Geographical Information systems for Sustainable Management of Built Environment

ABSTRACT

In the building and construction sector all features are location based. The world of geographic information and application orientation is moving extremely fast, and there is a real danger that the slow uptake of new technology and applications in the building sector will again leave the sector trailing behind, also implying a loss in sustainable development and competitive edge.

In order to deal with this issue CIB in 1996 established the task group CIB/TG20-GIS. Based on the report CIB 256 from this group and its recommendations, CIB in 2000 established the working commission CIB W106 “Geographical Information Systems”, with the overall objectives to provide an international platform for R&D of GIS applications for the built environment, and to promote and encourage the use of GIS in the building sector. The W106 has members from 14 countries/organisations and will present its progress report at this Congress, while its final report with conclusions and recommendations is due for the 10DBMC conference in 2005.

The work is divided into the following four Tasks: TG1- GIS-requirements and availability of geographic standards-, -data and infra-structures, TG2- GIS-based analysis and modelling of flow and distribution of materials in the built environment, TG3- Spatial dynamic modelling for Simulation of the interaction between the natural and the built environment, TG4- GIS in Education and Info sources.
Objectives and work programme for each of these tasks are given and illustrated with examples, taken from state –of-the-art reports on the use of GIS elaborated by the participating countries/organisations.

1 INTRODUCTION.

In order to deal with the issue of the exploitation of GIS in the building sector, CIB in 1996 established the task group CIB/TG20-GIS, with the following terms of reference:

1. To provide an international focal point for the development and utilisation of geographical information techniques for simulation and calculation of the influence of external factors in a broad sense on the built environment.
2. To investigate the potential and validate the geographic information technology as a tool to model the degradation environment to buildings and technical infrastructure.
3. To explore the techniques for creating and visualising models of the built environment, not only in 3D but also over time by using digital aerial and satellite images.

Based on the report CIB 256 from this group, and its recommendations, CIB in 2000 established the commission CIBW106 “Geographical Information Systems”, with the overall objectives to provide an international platform for R&D of GIS applications for the built environment, and to promote and encourage the use of GIS in the building sector (CIB, 2000). The W106 has members from 14 countries/organisations and present its progress report at this Congress, while its final report with conclusions and recommendations is due Summer 2005.

2 REPORT 256.

The report dealt with:

- the emerging Geographic Information Infrastructure –its definitions, the background and the accelerated development during the late 90-ties triggered by the ICT revolution. The concept *National Spatial Data Infrastructure* (NSDI), which is today driving the development (see below), was defined as: *"The means to assemble geographic information that describes the arrangement and attributes of features and phenomena on the Earth. The infrastructure includes the materials, technology, and people necessary to acquire, process, store, and distribute such information to meet a wide variety of needs.",* and used the Singapore case to prove its point.

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The Singapore report was given by Dr Sun Han and Dr Willie Tan of the National University of Singapore. With careful planning and strong commitment, Singapore's integrated GIS database has progressed through several stages, including prototyping and testing on Internet and Intranet, thus forming the backbone in government's efforts to make Singapore an "intelligent island." The unique approach that Singapore provides in constructing an integrated GIS database, may be a useful reference for other countries for improving their competitive edge in today's global economy.

- the visions and prospects of the use of GIS for improving the planning and management of a sustainable built environment. It is often stated that 80% of all data can be tied to a location. In construction we deal with location of constructed objects and of activities in the built environment. By considering the whole life cycle of each object together with its usage and user(s) it is easy to realise that the ability to handle location has a great potential, which includes many possibilities to increase the efficiency. As almost all countries are in the process of establishing a NSDI, and furthermore, the infrastructure for telecommunication will facilitate the accessibility not only to office use but also for use in mobile units, it is clearly envisage that the vision of ubiquitous geographic information will be a reality in many countries within a few years.

- the use of GIS in modelling and mapping the durability and service life of the built environment-case studies, which described:
    - modelling of degradation and performing cost-benefit analysis of the building stock on various geographical scales, based on dose-response functions and lifetime equations and the resulting cost of maintenance, repair and replacement, see Figure1.
    - Inspection and condition assessment of buildings (EU-projects Wood-Assess and MMWood)
    - Mapping and modelling of corrosion of metals as function of climate and marine salt in Australia, see Figure 2

Figure1 Modelling distribution of SO2 and of Service life of painted wood in Oslo (year 1994), exhibited in the GIS based system CorrCost.

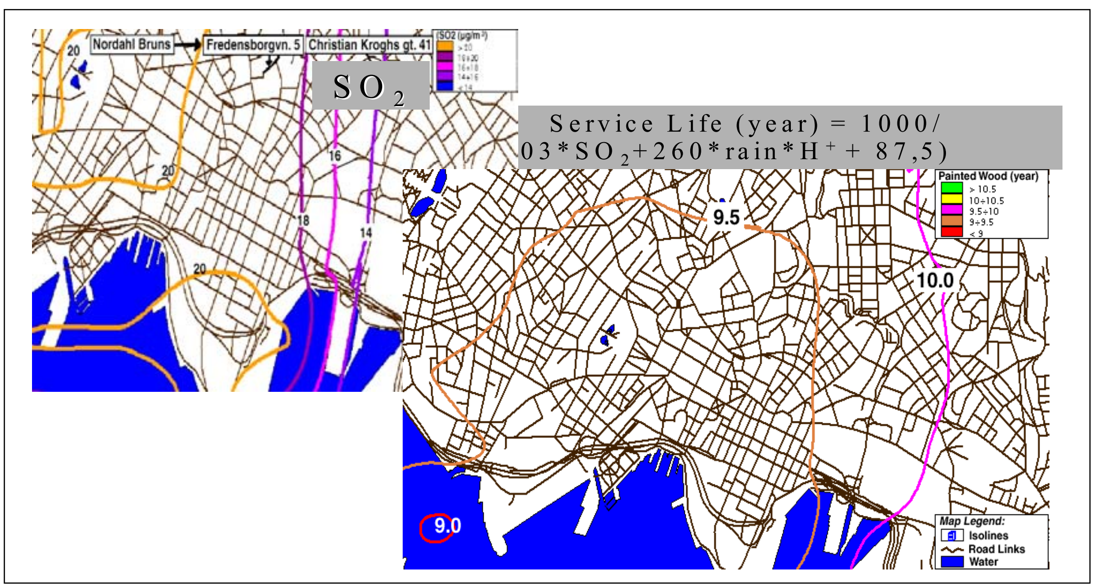
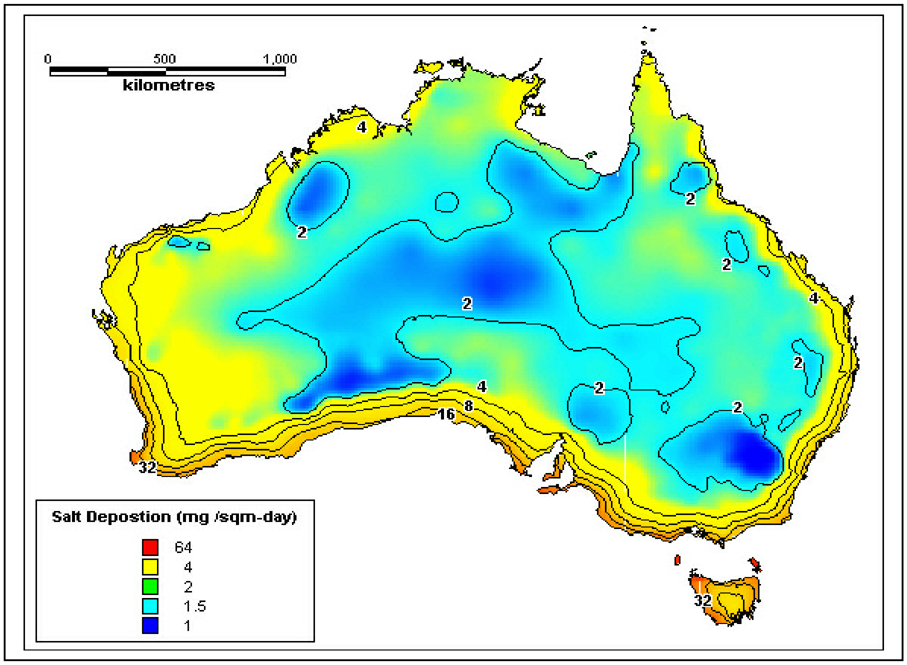


Figure 2 Estimated salinity in Australia using a holistic model (Cole et al, 2003B)



Based on this report and its recommendations, CIB in 2000 established the working commission CIBW106 “Geographical Information Systems”. Its objectives, work plan and excerpts from its progress report are presented below.

3 OBJECTIVES AND SCOPE OF CIB W106 “GEOGRAPHICAL INFORMATION SYSTEMS”

CIB W106 has the following main objective

- To produce reports on existing or completed projects in four main topic areas/TGs in order to facilitate the implementation of GIS in the building sector.

and strategy:

- Each task should have a single or shared Task Group leadership, and a broadest possible global participation should be pursued in order to explore and promote a widest possible implementation of GIS applications for the Built environment.
- A very important aspect would be to have links to national geographic and cartographic infrastructure and to exhibit national and regional demonstration projects for deployment of GIS. Such national representation would be pursued.
- Standardisation will be a permanent point of attention in the Work programme, f. ex to:
  - support the ongoing work in ISO TC211, Geographic Information/Geomatics, with specific built environment/construction sector aspects and needs;
  - interact with ISO TC59/SC14 Design life, as regards e.g. GIS-aspects on design/service life modelling and characterisation of degradation environment

In addition the Commission defined the three priority tasks, TG 1-3, which was later on in the work period extended with a new TG4 on Education. Originally the intention was to produce the final report to be presented in conjunction with the CIB World Congress in 2004. To cope with the ambitions for broadest possible contributions, it was also decided to promote national reports from participants, and to extend the working period up to Summer 2005. So far, draft reports were produced by Australia, Canada, France, Italy, Japan, Norway, and Sweden up to the Working Group meeting in Milan June 2003.

TG1: GIS- requirements and availability of geographic standards, -data- and infrastructure.

Rationale. The world of geographic information and application orientation is moving extremely fast, shown by f.ex the Business plan of ISO/TC211 Geographic Information/ geomatics, stating

"the increasing recognition of the value of spatial data and geographic information has spawned the entry of new players into the spatial standardisation arena, both from within ISO and externally. Consequently, a new agenda is emerging for international spatial standardisation that includes traditional and new innovative applications across a spectrum of disciplines". All businesses that produce, distribute, or utilise spatial information, either alone or in inconjunction with non- spatial information, benefit from spatial standards. Environments supported by standards include geographic information, decision support, data mining, data warehousing, modelling and simulation. Application area includes –but are not limited to - automated mapping, geo-engineering, computer- aided drafting and design, entertainment, modelling and simulation. These broad categories span the planning, design, construction, operation, and maintenance of facilities and their supporting infrastructures such as communications, transportation and utilities.

The mandate for ISO/TC211 is therefore to develop an integrated set of standards for geographic information. The market will be fundamentally different by 2002. Velocity of change is a critical gating factor for spatial technology, and the standards will have to adapt to new customer requirements, risks and rate of change".

The notion of a spatial data infrastructure (SDI) has become more and more widely used. For more than 10 years countries and regions have tried to define and implement this concept. Over the last few years, these activities have been structured in a more homogeneous way, not at least through the work of the Global Spatial Data Infrastructure (SDSI) initiative (Norway mapping, 2003).

Last year the European Commission launched an initiative to establish a European spatial data infrastructure – this initiative is called INSPIRE- Infrastructure for Spatial Information in Europe. The initiative aims at making available relevant, harmonized and quality geographic information for the purpose of formulating, implementing, monitoring and evaluating Community environmental policy making, At a later stage, the initiative will be broadened to other sector policy areas such as transport and agriculture, and will eventually culminate in the establishment of a multi-sector spatial data – infrastructure (http:\\www.inspire.com)

The Building sector has not even started to present their requirements. Objectives for this group is thus:

Objectives

- to increase the understanding and usage of geographic information within the built environment
- to promote the exploitation of efficient, effective, and economic use of digital geographic information for the built environment
- to contribute to a unified approach to addressing global performance requirements for the built environment

TG2: GIS-based analysis and modelling of flow and distribution of materials in the built environment.

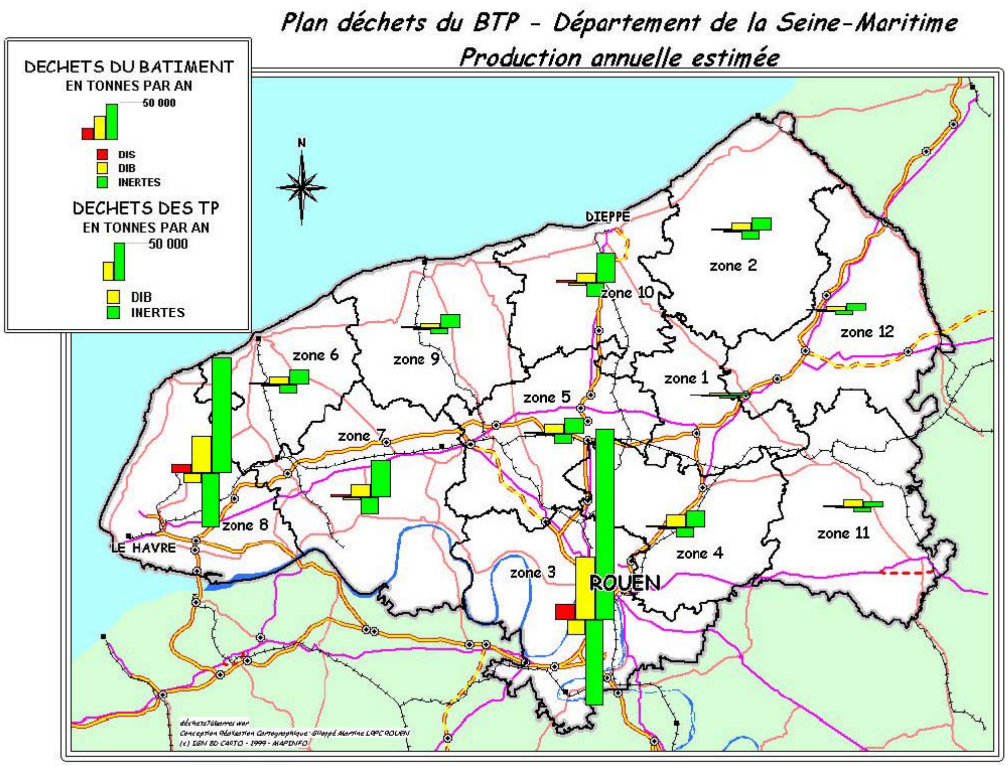
Rationale. The building and construction sector is the major consumer of materials and energy resources. In the industrialized world, building is estimated to account for some 40% of the total energy consumption and construction itself produces approximately 40% of all man-made waste. The transport of building materials is energy intensive and contributes to the burden on the traffic system. These facts are today receiving high attention. Techniques and methodologies for reuse and recycling of materials and building products are being developed. There exist a few good examples, both regionally and locally in different countries, of growing markets for reuse of materials and recycling.

Development of GIS based techniques for the modelling of amount, distribution and flow of materials in the built environment is, in this perspective, a priority area. Seeing the materials in the existing building stock as a presumptive resource for new and re-construction meets well the priorities of the Sustainable Construction approach. Objectives for this group is thus:

Objectives
• To promote the exploitation of the geographic information technology as a tool to model the amount, distribution and flow of building materials in the built environment.
• To explore the material data availability and data sharing possibilities for an efficient, effective, and economic use of digital geographic information for modelling and mapping materials (amounts, distribution, flow) on various geographic levels of the built environment
• To contribute to a unified approach to characterize the built environment as to the amount, distribution and flow of materials, with regard to boundary conditions such as resource availability, environmental impact, etc.

France addressed in their national progress report " The use of GIS as a tool for waste management", the TG2 area (Lair, 2003). The report first presented the main European and French regulations concerning waste classification and transportation, especially also the management of construction and demolition wastes, including the national plan for waste management. Its implementation would be strongly facilitated by extensive use of GIS, see Figure 3.

Figure 3 Use of GIS for buildings and construction waste management in France (Lair, 2003)



TG3: GIS- Spatial dynamic modelling of the interaction between the natural and the built Environment.

Rationale. Interaction of the environment with infrastructure is a complex process, involving a range of environment factors whose impact is very sensitive to spatial position and form. This is both the case with infrastructures reaction to severe events (flooding, cyclones, earthquakes etc) and to long term exposure to the "normal" climate. GIS offers a tool that can integrate together the data and models on the critical factors within the natural environment and the resulting response of the built environment to the natural. The data can then be presented in an elegant manner of use not just to scientists and researchers but to planners, maintainers and owners. This development of spatially sensitive models is advancing on a number of fronts in the research, planning and regulatory community.

International standards for service life planning of materials/components and buildings are being elaborated within ISO/TC59/SC14, and the first three standards in the ISO 15686 series "Service Life Planning of buildings" have been published (Sjöström et al, 2002). This standardised methodology encompasses prediction models, which rely on knowledge of performance-over-time functions (P-T), degradation mechanisms, dose-response functions, environmental exposure data, and prediction models.

For industry to respond to these standards and requirements a lot of data and knowledge in this field needs to be compiled or generated. The CIB W080/RILEM 140 PSL group is dealing extensively with these issues, acting as a R&D resource for the ISO work. Implementing these standards will also depend on the development of user-friendly ICT tools, supported by national information data-bases on environmental exposure, use factors etc., Reference Service Life, etc. Much of these data could be provided for through extensive co-operation with the meteorological and environmental research community, and by use of Geographical Information Systems (GIS).

In many parts of the world GIS-based air quality surveillance and planning systems, that also include modelling tools down to the micro-level, are being used to enable actions when environmental actions and limit values are violated (Haagenrud, 1997).

Full development of GIS as an integrating and modelling tool will be facilitated by devising protocols and preferred data bases that permit common access to wide variety of geographically sensitive information. This information may range from climate and pollutant information to landscape or hydrological data. Objectives for this group is thus:

Objectives
• To promote the exploitation of the geographic information technology as a tool to model the degradation environment to buildings and infrastructures
• To explore the environmental data availability and data sharing possibilities for an efficient, effective, and economic use of digital geographic information for modelling and mapping the degradation environment on various geographic levels.
• contributing to a unified approach to characterize the exposure of the built environment.

Examples of extensive use of GIS within the TG 3 field of work is quoted from the Australian report, as follows:

" While geographic information systems are widely used in Australia in assisting land-use planning and management (Trinidad and Marquez, 1998), they are also of increasing use in managing risk to infrastructure (Trinidad and Cole, 2000) and in transport design (Marquez et al, 2001). In most cases they are used primarily for information storage and retrieval, however, in some cases their capacity to integrate data and to make decisions based on this integrated data is being used in commercial settings.

In the research arena a much greater emphasis is placed on active use of GIS not only to integrate diverse data sources but also to transform data though manipulation within the GIS system (Trinidad, 1999). This is particularly notable in the GIS work within CSIRO on impact of severe events (Chan et al, 1998) and degradation of structures and materials (Trinidad and Cole, 2000, Trinidad et al, 2001)). CSIRO has developed GIS systems for predicting the impact (in terms of structural material and cost damage) of floods on housing (Chan et al, 1998), the variation on climatic, microclimatic and pollutant parameters affecting degradation around Australia, the lifetime of metal components in buildings including both fasteners and sheet or structural metal components, the life and degradation of timber structures (Cole et al, 1999) subject to both fungal decay and termite attack.

Perhaps the most sophisticated model is the one for predicting the life of metal components. This model is based on the holistic model of corrosion (Cole et al, 2003). It integrates models of marine aerosol production, transport and then deposition with models of surface response including surface wetting and cleaning with corrosion models. Of interest from a GIS perspective is the need to integrate and transform data. For example in terms of salt production The GIS system (Cole et al, 2002) requires an estimate of the salt production around the Australian coast (at points spaced at 5Km intervals) over 3 hour periods for typical years.

Salt may be produced both by ocean whitecaps and by breaking surf. Whitecaps are the foamed crest of ocean waves. The extent of white caps can be estimated from satellite data (in which case the GIS system is functioning as a data storage and retrieval device). However the salt production from surf depends not only on ocean condition (as defined by whitecap) as well as local winds, sea bed bathology and fetch. Fetch is the distance an ocean wave can travel without interruption. The GIS system is ideally suited to generate data on oceans bed bathology and fetch and then combine it with three- hour wind speed direction data to produce a 3 hourly estimate of salt production. Fetch is defined (at each coast point) for each of the eight principal wind direction by defining the distance of a vector drawn along each wind direction to the nearest land mass. Thus the GIS system combines a vector matrix (fetch) with temporal data base (wind data) and simple data (whitecap coverage) to estimate salt production. Similar integration of data sources is required for other modules of the corrosion model.

What this application illustrates is that GIS systems can be used to solve complicated problems involving a variety of data sources that could not be readily resolved by non-spatial systems.

As for cultural heritage management the UNESCO division for Asia and South Pacific has developed an impressive and wide ranging strategy for managing cultural resources in these regions based on GIS (http:\\ www.unescobkk.org).

TG4: Education on Geographical Information Systems and Information Sources.
Rationale

Rationale. TG4 is focused on Educational issues that look trailed behind especially because in Architecture and Civil Engineering Degree Courses GI and GIS are considered a matter for geographers. In our opinion it would be the same as to consider automated calculation and spread sheets a mathematician matter.

In several cases Academia itself has responsibilities. In High Education Courses design often seems to be not aware itself of the strategic importance of GI application in the Built Sector, and especially today, when sustainability issues are rising for Architecture and engineering design. Some of the strategies proposed are:

- State that GI is a basic information for analysis, design and evaluation of the Architecture and Civil Engineering projects in the 21st age
- Define the need of GIS and ITC, as these are the soft technologies and necessary tools for Architects and Engineering like the hard ones (steel, concrete, wood etc.)
- Define Education and training pathfinders to achieve a better awareness in usefulness of GI, ability in use GIS, and culture about Information importance and targeted creation from complex spatial data sets.
- Create a common language among the GIS Community and the Built Sector Community
- Direct no cost use of spatial data sets accumulated across Europe to create pilot
- Education interoperable applications (e.g. to be used for distance learning).
- Stress the importance to create a critical mass of investments, in term of direct EC grants, to support such action lines.

The TG4 is open to the participation of all interested parties and stakeholders both of Built sector and GI world and it will organise an internet discussion list to gather participants subscription and comments in real time. The TG4 expected results look forward to achieve a broad participation also within of European initiatives and programmes, being able to help the process of Education evolution in the Built Sector. Objectives for this group is thus:

Objectives

- Education requirements for GIS use by Architects and Engineering.
- Courses planning presenting the GIS as a technology for the architectural design process.
- The glossary representing the common language among the GIS Community and the Built Sector Community.
- The list of the info sources of free spatial data sets location accumulated across Europe.
- The methodology to create some pilot Education interoperable applications (e.g. for distance learning).

One example of courses aimed to develop both the cultural aspects of GI impact on the design process as well as the technical aspect of the GIS use is the pilot course titled "Assessment techniques for Built Environment" (www.dpmpe.unifi.it/histocity/esposito/mae_courses.html) started since 2000 at the Faculty of Architecture of the University of Florence. The course's aim is to teach advanced techniques needed to integrate GIS technologies in the design process (Esposito, 2003).

The target of the built environment assessment techniques is to supply both methodologies and effective management techniques to support decisions in all different phases of the design process seen as analysis, planning, design specification, management, exploitation and control chain of the built asset. It may be applied to the public and private asset both in the civil and infrastructures sector and also it may be used in the historical asset (e.g. historical building, public spaces like squares, historical parks, river sides as well) management.

Scope of such techniques based on advanced Information System is to draw scenarios of the built environment that, in general, also includes several aspects like as the environmental ones as well the socio-economic variables, the cultural variables that characterises a specific project site. Such a scenario also allows the quality, quantity and reliability of Information handling in the design decision process also accordingly both with user (the designers) requirements and methods (e.g. graphic interfaces and reporting capability) shared in the European Union territory.
The Course presents the following issues:

- Rationale of the problem confronted with the post-industrial design era.
- Reference documents and Projects at European level and norms in Italy.
- The economic value of Information.
- Decision theory applied to the design process.
- IT standard glossary (ISO).
- Methods and techniques.
- The entity/relationship model and the relational data bases.
- Available Information and Technology supports.
- Spatial Data.
- Training to GIS in practice.
- Strong and weak points of such kind IT based supports utilisation in the design process.

On the other hand actions to be taken at European level regard both join to INSPIRE and ESDI initiatives as user group and on the other hand start a lobbying action to aware the EC on the need to support our effort in Education in the 6th Framework Programme calls. A way to be verified by CIB W106 is the Marie Curie Programme opportunities until 2006.

4 CONCLUSIONS

- The world of geographic information and application orientation is moving extremely fast, driven by fast emerging National Spatial Data Infrastructures (NSDI) in almost all countries and regions, and the rapidly developing infrastructure for telecommunication. There is a real danger the slow uptake of technology and applications in the building sector will again leave the sector trailing behind, also implying a loss in sustainable development and competitive edge.
- Thus CIB established CIB W106 with the objectives to provide an international platform for R&D of GIS applications for the built environment, and to promote and encourage the use of GIS in the building sector. In order to facilitate this, and at the same encouraging a widest possible, global participation, W106 aims to produce reports on existing or completed GIS based projects in four topic areas of utmost importance to the building sector.

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http://www.fgdc.gov/framework/frameworkintroguide/overview.html
Global Mapping: http://www1.gsi-mc.go.jp/iscgm-sec
ISO/TC211. http://www.statkart.no/isotc211
http://www.opengis.org

http://www.ec-gis.org
http://www.ec-gis.org/inspire/
http://www.unescobkk.org

European Community research on information technology related sites:

- http://www.cordis.lu/tmr/src/res970265.htm
- http://inspire.jrc.it/
- http://www.ec-gis.org:8080/wecgis/ecgis.dyn_wec_home.show
- http://www.civitas-initiative.org/civitas/html/about_projects.htm
- http://www.ec-gis.org/egip/
- http://europa.eu.int/comm/europeaid/projects/asia-urbs/index_en.htm
- http://www.ec-gis.org/ginie/
- http://europa.eu.int/comm/education/index_en.html
- http://europa.eu.int/comm/research/era/pdf/benchmarking2002_en.pdf
- http://europa.eu.int/information_society/istevent/2003/networking/index_en.htm
- http://europa.eu.int/comm/education/programmes/eu-usa/usa_en.html
- http://www.pvl.at/

GIS conferences related sites:

- http://www.urisa.org/2003AnnualConference/Program/mainprogram.htm#Program%20Tracks
- http://gsdi.org/GSDI7/Gsdi7FirstAnnouncementFinal.pdf

GI_GIS Education:

- http://web.taed.unifi.it/esposito/Cdl_Arch_03-04/Esposito-%20Tecniche%20di%20valutazione%20AC-0304.htm
- http://sit.iuav.it/