Sustainability of Constructions
Integrated Approach to Life-time Structural Engineering

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ABSTRACT: The main objective of the COST Action C25 "Sustainability of Constructions: Integrated Approach to Life-time Structural Engineering" is to promote science-based developments in sustainable construction in Europe through the collection and collaborative analysis of scientific results concerning life-time structural engineering and especially integration of environmental assessment methods and tools of structural engineering.

1 INTRODUCTION TO COST ACTION C25 – SUSTAINABILITY OF CONSTRUCTIONS

1.1 *Aims and objectives*

The Action C25 aims to promote a scientific understanding of life-time engineering and to boost science-based advancement of sustainable construction in Europe.

The Action is focused on an integrated approach to deal with the end-products of construction, clearly targeted at the development of R&D and engineering methods from structural points of view. It aims at providing the construction sector with a new framework and ideas based on the integration of approaches and results of ongoing research and development projects.

The Action establish a broad network of European universities and other research centres in the field of structural engineering in order to transfer the state-of-the-art of technologies, design methods and practices through the existing and new links of members of the Action in several international organisations.

The Action involves collaborative analysis of results concerning design and assessment methods and tools, advanced materials and technologies as well as construction processes, both for new constructions and the rehabilitation of the existing ones.

1.2 *Background*

The urban and natural environments are inseparably linked. Energy, materials, water and land are all consumed in the construction and operation of buildings and infrastructure to such an extent that sustainable development can be said to decisively depend on the built environment. The urban environment itself influences our living conditions, social well-being and health. The European Commission has adopted a thematic strategy on the urban environment; one of the four priority themes is sustainable construction. All themes are cross-cutting in nature and have strong links with many environmental issues.

Environmental, socio-economic and cultural issues in the construction sector are characterised by their complexity, the diversity of actors concerned and the need for innovative and multidisciplinary solutions. As the largest and most fragmented industry, the sector faces huge chal-

lenges in the pursuit of sustainability.

Enhanced sustainability can be met only through innovations in technologies. Technological progress is both a global super-trend and a super-force that promotes economic growth, improvement of health and the increase of mobility but also the decline of the environment. Science-based development is essential for transforming the potential of the enabling technologies into practice. The information and communication technology, biotechnology and advanced industrial materials represent an opportunity to move towards more sustainable construction processes and products.

Innovations in construction to cope with sustainability demands require knowledge on technology foresight and industrial product development methods, and also tools to assess and manage the evolution. Fundamental changes in construction technologies and design practices concern the whole sector and various stakeholders. The role of universities and other research organisations is crucial in establishing excellence in sustainable construction. Structural engineering is beginning to develop an integrated design approach in which advanced tools are used to analyse and verify the various performance aspects and sustainability demands. Performance characteristics and the structural quality of buildings are of fundamental importance to urban sustainability as well as to environmental sustainability.

1.3 *State-of-the-art*

The first steps on developing a method for assessing a product's environmental impacts were taken in the late 1960s. The first methods to assess environmental impacts of a product considering a life-cycle approach were undertaken in the beginning of the 1970s; however practical applications did not begin until the 1990s.

The need for standardisation in environmental reporting became clear by the end of the 1980s, when environmental reports on similar products often contained conflicting results because they were based on different methods, data and terminology. This resulted in the first international formulation of a Code of Practice for Life-cycle Assessment (LCA), under the umbrella of the Society of Environmental Toxicology and Chemistry (SETAC). Starting in 1990, SETAC took the lead in LCA development.

Since 1993, the International Standards Organization (ISO) is also working to establish a uniform framework, uniform methods and procedures, and a uniform terminology for LCA. These efforts produced a series of international standards for environmental performance analysis and management – the ISO standards series 14040.

In 1995, the International Council for Research and Innovation in Building and Construction (CIB) decided to make sustainable construction the focal point of the three-year period up to the 1998 World Building Congress. In 1999 the *Agenda 21 on Sustainable Construction* was published (Report Publication 237) in order to create a consensus-based framework and to give a detailed overview of the concepts, issues and challenges of sustainable development and sustainable construction, and posed certain challenges to the construction industry.

Researchers and practitioners together have been developing environmental assessment and classification systems for buildings in some European countries (Finland, France, Germany, Norway, Sweden and the United Kingdom,). These tools provide a wide coverage of environmental, economic and building performance issues that are deemed to be relevant to sustainability. In the USA, the Green Building Council developed the tool "Leadership in Energy and Environmental Design (LEED™) Green Building Rating System" which is a first step towards the certification of "green buildings".

In Europe, the United Nations Environmental Programme is promoting the implementation of life-cycle management tools in its programmes in order to provide the world community with improved access to meaningful environmental data and information, and to increase the capacity of governments to use environmental information for decision making and action planning for sustainable human development.

Today, knowledge of how to carry out a life-cycle analysis is improving rapidly. The value of the technique is being increasingly recognised and it is now being used for strategic decision making and for designing environmental policies.

Recently, new models for integrated life-cycle design have been developed and proposed with the aim of combining all the different aspects of sustainability in the same analysis.

1.4 *Raising the level of Sustainable Construction*

The environmental aspects of sustainable construction consider the use of resources and the harm caused to ecosystems. Construction activities consume as much as half of all resources taken from the Earth, a value higher than for any other industrial sector. The construction, operation and subsequent demolition of built facilities accounts for about 40-45% of all energy end use. Consumption levels of energy per square metre and per person are increasing. The built environment moreover, accounts for about 40% of world greenhouse gas emissions.

Sustainable construction ensures a more economical use of finite raw materials and reduces and above all prevents the accumulation of pollutants and waste. The complete cycle of sustainable construction activities comprises the way in which built structures and facilities are procured and erected, used and operated, maintained and repaired, modernised and rehabilitated, and finally dismantled and demolished or reused and recycled. Compared with other industrial products, construction products are long lasting. This fact emphasises the need to incorporate methods of life-time engineering in the first stages of product development or a building project.

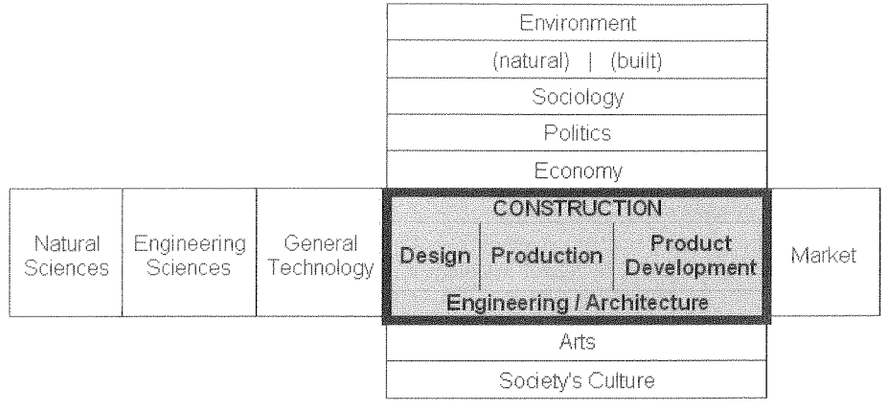


Figure 1. Development environment of construction technology.

Environmental assessment methods and tools involve the development and application of various assessment approaches and management tools. Assessment of environmental impacts over the life-time of built facilities as well as estimates of life-cycle costs should be made available for clients before construction work begins. Extensive research and development in order to establish reliable and unanimous methods is ongoing worldwide. In the future, architects and consulting engineers should be motivated, to take environmental aspects into more detailed consideration in their designs, especially LCA and LCC methodologies Therefore there is an urgent need for clear and practical guidance on these methodologies to make them feasible. The different methods should be integrated with other tools such as quantity surveying or energy simulation. Methods for service-life design need to be combined with structural design. Tools for these must be developed and integrated with each other in order to simplify evaluations. For the manufacturers of building products, the verification methods for durability of construction products are an essential part of verification of the overall performance.

Life-time engineering aims to translate the requirements of all the actors involved (owners, users and society) into performance requirements of the technical systems and ensures that those requirements will be fulfilled over the entire design service-life. Life-time design or integrated life-cycle design implies a new thinking about current design methodologies and it is highly dependent on aspects such as durability, maintenance and service life prediction.

New materials, products and technologies are in the long term the necessary way to reduce environmental impacts. Construction products play a major role in improving the eco-efficiency of buildings. Radical innovations are needed for a real change towards sustainability. Application of developments in other industrial branches can also be regarded as a significant potential, and it will generate new construction products and re-engineering of the processes. Construc-

tion products need to be viewed in terms of functional units, how they perform throughout the life-time of a built facility and what happens to them when deconstruction or demolition takes place. Focusing on integrated and holistic research is necessary as the associated problems are interrelated and wide. Further, a single building may consist of tens of basic materials and thousands of separate products. The challenge is how to measure and manage the impact of construction products. Generic performance-based design and product development technologies offer tools for management of research and development work.

Reuse and recycling of materials and components achieve a rate of over 80% in some OECD countries, but it should be noted that much of the material is used in a low value-added form. Increasing the use of recycled waste as building materials is one of the steps to positively address the environmental impacts.

Environmental management of a construction project for a new building or for a renovation project incorporates an integrated and performance-based approach for management of the overall functional properties of a facility. There is a need to develop methods to integrate environmental and fiscal analyses that take into account the different phases of the life-cycle.

Energy-efficiency in buildings is the most environmentally benign way to improve eco-efficiency of construction. From the viewpoint of EU policy, it is one of the three key issues identified as an area of necessary action. The influence of the EU Energy Performance of Buildings Directive (EPBD) is expected to grow more and more. Technical systems and envelopes of the existing building stock are especially critical. From a product-related point of view the actions include designing and selling more energy-efficient products that use fewer or new or different materials with an equivalent or superior performance. Improvement of energy efficiency also brings several benefits for urban sustainability.

1.5 *Relationship with other COST Actions*

The impetus for this COST Action resulted from the work within COST C12 "Improvement of Buildings' Structural Quality by New Technologies", where the need to create a specific Action on sustainability of constructions emerged. The Action C25 has also some complementary objectives to the COST Action C16 "Improving the Quality of Existing Urban Building Envelopes". The relevant results achieved in C16 are taken into consideration as a base of knowledge and, to some extent, have been further developed within C25.

Additionally, there are also a few complementary objectives with the COST Actions C23 "Strategies for a Low Carbon Urban Built Environment" and C24 "COSTeXergy". The main objectives of these two Actions are focused on the direct or indirect energy impacts of infrastructure developments on energy issues.

This Sustainability of Constructions Action does not focus its research work on energy issues. However, the integrated approach to life-time structural engineering needs to take into account energy-related issues such as building energy performance and building energy saving as well as the thermal comfort in buildings. In order to avoid overlapping activities and to coordinate the cooperation of complementary activities with C23 and C24 Actions, close contacts with COST Actions C23 and C24 have been established, particularly regarding the coordination of complementary activities, avoiding overlaps and fostering synergies.

Sustainability of Constructions has a broad scope, that can be divided into two main dimensions: Structural Life-time (where the main focus is on the construction itself, taking into account, in an integrated way, the environmental, economic and social life-cycle impacts of the structure), and Energy Efficiency of the Construction (where the energy consumption due to occupancy by people is the main focus), as illustrated in Figure 2.

This Action is focused on an integrated approach to deal with the end-products of construction, clearly targeted at development of methods and practices of life-time engineering from a structural engineering point of view. It aims to provide the construction sector with a new framework and ideas based on the integration of approaches and results from a diversity of ongoing research and development projects. It also aims at improved interaction between different disciplines such as the development of assessment methods and energy-efficiency of technical service systems.

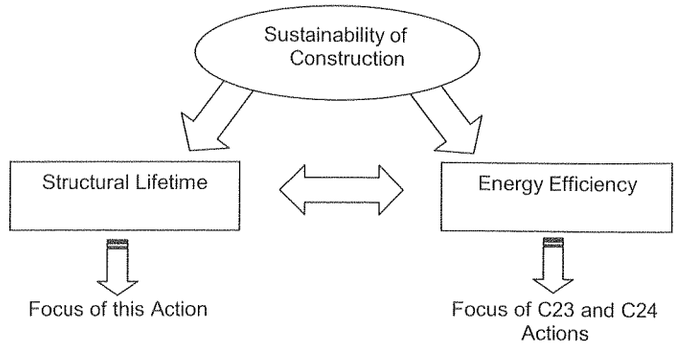


Figure 2. Different approaches to Sustainability of Constructions.

2 SCIENTIFIC PROGRAMME AND WORK PLAN

2.1 *Scientific programme*

The Action C25 focuses on integrated approaches to develop methods and technologies for sustainable construction. To achieve this objective, the following major areas are identified:

- criteria for sustainable constructions (global methodologies, assessment methods, global models and databases);
- eco-efficiency (eco-efficient use of natural resources in construction (materials, products and processes);
- life-time structural engineering (design for durability, life-cycle performance, including maintenance and deconstruction).

Given the complexity and the nature of the topic, where meaningful results can be obtained only if all aspects are adequately covered, the methodology to carry out the Action and achieve a coordinated outcome is a **case-study approach**. The case-studies that will be continuously reassessed throughout the Action will be increasingly complex (from essentially bare structures such as a bridge to complex buildings including structural parts, non-structural parts and equipment) and to allow for a clear identification of all relevant aspects.

By the aid of case-studies, the current technologies and methodologies will be compared and initiatives for further developments will be established as collaborative efforts. The achievements of standardisation and administration will be incorporated in order to

- provide a rational and integrated framework for the seamless application of the new ISO/CEN series of standards on Sustainability of Constructions (ISO TC 59 SC17 and CEN TC 350);
- integrate the essential requirements from the European Construction Products Directive (89/106/EEC): ER1, mechanical resistance and stability; ER2, safety in case of fire; ER3, hygiene, health and the environment; ER4, safety in use; ER5, protection against noise; ER6, energy economy and heat retention in the global methodology for sustainability of constructions;
- provide technical guidance on the application of the European Directive on Energy Performance of Buildings and the forthcoming need to fulfil an Environmental Declaration of Building Products.

2.2 *Work plan*

The Action consists of several work packages in order to cover all the important aspects of sustainable construction. The Action focuses are the environmental issues related to constructions and the overall sustainability of the built environment. A more detailed description of the tasks involved is presented in Table 1. Each task will result in a clear outcome in the form of state-of-the-art, report, guidelines, case-study publication, datasheets and/or Website content.

Table 1. Tasks involved in Action C25.

WP#	Description of the contents	Deliverables
WP1	**Global methodology for the assessment of Sustainable Design and Construction:** ➢ Review of standards and literature on lifetime engineering, ➢ Identification of EU policy drivers and directives regarding life cycle thinking; ➢ Links to other lifetime projects (LIFETIME, LIFECON, etc); ➢ Review of current methodologies in participating countries; ➢ Implementation of a global life cycle approach.	State-of-the-art of global methodologies Guidelines for a global approach
WP2	**State-of-the-art on LCA and LCC methodologies:** ➢ Review of standards and literature on LCC & LCA; ➢ Identification of LCC methodologies and case studies in participating countries and others; ➢ Identification of LCA methodologies and case studies in participating countries and others ➢ Adaptation of a LCA and LCC methodology for the case studies	State-of-the-art of LCA & LCC, with references to previous documents Guidelines to perform a LCA according to the implemented methodology Guidelines to perform a LCC according to the implemented methodology
WP3	**Databases for LCA and LCC:** ➢ Collection of information on databases of LCI and LCC for construction materials, construction products and processes; ➢ Assessment of existing data and criteria; ➢ Links to other databases; ➢ Guidelines for the creation of a global database.	Datasheets of current databases for LCI and LCC Links to other selected databases Guidelines for a global database
WP4	**Application of the global methodology to several case-studies:** ➢ Contribution to the general Case-study	Case-study publication on implementation of methodologies; e.g. to a bridge
WP5	**Application of new materials and new technology:** ➢ Evaluation of existing and new functional materials; (structure-structural issues) ➢ Introduction of new construction products and technologies to comply with decrease of material use, decrease of waste, decrease of emissions and energy saving goals.	Reports and datasheets on new materials Reports and datasheets on new technologies
WP6	**Improvement of the global performance of constructions: (envelope-construction)** ➢ Techniques for the improvement of the environmental performance of buildings and infrastructures; ➢ Techniques for the improvement of the comfort in buildings (thermal, acoustic, lighting and quality of air); ➢ Maximization of the energy performance and the integration of innovative systems in buildings (mechanical, electrical and automation); ➢ Maximization of water resources.	Guidelines for the creation of an healthy indoor environment Guidelines for improvement of the comfort in buildings Guidelines for energy efficiency Guidelines for the optimisation of water management Guidelines for the use of alternative energies
WP7	**Analysis of functional materials and new technologies – case-study:** ➢ Contribution to the general Case-study	Case-study publication, with recommendations and guidelines
WP8	**Life-cycle performance:** ➢ Literature review of current methodologies; ➢ Verification methods for durability of constructions; ➢ Deterministic and probabilistic degradation models (corrosion, fatigue…); ➢ Probabilistic prediction of the service life of a structure; ➢ Risk and reliability analysis.	State-of-the-art report on deterministic and probabilistic degradation models
WP9	**Monitoring of life-cycle performance:** ➢ Maintenance, repair and rehabilitation techniques and planning; ➢ Survey and condition assessment of structures (safety and functionality); ➢ Demolition and deconstruction techniques and planning.	Guidelines for the planning of Maintenance, Repair and Rehabilitation Guidelines survey and condition assessment of structures Guidelines for deconstruction
WP10	**Analysis of life-cycle structural performance – case-study:** ➢ Contribution to the general Case-study	Case-study publication (technologies, evaluation methods, recommendations, basics for guidelines)
	Conclusion of the global methodology for the assessment of Sustainable Design and Construction: ➢ Sustainable construction assessment and classification systems	Guidelines for Global Sustainable Construction Compilation of case-studies performed during the action in different working groups Detailed description of global case studies

2.3 *Organisation of the work*

The development of the Action need the involvement of experts from a variety of disciplines related to the construction sector. Luckily most of the expertises could be found in the delegates nominated by the participating countries.

In accordance with the scientific programme stated in the Memorandum of Understanding, the following three Working Groups were created to cover the three main areas of the Action:

WG1 – Criteria for Sustainable Constructions (global methodologies, assessment methods, global models and databases)

WG2 – Eco-efficiency (eco-efficient use of natural resources in construction - materials, products and processes)

WG3 – Life-time structural engineering (design for durability, life-cycle performance, including maintenance and deconstruction)

Table 2 illustrates the subdivision of tasks between the three Working Groups.

Table 2. Work packages undertaken by each Working Group.

Work Packages	WG1	WG2	WG3
WP1	x		
WP2	x		
WP3	x		
WP4	x	x	x
WP5		x	
WP6		x	
WP7	x	x	x
WP8			x
WP9			x
WP10	x	x	x

In order to achieve a good coordination between the three Working Groups, almost all the Action meetings have parallel Working Group meetings and a plenary meeting where all participants meet and report on the progress of the various tasks. On the other hand, this large participation requires more co-ordination activities, and this issue has been taken care of by organizing Core Group of the Chairs and Vice-Chairs and Website holder meetings. These meetings, where the developments of work plans are prepared an analysed by the Core Group, have helped to conduct the Working Group and Management Committee meetings in an efficient way.

Besides the standard structure of the Management Committee and Working Groups, the organisation of C25 includes:

- coordinators for case-studies
- ad hoc working groups, which are appointed by the MC for specific tasks
- organising committees for the workshops
- organising committee for the mid-term seminar
- an organising committee for the final conference
- an editorial group for the final report
- a scheme of short-term scientific missions (STSMs) between the participating countries, coordinated by the Core Group.

3 RESULTS ACHIEVED BY COST ACTION C25

3.1 *Involvement of the researchers in C25*

There are 28 countries and one EU Joint Research Centre involved in C25: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Rep., Denmark, Finland, Macedonia, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Sweden, Switzerland, Turkey and United Kingdom. From the 35 COST Countries only Estonia, France, Iceland, Ireland, Israel, Slovakia and Spain do not participate in C25.

Twenty countries joined C25 during the start year, in 2006. During 2007, more six countries joined: Croatia, Macedonia, Luxembourg, Malta, Serbia, and Turkey. In 2009 there were two requests, from Switzerland and Bulgaria, which were approved by the Management Committee.

Since the beginning of the Action, the total number of individuals that participated in the Action work was 128, being:

- 108 members that participate regularly
- 32 females, corresponding to 30% of the members
- 31 Early Stage Researchers, corresponding to 29% of the members
- 32 Invited Experts that participated in at least one meeting

Since the very beginning there were good signs of the involvement and participation of the members in the Action. A competition for the selection of the "C25 Logo" took place in the first year and the good results obtained, where 27 different proposals were submitted, pointed out the commitment, vitality and closeness of a group of people coming from different regions with different cultures and approaches that wish to have a symbol to brand their involvement in the Action.

The involvement of the researchers in C25 is not only due to the Management Committee members but also Early Stage Researchers are actively participating in the meetings, work packages, collaborative works and in the production of the deliverables.

Early Stage Researchers are also invited to participate actively in Short-Term Scientific Missions (STSMs) recommended and selected by the Management Committee. This way, they can contribute to the achievement of the scientific objectives of the Action and promote networking within the participating countries and institutions. The STSMs are used as an instrument to ensure in-depth technical cooperation in the development of the various tasks. In order to ensure the success of this instrument the Core Group evaluates the STSM proposals and the outcomes of the completed Short-Term Scientific Missions. So far, eight Short-Term Scientific Missions took place. There are 2 other that are approved by the MC but not yet taken place and 5 are still under preparation.

In the context of the Action a competition among students for the design of an Office Building according to the aims of Sustainable Construction was approved by the MC in 2007, and was concluded successfully in May 2009. This competition was initially started by the Working Group 1; however it has been taken over and brought forward by many other COST C25 members. The competition has contributed to a greater awareness about the main topics of the C25 action and increased the interest of young students and researchers in the fields of integrated life cycle design of sustainable constructions. This competition provided an opportunity for students to demonstrate their sustainability design skills in an international competition against their peers. Design programs in universities around Europe were encouraged to participate in this competition and to consider it into their academic curriculum for interested students. Early Stage Researchers also had actively participated in the "Student Competition" organized by COST C25. About 40 students expressed their interest in participating in. At the end 23 students belonging to 8 teams submitted their projects. The 3 first prizes offered by the Association of Architects of Naples were awarded to 4 teams (2 teams in the 3rd place ex aequo) during the C25 Naples Symposium (11-12 May 2009).

The competition was very successful in attracting a big number of student groups to participate and it has further enlarged the awareness about the COST C25 topics at the universities and at the student's level and brought extra publicity of the C25 activities.

Another good indicator of the involvement of the researchers is the participation of members in the C25 case-studies. The complexity of the topic "sustainability of constructions" and the holistic approach needed to deal with it stimulated the members in concentrate efforts in seven case-studies. For "Bridges" there three on going case-studies:

- Integral abutment bridge
- Three-span motorway viaduct
- Existing 30 years old bridge

and four on going case-studies for "Buildings":

- Light steel frame residential building
- Concrete structure multifamily house
- SPEAR Building
- Virtual Office building.

These case-studies are being continuously reassessed throughout the Action and the complexity is being increased from essentially bare structures such as simple bridges to complex buildings including structural parts, non-structural parts and equipment and to allow for a clear identification of all relevant aspects.

For each case-study, a coordinator was nominated by the working group. The case-study coordinators are in charge of:

- establishing the appropriate structural applications
- providing information to the participants
- proposing a programme of the activities to the Management Committee
- collection of task forces for specific duties
- follow-up of the activities in the Working Groups
- reporting to the Management Committee and
- organising workshops together with the WG Chairs.

3.2 *Key scientific and technical outcomes*

The Action C25 developed an innovative networking aiming to promote a scientific understanding of life-time engineering and to boost science-based advancement of sustainable construction in Europe. The combination of expertises and research fields has resulted to new research and educational strategies and new mixed research methods to understand interaction of users, society and technologies. Some specific examples of innovative knowledge resulting from the networking through the Action are:

- Integration of LCA in sustainability rating methodologies
- Recognition of LCA as an integral part of structural engineering
- Integration of degradation models in methods of lifetime engineering
- Finding weighting methods for global assessment
- Development of recycled construction materials

In this context, significant scientific breakthroughs were achieved and for the first time there

is a methodology to assess sustainability of bridges and guidelines on how to perform life-cycle analysis in construction projects (both bridges and buildings). Science based approaches (modelling and simulation) to lifetime engineering including maintenance scenarios are also bring developed as part of the COST Action.

Other important "Key outcomes" are also the socio-economic impacts achieved so far. Many members of C25 are now regarded as frontrunners in the particular field of expertise of "Sustainable Construction". Local authorities like e.g. the city of Eindhoven (NL) and the city of Espoo (FI) are asking advices about sustainability of constructions to local C25 members. Other members are being asked to join advisory panels of EU FP7 Projects.

National assessment and rating systems like e.g. in PT, FI, UK and DE are integrating methods of lifetime engineering and some C25 members are being invited to participate EU's Enterprise Construction LCA Workshops.

Some other tangible positive impact is the participation of "New Member States" and "Candidate States" in the harmonization process and knowledge transfer, through the participation of several new C25 members in the European networks. Another example is the 1st National Conference on Sustainable Civil Engineering in Belgrade on 4-5 June 2009, organised by the Faculty of Civil Engineering of University of Belgrade and the Faculty of Technical Sciences of University of Novi Sad, which helped to disseminate the C25 scientific and technical outcomes.

In the medium term it is expected the uptake of advanced science-based methods and tools in everyday design processes (bridges and buildings), like e.g. assessment method of flexibility/adaptability to be used building design process. Also several members are planning new educational courses and programmes in their universities that will bring environmentally literate workforce to companies and society.

3.3 *Spin off of new projects*

Almost all the members have their own projects that support the research activity that is needed to carry to contribute to C25. Nevertheless, C25 also helped in creating new networks and stimulated the capacity of the Action members to raise research funds.

As an example, the following lists show the efforts of C25 members in the spin off of new projects.

EC RTD Framework Programme proposals/projects:

- FP7 2007: Proposal ProSEED - Processes and Technologies for Energy Efficient and Sustainable Construction (C25 participants: VTT – FI, U of Luleå – SE, U of Coimbra – PT, U of Timisoara – RO, Aristotle U of Thessaloniki – GR, U of Ljubljana – SI, U of Liege – BE, U of Stuttgart – DE and U of Minho – PT)
- RFCS 2008: Project SBRI - Sustainable Steel-Composite Bridges in Built Environment (C25 participants: University of Stuttgart – DE, University of Coimbra – PT and Arcelor-Mittal S.A. – LU)
- FP7 2008: Coordination Action PERFECTION - Performance Indicators for Health, Comfort and Safety of the Indoor Environment (C25 participants: VTT – FI and TU Prague – CZ. C25 members of expert panel: U of Ljubljana – SI, U of Karlsruhe – DE and U. of Minho – PT)
- ERASMUS MUNDUS 2009-2013: EMJD, Joint doctorate programme, Proposal for a doctorate course in sustainable steel constructions (C25 participants: University of Coimbra – PT, Lulea University of Technology – SE, "Politehnica" University of Timisoara – RO, University of Stuttgart – DE, University of Naples Federico II – IT)
- FP7 2009: Project OPEN HOUSE- Benchmarking and mainstreaming building sustainability in the EU based on transparency and openness (open source and availability) from model to implementation (C25 participants: University of Ljubljana – SI. C25 members of expert panel: VTT – FI, University of Naples – IT, Aalborg University – DK and University of Minho – PT)
- RFCS 2009: Proposal SB_Steel - Conceptual decision making tool for a sustainable steel framed building (C25 participants: VTT – FI, U of Coimbra – PT, Aristotle U of Thessaloniki – GR and U of Minho – PT)

National Programme proposals/projects:

- 31042/2007 PNCDI2 – PROACTEX. Structural systems and innovative technologies for protection of buildings under extreme actions taking into account sustainable design criteria. ("Politehnica" University of Timisoara – RO)
- Joint Nordic Call 2008: Methods and Concepts for Sustainable Renovation (VTT – FI)
- FI 2008: Adopting new processes for sustainable building and built environment (VTT)
- Serbia 2008: Project Recycled Aggregate Concrete Technology Properties and Application in Reinforced Concrete Structures (C25 participants: Faculty of Civil Engineering of University of Belgrade and the Faculty of Technical Sciences of University of Novi Sad)
- SE 2009: Project Application on Integral abutment bridges (C25 participants: University of Luleå)
- FORGIARE Project; Proposal for a post-doc grant in the field of sustainability of construction (C25 Participants: University of Naples – IT)
- FUTURO IN RICERCA 2009 call. Proposal for a national funding programme devoted to sustainability of constructions. "Methods and criteria for the decision making in sustainable seismic protection of constructions" (C25 participants: University of Naples – IT)
- FCT-PT 2010: Proposal INNOVCOMP - Innovative and sustainable floor and wall systems for light steel residential buildings (C25 participants: University of Coimbra – PT and University of Minho – PT)
- FCT-PT 2010: Proposal SSB2All - Sustainable Steel Building Affordable to All (C25 participants: University of Coimbra – PT and University of Minho – PT)
- SE 2010: Climate and environmentally related life cycle modelling and optimized structural design of sustainable civil and building structures SELCO (C25 participants: University of Luleå)

4 DISSEMINATION OF RESULTS

4.1 *Conferences and workshops*

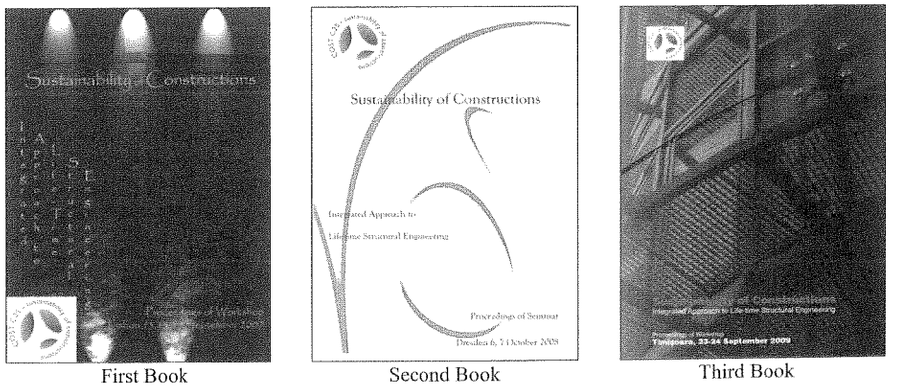
The outcome of the work developed during the first three years of activity of the Action was, respectively, disseminated in three major events, one in each year.

The first event was the 1st Workshop of C25 on "Sustainability of Constructions" that took place in Lisbon, Portugal, on 13, 14 and 15 September 2007.

The second event was the Seminar on Sustainability of Constructions that took place in Dresden, Germany, on 6-7 October 2008.

The third event was the International Workshop on Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering that took place in Timisoara, Romania, on 23-24 October 2009.

The Seminar and the two Workshops main topics covered a wide range of up-to-date issues and the contributions received from the delegates reflect critical research and the best available practices in the Sustainable Construction and Life-time Structural Engineering fields. Due to the efforts and commitment of C25 members, three books could already be published. Figure 3 shows the front covers of the three books.



First Book Second Book Third Book

Figure 3. Front covers of the three C25 books.

The full references of the C25 books are the following:

- L. Bragança, H. Koukkari, R. Blok, H. Gervásio, M. Veljkovic, Z. Plewako, R. Landolfo, V. Ungureanu, L.S. Silva, (eds). Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering. Proceedings of the First Workshop. Lisbon, Portugal. September 2007. 41 papers; 328 pages; ISBN: 978-989-20-0787-8.
- L. Bragança, H. Koukkari, R. Blok, H. Gervásio, M. Veljkovic, Z. Plewako, R. Landolfo, V. Ungureanu, L.S. Silva, P. Haller (eds). Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering. Proceedings of the Seminar. Dresden, Germany. October 2008. 55 papers; 436 pages; ISBN 978-3-86780-094-5.
- L. Bragança, H. Koukkari, R. Blok, H. Gervásio, M. Veljkovic, Z. Plewako, R. Landolfo, V. Ungureanu, L.S. Silva, (eds). Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering. Proceedings of the International Workshop. Timisoara, Romania. October 2009. 38 papers; 390 pages; ISBN: 978-973-638-428-8.

The Final Conference of C25 will take place in Innsbruk, Austria, on 03-05 February 2011. It will be organised as an open international conference and it is expected to gather about 200-250 people interested in learning and sharing knowledge in Life-time Structural Engineering.

4.2 *Action related publications*

Considering the originality and the high level of the work done so far in the Action, contacts with editors of international journals were established in order to publish and disseminate a selection of results achieved by C25.

The MDPI Journals on Environmental Issues of Built Environment agreed to publish a Special Issue on "Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering" of the International Journal "Sustainability" a selection of the papers from C25 members in 2010:

http://www.mdpi.com/journal/sustainability/special_issues/sustainability-constructions

4.3 *Training Schools*

Some of the good results achieved by the Action were already disseminated and brought to use due to the Training Schools organised by C25. So far, two very successful Training Schools were organised; the first one was "The LCA Training School" that was organised for 16 participants in Eindhoven, Netherlands, on 13-15 February 2008. The participants were mainly Early Stage Researchers from C25.

The second Training School "Sustainability in structures and structural interventions: Improving the contemporary and historical urban habitat constructions within a sustainability and risk assessment framework" was held in Thessaloniki, Greece, on 17-24 May 2009. It was jointly organised by C25 and C26 and the number of Early Stage Researchers was 40, from these two Actions.

A third Training School is being organised under the theme "Sustainability in Engineering: A Life Cycle Approach in Structural Engineering". The aim of the International School is to address Sustainability in Engineering, and the Life Cycle Approach in Structural Engineering. The Training School is intended for Early Stage Researchers and PhD students. An international group of lecturers and experts in this field was selected for the preparation of the Programme and a group was selected to deliver lectures during the duration of the School. The scientific content of the School was prepared with the support of experts from COST Action C25. The Training School is hosted by the Department of Building & Civil Engineering of the University of Malta and offers various opportunities for collaboration among the researchers taking part. It will also serve as an important forum for the development of new ideas in the emerging field of Life Cycle Analysis in construction.

4.4 *Website*

The website of C25 was established in the beginning of 2007 and since then has been continuously updated in order to be easy to navigate and provide useful information for C25 Members and Non-members. The website contains the information that has been produced by members of the Action and turns it publicly available to other interested stakeholders. It includes the sections:

- Introduction to the aims and objectives of the Action "Sustainability of Constructions: Integrated Approach to Life-time Structural Engineering" and the Memorandum of Understanding;
- Management Committee and Working Groups, including Lists of Members, Meeting Agendas and Minutes, Presentations given in all meeting and additional documents;
- Case Studies descriptions;
- Student Competition description and rules of the competition;
- Logo Competition containing the 27 proposals for the C25 Logo;
- Database (to be available as soon as this task is finished);
- Links to LCIA Methodologies, Databases, Tools and other useful links
- A Glossary containing a list of "sustainability" related terms and the respective definitions.

The Action website can be found at: http://www.cmm.pt/costc25

5 CONCLUSIONS

The Action has achieved such a great number of members that it is one of the largest in TUD Domain. It proves that the scientists have needs and interests for European level co-operation in life-time engineering and other sustainability issues. The new Member States are well present, and that was also one of the original targets of the proposal. The Action has brought together European experts in material and structural engineering as was the plan of the proposers. Also, architecture is well represented adding valuable insight to design processes and applications of LCA methods.

On the other hand, this large participation requires more co-ordination activities, and this issue has been taken care of by organizing Core Group of the Chairs and Vice-Chairs and Website holder meetings. These meetings have helped to plan and conduct the Working Group and Management Committee meetings in an efficient way as well as the other Action activities like Training courses. Based upon the MoU, a more detailed work plan was prepared by the Core Group and presented to the Management Committee in the second meeting and approved also by the Working Groups as their basis to plan their activities.

The core members of C25 have contributed in writing "ECCS resolution for improvement of current draft of CEN TC 350 prEN 15978". This document was circulated among the wider group of members for the consultation. The main message of the resolution was the inconsistency of this draft with the latest development. Fortunately, the documented did not pass voting. It is, of course, difficult to estimate the impact of the action of C25 members, but awareness of importance of the network was evident.

The Action has fostered the fruitful interaction between performance-based design, life-cycle assessment processes and structural engineering within the framework of sustainability. Life-time engineering itself adopts and develops new approaches of interdisciplinary methods. Sustainable construction aims at balanced results of construction projects in which life-cycle assessments are the way to value and steer decisions. During the Action, combination of these approaches has been the basic line that was also expressed as a main objective in the MoU. The fundamental meaning of durability and structural service life design for the reliability of LCA results has been shown and methods have been developed. Members are now able to apply LCA methods to structural design. LCA methods are mainly with architectural background and they are quite far from the classic background of structural engineer. Thanks to the interdisciplinary networking, structural engineers are now involved in case studies devoted to integrate the environmental performances of structures with the structural design requirements.

Among members of the Working Groups and MC, new European project proposals for the Seventh Framework Programme and for the Research Fund for Coal and Steel Programme have been initiated. Although this achievement is one of the secondary objectives of the Action it is very important to show the high level of the work that is being carried out in COST Action C25.