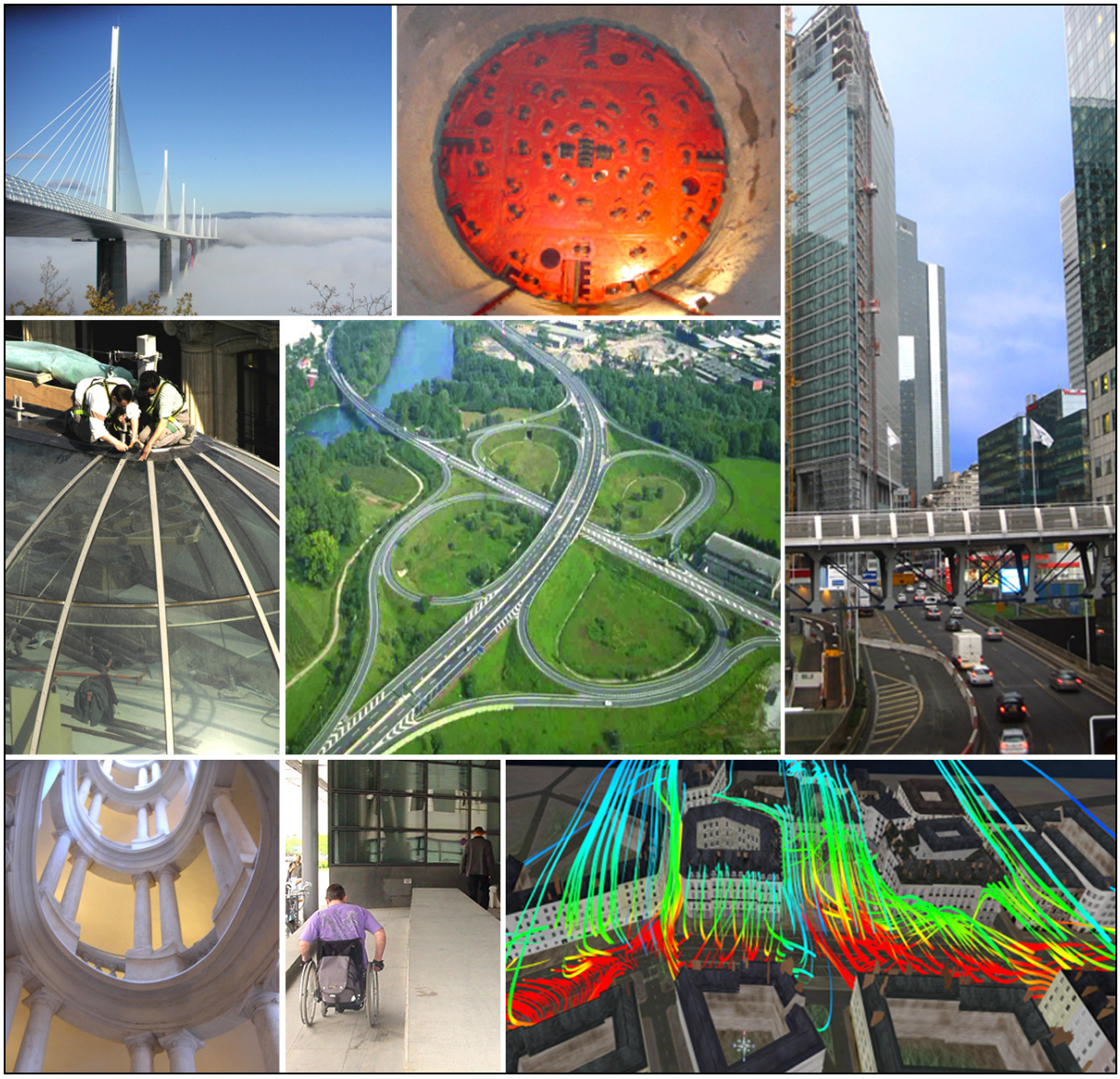
EUROPEAN CONSTRUCTION TECHNOLOGY PLATFORM



Strategic Research Agenda for the European Construction Sector

Achieving a sustainable and competitive construction sector by 2030

December 23rd , 2005

European Construction Technology Platform (ECTP)
www.ectp.org

Preamble

This document is the first version of a Strategic Research Agenda (SRA) established by the European Construction Technology Platform (ECTP) to address the research needs of Europe in the field of Construction over the next 25 years. It sets out the likely directions of technological and organisational changes that will then need to be converted into specific research programmes over the coming years.

The SRA was created following a high-level report outlining a vision for a sustainable and competitive construction sector by the year 2030. This report, entitled "Challenging and Changing Europe's Built Environment", was endorsed by the High Level Group of the ECTP on the 1st of March 2005.

The Vision 2030 document recommends that the design and construction sector actively engages with a sustainable and competitive Europe. It presents a construction industry that is increasingly client/user-driven, sustainable and knowledge-based, and proposes two inter-linked key goals to achieving these:

- *meeting client/user requirements;*
- *becoming sustainable.*

These two goals are present throughout all of the objectives, and typical research targets are gathered under main research areas, which include:

- *process, product, infrastructure, cultural heritage, hazards, and social sustainability for the goal of meeting client/user requirements;*
- *interaction of the built and natural environments, in addition to interaction of the built environment with citizens, without discrimination, together with production and upgrade of buildings and infrastructure for the goal of becoming sustainable.*

These two key goals are supported by strategic research themes dealing with materials and technology, industry transformation, and service.

This Strategic Research Agenda is based on the preparatory elements of the Vision 2030 report. Its purpose is to guide and stimulate all those who are interested in the relevant European and National research programmes, whether from a governmental, industrial, social, funding, policy or regulatory perspective. The SRA does not list specific research programmes or collaborating actors; instead, it paves the way for future research by establishing a clear sets of directions and priorities.

The SRA proposes a set of Research Priorities that are organised along the two main goals of the Vision 2030 report: meeting client/user requirements and becoming sustainable. An additional goal on the required transformation of the construction sector has been singled out. Under each goal, detailed research topics that are derived from research domains presented in the Vision have been sorted out according to major strategic research priorities agreed by the Focus Areas of the ECTP.

This Agenda has been prepared by the ECTP Support Group with relevant contributions from the Focus Areas and various National Construction Technology Platforms. It has been approved by ECTP HLG on the 22nd of November 2005. This Agenda makes an important contribution to research efforts in the Construction Sector, enabling discussion to begin at European level to reach consensus on the ways and means by which the Vision 2030 objectives can be achieved. It is also complemented by a range of documents prepared by the Focus Areas.

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1. Introduction

In the last 100 years, the Construction Industry has been focused on the construction of products. The combination of industrialisation, efficiencies in the construction process and in the performance of construction materials brought about dramatic improvements. For example, skyscrapers could be built reaching 500 m or more; magnificent viaducts and bridges could span more than 1400 m; record tunnels could reach 56 km length; and record-breaking deep foundations could reach 120 m. All of these remarkable achievements were driven by technology and set the pace of innovation for the Construction Sector of the 20th century.

As we enter the 21st century, European Society is facing an overwhelming number of challenges. Demographic changes, climate change, globalisation, and the sobering prospect of declining natural resources – such as drinking water and oil – create pressing problems to which we must find urgent solutions. And yet, European Society is still relying on the Construction Sector to produce better living and working conditions in the built environment. Society demands that it is accessible and comfortable for all, safe and secure, durably enjoyable, efficient and flexible to changing demands – while being both available and affordable.

For the Construction Sector, this represents a dramatic upturn, providing the opportunity to convert a technology-push industry into a demand-driven sector. A race for performance is not the objective any more; the new objective for development is sustainability. This means building durable structures which do not impact on the environment, and which instead consume a minimum of resources. The new measure of success is the ability to satisfy all of the customer's needs.

This Strategic Research Agenda is presented by the European Construction Technology Platform (ECTP). It builds upon a previous document, "*Challenging and Changing Europe's Built Environment - A vision for a sustainable and competitive construction sector by 2030*" which proposed a 'vision' for the construction sector in Europe up to 2030. This document marked a change in the ECTP's approach to research and development activities and the report was officially endorsed by the High Level Group of the ECTP at its first meeting on March 1st, 2005 in Brussels.

In the real world, the demand for Research and Development is rightly driven by today's market forces, rather than by the need to turn tomorrow's visions into reality. The essence of the Strategic Research Agenda is to establish long-term research objectives, and to organise research actions that correspond with both market-driven innovation and a long-term vision. A well-crafted Strategic Research Agenda will balance both of these objectives by creating a consensus between stakeholders on priority objectives, and by organising the progression from today's reality towards the vision's objectives.

This Strategic Research Agenda document is the result of a complex consultation process, aimed at reaching the best possible consensus of all stakeholders of the Construction Sector based on a reduced set of priorities. The Vision for 2030 should remain globally unchanged throughout this time period, but all of the main drivers for research will continuously change with fluctuations in the global context, technology, and market forces.

Therefore, this SRA is not crafted as an unchanging document. The role of the ECTP will be to keep this document regularly updated.

2. The context of the European Construction Sector

2.1. Societal needs

An examination of the current built environment in Europe reveals a starkly contrasting scene. In it, the best of technological achievements such as the recently completed Viaduc de Millau, or the most beautiful examples of cultural heritage co-exist with significant amounts of sub-standard housing and infrastructure, abandoned brownfield sites and neglected waste lands.

Our built environment shapes our society, influencing the way we live, work, entertain and move around. The development for everyone of a sustainable built environment is essential to realising a society that is based on equality of rights and opportunities. Many people depend on an accessible built environment in order to live autonomous and active social and economic lives. This number will increase significantly with the demographic changes taking place in Europe that make a "design for all" approach particularly relevant.

Maintaining and upgrading the built environment to a common standard, in effect re-inventing a huge asset that has accumulated over centuries, is one of the main challenges confronting the enlarged European Union. A specific challenge of the new Europe is taking care of an omnipresent heritage while building a new society with high-quality standards that are required by increasingly demanding users. This places unavoidable and urgent social demands on the Construction Sector:

- **Creating a built environment that is accessible and usable for all:** action is urgent and necessary to cater for the diverse needs of all, including people with disabilities, people with reduced mobility, young people etc. Centuries of neglect and discrimination-by-design need to be compensated for in both existing and new built environments;
- **Providing decent, well-designed, energy efficient housing for all**: action, at European level, is urgently required to address the emerging crisis in housing which sees a severe shortage occurring in many countries and by severely run-down or ill-conceived housing in others.
- **Improving health, safety and security of the built environment**: low indoor-air quality will continue to cause health problems and loss of productivity at work unless improved technology is introduced. As for safety, special consideration has to be given to people with impaired orientation capacity. The possibility needs to be ensured that all, including those with reduced mobility, can evacuate buildings in case of fire or any other emergency situation. Earthquakes, fires and other accidents will continue to cause significant loss of life and destruction to property unless buildings are made safer. The threat of crime and terrorism will hamper the well-being of people unless protective measures are taken into account in the design and maintenance of the built environment;
- **Contributing to objectives of the Kyoto Protocol**: action is urgent and necessary in order to dramatically reduce greenhouse gas emissions and the huge amounts of energy

produced for heating and lighting buildings in an unsustainable manner from fossil fuels. Such uses account for around 42% of all energy consumed in Europe, whereas construction activities account for about 5% of energy used, including construction related transport;

- **Adapting to climate change**: urgent action is required to address the growing expected threat of disastrous damage to the built environment caused by floods, storms and rising sea levels arising as a direct consequence of climate change. Rising temperatures are expected to increase the demand for air-conditioning in buildings, the majority of which are ill-adapted to accommodate it. This tendency will further increase the demand for energy and, if not urgently addressed, will lead to even more greenhouse gas emissions which will aggravate an already precarious situation;
- **Preserving the natural environment**: urgent action is required to avoid the continuous shrinking of green-field areas and bio-diversity, to avoid the spreading of brown-fields and to mitigate contamination of rare and vital water resources;
- **Preserving the natural resources**: billions of tons of natural materials are used each year for construction. Construction and demolition waste is increasingly recycled, but still amounts to about 22% of all waste measured by weight, although most of it is inert. It is increasingly urgent to conserve non-renewable assets and increase the construction sector's efforts to reduce environmental impacts;
- **Preserving our cultural heritage**: European cultural heritage bears witness to our common past and is a basis for our common identity; it enriches the collective memory and is indispensable for the future of European citizens. As such, it needs to be conserved with great care. Action is now urgently needed to preserve it from neglect and poor maintenance, which currently destroys 10% of tangible cultural heritage every 20 years;
- **Enhancing the urban environment**: action is urgently needed to significantly reduce traffic congestion in the main European cities and to preserve the chances of economic and social development of Europe;
- **Maintaining at a high level of efficiency and service the patrimony of infrastructure systems:** it is necessary to meet the increasing and demanding needs of transport of persons, goods, energy, supply and information, matching the need of new constructions against the preservation and upgrading of existing assets. Action is urgent to avoid congestion spreading along major roads and railways; it is required to prevent infrastructure prematurely reaching the end of their service life, which would lead to an unbearable level of investment, particularly for new Member States. Systems for water supply and wastewater networks and installations must be prevented from dilapidating all over Europe; security and continuity of energy supply must not be impaired throughout Europe;
- **Optimising the life-cycle cost of the built environment**: demand exists for a high quality of built environment for all, but the next imperative is to closely control its costs. Action is urgently needed to reduce housing costs to an affordable level, bringing them to within the reach of growing numbers of European citizens – whatever their needs, whatever their region;
- **Improving its Health and Safety conditions**: although tangible progress has been made in recent years to reduce the incidence of accidents on construction sites, unless pressure and initiatives to reduce them further are continually maintained, additional progress will be elusive. The image of the sector will consequently fail to improve, and recruitment difficulties will worsen.

The quality of life of European Society, together with its economy, is impacted hugely by the dimension and number of constructed facilities, together with the duration of their expected life-cycles. The Construction Sector is involved at all stages of the life-cycle of these facilities, ranging from the design, planning and material production, to construction, facilities management, refurbishing, demolition and replacement. The sector's performance has an instrumental role to play in meeting these pressing social demands and has a direct and crucial impact on the European economy

Society demands that the Construction Sector contributes to a competitive European industry. As the largest cluster employer in the EU, it accounts (including contractors, architects, materials companies, facilities operations…) for nearly 20% of the gross domestic product (GDP) and 50% of the gross fixed capital formation (GFCF); it has the capacity to provide employment for all levels of skills. This places upon the Sector a responsibility to **ensure good working conditions for all its employees**. Thanks to a declining birth rate and an ageing population, shortages in the availability of a competent work force will become more and more evident. Creating more attractive work places, and bringing about an improvement in productivity will be major challenges for the Construction Sector.

Moreover, poverty is strongly linked to the quality of the existing built environment. In many instances it is the unemployed or the poorly trained members of our society who live in sub-standard accommodation. This, in turn, blights the built environment. Carefully crafted policies that provide construction-skills training for the unemployed and/or the unskilled can simultaneously combat poverty through using those skills to improve the quality of the built environment. The Construction Sector can also be seen as an instrument of Europe's regional economic cycles; it provides employment and adds value in rural areas as well as in urban areas, contributing to stabilise rural areas and thereby enhancing the global performance of national economies.

Finally, the Construction Sector must also develop for itself a sustainable economy. It must maintain its technical leadership, which is a critical condition to keep ahead of a fierce and growing international competition. It must preserve its internal market shares and consolidate its international positions, especially in relation to the US, China and India. It must confront persistent challenges in transforming and modernising itself. It must continue to strive for sustainability while addressing daunting and complex issues arising from climate change and the demographic evolution of Europe's society. In responding to these changing demands, carefully planned and targeted research and development efforts have a major role to play.

2.2. The European policies

The first requirement of the Construction Sector is to contribute to and strive for the strategic goals of the European Policy:

- The **Lisbon strategic goal** (2000) to become by 2010 "the most competitive and dynamic knowledge-based economy in the world";
- The **Barcelona goal** (2002) of raising Europe's overall level of research investment from its current level of 1.95 % of GDP to 3 % by 2010, of which two-thirds should be from private sources.
- The **renewed Lisbon Strategy** (2005), with ambitions for Europe to be a more attractive place to invest and work, shapen by knowledge and innovation, creating more and better jobs (COM(2005)24 , 2/2.2005).

Furthermore, the social demands must be placed in the perspective of the enlargement of the European Union and development of the single market. They are taken

in account in European policy, which imposes many new requirements on the Construction Sector. Annex 1 is a tentative attempt to identify the principal legislative acts affecting the Construction Sector. This impressive list also reflects the social impact of construction activities.

The continuous evolution of the European regulatory framework is an important consideration for any research actions that are to be undertaken, both in order to anticipate the application of the directives in the context of the sector's activities, and to prepare the new products and processes which are called for. Research and development actions undertaken by the Sector can assist the regulatory framework's implementation in a truly European way, being harmonised and homogeneous in all Member States.

2.3. New Opportunities for Change Offered by Technology

The constant and fast evolution of technology imposes another pressure on the Construction Sector. Keeping ahead of international competition calls for rapid integration of the most recent technological advances. This pressure must be seized as another opportunity to transform the Sector into a knowledge-intensive industry, by the:

- Introduction of more human sciences to develop new business models based on customer focus, and to develop human-oriented innovative construction processes ;
- Introduction of information and communication technologies at all levels of the construction process and of the life-cycle of structures. This means: a continuous flow of information that disseminates knowledge throughout all players on the construction sites; advanced design based on modelling and simulation; automation of construction plant and equipment, including advanced embedded electronics; advanced possibilities offered by wireless or mobile communication technology; advanced monitoring techniques and wireless intelligent sensors; integrated demand and asset management;
- Introduction of nano- and bio-technologies to develop new advanced multifunctional materials and to re-engineer the corresponding components and construction processes;
- Introduction of new services offered by satellites for positioning construction equipment, and for monitoring works and their impact;
- Adaptation of new concepts developed by other manufacturing industries like automotive or aerospace, including just in time production, Design for Disassembly and Design for Recycling.

3. Europe 2030: A vision for the Future of Construction

The European Construction Technology Platform's published "vision" for the construction sector in Europe up to 2030 marked a new departure in the organisation's approach to research and development activities. This vision was officially endorsed by the High Level Group of the ECTP at its first meeting on March 1st, 2005 in Brussels. Significantly, this document fulfilled an important need for a long-term perspective on research-needs and set ambitious objectives for the sector:

Challenging and Changing Europe's Built Environment.
A vision for a sustainable and competitive construction sector by 2030

"In the year 2030, Europe's built environment is designed, built and maintained by a successful knowledge- and demand-driven sector, well known for its ability to satisfy all the needs of its clients and society, providing a high quality of life and demonstrating its long-term responsibility to mankind's environment. Diversity in age, ability and culture is embraced. Equalisation of opportunities for all is an overarching principle; construction has a good reputation as an attractive sector to work in, is deeply involved in research and development, and whose companies are well known for their competitiveness on the local and regional as well as global levels."

The "vision" for the ECTP identifies a number of important and desirable objectives that should enable the development of better technologies, and to raising the level of "sustainability" in the sector. This would occur both in terms of the characteristics of buildings themselves as well as in the processes of actually carrying out construction works.

In order to fulfil this vision, objectives and typical research targets are specified for two key aspects of construction: meeting client/user requirements and reaching sustainability.

Meeting Client/User Requirements

"Europe provides a variety of attractive, healthy, safe, accessible, useable and sustainable environments in which a diversity of social and cultural values are welcomed and fostered; places where significant economic prosperity is underpinned by social cohesion.

Advanced techniques and know-how for urban design and buildings enhance the competitiveness of the European construction industry. The construction sector is based on client- and user-driven complete life-cycle processes. Cost reduction of the overall value chain results in increased competitiveness, new business opportunities, new investments and in economically viable services to the largest possible client base. Optimal allocation of available economic resources is met.

New research focuses on how technology can address human sciences and socio-economics, and how the sector can profit from exploring the current design gap. Inclusion of diversity and the equalisation of opportunities for all are overarching principles that strengthen the sector by enabling it to reach new users and make contacts in many different communities. The design and construction sector is recognised by the public as indispensable to development of the built environment."

Becoming Sustainable
"Europe combines 'high tech' with 'high culture', and is a natural leader in creating a sustainable built environment. The built environment links nature and citizens in a sustainable way. The built indoor environment enables health and comfort in living, moving and working. The negative impacts of construction's whole life-cycle on the environment are radically reduced, thereby substantially improving the sustainability of the construction sector in Europe, with policies such as aiming for zero-waste construction and an efficient use of all resources. Environmental life-cycle approaches are adopted for design, construction works, maintenance and operation, as well as product development."

Besides these two major objectives, the Vision 2030 document introduces another objective for research: Industry Transformation. New materials, innovative technologies and services are necessary to reach the objectives of Meeting Client/User Requirements and Becoming Sustainable. But, to reach the market and bring about a radical change, this research must be underpinned by a much more fundamental and necessary evolution of the construction process itself: it is necessary to include all users in the construction project, to include more knowledge in the products, to diffuse this knowledge on the whole value chain – from end-users to rank-and-file site workers.

Transformation of the Construction Sector
Society is the client and the end-user of the Construction Sector; it is the main driver for change of the construction process.
Cities, buildings, are built, and technologies are developed with human behaviour and needs constantly in mind. A high level of technology is supported by a comprehensive knowledge base which is shared throughout the value chain, from the client to the rank and file site worker. Quality of the construction is continuously assessed and tracked throughout a transparent process.
The Construction Sector conveys a new image of innovation, creates new business opportunities and offers good working conditions to all.

4. Strategic Research Priorities

In the real world, demand for R&D is, quite correctly, driven by today's market forces, rather than the need to turn tomorrow's visions into reality. Notwithstanding the existence of the vision for the future, –it is important that this demand remains substantially the case. The essence of the Strategic Research Agenda is to establish long-term research objectives, and to organise research actions that correspond both with market-driven innovation and the long-term vision. A well crafted Strategic Research Agenda will closely maintain the balance with each of these objectives.

The SRA defines the research that needs to be carried out to achieve the vision, while at the same time taking into account market forces. It is for these reasons that the SRA is inherently difficult to get "right", while being at the same time a document of crucial importance. Ultimately, the success of the document will be judged on just two criteria, by two very different stakeholders:

- The users will expect to see the realisation of the vision, while
- The researchers will look for a framework where their talents can contribute and respond to the needs of the market place.

Construction is a huge industrial sector which involves more than 2.5 million enterprises. Furthermore, there are many different dimensions to the social demand, which makes the selection of a coherent set of priorities a difficult task. Table 1 below gives the list which is proposed by the ECTP.

Meeting Client/User Requirements

1. Healthy, Safe and Accessible Indoor Environment for All
2. A New Image of Cities
3. Efficient Use of Underground City Space
4. Mobility and Supply through Efficient Networks

Becoming Sustainable

1. Reduce Resource Consumption (energy, water, materials)
2. Reduce Environmental and Man-Made Impacts
3. Sustainable Management of Transport and Utilities Networks
4. A living cultural heritage for an attractive Europe
5. Improve Safety and Security

Transformation of the Construction Sector

1. A New Client-driven, Knowledge-based Construction Process
2. ICT and Automation
3. High Added-value Construction Materials
4. Attractive Workplaces

Table 1 List of Strategic Research Priorities

4.1. Meeting Client/User Requirements

Society has a dual role in the Construction Sector: it is simultaneously the end-user and the client. Society is in permanent evolution, confronted today with an aging and growing population, with new and increasingly diversified demands for more equity, more comfort, more safety, better health and better mobility. Society demands a new approach to our built environment – houses, cities, transport infrastructures and networks. The challenge for the Construction Sector is to meet this demand not only by creating new constructions, but especially through the renovation and upgrade of existing structures.

4.1.1. Healthy, Safe, Accessible and Stimulating Indoor Environments for All

4.1.1.1 State of the Art

The well-being of people is largely affected by the level of health and comfort experienced in the main activities of living, working and transportation in enclosed (and semi-enclosed) spaces. European citizens spend more than 90% of their time in these environments. In more than 40% of the enclosed spaces, people suffer health- and comfort-related complaints and illnesses. Improving the health and comfort of the European population in those spaces consequently creates huge potential for economic and societal benefits, manifested in increased productivity, reduced sick leave and medical costs, but also by the prevention of potential liabilities.

On the other hand, many people today find themselves excluded from using parts of the built environment because the designs did not consider the different needs of persons. Accessible built environments allow those with disabilities and those with reduced mobility, including many elderly people, to live a more independent life and to stay autonomous for longer. This is important not only for social sustainability, but also for economic prosperity: an accessible environment encourages active participation in the economy by a higher number of people.

Beyond satisfying these baseline conditions, built environments have the potential to be attractive and stimulating and when the serious demands are resolved they can contribute strongly and elegantly giving pleasure as cultural artefacts and supporting effective and efficient activities in the workplace.

Research is necessary to address and understand the environments created by new construction projects. Yet upgrading the region's existing building stock represents an even bigger challenge. The recent enlargement of the European Union creates the opportunity to undertake vast rehabilitation or re-construction programmes, and is also a massive opportunity to understand and incorporate the new needs of the population. This opportunity cannot be missed, and research must support this effort.

4.1.1.2 Objectives

New concepts, technologies, materials and processes must be developed to design, build and upgrade the built environment. These must be inherently safe, attractive, environmentally friendly, healthy, comfortable and accessible for all, providing solutions in a cost effective way and with regard taken to human behaviour, with the objectives of:

- Accessible and safe indoor environment for all ("indoor environment" here and after also includes semi-enclosed spaces such as open stations, areas around buildings…);
- Reduction by 50% of the number of accidents at home due to poor indoor environment;

- Improved feeling of safety and security at home, at work and travel to and from these places;
- Improved general well-being of people through creating a better indoor environment (lighting conditions, air quality. acoustical quality, thermal comfort, accessibility, usability);
- Increased productivity in the workplace through spaces that support effective and efficient working by individuals, groups and virtual communities;
- Reduction of Sick Building Syndrome by at least 20%;
- Reduction by at least 20% in the number of people suffering from asthma, allergies and other respiratory diseases due to unacceptable indoor environmental conditions;
- The goal is to achieve optimisation of healthy and comfortable indoor environments on the one hand and a sustainable, low-energy built-environment on the other.

4.1.1.3 Research Areas

Medium-term

- Methods and strategies to ensure the design-for-all approach to new construction and to the retrofit of existing structures, including the possibility for the evacuation of all – including those with reduced mobility –in case of a fire or any other emergency situation;
- A better understanding of the impact of the built indoor environment on health, comfort, feeling of safety and positive stimulation. This understanding has two elements: understanding the demands, desires and needs of all occupants, expressed in harmonised performance indicators; and understanding the information-chain required and improving the information transfer;
- Development of harmonised assessment methods from the human point of view (a holistic approach), focused on: objective relations between stimulus and perceptual behaviour; and on sensors, actuators and systems that anticipate human perception;
- Improved knowledge of relevant needs for different groups of people in a range of work, home, leisure and care settings, including those with impaired cognitive, sensorial or motor capacity. Most existing guidelines are based on old studies or simply on estimations. A comprehensive approach needs to be applied in order to consider the requirements for different groups and their interaction with the different environments they may find themselves in. This approach has to also consider new augmentation products which range from wheelchairs to domotic systems, to advanced communications and visualisation technologies.

Long-term

- Innovative concepts for safe, comfortable, healthy and stimulating indoor environments with full participation of all stakeholders in environment and health, comprising new inter-relationships between demand and supply;
- Realisation of healthy, comfortable and safe indoor environments, making use of the above and of innovative, sustainable and smart materials and systems, which are accessible to all people; and new construction, operation and maintenance processes.

4.1.2. A New Image of Cities

4.1.2.1 State of the Art

Sustainable urban policies are necessary to ensure the holistic development of cities, that include a significant involvement of citizens in the decision-making process. A new understanding must be developed of the city as a system of buildings and other urban elements. This must be accompanied by the systematic adoption of a holistic approach that

includes ways in which all of those that have an interest in city development can achieve consensus on a new image for cities – that they are the most desirable places to live and work.

Cities are made up of buildings, streets, squares, and parks separated by spaces; they are supported by services and transport infrastructures. The inter-relationship – or architecture – of these various elements are what gives character to a city. Its quality has a fundamental impact on the well-being of those who live and work in them. There is a need to better understand these interrelationships and the various ways in which their impacts are felt in urban situations. The challenge is to integrate the resulting conclusions into development policies, planning decisions and the design of cities and their components.

The success of European society largely rests on the quality of its urban environment. This has been recognised by the European Commission and it has undertaken work to develop a thematic strategy on the Urban Environment. This has been underpinned by official recognition of the strategic role of cities in the achievement of the Lisbon Objectives of the European Union. In adopting an integrated, holistic and coherent approach towards the delivery of real added-value, a wide range of research must be undertaken.

This integrated approach to urban issues will need to address a number of medium- to long-term challenges that now face society as a result of earlier policies. Principal among these are: urban regeneration for run-down city quarters; rehabilitation and re-use of industrial brown-field sites; renovation of large housing estates in peri-urban and urban areas; upgrading the energy efficiency of existing buildings; and the rehabilitation of cultural assets. Central to this work is the issue of social housing, which has reached a state of crisis in many EU Countries. The provision of decent, well-designed and comfortable housing is needed to ensure that citizens enjoy a sense of well-being that will result in a higher commitment to social activity, higher productivity at work and less discontent in society. In considering these issues, it is important to ensure that such housing is appropriately located in relation to the work and leisure facilities that each combine to provide a full range of services for the creation of a community.

4.1.2.2 Objectives

Well-designed, well-functioning, technologically-advanced cities support a creative business life and a strong social life for all; they create engaged citizens, and optimise resource use within the ecological space. By 2030, cities will have become the most desirable places in which to live and work

4.1.2.3 Research Areas

Medium-term

- The Behaviour and Flows of People, Energy and Materials in Cities
  - Developing indicators that assist in assessing the attractiveness of cities and their individual constituent quarters, in economic, social and cultural terms
  - Devising tools for the measurement of how a city consumes resources
  - Developing a deeper understanding of the city as a system
  - Developing tools for the integration of "green" practices in procurement by cities
  - Researching the factors that affect the planning and location of housing estates that have proved to be socially and economically successful – which in turn will inform rehabilitation policies for existing run-down estates
  - New methods of urban design, construction and exploitation based on an integrated approach of needs and uses (sociology, economy, urbanism).

- Policy Development to Ensure that Capacities are Harnessed and Organised
  - Developing models of tenure to inform approaches to spatial planning policy
  - Devising indicators to measure the extent of "path dependency" in policy formation at city level
  - Analysis of the qualitative aspects in the built environment that support social cohesion and attract knowledge-based business life; these are the elements that help to prevent problematic 'monocultures'
  - Analysis of future demographic changes and changing housing preferences and their impact on housing demand
  - Development of advanced models of urban development that take the economic, socio-cultural and ecological perspectives of sustainable development into account.
  - Mapping policy development processes in order to draw on experiences across the European Union
  - Assessing the impact and effectiveness of existing indicators and benchmarks for city development and regeneration

- Designing Cities Accessible and Useable for All Regardless of Age, Ability or Social Group
  - Mapping of existing urban strategies in the field of accessibility
  - Developing indicators for the assessment of 'accessibility appropriateness' of spatial development plans and policies
  - Developing tools for the integration of accessibility in all policies

- Mechanisms for Engagement with all Actors
  - Mapping existing models for participation in city development and policy making
  - Developing indicators to measure how projects can benefit through participation
  - Developing new models for participation from all interested parties in city development processes

- State of the Art Techniques and Their Applicability
  - Mapping of the techniques and technologies that need to be harnessed in order to make cities more desirable places in which to live and work
  - Benchmarking of existing models for the integration of research results into policy formation and city development
  - Benchmarking the effects of networks on the evolution and environment of the city.

Long -term

- Governance Models – their Successes and Failures
  - Developing an in-depth understanding of existing governance models and their impact on political decision making
  - Mapping emerging governance approaches and benchmarking them for the benefit of cities across the EU

- Path Dependency in Planning Policy and new Models to Address Urban Sprawl
  - Developing indicators that expose to what extent new planning policies are based on historical models
  - Mapping of existing models of urban sprawl that contribute most to a sustainable and creative city for all

- Developing a deep understanding of the functional and policy relationship between a parent city and its suburbs and other nearby towns

- Territorial Regeneration and Cohesion
  - Devising tools that show how territorial infrastructures and services can be optimised
  - Developing indicators on city complementarities, within territories and regions, showing how these can be articulated and harnessed
  - Developing 3-d geographical information systems (GIS) that improve public management, private investments, citizen's integration and participation

- Integration Techniques for Technological, Process and Governance Innovations
  - Setting out models, roadmaps and indicators that demonstrate how the various divergent aspects of research can be brought together to form truly holistic approaches to the creation and maintenance of our cities and urban areas

4.1.3. Efficient use of underground city space

4.1.3.1 State of the Art

Congested European cities always need more space for their harmonious development. The traditional construction model is to develop cities both in elevation and horizontally: this means ever-higher buildings, sprawling further and further across the countryside. On the other hand, underground space is largely available: it must be employed now to provide congested European cities with the space they need for their harmonious development. To address this challenge, the underground built facilities must be safe, sustainable, with minimum impact on the environment and economically competitive against above-ground solutions.

4.1.3.2 Objectives

New construction concepts must be invented to support this radically new model proposed for the development of cities, whereby sustainable cities extend downwards in an unlimited ground space, limited only by the borders of technology and imagination-:

- Underground spaces are designed for all and accessible for all, have the same level of comfort, safety and security as surface spaces, and are closely interconnected to the surface living space;
- Affordable and competitive new underground space relieves congestion at the surface and integrates facilities which are today dispersed in cities;
- Underground space contributes to the protection of the environment and of Cultural Heritage;
- Underground space contributes to the energetic balance and to the development of new energy sources;
- Underground spaces are linked together or are linked to the airports by high velocity and high capacity transportation lines for passengers and freight, offering an efficient alternative to road surface transport.

4.1.3.3 Research Areas

Medium-term

- Development of new approaches for social and human relations for underground spaces; developing psychological and social acceptance of the underground space;

- Improved understanding of human behaviour for use of underground spaces, to adapt 3D movements in a vertical city, instead of only 2D movements in today's horizontal cities;
- Development of new architectural design for the unlimited conquest of deep available space for services and infrastructures, playing with voids, filling spaces and caverns with new inverted concepts of facilities, interacting with surface services and spaces, including human-friendly approach and facilities designed for all kinds of users;
- New materials for waterproof and self-caulking, insulation, fire safety, all being strong enough to withstand ground pressures, flexible enough to absorb ground movements and with high durability in an underground environment;
- Construction processes for large underground spaces below cities and interurban connections:
  - New tunnelling technologies: long tunnels, air-tight lining, specific materials;
  - ICT controlled, fully automated excavation procedures with low impact and flexible equipment, for any size and shapes of excavations;
  - Fibre ground support with re-absorption, modular and flexible ground anchors, sustainable grouting and lining;
  - New techniques for ground treatment, recycling of materials;
  - Special devices for ground conditioning, ventilation, air regeneration and conditioning, exhaust absorption, communications, transport systems, ground water treatment;
- Development for the medium term research of new standards and codes for the new underground spaces and facilities generated and the safe use of them.

Long-term

- New concepts for the comfort of underground spaces: air-conditioning, artificial sun, etc;
- Perfect knowledge of surrounding soil condition and its evolution along the life-cycle of the projects;
- Life-cycle assessment of underground structures under existing premises;
- Development for the long term research of new standards and codes for the new underground spaces and facilities generated and the safe use of them.

4.1.4. Mobility and Supply through Efficient Networks

4.1.4.1 State of the Art

The network systems of highways, railways, waterways, air traffic and of utilities (water, sewage, gas, electricity) represent a huge investment and are essential to the economic and social well-being of society. They are expected to provide reliable service for very long periods of time, spanning several generations, covering dramatic evolutions of technology and of society's aspirations for quality of life. The increasing demand for mobility and supply is driven not only by demographic growth, but mostly by a number of factors like urbanisation or macro economic development. Climate change is another major driver that determines the intensity and the overall pattern of energy, supply and transport. All these factors come together to create a critical saturation of infrastructure lines and nodes.

The competitiveness of Europe and its social and economical development depend heavily on the full integration of networked systems providing a quick and safe exchange of mobility, goods and supply – within, between and across the borders of Member States. The impact of networked systems in the urban context must be reduced. Minimum levels of

service, reliability, security and information, even under critical conditions, must be pushed to a higher level of efficiency.

4.1.4.2 Objectives

The objective is to enhance the level of service offered to all European citizens, without discrimination in terms of demand for mobility and supply, while meeting social, environmental and economical objectives, and achieving interoperability of infrastructure and information.

Construction R&D will support the creation of a unified trans-European Network, complying with the new needs of users and citizens;

- interoperable and inter-modal networks assure fast and safe mobility in a competitive Europe;
- utility networks are easy to access, and can be maintained with minimimal impact on users and environment.
- improved coordination among operators assures an enhanced service with a minimum number of interruptions;
- integrated information and communication systems improve communication between users, infrastructure and operators, improving mobility and supply.

4.1.4.3 Research Areas

Medium-term

- New models to simulate transportation use and cost/benefit; new models to promote multimodal use against monomodal use;
- New information system between modes of transport and new coordination requirements for exchanging information among infrastructure and operators;
- Systems for the management of risk and emergencies and partial functionality of the networked system;
- Smart and Safe Utility concept: new concepts and models based on integrated sensors and information technologies for real-time control of network operation;
- Development, implementation and application of ICT systems to optimise the traffic, serviceability and security of networks, integrating fleet and freight management, traffic monitoring, tolling, information to users, incident and crisis management, transport of hazardous goods, and service in adverse climate conditions.

Long term

- Creation of multimodal centres allocated through the European Network system, and the coordination of the different means of transport that converge in a multimodal centre, including their timetables, allowing users with various needs to easily plan a trip, avoiding wasted time waiting;
- New concepts for modernising sea and inland transport and reviving rail transport, taking into account the requirements of a pan-European traffic network.
- New concepts of design and construction of infrastructural nodes to form a pan-European transport network
- New concepts of design and construction of multiple choice/multiple speed infrastructural systems near roads;
- Points of interoperability and inter-modality: new ways to exchange goods and passengers among nodes, in both urban and extra-urban environments.

4.2. Becoming Sustainable

Our built environment is intimately linked with nature and its natural resources, and should make the most of our interface with the natural environment. The impact of our built environment on nature is considerable through the resources it consumes, through the land it occupies and transforms, and through the nuisances it imposes. It is therefore vital to strive for a sustainable built environment.

4.2.1. Reduce Resource Consumption (energy, water, materials)

4.2.1.1 State of the art

As a major industrial sector, the construction sector must contribute to reduce the consumption of natural resources, especially energy, water and materials.

Although not visible, energy supports vital services and societal comfort, which are the main components of the European way of life. But energy consumption also has major impacts on the environment and the European economy. The European energy policy is dominated by two main concerns:

- reducing greenhouse gas emissions in order to reduce global warming and the damaging economic and ecological consequences that it implies (Kyoto's protocol);
- reducing Europe's reliance on imported energy.

As far as the construction sector is concerned, European buildings are deeply affected by these two main objectives:

- In 2002, the domestic and service sectors accounted for 41% of all final energy consumption in the EU-15
- Households and services are the third largest source of CO2 emissions in the EU-15 if electric power generation is not included (Electric Power: 31%, Transport: 29%, Buildings: 18% in 2001). It becomes the first emitter of CO2 if electricity is included in final sectors (buildings: 36%, industry: 33%, transport: 27% in 2001) .

For this reason, energy consumption of urban areas and of buildings must be dramatically reduced. The first requirement is to develop a new generation of "highly efficient buildings", with reduced energy demand, and as net producers of CO2-free energy. But the existing stock has a long life-time and solutions to retrofit existing buildings are lacking: it is even more necessary to upgrade the existing built environment to a high level of energy efficiency in order to to comply with Kyoto's protocol.

In today's context, 80% of energy consumed during the whole life-cycle of a building is consumed during its service life (only 20% for materials, construction and demolition). The priority is to reduce energy consumption of buildings during their lifetime.

This must be done for existing and new buildings. The problems look similar, but difficulties and solutions are not always the same. The two markets need different R&D programs:

- many technical solutions already exist to build new energy-efficient structures. The difficulties are focused more on affordability of such buildings and on the ability of the sector to implement efficiently a large amount of these new concepts. On the other hand, the impacts of human behaviour on energy-efficient buildings and their subsequent impacts on health are not very well known.
- for existing buildings, technical possibilities to create a more energy-efficient structure are poorer and most of them remain to be invented. Low-intrusive retrofit

techniques are lacking; affordability is still a major problem, and social demand and acceptance are not very well known.

Natural resources (water, materials) must also be saved. As much as 50% of all materials extracted from the earth's crust are transformed into construction materials and products. Moreover, when these same materials enter the waste stream, they account for some 22% of all final waste. Reductions must be sought both in the amounts of raw material used and in the energy content of construction materials.

4.2.1.2 Objectives

The main target for energy consumption is to quarter the building sector's CO2 emissions by 2050, to halve the final energy consumption of buildings, and to enable buildings to produce at least 50% of their energy needs themselves with CO2-free technologies. The following agenda is proposed:

- Medium Term: first demonstrations of feasibility are achieved for new buildings, existing solutions for building renovation are identified, and development of specific retrofitting products is started.

- Long Term: 30% of existing buildings are upgraded to a high level of energy efficiency. Average decrease of energy consumption is about 50%. New highly efficient buildings are affordable and represent a significant part of this market.

- By 2050, the majority of new EU buildings produce nearly zero CO2 emissions and produce by themselves the main part of their energy demand. 100% of 2005 building stock are retrofitted. Energy consumption of the Construction Sector is decreased by about 50%, and CO2 emissions by about 75%.

Concerning the reduction in natural resources consumption, the following targets are:

- 30% reduction of the embodied energy in construction materials and components of equal performance;
- 30 % reduction of the specific raw materials;
- 40% waste reduction in the manufacturing processes for construction materials and components;
- Provision of on-site storage and segregation of waste;
- <1% of construction waste going to landfill disposal;
- Striving towards 100% of new construction materials which are recyclable and towards 100 % re-utilization of construction and demolition waste;
- Substantial reduction of water consumption.

4.2.1.3 Research Areas

➢ <u>Energy Efficient Buildings</u>

Two main research areas are identified: the development of new comfortable and affordable buildings with high energy efficiency; and the development of technologies to upgrade existing buildings to a high level of energy efficiency and comfort.

Medium term

- New concepts, technologies, design tools for the retrofit of existing buildings, to make them highly energy-efficient, supplying their remaining energy needs with renewable energy technologies;

- New concepts, technologies, design tools for the large-scale development of affordable new buildings with very low energy consumption, able to meet their own energy demand through renewable energy source;
- Developing new technologies for embedded renewable energy sources, cladding and ventilation technologies, sensors and pervasive computing systems to develop the concept of the "Intelligent Building" to improve building energy performance.
- Accompanying measures for training, dissemination, and support to legislation,

Long term

- Develop an ambitious pan-European vision for eco-design around which all stakeholders are united;
- Develop net CO2-free, and energy-producing new buildings, able to produce the energy they consume without CO2 emission;
- Develop buildings as an active part of the energy systems (consumers, producers, stores and managers) and networks;
- New concepts of energy-optimised city districts.

➢ Efficient and Environmentally Friendly Construction Materials

Medium-term

- Creation of environmental performance indicators and performance rating systems for materials, buildings and infrastructures;
- Understanding and control of degradation phenomena to improve the service life of building materials;
- Development and improvement of manufacturing technologies focused on the reduction of embodied energy and resource consumption in construction materials and components;
- New manufacturing processes of construction materials with high performance and with a reduced environmental impact, through reduced energy, reduced raw material demand and use of large quantities of residual products and waste;
- Improvement and development of durable materials with prolonged and predictable service life under aggressive conditions, including self-assessment and innovative and non-intrusive in-situ inspection techniques;
- Innovative materials and technologies for the recycling/reuse of construction waste and incorporation of other waste streams into building materials;
- Development of construction components and processes with the objective of optimising the deconstruction processes;
- Integrated life-cycle process for flexible buildings and infrastructures:
    - integration of the processes of design, planning, procurement, construction management and management during use;
    - new logistics management systems;
    - development of methods for service-life prediction of products, service life design and service life management of buildings.

Long-term

- New logistic concepts and manufacturing technologies for full use of construction and demolition waste.

4.2.2. Reduce Environmental and Man-Made Impacts

4.2.2.1 State of the Art

The Communication from the European Commission, "Towards a Thematic Strategy for Soil Protection", establishes eight threats to soil in the EU and Candidate countries: erosion, decline in organic matter, soil contamination, soil sealing, soil compaction, decline in soil biodiversity, salinisation, and floods and landslide.

Construction activities have a very high relationship with land use. The Sector must develop specific concepts for the construction of surface and underground structures to face and mitigate these threats to soil and water resources. In the end, construction activities have to enhance the different soil functions: food and biomass production; water filtering and storage; habitat and gene pool; physical and cultural environment for mankind; and the source of raw materials.

Some examples of the influence of the construction sector on the natural environment are set out below:

- The covering of soil for housing, roads or other land developments is known as soil sealing. Soil sealing dramatically reduces the capacity of soil to absorb and filtrate rainwater. Moreover, it has severe impact on surrounding soils by changing water flow patterns and by increasing the fragmentation of biodiversity. It is almost irreversible, and its consequences are damaging to sustainable development.

- Large surfaces of natural European land are used every year for construction of buildings, transport and infrastructure. The amount of urban soil increases rapidly exponentially and the amount of natural land which can perform more sensitive functions than "built" land is severely reduced. A number of measures must be adopted to protect the remaining greenfield areas: increase the density of urban patterns, re-use "brownfield" land, develop underground construction, etc. The main issue associated with brownfield redevelopment is the lack of safe, predictable and cost-effective tools to assess the content and nature of the pollution remaining in the soil, to elaborate a mitigation strategy, and finally treat the pollution.

- The built environment, modified by mankind, must preserve soil functions during its whole life cycle and restore them where they have been drastically altered. New concepts, materials and processes should be developed for optimised use of the land, for the re-use of brownfields, and for the protection and rehabilitation of contaminated water resources. For instance: development of underground spaces can solve specific problems of waste management; cities and roads must avoid the problem of soil sealing; construction activities must avoid compaction of natural soils; contaminated soils and contaminated groundwater must be remediated to prevent contamination spreading.

- The largest resources of drinkable water in Europe are located underground in aquifers. In coastal areas, the majority of these aquifers are salinated by seawater encroachment, further exacerbated by over-exploitation. Remedying polluted aquifers is an extremely long process, and many aquifers are left practically unsuitable for pumping drinking water. Construction can play a role by providing new concepts of surface and underground structures to optimise the exploitation of these vital water resources.

It is also necessary to address the impact of infrastructure networks on the Environment, understanding the effect of pollution, vibration and noise, for example.

4.2.2.2. Objectives

➢ Protecting Land and Water

- By 2030, brownfield sites are reused and preferred to greenfield sites;
- By 2030, decontamination techniques are available and are cost-effective on all pollutants and are a preferred technology to dumping in landfills;
- By 2030, reliable systems for pollution monitoring are available for public health protection;
- By 2030, land occupancy has reversed its growing tendency;
- By 2030, all new developments consider measures to minimise soil threats: erosion, decline in organic matter, soil contamination, soil sealing, soil compaction, decline in soil biodiversity, salinisation, and floods and landslide.

➢ Reducing Impact of Infrastructure on the Environment

- Reduced negative impacts of infrastructure on users and communities;
- Very high percentage of 'no-dig' interventions;
- Fully conforming to environmental and sustainable standards;
- Radically innovative approaches to gas and water network installation, maintenance and repair which minimise environmental impacts on communities;
- Improved relation of networks with the territory, avoiding environmental conflicts with sensitive land use;
- Insertion of new networks in the environment.

4.2.2.3 Research Areas

➢ Protecting Land and Water

Medium-term

- Development of monitoring tools, and especially the development of reliable in-situ chemical sensors for the real time monitoring of groundwater quality;
- Development of methodologies and tools for the risk-assessment of contaminated soils and their impact on human health and ecosystems, based on a better understanding of geochemistry, and using databases of public access;
- Development of prediction methodologies and tools for the assessment of the short-, medium- and long-term impact from the built environment to the soil-water-atmosphere-biodiversity system;
- Development of new cost-effective materials and technologies for the protection and for optimised exploitation of water resources;
- Development of new, cost-effective in-situ and on-site technologies for the remediation and containment of contaminated soils and groundwater, in order to decrease the price of brownfield reuse, and prevent the use of external landfills;
- Innovative materials and technologies for the reduction of damage to natural land and/or the restoration of natural land during construction and management processes;
- Technologies for reduction of soil erosion;
- New construction materials and concepts to maintain or enhance soil functions (permeable cover materials, non soil-compaction construction methods, etc).

Long-term

- Development of new integrated services for the regeneration and re-development of brownfield sites, supported by holistic decision taking tools (environmental-economic-social);

- Integrated monitoring and remediation technologies focused on the protection of land and water resources against emergencies or drastic changes.

➢ Impact of Infrastructure on the Environment

- New technologies for the construction and maintenance of infrastructure, reducing construction costs and delays: solutions include reducing traffic noise, vibration, air and water pollution, and trenchless construction or using small size trenches;
- New concepts and procedures to reduce the impact of accidents involving dangerous and hazardous goods;
- New concepts for construction and maintenance of infrastructure, for a better integration of transport infrastructure in the landscape;
- Technologies for waste collection and waste treatment in the new environment of underground spaces;
- Technologies to reduce the impact of underground spaces on groundwater flows and underground hydrogeology.

4.2.3. Sustainable Management of Transport and Utilities Networks

4.2.3.1 State of the Art

The European environment for transport and utilities networks result from centuries of construction activities, progressively accumulating these invaluable assets. In comparison, the availability of economic resources to maintain, upgrade and retrofit these assets are extremely limited. R&D is necessary to optimise these resources.

To manage these assets it is necessary to maintain and upgrade them at a minimum cost, to extend the life-span through a better understanding of degradation and ageing processes, to reduce disruptions from networks jamming and their impact on transport, energy and trade.

Functional networks of transport and services must respond to the needs of users and clients, while maintaining a good balance between the needs for new infrastructure and the need to preserve existing infrastructure heritage. This requires the industry to adopt new materials, new construction techniques, rehabilitation and maintenance concepts, new management tools that are capable of extending the life-cycle, to increase capacity and durability and at the same time present high standards of safety and security and demonstrate a low impact on operations.

4.2.3.2 Objectives

- Reduction in service failures and mitigation of consequences;
- Reduction in number of accidents and mitigation of consequences;
- Reduction in number, size and duration of maintenance interventions (congestions and interruptions);
- Enhanced efficiency;
- Full asset management;
- Extension life cycle and improved knowledge;
- Cost optimisation;
- Increase in recycling and re-use of materials and reduction in waste materials;

- Reduction space used/territorial impact;
- Reduction of construction time;
- Increased competitiveness of the sector toward non-EU countries.

4.2.3.3. Research Areas

Medium Term

a. Modelling the performance of the infrastructure

- European standards and new theoretical and numerical models to assess, follow and predict the long-term performance of structures and components (bridges, tunnels, foundations, embankments, pavements, pipelines, water mains and sewers, etc) subject to ageing and deterioration;
- New concepts to extend the life time of structures, increase their capacity or to improve their response to natural and man-made hazards, with no reduction in safety and with positive impact on maintenance;
- Development and establishment of European databases for the maintenance and management of network assets, based on homogeneous nomenclature of elements (including materials, construction technology, condition), of incidents, etc.

b. Monitoring performance

- Identification and integration of the minimum number of significant parameters and their measurement;
- Integrated long-term monitoring of materials and components for new and existing infrastructures based on innovative, cost-efficient wireless sensors using bio or nano-technologies;
- Development of integrated life-cycle assessment systems combining cost-efficient and easy-to-maintain sensors, monitoring and performance prediction systems, and covering all stages of construction control, asset management, and optimisation of maintenance;
- Risk-based inspection regimes for low impact on demand and costs;
- New testing methods for early detection of damages; new non-destructive, automated, inspection/testing techniques to control, identify, localise and monitor structures and infrastructures, even those that are buried, with minimal impact on traffic and supply.

Long Term

a. To improve the performance of the network

- New construction, maintenance or upgrade technologies for structures and elements:
  - using high added-value materials, self-learning devices, industrialised or precast elements with value-added services for demand management and flexible plant equipment, for example;
  - that are easy to build, install, inspect and maintain, with low environmental impact (e.g. repairing with no loss of gas).
- New demolition techniques that allow recycling and reuse of materials (considering internal re-use or towards other applications), even to be used more than one time. New techniques for dismantling, decommissioning and re-employment of components;
- New concepts and technologies for the integration of new utility networks (gas, water, sewer, electricity, etc) in a single built infrastructure or duct;
- Develop, design, build and operate with new or non-conventional materials, ones which have multifunctional characteristics, or with traditional existing materials of enhanced

performances. These would have low environmental impact, high durability and resistance to environment aggression, reduced maintenance and operation costs, and provide increased comfort for users and citizens

b. Enhanced management

- New concepts for network-wide management and operations, with an emphasis on customers in the provision of services;
- New asset management systems that integrate all important infrastructure components, related activities and constraints (data management, inspection, planning and realisation procedures, cost-benefit analysis procedures) for all types and scales of networks;
- New methodologies for the optimal and comprehensive management of operation, maintenance and upgrading of transportation infrastructures in the urban and extra-urban context; high pressure transmission pipelines; gas, water and sewerage networks, that reduce impact on service;
- Management procedures tailored for all types and scale of networks.

4.2.4. A living cultural heritage for an attractive Europe

4.2.5.1- State of the Art

The concepts of Sustainable Development must be translated in a specific way when dealing with Cultural Heritage. There is a need to develop a knowledge-based and interdisciplinary approach for the sustainable protection of cultural heritage. It must ensure safety, authenticity and compatibility, and apply minimal interventions. We are now building what will be the Cultural Heritage of the next generations of Europeans. A knowledge-based approach must be used to protect and promote our cultural heritage, keeping it alive in an attractive Europe. New sustainable strategies, concepts, methodologies and techniques for preventive conservation and restoration of the cultural heritage should be developed to promote and increase the attractiveness of cities and buildings.

R&D activities should be accompanied by active communication and public participation in order to develop interaction with European citizens and to re-establish preservation of cultural heritage as a priority in city management.

The aim is to establish systems for the integrated management of cultural heritage in Europe. These would ensure the safeguarding, regeneration and development of the Historic European Urbanized Environment, based on research-supported development and implementation of standardised modular hard and soft tools. These include technologies and systems for monitoring, surveying, documentation, evaluation, sustainable maintenance, public participation, communication and networking of units with cultural and natural heritage territorial values.

Six main research topics must be developed to support this aim. In the medium term, the research has to be focused on new assessment and management tools, new safeguarding and maintenance projects. In the long term, new applications should ensure implementation of the research results.

4.2.4.2 Objectives

- Cultural Heritage is accessible for all;
- All information generated during the study, restoration and maintenance process will be available and used for appropriate management;

- The service life of Cultural Heritage materials and structures can be predicted with 20% error and is the base of predictive maintenance plans;
- 25 important EU cultural heritage sites should be assessed using new specifications between 2010 and 2030;
- Reducing the decay of Cultural Heritage by 95%;
- Improved safeguarding and consolidation of Cultural Heritage values in risk territories.

4.2.4.3 Research Areas

a. Assessment, monitoring and diagnosis

Integration of new technologies for building diagnostics and monitoring the safeguarding and long-term management process of Cultural Heritages. These will enable sustainable and cost-efficient maintenance:

Medium Term

- Setting up databases, standard protocols and criteria for an integral structural assessment of cultural heritage, including those in seismically-active regions;
- Development of innovative monitoring and diagnosis methods and non-destructive sensors, for the investigation and assessment of material properties, and for the sustainable maintenance or reconstruction of historic masonry structures;
- Knowledge-based diagnosis and decision-making tools to preserve authentic materials and structures, combining non-destructive techniques in order to evaluate physicochemical and mechanical characteristics of materials in relation to environment, and in structure-scale;
- Development of mathematical modelling and image processing methods for 2D and 3D damage detection and surveying techniques;
- Development and adaptation of theoretical models for long-term simulation of structural and physical properties. Input of experimentally-determined parameters (determined from an integrated process of modelling and monitoring) into these models.

Long Term

- Development of strategies of assessment and of larger databases;
- Classification and characterisation of damages generated from the surface, together with investigation of the interaction between surface damages and structural defects in depth with long-term monitoring, non-destructive and minor destructive testing methods;
- Development of documentation, mapping and interpretation of damages with 3D-techniques as a tool for planned maintenance;
- Set up long-term monitoring and periodic assessment of cultural heritage as part of a management system.

b. Materials

Assessment of the degree of decay of heritage buildings due to the degradation of modern or historic materials, including development of innovative materials that mitigate the effects of natural hazards and environmental stresses. A research theme for this area is the compatibility of conservation materials.

Medium Term

- Demonstration and dissemination of the knowledge accumulated during the last thirty years about materials used for repair, developing methodologies for testing their suitability and their performance through:
    - Built-up and networked specialised laboratories;
    - Development of "easy to use and "highly efficient" materials for strengthening and reinforcing of structures;
- Development of smart materials with flexible physicochemical properties adapted to specific technical requests.

Long Term

- Development of intelligent, high added-value materials and structures to improve the long-term performance, reliability and safety of traditional building materials

c. Intervention and Techniques

Development of new process solutions and of low intrusive retrofit techniques, in order to reduce interventions in cultural heritage; the objective is to realise no consequences from the interventions:

Medium Term

- Development of performance criteria based on experiences gained from past interventions and observations of their efficiency, including cataloguing and definition of techniques;
- New low-impact and easy-to-operate technologies and protocols for reduction of damages from the environment.

d. Energy and environment

Medium Term

- Development of special measures for climate control of the various cultural heritage units;
- Development of highly energy-efficient or energy-producing retrofits for Cultural Heritage buildings.

Long Term

- Development and use of a database in combination with simulation tools for analysis of long-term hydrothermal performance of building envelopes and constructions, as well as for service-life predictions;
- Development and improvement of use of climate control methods for preserving Cultural Heritage.

e. Management, exploitation and maintenance

A rational and long-term management process of Cultural Heritage to enable sustainable and cost efficient maintenance:

Medium Term

- Creation of new economic models for interactive and flexible cultural heritage management

- Establishing a complete catalogue of European Cultural Heritage

  Long Term
- Managing Cultural Heritage based on a sustainable interaction with its environment;
- Conservation strategies based on predictive maintenance plans.

f. Cities and Territorial Aspects

Medium Term

- Developing indicators to measure the impact of cultural tourism on economic and social development in Europe;
- Setting up research programmes on the interaction between Cultural Heritage and European identity, social cohesion and creation;

  Long Term
- Development of networks and databases to set up global practices in territories for the safeguarding and the enhancement of Cultural Heritage, inherently linked to social, environmental and economic objectives.
- Research on new tools to improve both communication and interaction with the public on Cultural Heritage. R&D to be undertaken on a new planning approach for safeguarding historic cities and villages.

4.2.5. Improve Safety and Security

4.2.5.1 State of the Art

Since natural and man-made hazards do not respect national boundaries, coordinated and collaborative research is required at the European level to reduce the uncertainty, the unpredictability and the consequences of natural and man-made hazards. The ultimate aim is to achieve timely and appropriate holistic solutions so that losses and disruptions by natural and man-made hazards become marginal, acceptable and insurable. Mitigation of natural and man-made hazards should be reached by the development of integrated assessment, management and prevention methods, new materials and technologies. The disproportionate risk of loss and damage by natural and man-made hazards such as earthquake, flooding, fire, storm, landslide, blast and traffic are considered.

Safety and security of all infrastructure must also be ensured, as any disruption of service may result in large socio-economic consequences for Europe's citizens. Safety of users and supply must be assured (i.e. road accidents, gas supply). Mobility and supply must be guaranteed under critical circumstances (i.e. climate conditions), but especially against man-made hazards. Interruption of service must also be avoided after seismic and other natural hazards, as the functionality of the networks is fundamental to rescue and emergency activities. ICT methods can be implemented to ensure improved safety, efficiency, information, communication, travel comfort and a safe and sustainable environment, even when subjected to the rigours of an increasingly demanding client or user.

This part of the Research Agenda must be coordinated with the European Technology Platform for Industrial Safety.

4.2.5.2. Objectives

➢ Reducing Risks from Natural and Man-made Hazards

- Advances in predictability and insurability of elements at risk under natural hazards;
- Reliable vulnerability mapping (pre-disaster) and damage assessment (post-disaster) methods are applicable;
- Protection and warning systems for natural hazards all over Europe;
- People living in risk areas are prepared to counteract against hazards and their consequences by dedicated continued work placement;
- Practical computer simulation methods for determining load conditions, global and local damage, as well as progressive damage assessments are available. Simplified computer-aided design tools based on comprehensive computer simulations are widely available;
- Technologically-improved, aesthetic protection materials and structures at reasonable costs for extreme actions;
- European design guidelines for buildings and structures subjected to natural and man-made hazards are available, defining load scenarios and a minimum standard of hazard protection.

➢ Safety and Security of Infrastructure Against Natural and Man-Made Hazards

- European transport and supply networks are safe and secure from seismic risk, natural and man-made hazards;
- Risks are mitigated and emergencies are managed; critical nodes of transport infrastructure (e.g. main road corridors, freight terminals, etc) are identified;
- An integrated pipeline protection system ensuring security of supply in the EU.

4.2.5.3 Research Areas

➢ Reducing Risks from Natural and Man-made Hazards

Medium Term

- Develop risk assessment, management methods and insurability:
  - Advanced hazards mapping and monitoring systems;
  - Event specific vulnerability mapping;
  - Innovative risk assessment improving safety of people from man-made hazards;
  - New models and tools for risk and safety management, integrating issues such as safety culture, public awareness, emergency preparedness, business processes, roles and responsibilities, training and competency, quality and performance management;
  - Decision Support Systems for priorities and impacts of risk mitigation.

- Development and harmonisation of European guidelines for performance-based and innovative design, relating to:
  - Earthquake-resistant structures;
  - Tsunamis;
  - Flood and erosion defence systems (rivers and coasts);

- Triggering and propagation of landslides (on-shore and off-shore);
- Terrorist threats to industrial facilities, and especially exposed buildings and infrastructure;
- Fire-safety design of buildings and underground premises.

Long Term

- Prediction and simulation tools for hazards and their impacts on the built environment
  - Engineering tools for multiple threat scenarios and design options;
  - Programs for calamity simulation and training;
  - Advanced constitutive equations for soils and building materials;
  - Prediction and development of mitigation strategies for transient response (eg. wind storms, explosion, traffic);
  - Upgrading and/or development of testing methodologies and infrastructures for vulnerability assessment and calibration of numerical models.
- Development of protection systems, techniques and materials:
  - Simple and easy-to-handle seismic strategies to retrofit existing buildings, particularly residential houses and cultural heritage;
  - New concepts to retrofit existing hazard-defence systems to accommodate for changes in climate and land use;
  - Unobtrusive and aesthetic protection structures against man-made hazards (e.g. impact, blast, fire);
  - Development and application of innovative construction methods;
  - Developing methods to improve the resistance of existing buildings against extreme weather conditions;
  - Extensive soil stabilisation using bio-technology (cementation).

- Remedial measures
  - Develop specific warning systems;
  - Develop specific post-disaster strategies according to risk categories and sources;
  - Raising awareness and alertness of the public.

- Consequences of climate change on the built environment:
  - Understanding of the increasing effects of floods, rainstorms, windstorms, coastal erosion etc. on actions induced on structures.

➢ Safety and Security of Infrastructure Against Natural and Man-Made Hazards

Medium Term

- Safety and security management tools for underground premises to guarantee trouble-free activities in the event of natural phenomena. These include, for example, floods, poisonous gases, earthquakes, or man-made threats such as fire, terrorism, vandalism and crime;
- Reliable and long-life systems to monitor and control all parameters of underground spaces;

- Development of models and tools for risk and safety management, integrating issues such as safety culture, business processes, roles and responsibilities, training and competency, quality and performance management;
- Methodologies and tools for an integrated approach to the vulnerability of urban networks.

Long Term

- Reduction of the vulnerability of networks from natural or man-made hazards by new risk assessment systems;
- Monitoring and assessment methods to evaluate consequences, and to prove the accessibility and availability of infrastructure of transport and supply after damage;
- Mitigation of consequences by the use of innovative materials, components, design, construction and retrofitting techniques;
- Incident reaction in order to mitigate the effects of an attack on people and infrastructure;
- Definition of a common EU regulatory framework on security and institutional continuity.

4.3. Transformation of the Construction Sector

Previous chapters have explored the demands of European customers and European Society both in terms of products and functions to be provided by the Construction Sector. But all of these demands can be placed in a more universal objective: the Construction Sector must be at the service of society, a key player in improving the competitiveness of European industry.

Innovation is needed to support the growing trend towards integrated construction teams and long-term supply chain collaboration. Although off-site techniques are not applicable in all cases, advanced manufacturing techniques must be introduced either on- or off-site to enable suppliers and manufacturers to undertake the following: to reduce costs; to enable mass customisation; to reduce installation problems and health and safety risks; to facilitate design; and finally, to improve quality and consistency. The challenge here is to **re-engineer the construction process**, to transform a technology-driven sector, one that is slow to integrate innovation, into a sustainable demand-driven sector, one that is creative, flexible, innovative, knowledge-based, and which offers new business opportunities and attractive work places to all.

Another important challenge is to incorporate the myriad of small and medium-sized enterprises (SMEs) into this global innovation process, a necessary move to increase the impact and application of new ideas in construction. A knowledge-based construction process will sustain the importance of the sector for our economies, both in urban and rural areas. The built environment will be of growing value and comfort for people in our cities and villages. There will be a shift away from new construction to renovation and refurbishment, always following the target of improving comfort for consumers, sustainability and value for investors. The construction sector will maintain its importance as an employer of people with a range of skills from both urban and rural areas. Construction will diversify to embrace entirely new performances and methods, but will also remain a craftsman-oriented business for SMEs.

4.3.1. A New Client-driven, Knowledge-based Construction Process

4.3.1.1 State of the Art

The vision of a client-driven and sustainable construction sector which meets all of the requirements placed upon it is based on having active construction clients, ones who can manage all relevant demands from owners, society and different customers into briefing and programming. Construction clients with the ability to cooperate with owners, customers and society and with the sector as a whole are a strong driving force for the transformation of the construction industry.

A range of concepts must be developed and assessed. They include concepts such as wholelife thinking –(from inception through to construction and facilities management and including eventual demolition and re-use), lean production, industrialisation, integrated delivery (notably through the development of partnership relationships and of integrated ICT system), performance and improvement of the working environment. Fully interoperable and integrated ICT systems must be developed to encourage the free flow of knowledge throughout all elements of the industry.

The progressive reduction of waste (not only in wasted materials, but also in wasted design resources, wasted communications resources, wasted labour input on site), becomes

the guiding principle in seeking change within the construction process. R&D can support the realisation of a 'lean', waste-minimising, value-maximising construction process, through enhancing the sector's understanding of the process and the development of tools and techniques.

New business and site construction processes should be developed, including increasing off-site manufacture and production, on-site automation, knowledge-based communication and teamwork, and adapted materials, all of which will create an inherently safe, efficient and human-friendly production of buildings and infrastructure.

Industrialisation of the construction processes (in which industrialisation changes from an on-site construction process to a more controlled factory-like construction process) should be looked for: the attractiveness of workplaces will strongly be enhanced by vigilant organisation, new manufacturing methods, new architectural typology based on 2D and 3D components, new components, new connections and interfaces, and new on-site assembly methods.

4.3.1.2 Objectives

The construction client is an important agent of change, one that is deeply involved in the development of a sustainable built environment.
The demands of owners, customers and society are met while optimising the use of resources; the technology available to achieve sustainable development is integrated in a systematic way in construction and management.
The procurement of services or products is done in ways that improve quality, encourage competition and stimulate innovation.

4.3.1.3 Research Areas

Medium-term

- Better knowledge of the role of construction sector in regional economic cycles;
- Tools for analysis of customer requirements, comparison and evaluation of requirements with a mutual impact;
- Methods for verification and documentation of functionality, comfort and other quality requirements from customers;
- Models for handling management programme requirements, including documentation demands relating to operation and maintenance;
- Tools for financial analysis of investment, annual costs and revenues in a whole-life perspective, including handling uncertainty and risk;
- Tools for the assessment of overall life-cycle costs of the construction;
- Knowledge-based construction processes and products for a vigilant site organisation, centred on the needs of clients and of site issues: using Knowledge Management tools and new models based on human sciences principles, linking together the value and supply chain in construction; bridging the gap between "knowledge production" and "knowledge use"; supply and logistics processes in the conceptual design stage; procedures for continued development in strategic business relationships.

Long term

- Service-oriented business and systems, ranging from "design for the customer" to "design by the customer"; new business models and new management of relationships to establish world-class customer and supplier networks;
- The development of an industrialised construction process: process theories adapted from the manufacturing industry to the construction sector, including production technologies, and development of the component industrial market-place;

- Develop new sustainable models, design and building techniques that increase the design possibilities, efficiency and safety, and which reduce the risks for users and citizens from hazards, focusing on the whole life-cycle cost;
- Develop standards that are performance-based and inherently open to innovation: suggestions for performance-based legislation, including performance indicators based on demonstration projects;
- Develop the architectural knowledge-base and its implementation in construction: integrating the diversity of citizens' needs, addressing the interaction between architecture and technology, production and economy in the conceptual design stage, together with mechanisms for mobilising architectural good-practice in construction.

4.3.2. ICT and Automation

4.3.2.1 State of the Art

Advances in information and communications technology (ICT) can produce 'intelligent products', capable of communicating location, orientation and condition. RFID chips represent the first generation of cheap identification devices which can be incorporated in any product. MEMs will soon represent the new generation of miniature and intelligent networked wireless sensors and actuators; these can be dispersed in large numbers in the built environment to monitor the condition of structures. The continued reduction in the cost of communications and data processing will enable construction processes to be fully monitored, and to incorporate all actors on the construction site in the same chain of information. ICT can provide the means to enable the new era of a knowledge-based Construction sector.

Automation and robotics also offer many important possibilities to improve construction processes. To date, the Construction Sector has been very slow in integrating these possibilities into working practices. Recent trends in miniaturisation and in the mass production of robots open the way to much larger implementation of these concepts in the construction workplace.

Despite the development of object-model data standards such as IFC, current use of ICT in the construction industry is based mainly on domain and application-specific data; integrated 'nD' models are used in some pilot projects only. The main reasons for the slow adoption of integrated models are industry practices, inadequate software support for existing data standards and fundamental problems related to the use of file-based data exchange; these do not enable true interoperability. The paradigm shift from fragmented domain-specific processes to integrated life-cycle models requires the development and deployment of new business contracts and integrated model-server technologies

4.3.2.2 Objectives

The objective is to boost the development of construction processes by developing ICT tools that address the specific needs of the Construction Sector:

- All mobile sites are effectively connected to corporate information networks;
- High tech construction integrates IT services, sensors, actuators and diagnostic tools. In the same way that advances were achieved in the automotive industry, buildings and infrastructure have turned into systems where the most important states of operation and most of their maintenance needs are no longer controlled manually, but are instead offered by the system through convenient user interfaces. These have the potential to

transform the ability of people to live, move and work, even when their abilities are impaired.
- Information is shared by the Construction Sector throughout the whole life-cycle of buildings and the built environment by means of integrated information systems encompassing all processes.

4.3.2.3 Research Areas

Medium-term

- Development of industry standards and effective de-facto standards for data exchange, object definitions, and integrated model servers;
- ICT tools for the efficient connection of all those involved in mobile sites to corporate information networks, and to develop ubiquitous access to health and safety knowledge;
- Intelligent equipment and materials for construction based on mechanisation, automation or robotisation;
- ICT, sensor technologies and micro-mechanics to monitor and control the built facilities and their environment, including wireless communications and new communication channels between the underground and the surface;
- Development of new visualization, virtual reality and communication tools, based on advanced ICT systems and using shared integrated data models, enabling a 'value' assessment of the built environment asset to take place in many dimensions: energy consumption, visual impact, functionality, internal environmental quality, safety, security, flexibility, operating costs and expected lifetime, for example;
- nD modelling and grid computing for construction design.

Long-term

- Adoption of radically-advanced construction concepts such as integrated and intelligent agent systems, programmable nano-materials and nano-constructors, bio-mimetic materials, structures and facility systems;
- Construction will be opened to a wider range of potential workers by: the development of new manufacturing systems and automation; rationalization of construction processes, with off-site assembly of large, fully-fitted components; mechanization of site activities aided by new automation and guidance technologies..

4.3.3. High Added-value Construction Materials

4.3.3.1 State of the Art

Materials for construction projects are usually considered and classified as having traditional functionalities (structural or covering, for example), and as a consequence, they are only used by constructors in a traditional way. This poses limitations on the development of new ideas and concepts in building, cities and construction projects and in networks of the future.

Successful technological solutions have to be sought increasingly upstream in the design and production processes; new materials and the development of traditional materials, together with other research approaches such as *nano-technologies, sensor technologies and information technologies,* will all have a crucial role to play as drivers of innovation.

The way that construction projects are conceived from the design stage to their ultimate use and occupation are given new potential by the possibilities created by materials with new and improved functionalities. For example, important innovations can be achieved in indoor quality and comfort by using smart, sensing and "active" or ergonomic materials;

these can be integrated into our daily life. New functionalities will also bring innovation to construction processes.

New "high value" construction materials, manufacturing technologies and processes for new materials that have new multi-functional properties – all of which improve the comfort of living – should be developed that are easy to install and are optimised for industrial pre-fabrication.

4.3.3.2 Objectives

- Building materials that are capable of adjusting their characteristics to indoor environmental conditions and to changing their use requirements (temperature, odours, hygienic properties, depending on the destination of use or level of occupation, for example);
- Insulation and storage (thermal, acoustic, electro-magnetic) capabilities increased by 20% compared to current building materials;
- Knowledge-based control of properties of building materials (such as porosity, microstructure and behaviour at a nano scale) are 100% under control to allow total architectural freedom in structural design and in the design of surface appearance;
- New and innovative building materials and production technologies are compatible with the application of ICT technologies within the building (sensoring or monitoring, for example);
- Production time and costs reduced by 30% through innovative, efficient and predictable manufacturing processes;
- Reduction of assembly, repair and maintenance costs by at least 20%.

4.3.3.3 Research Areas

Medium-term

- Development of materials with new functionalities and improved properties and comfort (resistance against an aggressive environment, that are hygienic and easy to clean, with moisture control, thermal, electro-magnetic and acoustic isolation, heat storage and climatic functionality, creating a "warm feeling" and aesthetic appearance);
- Exploration of the potential for application of biological technology in the production of building materials;
- Development of simulation tools for predictable and multi-functional products and manufacturing processes (innovative automated manufacturing, control and measurement strategies) for reduced production time and costs;
- Development of "easy to use and install" building materials for friendly and safe construction processes;
- Life-cycle analysis of products with new functionalities, addressing durability of new building products and improvement and rehabilitation of existing structures;
- Development of materials with smart and sensing capabilities for self-assessment of integrity, functionality control and self-maintenance, with improved structural and aesthetical properties;
- Active, multi-functional materials, which improve the indoor climate and energy consumption of buildings by means of nano, sensor and information technology;
- Development of new materials based on bio-technologies, for example embedded bio-electronics, active surface properties, or natural process technologies;
- Improve the predictability and efficiency of production processes for new building materials by innovation in manufacturing, control and measurement processes: this is to ensure quality throughout the production batch, with manufacturing flexibility.

Long-term

- Tailor-made materials which can fulfil any demand placed upon it for durability, strength, active responses, heat storage and aesthetics;
- Development of virtual design or virtual construction programs based on service-oriented materials that drastically increase the range of utilization ("design by the customer");
- New and integrated concepts and networks, ranging from material producers to facility management suppliers and clients, that exploit the full benefit of multi-functional materials.

4.3.4. Attractive Workplaces

4.3.4.1 State of the Art

The Sector must acknowledge and respond to society's '3D' perception of the industry – that it is dirty, difficult and dangerous –, which results from poor ergonomics and a high level of hazards from accidents at work and occupational diseases. Efforts are absolutely necessary to transform the working conditions and skills base of the workforce, to make the Construction Sector attractive to the most competent and skilled young people that it needs: shortages in workforce are already a reality in several Member States.

A major difficulty is that construction sites are, in an evolutionary context, inherently dangerous places. Uncertainty is always present, however detailed the risk assessment studies may be. This feature is very specific to this industry and calls for specific R&D programmes.

The first necessity is to develop a culture that embraces Health and Safety on construction sites. Site construction teams have the necessary practical knowledge to analyse situations; they are the sole actors with the capacity to re-engineer their work processes. "Joined-up thinking" and coherent collaboration by all parties involved is essential from the initial design stage right through to project completion.

It is essential that human science that is based on a global approach, and which encompasses all relevant scientific disciplines (including psychology, organisation, sociology, occupational medicine and ergonomics) develops a new model of vigilant organisations. This is essential to put together site construction teams that can permanently re-engineer the complete supply and construction chain. Within such a renewed business model, the construction process will become health and safety friendly, with the sites being attractive and empowering workplaces for the employees. This will be achieved through, among other things, increasing off-site manufacture that includes new 2D and 3D components, on-site automation, new on-site assembling methods, knowledge-based communication and teamwork and selected use of materials.

This approach must include personal development, teamwork and knowledge access. Beyond its positive effect on attractiveness and the well-being of the workforce (see also 4.3.1 above), knowledge flow and management is also a fundamental element of any business process and of project development.

Another approach to improving the workplace is to physically move workers away from tasks which expose them to hazardous, arduous or demanding conditions. Labour requirements can be reduced significantly by mechanisation and by greater use of off-site production. ICT and automation can provide progressively more sophisticated monitoring

and control systems for construction equipment. The goal will be the complete replacement of human labour in the most hazardous of conditions, such as the excavation of tunnels.

Complete automation may not be necessary, nor may it be possible for the increasing proportion of construction that is concerned with repair and refurbishment. However, the application of technologies for remote operation, assisted by progressively more intelligent systems for capturing and interpreting visual data, will serve to reduce direct exposure to risk. The 'site control room' that is comparable to the control centre of a production plant, together with similar controls and displays, can become a feature of construction.

4.3.4.2 Objectives

- Construction processes have been re-engineered from the H&S point of view;
- Human factors are considered in the design of machinery, equipment and tools for the Construction sector;
- Elimination of occupational diseases;
- Zero-accident target, or at least at the level of the best performing industries;
- All dangerous occupations have been transformed by the use of remote control techniques or replaced by automation.

4.3.4.3 Research Areas

Medium-term

- Development of tools to enable the creation of a vigilant organisation, based on collaborative work on construction sites:
  - Unified H&S assessment system;
  - Free and voluntary H&S certification label;
  - Collaborative working and training methods for inherently safe site construction teams, balancing individual aspirations and instilling a collective sense of responsibility;
- Development of new systems for preventing workplace hazards, independently of the worker's will; new concepts of intrinsically-safe and ergonomic temporary equipment to be used during the construction process: these include cradling, formwork, scaffolding and access systems;
- New technologies to improve ergonomy and to reduce the impact of construction sites to workers and people adjacent to the construction site. These range from the reduction of dust, noise and access; innovative fixed or mobile safety or protection systems, including signposting, temporary diversions and security fences;
- Construction technologies:
  - New intrinsically safe and healthy construction processes and materials, including consideration of the interaction of workers;
  - Erection and assembly processes: new and lightweight high-strength materials and components, innovative assembly and joining methods, applied by new generations of automated smart tools, equipment and systems;
  - Knowledge-based construction processes and products, using Knowledge Management tools and new models based on the principles of human sciences.

Long-term

- New tools for the assessment of intermediate construction stages and for automatic evaluation of hazards and uncertainties in the construction processes at project and site level;

- Knowledge-based construction processes and products, using Knowledge Management tools and new models based on human sciences principles to ensure worker's health, safety and quality of life;
- Service-oriented business and systems: from "design for the customer" to "design by the customer"; new business models and new management of relationships to establish world-class customer and supplier networks.

5. Making the Vision a Reality

5.1. Role of the ECTP and the National Technology Platforms

The European Construction Technology Platform (ECTP) was created as a response by the Construction Sector to the demands of European society. It is an open and industry-driven entity, acting as an umbrella for research initiatives in Europe. This initiative brings together more than 600 partners, and is supported by committed stakeholders at all levels of the supply chain (including users, clients, contractors, authorities, architects and designers, purchase, material producers and all kinds of suppliers).

The ambition of the ECTP is to play a major role in creating a better synergy between European and national initiatives, between public and private efforts. Its target is to identify and structure research needs, in order to generate an efficient response. By bringing together a wide range of stakeholders in the Construction Sector around a clearly specified set of priorities, it aims to optimise investment in innovation. This strong commitment from industry is a guarantee that innovation will find its way to achieving practical implementation and true market penetration.

The shape of the Construction Sector and its clear impact on society gives the ECTP an important European dimension. Addressing research needs and coordinating research efforts at a European level, involving all stakeholders, requires a huge effort. For this reason, the ECTP has promoted from the very beginning the creation of a network of National Platforms. 18 NTPs are currently gathered in this network. The ECTP is now supported by a strong network that covers nearly all of the European Member States and some of the Accession States, acting on the principle of subsidiarity. These Platforms provide vital resources to the ECTP: a direct link to the reality of each of the national construction sectors; a direct link with national authorities and standardisation committees; the possibility to establish a synergy between European and National projects; and last but not least, an efficient link with the many SMEs which form the largest number of construction companies in the region.

The creation of such a powerful European network is an impressive achievement for such a large Sector, one which is usually driven by relentless competition. It has already created significant momentum and generated renewed interest for research in the Construction Industry.

5.2. Removing barriers to innovation

The classical structure of procurement in the construction sector can be a major obstacle to innovation:

- contracts are normally awarded on the basis of the lowest cost, favouring well-known and well-managed techniques;
- innovative techniques are lacking in previous references required by the client, or cannot be covered by appropriate insurance contracts;
- project design is generally based upon and optimised from well-known techniques. Alternatives that could magnify the innovative techniques are often not accepted.

New approaches must be developed and encouraged to help in promoting innovative results, such as:

- public support given for innovation policy, and for experimental infrastructure;
- the development of Public Private Partnerships;
- the development of risk-assessment techniques, such as the Observational Method.

The greatest barrier of all to innovation lies in national liability regimes in many EU member states and the way in which they are insured. All efforts must be undertaken to develop the legal framework for cooperative teamwork between consulting architects, engineers and contractors. They would need to include efforts to rationalise the design, to develop innovative solutions that actually reduce costs, and ultimately to offer their clients better value for money. Whenever possible, contactors should be encouraged to propose alternative technical solutions ("variants", in the wording of the public procurement directives) that offer clients better value for money while maintaining equivalent quality in the resulting project.

Such procedures will encourage all stakeholders to innovate, therefore liberating the most effective driver for innovation (as well as the research and development that underpins it), namely increased financial returns. There are, however, two essential ingredients that are necessary to facilitate this process:

- That contractors take advantage of the new provisions in the public procurement directives for the confidentiality of alternative technical solutions (i.e. they cannot be used by the client as the basis for re-tendering a construction project);
- That clients are encouraged to make use of single-point liability insurance arrangements under which all actors in the construction process are insured under a single policy of insurance. This effectively covers the contractor against liability risks linked to his proposed alternative technical-design solutions, while also dramatically reducing the sources of conflict between the various actors in the construction process. This leads in turn to integration of the supply chain and its resulting economies

Moreover, in addition to existing collaborative research instruments, a framework for Experimental Projects is necessary to provide an opportunity to create the necessary references for deployment of innovative construction processes in Europe and on the international markets.

5.3. Developing a Single European Construction Market

Further integration of the sector across Europe can be expected to continue to evolve over time. The ECTP will promote research at European level, but the underlying infrastructure of a single European market calls for further initiatives to promote harmonisation of construction processes. There is a need to learn from one another through exchanges of best practices, and to encourage cross-border collaboration for large infrastructure projects.

Many national practices and regulations will continue to remain, creating barriers to the take-up of new products and processes at European level. Specific actions are necessary to overcome these barriers, including:

- **Eurocodes:** the deployment of the European construction codes is far from complete. Many of their provisions still remain at a national level. Efforts must continue in order to arrive at a truly European set of construction codes that do not require national application documents, unless specifically foreseen in the Eurocodes. These further efforts should address the development of new codes supporting the use of emerging materials and technologies in the construction sector. Pre-normative research as an essential part of codes and standards development should be strongly supported.

- **Environmental impact of construction materials:** there is a clear need for a harmonised and realistic set of specifications regarding the impact of construction materials on human health, and on air, soil, underground water, for example. There is also a clear need to assess in a harmonised way the content of all raw materials and to collect this information in databases that are then accessible to all actors in the Sector. The foreseen development of Environmental Product Declarations should address this aspect in due course.
- **Product certification**: this also needs to be harmonised in Europe.
- **Health and Safety**: H&S reporting is not harmonised in Europe, making benchmarking and comparisons difficult at European level. The development of harmonised H&S standards and reporting is a condition for further progress; it will be beneficial for the future multi-national and multi-lingual European construction sites. This work should also lead to the introduction of a voluntary H&S label, supported by the construction industry, certifying that appropriate management models and vigilant organisations are applied to progress towards zero-accident, zero-disease goals.

5.4. Implementing the Research

Implementation of this Research Strategy will involve a combination of collaborative research instruments and of Joint Technology Initiatives, underpinned by an Action Plan that coordinates the construction research priorities at European and National levels.

The European Construction Technology Platform has the capacity to generate Joint Technology Initiatives, and an initiative is already under preparation. The construction of very large infrastructure projects could provide an excellent opportunity to develop Joint Technology Initiatives in the Construction Sector. Past examples such as the construction of the Channel Tunnel between France the United Kingdom demonstrate that such large projects combine many characters of the JTIs:

- Based on private funding;
- Association of a very large number of stakeholders;
- Size and ambition of the project, responding to a major social need;
- Innovative character of the technology employed;
- Large impact on the competitiveness and public image of the Construction Sector.

5.5. Training and Education

The Sector is already facing a shortage of skilled young people, partly due to demographics and partly due to the reduced attractiveness of industrial activities, when compared to other activities such as finance and services.

The first action is to engage the Sector in massive research efforts to change the Sector profile towards a knowledge-based, demand-driven sector. These efforts should be based on cooperation with academic partners.

Research in the Sector combines a wide scope of technologies with environmental, economic and social issues; it requires a careful cross-disciplinary and critical analysis of the construction process from the perspectives of both builders and users. It will also need to define with academic partners the best suitable sets of training programmes that have a suitable mix of specialisation and multi-disciplinarity.

Training the personnel is another priority, and is a necessity for any knowledge-based process. The objective is to bring high-level knowledge to the closest point of its application

– ideally, on the construction site itself. New training methods and new training tools must be developed with the cooperation of academic partners to reach this goal.

International cooperation is another suggested path: knowledge exchange programmes, mobility schemes and international training that addresses both developed and developing countries can be used to transfer European experiences. This will raise awareness on sustainability in other countries, and ultimately will provide new opportunities for European stakeholders in overseas markets.

5.6. Linking with other Technology Platforms

Many concepts which are now being considered by the Construction Sector have been the subject of previous research, or have been already applied to other industrial sectors. An example is the "Design for Disassembly" concept developed by the automotive industry. However, significant effort is still necessary to adjust these concepts to the specific needs of Construction.

An ambition of the ECTP is to organise an efficient dialogue with other Sectors wherever a fruitful synergy can be identified, by developing active and living links with other Technology Platforms. A number of relevant Technology Platforms have been already identified:

Manufacturing Technologies ("Manufuture");
Steel;
Road Transport (ERTRAC);
Rail Transport (ERRAC);
Industrial Safety;
Water Supply and Sanitation;
Forest-based Sector Technology Platform.

The network of National Construction Technology Platforms will provide more opportunities to link efficiently to the other sectors and their Technology Platforms, be it at a European level, or at the level of their respective National Platforms.

6. The Way Forward

The European Construction Sector has a tradition of being pioneering. Construction techniques that were invented and developed in Europe form the basis of our built environment and influence the core businesses of today's construction industry throughout the world.

The Sector faces today the impressive challenges of an enlarged European Union existing in a global market: this requires adapting to a single market and keeping ahead of international competition. A new approach is necessary, mobilising all resources to satisfy all of the customers needs and to strive for sustainability.

The European Construction Sector must be a pioneer and the leader of this new approach.

The ECTP is committed to coordinating this effort. It benefits from the large support of all its stakeholders and of a European network that covers most Member States. The impressive momentum it has already created towards R&D provides the best guarantee that it has the capacity to make the Vision a reality and to fully exploit what has been called "the knowledge triangle: the creation, transmission and use of knowledge, through research, education and training and innovation."[1]. This Strategic Research Agenda is only the first step.

[1] Lecture given by EU Commissioner J Potocnik to the ECTP High Level Group Meeting, 1/03/2005

ANNEX 1

Most Relevant Decisions of the European Institutions Affecting the Construction Sector

	Title	Act	Publication Reference	Date of Adoption
Enterprises	Multi-annual program for enterprise and entrepreneurship	Dec. 2000/819/EC	OJ L 333, 2000	20/12/2000
	Amendment to Regulation 1260/1999/EC laying down the general provisions on the Structural Funds	Reg. 1447/2001/EC	OJ L 198, 2001	28/06/2001
Public Procurement	Coordination of procedures for the award of public supply, public service and public works contracts	Dir. 2004/18/EC	OJ L 134, 2004	30/04/2004
	Coordination of procedures of entities in the water, energy and transport sector	Dir. 2004/17/EC	OJ L 134, 2004	30/04/2004
	Proposal for a European Parliament and Council Directive on services in the Internal Market			
	Public-Private Partnerships and Community Law on Public Contracts and Concessions	COM (2004) 327		30/04/2004
	White Paper on Services of General Interest	COM (2004) 374		12/05/2004
	Implementation of the Internal Market Strategy (2003-2006)	COM (2004) 22		21/01/2004
	Common Procurement	Reg. 2195/2002/EC	OJ L 340 2002	05/11/2002
R&D	Multi-annual framework program (2002-2006) aimed at creating a European Research Area	Dec. 1513/2002/EC	OJ L 232, 2002	03/06/2002
	Europe and basic research	COM (2004) 9		14/01/2004
	Integrating and strengthening the European Research Area (ERA)	Dec. 834/2002/EC	OJ L 294, 2002	30/09/2002
	Implementation of the community framework program 2002 – 2006	Reg 2321/2002/EC	OJ L 355, 2002	30/12/2002
Environment	Effects of certain plans and programs on the environment	Dir. 2001/42/EC	OJ L 197, 2001	21/07/2001
	Action Plan promoting NGOs	Dec. 466/2002/EC	OJ L 75, 2002	01/03/2002
	6th Environmental Action Program	Dec. 1600/2002/EC	OJ L 242, 2002	10/09/2002
	Environmental Liability	Dir. 2004/35/EC	OJ L 143, 2004	21/04/2004
	Sustainable Development	COM (2003) 829		23/12/2003
	Revised eco-label award scheme	Reg. EC/1980/2000	OJ L 237, 2000	12/07/2000
	Community eco-management and audit scheme (EMAS)	Reg. EC/761/2001	OJ L 114, 2001	12/02/2001
	Guidance for implementing EMAS	Reg. 2001/680/EC	OJ L 247, 2001	17/09/2001
	Proposal for a Directive of the European Parliament and of the Council establishing a framework for the setting of Eco-design requirements for Energy-Using Products and amending Council Directive 92/42/EEC	COM (2003) 453		01/08/2003
	Environmental Aspects of Standardization	COM (2004) 130		25/02/2004

	Proposal for a Directive of the European Parliament and of the Council on the protection of groundwater against pollution	COM (2003) 550		19/09/2003
	Proposal for a Regulation of the European Parliament and the Council on the Registrating, Evaluation, Authorization and Restriction of Chemicals (REACH)	COM (2003) 644		29/10/2003
	Proposal for a Directive of the European Parliament and of the Council on batteries and accumulators and spent batteries and accumulators	COM (2003) 723		11/11/2003
	Environmental Impact Assessment	Dir. 2001/42/EC	OJ L 197, 2001	21/07/2001
	Proposal for a Directive of the European Parliament and of the Council on waste	COM (2003) 731		11/10/2003
	Lists of waste & hazardous waste, amending Directive 2000/535/EC	n/a	n/a	23/07/2001
	Packaging and Packaging Waste	Dir. 2004/12/EC	OJ L 47, 2004	11/02/2004
Economy	Authorizing Member States to apply reduced rate of VAT to certain labor-intensive services.	Dec. 954/2002/EC	OJ L 331, 2002	03/12/2002
	Reduced VAT to Labour-Intensive Services	Dir. 2004/15/EC	OJ L 52, 2004	10/02/2004
	Implementation of the 2003-2005 broad economic policy guidelines	COM (2004) 20		21/01/2004
	Late payments in commercial transactions	Dir. 2000/35/EC	OJ L 200, 2000	15/06/2000
	International Accounting Standards (IAS)	Reg. 1606/2002	OJ L 243, 2002	19/07/2002
Social	Social Policy Agenda 2000-2005	Communication	OJ C 157, 2001	09/12/2001
	Chemicals agents at work: list of indicative occupational exposure limit values	Dir. 2000/39/EC	OJ L 14, 2000	08.03/2000
	Use of equipment: 'work at height'	Dir 2001/45/EC	OJ L 195, 2001	27/06/2001
	Exposure to mechanical vibrations	Dir. 2002/44/EC	OJ L 560, 2001	05/05/2002
	Exposure to noise	Dir. 2003/10/EC	OJ L 230, 2003	09/12/2002
	Health & safety protection of workers at risk	COM (2003) 515		25/08/2003
	Protection of young people at work	COM (2004) 105		16/02/2004
	Health and safety at work	COM (2004) 62		05/02/2004
	Proposal for a Decision of the European Parliament and of the Council establishing an integrated action programme in the field of lifelong learning	COM (2004) 474		14/07/2004
	Proposal for a European Parliament and Council Directive on extending the freedom to provide cross-border services to third-country nationals established within the Community	COM (99) 3		27/01/1999
	Proposal for a European Parliament and Council Directive on the posting of workers who are third-country nationals for the provision of cross-border services	COM (99) 3		27/01/1999
	Proposal for a Council Directive on the conditions of entry and residence of thirdcountry national, paid employment and self-employed activities	COM (2001) 386		07/07/2001
	Proposal for a Council Directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (Optical Radiation) (Directive 89/391/EEC)	COM (92) 560		23/12/1992

	Proposal for a Directive of the European Parliament and the Council on working conditions for temporary workers	COM (2002) 149		20/03/2002
	Proposal for a Directive of the European Parliament and of the Council on the recognition of professional qualifications	COM (2002) 119		07/03/2002
	Protection of workers from the risks related to the exposure to asbestos at work	Dir. 2003/18/EC	OJ L 97, 2003	15/04/2003
	Safety, hygiene & health protection at work	Dec. 2003/218/EC	OJ C 218, 2003	22/07/2003
	Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents	Dir. 1994/284/EC	OJ L 159, 2004	29/04/2004
	Health & safety requirements (mechanical vibrations)	Dir. 2002/44/EC	OJ L 177, 2002	06/07/2002
	Coordination of social security systems to promote the free movement of persons	Reg. 883/2004/EC	OJ L 166, 2004	29/04/2004
	Rights of citizens of the Union and their families to move and reside freely in the Member States	Dir. 2004/38/EC	OJ L 158, 2004	29/04/2004
	Exposure of workers to the risks arising from physical agents	Dir. 2004/40/EC	OJ L 159, 2004	29/04/2004
Energy and Transport	Proposal for a Regulation of the European Parliament and of the Council amending Regulation 2236/95/EC laying down general rules for the granting of Community financial aid in the field of trans-European networks	COM (2003) 220		29/04/2003
	Trans-European networks guidelines	Dec. 884/2004/EC	OJ L 167, 2004	29/04/2004
	Energy Performance of Buildings	Dir. 2002/91/EC	OJ L 1, 2003	25/11/2002