lies more in finding the right competence for either meta-tagging or as a learning objective. As a conclusion the project developed a bottom up approach where educators can develop their own domain (or learning context) for competences. So a limited set of competences is defined in relation to an existing course and the educator can relate the

\(^{20}\) http://www.openarchives.org/pmh
domain to existing competence domains not on the level of single competences, what again would lead to the problems of a fine grained modelling of competences.

2. Secondly some discussion and research in the project was driven by question how to metatag learning content on different granularity levels with competence metadata. Basically the two extreme positions in the discussion have been argumenting that on the one hand it is not possible to metatag single assets on the lowest granularity level as assets can be used in a variety of learning contexts and therefore cannot be meta-tagged competences directly. Meta-tagging with competence metadata was much more considered on a level of complete courses and competence development paths. On the other hand a more social meta-tagging approach for competences has been discussed in which competence metadata is much more interpreted as achievement metatags or "What can I do with this?" metadata on learning content. This also allows a meta-tagging of even single images with the potential competences an educator could use them for. As a solution in MACE both methods have been made available within the mace toolkit. On the one hand OUNL has developed instructional designs in a repository, which can also be harvested in MACE. The instructional designs can be meta-tagged with competences and found in the mace federation and educational resources. On the other extreme the social meta-tagging components can be used to implement more purpose driven meta-tagging of assets in MACE.

Technically and as a basic approach to unify competence modelling and usage in informal and formal learning support the MACE project has developed an integration of services from the TENCompetence project and MACE. Complementary services have been developed and integration scenarios have specified. MACE concentrated on developing services for managing and developing competence vocabularies whilst in TENCompetence a complete integration with learning process support and information learning support has been done. New ways of navigating and describing competence based development approaches have been developed. On the one hand the consortium integrated faceted browsing approaches with competence metadata. This allows learners to understand the overlap between different classification systems from architecture and the underlying competences. The competence matrix enables learners to select specific competence development targets to select contents and assets from the MACE federation.

OUNL has conducted an evaluation of the competence toolset from teacher’s perspective. This evaluation shows that MACE is usable for teaching architecture and constructive engineering. MACE helps teachers to find relevant content for their teaching and supports teachers during their teaching process. The MACE competence toolset helps teachers to improve and complete their teaching competence profile. Through the usage of the MACE competence toolset more consciousness for competences, their meaning, acquisition and application in teaching were fostered. Furthermore, the evaluation provides good values of the competence toolsets functionality and usability from teachers’ perspective, the usage of it in teaching processes, and the functionality of it for learning and teaching. Through the flexible approach of competence management that has been chosen for MACE allowed the teachers to create tailored courses that meet their specific didactical needs. Moreover, the courses indicate the variety of applications, in which the MACE portal and the competence toolset can be effectively used for education.

4.3 MACE vocabulary

MACE aims at gathering architectural information, lying in many different and dissimilar repositories, and efficiently organizing them. The goal is to interface these repositories with heterogeneous kinds of users (e.g. students, designers, administrators, technicians, etc.), each
of one with particular interests and needs (architecture’s theories, design references, normative aspects, etc.) and allow students, engineers and architects to recognize, detect and link the contents through an interactive system which reflects their typical logical behaviour.

To make this possible we developed the **MACE Application Profile** that features a specific taxonomy dedicated to the architecture domain. The application profile is based on the Learning Object Metadata standard (LOM) with adaptations and extensions optimised for architecture and engineering. Moreover, in the LOM classification category we included additional attributes from architectural taxonomies and classification systems: a vocabulary on which a classification activity started by a group of experts and operated by a community in the long run. This classification activity had to be built upon a common, agreed-on basis, constituted by a hierarchical classification of terms in a controlled vocabulary. Through this taxonomy (see Table 1) it is possible to classify and find all the LOs according to a system that reflects the users’ typical logical behaviour.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Intervention type, Project type, Functional typology, Form typology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Location, Geographic context, Urban context</td>
</tr>
<tr>
<td>Technical design</td>
<td>Materials, Construction form, Building element, Technological profile, Structure profile, Systems and equipments, Technical performance, Maintenance and conservation</td>
</tr>
<tr>
<td>Constructing</td>
<td>Construction management, Construction phase, Construction activity, Machinery and equipments</td>
</tr>
<tr>
<td>Theories and concepts</td>
<td>Styles, periods and trends, Theoretical concepts</td>
</tr>
<tr>
<td>Conceptual design</td>
<td>Project cues, Project actions, Form characteristics, Perceptive qualities, Relation with the context</td>
</tr>
</tbody>
</table>

**Table 1:** The categories featured in the MACE taxonomy are grouped in five facets.

An important part of the work to build this taxonomy was to scan, check and gather already existing architectural thesauri. The need to rely on pre-existent and known thesauri follows from various reasons. First of all it was important to collect as many concepts’ keywords, definitions and names as possible to keep a balanced and neutral position, and to allow the expression of any point of view. Moreover, not less important was to collect a glossary of already defined and approved terms, to efficiently re-ordering and organizing them in synonyms groups. The combined use of already defined terms and of their grouping by synonymity should bring to express even debated theoretical concepts with an affordable optimisation, obtaining to limit the risk of information losses.

The MACE taxonomy consists of facets; each of them could be seen as an independent axis along which documents can be classified, and “addresses a conceptual dimension or feature type relevant to the collection”. A facet contains a number of hierarchical categories, which again contain a number of terms (compare Figure 6). To give an example, in the facet “Technical design” there is the hierarchical category “Material: wood” with the containing term “timber”. Through this structure and the resulting associative relationships between concepts (e.g. by looking at the parent of a term) a semantic map becomes visible for

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22 The main thesauri and classifications we relied on are: the “Art & Architecture Thesaurus Online” of the Getty Research Institute ([http://www.getty.edu](http://www.getty.edu)); the Ci/SfB classification ([http://www.ascinfo.co.uk](http://www.ascinfo.co.uk)); the UniClass classification ([http://www.connet.org/uk](http://www.connet.org/uk)) and the ISO12006 ([http://www.iso.org](http://www.iso.org)).

searchers as well as indexers, helping to create a mental image of the overall topic, and to select the most appropriate term.

A lot of the values are composed by a number of synonym terms. These are automatically assigned to a LO, once one of the terms a user has been chosen during manual tagging. In this way, finding content is simpler for the user, since he can rely on an architectural language as similar as possible to the one he is accustomed to.

Furthermore, users are able to add a keyword to a specific LOM, even if it does not exist in the application profile, yet. Such keyword is stored in a freeform text field not only to be included for search and other usages, but also for later reviewing by experts. If the keyword is commonly used and approved by experts, it is added to the classification vocabulary. This hybrid of a pre-defined top-down hierarchy and a bottom-up folksonomy allows us to utilize the wisdom of the crowds in a controlled manner to profit from existing personal knowledge. In this quality assured way, our taxonomy can be extended and improved over time, thus having the flexibility to adapt to emerging changes and arising innovations.

Figure 6: The user navigates through the taxonomy to the final term. During navigation the results are continually updated, enabling search refinement. He then can select one of the items for further inspection.

4.4 Protegé vocabulary maintenance
MACE vocabulary is not defined in an immutable and fixed way, but it can undergo some modifications and changes, when these are useful as updates of the glossary itself. Suggestions and criteria for a useful glossary updating process come mainly from three sources: first of all, the users tags: personal tags are in fact registered by the system and their usage is monitored and visualized periodically; if some tags are considered useful and proper enough to be added as official MACE Glossary entries, they are inserted in the glossary and

they are part of the MACE AP from the following release on. User suggestions via the helpdesk are a second source of glossary update: a certain user - or group of users - can ask at the helpdesk to have a defined keyword added at the MACE glossary; the request is taken in consideration by a panel, and inserted in the AP if the requested keyword is suitable with it. To analyze and debate the suggestions for new keywords coming from these two sources, an expert panel is meeting periodically. The third, but not less important, source of new keywords are new repositories joining MACE: in fact, in these cases, an AP matching protocol is used to confront and match the new repository archiving logic in MACE system. It often happens that some keywords of the new repository are not to be mapped, but simply to be added to MACE vocabulary; this third kind of glossary upgrading is obviously run singularly for every new repository, so it is not scheduled a-priori.

Once the updating needs have been considered and solved by the expert panel, the operative tool to modify and update the glossary is a software called Protegè. This software, connected to the server where MACE AP is stored, gives access to the glossary and allows to see and modify it via adding or deleting keywords, or simply to change some word features (eg. position in the hierarchy, selectability, etc.) This tool is used only by a small group of experts, which will make effective the panel decisions.

After every updating session a new version of the glossary is released, in .xls and .xml file format, and it is downloadable from the MACE project website; this service is in particular useful to those repositories willing to join MACE, to better understand which is the system logic - but it can be also be interesting for similar scientific researches still running.

The MACE vocabulary update is a fundamental activity, which allows the core of MACE system to be efficient, up-to-date, versatile and flexible to accept, store and organize all the kind of different materials coming from the various federated repositories.

4.5 MACE Integration

4.5.1 Columbus and author42
The aim of MACE is to link different repositories out of the architecture field and create therefore a consistent search interface. Consequently MACE provides consistent search results from different sources. With the integration into Columbus and author42 we complement the search with content reuse and distribution functionalities.
The **Columbus Portal** is an innovative E-Learning marketplace sponsored by the European Commission under the eTEN initiative, aimed at supporting lifelong learning processes of European citizens by offering:

- Professionally produced E-Learning courses,
- Special interest/hobby E-Learning courses created by users

**author42** is an easy-to-use authoring tool from the Humance AG. This web-based tool is for authors to create E-Learning courses very fast and easy.

To integrate MACE, Columbus and author42, we performed four steps:

1. Integrate author42 into the Columbus portal:
   
   This allows to directly create and publish online courses within Columbus.

2. Integrate MACE filtered search into author42:
   
   This allows to directly access the MACE search during the authoring process: search for objects, select some and reuse them to create a new online course.

3. Create architectural online courses:
   
   Three courses with MACE contents were created and published within Columbus.

4. Develop an OAI-target for the Columbus portal:
   
   Published online courses in Columbus are available through MACE search facilities again.

With these four steps, we have a complete "search > reuse > create > republish > search" roundtrip created:

- Through the author42 - MACE link, materials from MACE repositories can be re-used to create new learning objects;

![Figure 7: MACE filtered search in author42](http://www.columbus-portal.eu/)

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• Through the author - Columbus link, these materials can be published to the community portal;
• Through the new Columbus OAI-target, these created materials appear in the MACE search.

The benefits of the integration are the following:

• For MACE: The integration with Columbus adds a new use case, which enables to create new learning contents and recombined modules out of provided existing information’s.
• For Columbus: During the creation of courses authors can now use the comprehensive information of the MACE repositories and directly reuse them. Instead of relying on external resources authors can benefit from integrated search facilities.

4.5.2 MACE Helpdesk

Figure 8: MACE Helpdesk

To give the MACE community the possibility to provide feedback, to ask questions, or to get in contact with MACE we created the helpdesk. In the following section the four different helpdesk areas we created are explained:

1. FAQ
   The FAQ is divided into two target groups: end users and content providers. In each of these divisions the basic questions of each group should be answered.
2. Glossary
   The glossary explains the important or special terms in the context of MACE, for example “What does OAI?” mean or what is the “MACE metadata schema?”.
3. Tutorials
   In this section we provide two tutorials “First steps into MACE” and “The MACE Portal” to give a first and easy introduction into the MACE Portal.
4. Contact
   The contact form allows to directly contact MACE and ask questions which are not answered one of the other sections. Typical types of inquiries are out of the field “How to use the portal?” and “How can I attend MACE as repository?”.

We established a continuous improvement process for FAQ and Glossary triggered by questions and feedback coming in through the contact form.
The main activities after setting up the helpdesk are receiving inquiries from the contact form and classify them in two groups. One group includes easy and common questions which could easily be answered by non-expert people. The second group includes questions which are more complicated or indicate a technical support. These ones are sent to the correct contact persons out of a “helpdesk-expert-list” who is then taking care of the request.

### 4.6 MACE Quality Assurance

MACE Quality Assurance Tool is developed to provide Quality Assurance Managers with simple and user-friendly performance reporting support: this tool can be used to establish a standardized performance reporting and to formulate synthetic performance data that can be easily utilized to detect and solve performance issues.

In particular MACE Quality Assurance tool:

- Collects performance data;
- Reports on performance factors on a specified date and for a definite period of time;
- Provides access to performance information to selected groups of users;
- Provides support for end-user survey administration.

The application of MACE Quality Assurance tool in MACE project follows the organizational and operating flow described below:

- Quality Correspondents can be selected for every Work Package.
- The subjects in charge of Quality Control can implement reports and surveys related to the performance factors in the MACE Quality Assurance software.
- The Quality Correspondent coordinates data entering that result from system monitoring and/or from compilations of surveys by end users of Mace project.
- In predetermined dates Quality Assurance Manager generates automatic reports concerning data entered and publishes them on the web. In this way, the managers of every single Work Package can consult the results of the Quality Controls on the web as well as their variations in time.

The tool was specifically structured for quality assurance objectives, but it was successful used also for the reporting on experimentation evaluation carried out by Universities with students’ groups in Architecture faculties, in order to evaluate the pedagogic effectiveness of MACE project.

### 4.6.1 Functionality

The tool manages 5 categories of users: Administrator, Quality Manager, Quality Assurance Manager, Quality Correspondent and End User.

The web access permits to quality correspondents and end users to compile different questionnaires after registration, on the base of their privileges.
They can access the web tool at the address http://mace.nautes.eu (use “NAU” as username (no password)) and also via hyperlink from the MACE Portal. After log-in, the tool opens two macro-sections: the performance factor area and the surveys area. The external users are authorized only to see the surveys area.

### 4.6.2 The Performance Factor Area

After selecting the performance factor area, the Quality Correspondent can see the list of performance factors. Performance factors are hierarchically arranged according to the structure introduced in tables 6.1, 6.2, 6.3 of “Quality Control Plan” (Deliverable 2.3).

Each performance factor is represented by a folder icon; at the second level there are the evaluation classes (i.e. knowledge design, system design, etc.) and at the third level all the indicators.

Depending on the indicator type, data can be free text, a number or a multiple or single choice answer. Furthermore, each indicator can be filled once or multiple times.

Every time a value is filled in, the system stores the user name as well as the date on which it was completed. Periodically, for each performance factor and for each survey, automatic reports are generated and published on web by Quality Assurance Managers as excel sheets.

### 4.6.3 Survey Area

The survey area can be used to host electronic questionnaires in order to evaluate any complex performance factor by MACE partners or to obtain feedback from end users. Every user, in fact, is able to evaluate the quality of MACE tools giving an evaluation to different aspects of the services: usability, simplicity, quantity and quality of reachable contents and more. The survey interfaces are structured like Performance factors data entry interfaces. MACE partners can fill surveys and see the results.

End users must register to access surveys: they receive a username and password allowing them to access only the Survey area, where they can answer electronic questionnaires. During the data entry process, the interface highlights all required information and gives the user the opportunity to write his/her personal comments, impressions and opinions.

End users cannot access the results, unless the Quality Assurance Manager specifically authorizes them.

### 5 Target Users & their Needs

In the first year of the MACE project, the following groups and entities together with key users and their requirements have been identified that will benefit from MACE:

- Students and teachers of architecture
- Professional architects
- Online communities and portals of (architecture) students or professional users
- Other projects, networks and initiatives
5.1 Students and teachers of architecture

The main target group of MACE are students and teachers of architecture that are confronted with the need to search for and access large amounts digital contents related to architecture in their daily work. By making use of different kinds of metadata and combining these approaches, MACE is able to offer deliver better search results in a novel way, especially in comparison to other search engines and existing repositories.

Searching for architectural terms with traditional search engines often gives a lot of unwanted results, among others because “architecture” is an ambiguous term; it can be used in a variety of fields such as (physical) building, information technology, and biotechnology. Related terms like “construction” or “design” face the same problem. If users then try to narrow down their search by redefining their queries, the list of results gets smaller fast, but one ends up with relevant items missing, too.

MACE addresses this problem by using a structured application profile containing a hierarchy of attributes and a value space for these attributes. The value space has been developed in the project from lots of input from architects and architecture teachers.

Another problem for students is that, being new to Architecture, they do not know exactly how concepts are related, what exists and what to search for, so they need different approaches for navigating through the results and getting related content – a traditional search engine again is not a suitable tool to support this process.

We provide students with possibilities to find the results they look for, without the semantically incorrect “overheads”. By offering novel ways to navigate through these results, we further support the users to get familiar with relevant concepts and their relations, and to learn from exploring relations between contents that are not visible in traditional approaches. We do this by connecting repositories specialised on architecture to one large infrastructure, and by using new interaction metaphors that extend the classic web browser approach. We further connect contents and users, thus offering new ways to find related contents, and to get into contact with other users that have similar interests.

For teachers of architecture, the situation is a bit different. They are very skilled in the field and especially the terminology, but would gladly welcome support for acquiring and re-using existing contents from different repositories, e.g. for showing different solutions to a design problem. They are also stuck with traditional keyword search because the manual filtering of results costs time that can be invested better in creating great learning materials.

By allowing access to the MACE infrastructure from authoring applications, we enable teachers to reuse learning materials for their courses easier and more efficiently than before. An integration of MACE with the Columbus project26 and especially the authoring software author42 is already realized and allows integrating MACE contents into eLearning courses, as described above.

5.2 Professional architects

Like teachers of architecture, professional architects are also very skilled, yet, their focus is on getting facts (like regulations, prices or catalogues) delivered directly without searching for them endlessly.

In MACE, we help architects by marking such contents with appropriate metadata and by providing targeted search tools such as the MACE search widget. These tools can be

26 http://www.columbus-portal.eu
integrated directly into the architect’s workflow, making searching and accessing contents even easier for professionals.

5.3 **Online communities and portals**

Through dissemination activities, we know that online communities and portals (some of them listed in the next chapter) are interested in integrating access to the MACE infrastructure into their websites. This will be a mutual gain: the portal gets access to useful digital contents and the MACE gets additional users, which in turn increases use and reuse of the content repositories connected to the project. MACE therefore offers, e.g., search widgets that can easily be embedded in existing websites and allow immediate access to MACE contents.

5.4 **Other projects, networks and initiatives**

Other projects and networks like PROLEARN, STELLAR, ROLE, TenCompetence or TEL18 are not directly a target group of MACE. However, dissemination facilities of these projects are used to further promote MACE. By opening MACE to these projects and, in turn, getting access to contents and results created there, we also increase the impact of MACE and reach an even wider user base. E.g., MACE is used in ROLE for a recommender engine, and the Columbus portal offers access to MACE contents for the creation of new learning material. Cooperation activities are done within the eContentplus work programme or between projects and networks where MACE partners are involved, too.

The EAAE (European Association for Architectural Education) is via one of its members (ASRO at KU Leuven) a dissemination partner in the MACE project consortium. EAAE counts 110 European school (full) members plus associate members and individual membership, summing up to approximately 150 members. Prof. Neuckermans from ASRO has been reporting about what MACE is, does and offers to schools of architecture during the whole duration of the project via the EAAE News Sheet (three times a year), and on many conferences and workshops organized by or with EAAE. Two years ago EAAE has established a Joint Working Party (JWP) with the ACE (Architects Council of Europe) in order to discuss issues of common interest like the Qualifications Directive/2005 and the access to the profession. ACE is the association of professional architects associations in Europe. ACE knows about MACE via the JWP and attendance of the annual meeting of Heads of Schools of Architecture in Chania. ACE has advertised MACE in their electronic newsletter that reaches 3000 associations and institutions related to architecture worldwide.

6 **Underlying Content**

During the MACE project, the consortium partners have been actively scouting the domain of architectural repositories. Based on both teaching and research experience and the wide networks of contacts through the different schools and organizations MACE is affiliated with, it was possible to build up a quite extensive database of repositories. As described in (MACE conference proceedings 2008\(^{27}\)), the different possible repositories have been classified and organized into different categories, domains and user profiles.

While this study never attempted completeness, we feel that it covers a wide variety of themes and approaches. There are several institutional archives, from universities, museums and libraries. There is also a multitude of professional architectural sites, from discussion and opinion portals to project and photography collections. And then we have several education

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and learning oriented sites, with courses, tutorials and other learning content, often in a variety of multimedia formats. Individual architectural offices have their own websites, offering a wide variety of project information and images and in many cases also publications and writings.

However, what was directly noticeable is the lack of interconnection between the sites. There are affiliations, through mutual banners and sponsorships and many sites offer RSS feeds, allowing interested users to stay up to date, but in all, each site works quite individually. Moreover, even though many sites have comparable content, such as project descriptions, they structure them differently. At best, they adhere to a common classification system such as CI/SfB or the Art and Architecture Thesaurus from the Getty Institute.

By bridging these repositories, MACE is not competing but rather collaborating with repositories of architectural content, creating a mutual benefit for connected repositories:

| Integrated in MACE | DYNAMO, CuminCAD, WINDS, Iconda, Archiplanet, Baugedächtnis Schweiz Online, Nextroom, Arch’it, Architonic (subset), MACERepoDB, CAAD@ASRO, cad-3d blog, Copyrightbookshop, Mimoa (subset), UNESCO WH List of sites, Columbus, Architecture.it |
| Integration in progress | TOI-pedia, Archivio Progetti, World-Architects, ArchDaily, LightCampus |
| Negotiations in progress | Archinio, SAH, ANCE, ETSAV-UPC, RIBA, Infosteel, STRUCTURAE, WHTour and others |

Table 2: Repositories participating in MACE

The following list gives some more details on repositories and their status of inclusion in MACE. We deliberately provide this list as is without warranty as the efforts to include new repositories are continuing.

6.1 a-lab
This Norwegian architectural office asked how to be included in MACE. We provided all the necessary info, but they have not responded since.

6.2 ANCE / Industria Delle Costruioni-Edilstampa
MACE was described and they showed interest, but no decision could be taken yet, because of internal restructuring (change of director). We repeated our proposal of collaboration and our request for integration.

6.3 ArchDaily
A testing OAI-target based on the RSS feed was created, but it can only load the last 15 projects. After discussion with one of the site owners, they seem to be willing to assist, but lack the proper knowledge and structure to provide the proper metadata. They use the WordPress blogging and content platform, but have a mostly unstructured project list. To this extent, the MACE partners are looking at a WordPress extension, which could be offered to harvest the metadata from such a site. Since other candidate repositories use the same technology, this could be reused.

6.4 Architekturvideo
The owner of this collection of references to architectural videos was willing to provide the metadata for MACE. This site uses WordPress so we suggested the WP extension as a solution for harvesting. This is currently not available.
6.5 Abitari / Edil Portale
This portal site is also based on WordPress and could use the same extension. Currently not available.

6.6 Archinfo
After initial interest in the MACE project, they did not see the chance of pursuing. Since the MACE partners convinced them to assist and limit the efforts, the negotiations are still ongoing.

6.7 Arch’It
Almost 1000 articles from this website have been collected and included in the MACE content database. Since the original site used plain HTML without any database backend, the MACE consortium had to rely on using a web-crawler and some custom scripts to download the necessary metadata and translate this into the MACE structure.

6.8 architecture.it
MACE partner Collaboratorio is working on integration inside MACE. The implementation is final; few final validation errors will be corrected.

6.9 Archivio Progetti IUAV
A test was created with a first subset of publications. When the full collection becomes available, this will be used to create a proper harvesting target. The ASAC Archive of La Biennale di Architettura was also an interesting archive, but since their contents will be mostly available through the Archivio Progetti, there is no need for separate development.

6.10 Architekturmuseet (Sweden and Finland) and Irish Architectural Archive
While they are interested in the MACE initiative, they are currently not ready for harvesting as they are still in the organization and digitization process.

6.11 Archiplanet
This wiki about architecture was referenced inside MACE, using the Wikimedia API, allowing for the scripting of metadata collection. About 62,000 records are included.

6.12 Architonic
A first set of metadata was collected from Architonic, containing material descriptions from manufacturers. About 600 items were included.

6.13 ArchiTypes
The maintainer of the ArchiTypes list of architectural design patterns has provided a database snapshot which can be used for the development of a harvesting target. This work is currently unfinished.

6.14 Baugedächtnis Schweiz Online (retro.seals.ch)
About 53,000 records were collected through their OAI-target, by mapping the Dublin Core based metadata onto the MACE LOM profile. The most relevant collections of digitized journals will be selected for delivery in the public MACE portal.

6.15 CAAD@ASRO, cad-3d blog, MACE Repo DB
Based on a prototype php-implementation, the Computer Aided Architectural Design courses from MACE partner KUL/EAAE have been made harvestable. In addition, the implementation was retargeted for other databases, such as the cad-3d blog about software for
architectural students and the database of architectural repositories, developed for the MACE project. All of them are harvested and ready to be included in the MACE portal.

6.16 Copyright Bookshop
This art and architecture bookshop provided a database snapshot with references and descriptions of their offering of books on architecture, design, photography and art. This list was used by the MACE partners to create an OAI-target and is integrated into the MACE collection.

6.17 CuminCAD
This archive of references and publications from Computer Aided Architectural Design Conferences was the first repository that was not affiliated with the MACE consortium partners. With assistance from MACE, their OAI-target was extended to conform to the LOM structure and the MACE AP. More than 9000 publications have been included.

6.18 DBPedia
For the creation of references to designers (architects) and projects (buildings) the MACE partners used DBPedia to create the Real World Objects (RWO) in the MACE system. A first (short) list of 140 items was created and after proper testing the larger set of available records will be included.

6.19 DYNAMO
This repository of architectural projects was already included, but the OAI-target has been updated after some updates to the MACE AP and after some validation tests. About 1000 projects and 14,500 files have been references inside MACE. As a side-effect of MACE integration, the repository has seen an increased amount of registration requests from outside its Belgian homebase.

6.20 ETSAV-UPC
The negotiation with this institute about the repository material did not lead to results currently. They showed interest, but there is some uncertainty about exclusivity and external contracts. MACE offered to host the database on Ariadne as a possible technical solution.

6.21 Iconda
From the database of about 650,000 references to technical literature, a collection of 19,200 full text items was chosen to be included in MACE. The consortium partners also evaluated to incorporate the list of some 80,000 building references in the form of Real World Objects (RWO).

6.22 Infosteel
After negotiation with the project owner, they still have difficulties to understand what MACE attempts to do. As many other repository owners, they are quite sensitive about copyright issues with their images. Some examples have been manually created using the bookmarking option for MACE, but no proper OAI target is available.

6.23 IRB (FORS, BAUFO)
The integration is in progress. An OAI-target is available, but not in the MACE AP structure.

6.24 LANY Archive Grotto
The owner of this website contacted MACE for adoption of his site, since Geocities (the hosting provider) is closing down. However, the site is unstructured. There is no metadata and
no database, but only a complex web of interwoven HTML files. After only partially successful attempts of archiving the sites files, because of bandwidth and access problems, the owner asked not to keep a separate archive, as not to have scattered parts of this site on the web.

6.25 LightCampus
The MACE partners created LOM files for all the course material. They still have to be integrated in the MACE content database, but wait for some corrections and validation of the records.

6.26 Mimoa
They have been talking with MACE throughout a large part of the project. However, they kept their hesitations and instead of developing an OAI-target, they provide an online widget to perform queries. They suggested for MACE to collect a subset of 50 projects to evaluate the integration project.

6.27 NAi
The Netherlands Architecture institute is setting up an archive with references to Dutch architecture and was hoping to collect information from MACE. We also suggested opening the extensive archives for harvesting inside MACE, but the negotiations are still ongoing. It is planned that the full databases will only be available in 2010.

6.28 Nextroom
While the Nextroom partners have been in touch with MACE for more than a year and were present in the Venice Conference (REF) and the Hybrid Archives Conference (REF), they decided not to participate inside MACE for now. They will focus first on the relaunch of their website.
However, the MACE partners have collected the necessary metadata independently and about 4,800 records are made available as a service to Nextroom and as a demonstration of the possible full integration in the near future, which requires a proper metadata mapping to the MACE structure.

6.29 STRUCTURAE
The owner of this database of construction projects was willing to provide metadata, but could not continue working on the implementation. MACE offered assistance and suggested exporting the information in a simplified XML format. Work is still in progress, but without any results so far.

6.30 T-Labs
The experimental archive of student dissertations of some IUAV design courses would be interesting, but as it is not fully online available, it is impossible to integrate now.

6.31 UPOOL
This was created as a tool to compare architectural schools. However, they are currently mostly in a startup phase and lack proper content, so it is too early to be included in MACE.

6.32 World-Architects
They are in a quite similar situation as Nextroom. Only after a site relaunch are they willing to collaborate further. They still have hesitations because of copyright issues and the protection of their metadata. MACE offered help with the implementation, but without any results so far.
However, to develop a test implementation, the website was scraped to be used for a prototype OAI-target. So far, this has not been included in the MACE portal.
6.33 World Heritage (UNESCO list of heritage sites)
Almost 900 heritage sites of important cultural value have been described and documented by UNESCO. A first prototype, based on the RSS feeds and an KML file with geographic locations was created by MACE partners. After negotiation and meeting with the responsibilities for UNESCO, they will provide a new and more complete feed with metadata, which will be used to improve the harvesting. The closely related WHTour of panoramic images was also contacted, but they lack the proper metadata and interfaces to be integrated.

6.34 RIBA (Royal Institute of British Architects)
A MACE delegation has visited the RIBA in London to promote the MACE project and ask for collaboration. The large collection of digitized photographs in the RIBAPIX archive was also suggested as a useful repository to include in MACE. Negotiations are ongoing.

6.35 WINDS
The Web-base Intelligent Design tutoring System on architectural and construction course material was integrated. It contains theoretical paragraphs, including images and also case paragraphs. A total of 17,151 records is currently referenced. During the final year of the MACE project, the harvesting target was updated.

6.36 OAISTER, DOAJ, UGent, LIRIAS
There are several public repositories with OAI-targets that MACE could collect from, but at the moment, none of them supports the LOM structure and after evaluation, there are difficulties to sort out the relevant material for the architectural domain.
- OAISTER: Metadata collected from several OAI targets (DC-based) but only available as database snapshots.
- DOAJ: DC-only collection of open journals.
- UGent: No sets defined, impossible to filter architectural content
- LIRIAS: Sets defined, but not always correctly assigned. Also no way of knowing validated publications, which makes it impossible to filter out proper and relevant texts.

7 Summary of Activities / Evaluation
All activities in MACE have been geared towards the production, dissemination and exploitation of the MACE system. As such, describing the various activities here would be cumbersome as they are highly complex. Instead, the activities are explained in terms of their evaluation. Due to restricted space, we give an overview here only. The interested reader is referred to the Joint Deliverable DJ10/11/12, available through the project website.

The MACE system has been evaluated with respect to the following perspectives:

Infrastructure
The evaluation of the MACE infrastructure is based on established software quality attributes, such as: performance, reliability, interoperability, modifiability, portability, testability and scalability. Overall, the MACE infrastructure proved capable of responding also to higher number of concurrent requests in an efficient manner and is well able to handle the requirements for querying and editing the metadata needed by the frontend components.

Frontend usability
We conducted several usability studies to evaluate the tools we offer to the end users. In addition to an evaluation of the MACE portal with an unacquainted user group (questionnaires, task solving and free explorations, monitored by video and audio recordings as well as eye tracking), we evaluated the use of the mobile clients. These offer a location-based service to discover MACE contents related to objects in the user’s vicinity. The evaluation of the portal showed that, although the service was perceived as innovative and unfamiliar, all major portal functionality proved to be self-revealing and could be used effortlessly and was judged useful. The mobile clients were perceived as interesting and potentially useful, but revealed a larger potential for usability improvements.

**Resource and usage statistics**

Another important question is how well the MACE system is actually accepted by the community and how many contents and metadata are integrated. In 2009, with over 150,000 integrated contents and almost 120,000 classification assignments, we saw over 63,000 visits to the portal with over 200,000 page views, with a clear trend towards a higher number of page views per visit. This indicates an increasing adoption of the MACE portal as a platform in use.

**Use in learning and teaching**

We also evaluated the effectiveness of the MACE application profile as it was perceived by experts asked to tag a given set of contents. Testing results show an excellent performance of the classification schema, that has an almost complete coverage of the contents’ information type and that has been almost ever correctly understood and applied by the users.

Furthermore, we conducted three experiments in regular university courses to measure the impact of the use of the MACE system as a support for architecture and building construction design tasks. Although at the time of testing, the MACE content base was more limited than as of now, we could show a positive correlation between the use of MACE and a student’s performance, with particular improvements of consistency, clearness and structure of the work.

Finally, we evaluated the MACE competence toolset as it was perceived by teachers planning courses of curricula in architecture and construction engineering. The evaluation confirmed the expectations regarding the usage of the MACE portal in architecture education. MACE is usable for teaching, helps teachers to find relevant content for their teaching, and supports teachers during their teaching process.

Furthermore, the principles of MACE (chosen technology, methodologies and approaches) are validated and accepted by the European and world-wide scientific community. The consortium has published a large number of scientific papers at conferences and journals on the themes of MACE thus validating the chosen methodologies and approaches. One paper even won the “best synergies of disciplines” award at the 4th European Conference on Technology Enhanced Learning (EC-TEL 2009).

In summary, the evaluation of the MACE system and portal as presented in this deliverable clearly shows that the chosen approach of the MACE consortium has a highly positive impact on the architectural education community in Europe. Further activities are needed to even broaden this impact. These and further activities and ventures are outlined in detail in the next section.
8 Impact & Sustainability

The MACE project has produced impressive output to organize and manage knowledge in the architectural domain. Usability in the academic processes has been proven. Taxonomy and interfaces for the portal as well as underlying software have been created as assets after three years of research and development.

Projects like Green Prefab or Columbus as well as contacts to other vendors and even venture capitalists have indicated that the created assets can deliver further value in other phases of the life cycle of buildings in supporting professional services and education beyond academic education.

Markets in Europe, China and USA indicate demand for support in leveraging effectiveness and efficiency for new buildings and/or green buildings. Consequently, the question for this sustainability plan is whether the assets can be exploited in a profitable manner, i.e. that revenues should be greater than costs.

From the assumed numbers for revenues and costs, profitability is expected within three years after the end of the EU-project. But there will be a demand for cash to finance the start-up time. This demand will be smaller if the Green Prefab option as commercial entity is integrated.

We expect the following revenue streams to be relevant for MACE: Firstly, a fee per user to enter and use the platform should be charged for professionals (architects, town planners, construction engineers, etc.). The second income stream comes from the purchasing of an annual subscription fee for companies addressing their marketing budgets. The third income/revenue stream was developed around the idea of a return-on-investment calculation for process lifecycle management via Green Prefab.

All three sustainability scenarios share, that all universities and educational users get free access to MACE.

The consortium investigated the following three models:

1. MACE Non-Profit: To create legal entity as non-profit organisation

MACE goes for a legal entity of a foundation and a non profit scenario. Consortium members contribute mainly with service and manpower.

For MACE Non-Profit we expect the revenue to grow from 32K € by the end of the first year to 240K € by the end of the fifth year. Accordingly, the loss (result financial year) develops from 119K € in the first year to 16K € in the fifth year. To equal this loss, an according cash input or contribution from shareholders (former consortium members and third parties) is required yearly. MACE Non-Profit works continuously with two to three full-time employees. Service peaks can be handled by contracting to former consortium partners.

2. MACE Profit: Transfer the IPR to a commercial operation

The MACE consortium also aims for a profit scenario and a legal entity of a limited company under guidance of at least two former commercial partners. The rest of the consortium acts on the advisory board of this entity.

For MACE Profit, we expect the revenue to grow from 65K € by the end of the first year to 580K € by the end of the fifth year. We expect the profit ratio in the long run to be around 20%. To equal the loss, an according cash input or contribution from shareholders is required
yearly (decreasing). Additionally, to offer extended MACE services, financial input from investors is required in the first three years. MACE Profit works continuously with two to three full-time employees. Service peaks will be handled by contracting former consortium partners.

3. **MACEPro: Create legal entities as a mixture of 1 and 2**

The MACE consortium aims to combine MACE Profit and MACE Non-Profit. It collects risk capital to establish a shareholder company and integrates the Columbus Portal, lead by ILT UK. The rest of the consortium acts on the advisory board of this entity.

For MACEPro, we expect the revenue to grow from 106K € by the end of the first year to 1.730K € by the end of the fifth year. We expect the profit ratio in the long run to be around 25%. To equal the loss, an according cash input or contribution from shareholders is required yearly. This includes a higher input of partner Collaboratorio snc and new input from ILT UK (Columbus Portal). Additionally, to offer extended MACE services, financial input from investors is required. The initial investment is lower because we integrate existing revenues from Columbus and Green Prefab. MACEPro works continuously with two to three full-time employees. Service peaks can be handled by contracting former consortium partners.

Risk analysis: The main risk in the MACE sustainability approach lies in an eventually low market impact due to different reasons:

- Inappropriate (= too small) marketing budgets don’t allow us to penetrate the markets
- The technical complexity of the MACE toolset does not allow us to react fast and cost efficient enough to market changes
- Misunderstanding/miscommunication leads to the situation, where repository owners see MACE as competition rather than opportunity

We believe that our financial plan addresses a sufficient marketing budget, and that the technical competencies in the consortium are strong enough to handle the complexity. Furthermore, we are experienced in communication with repository owners and customers and can handle the miscommunication risk as well.