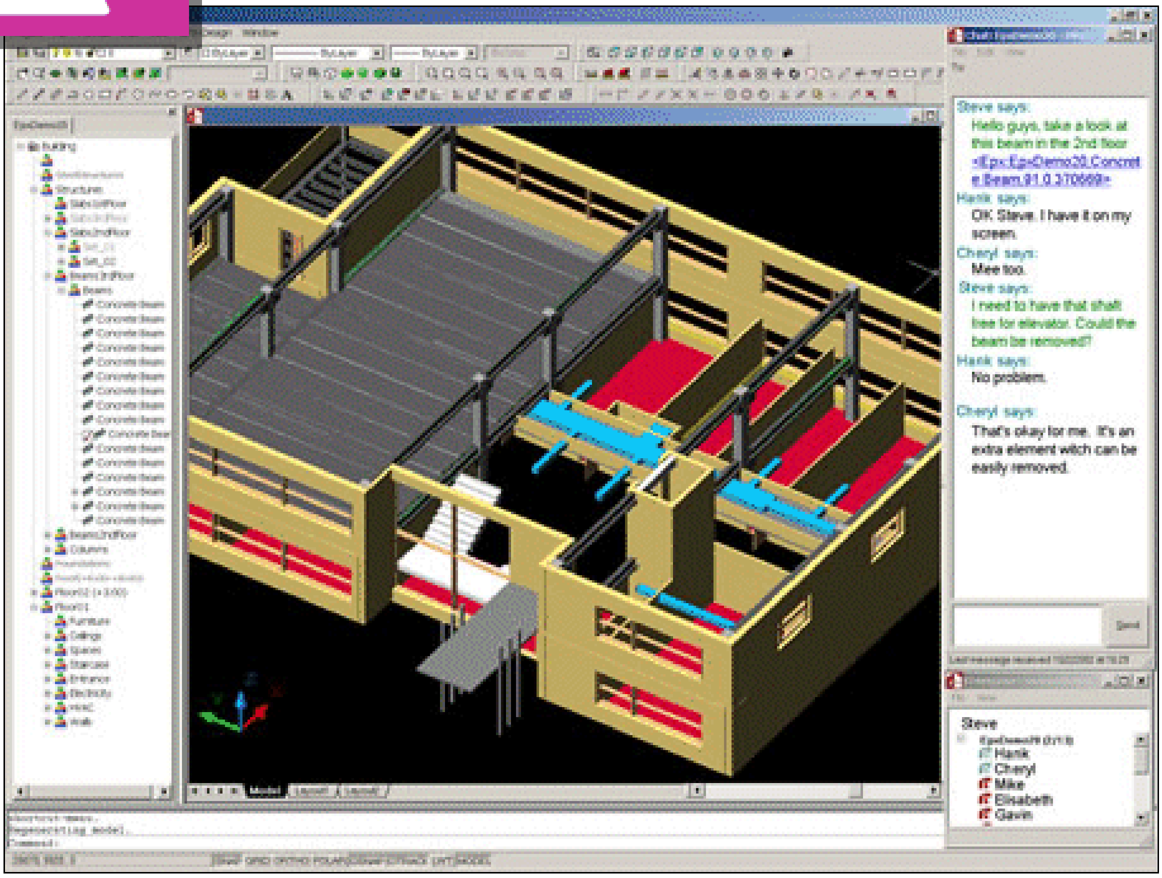
EUROPEAN CONSTRUCTION TECHNOLOGY PLATFORM

PROCESSES AND ICT



Vision and Strategic Research Agenda
Focus Area Processes and ICT

May 19th, 2008

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

Foreword

This Vision 2030 & Strategic Research Agenda (SRA) document is established by the Focus Area Processes & ICT (FA PICT) of the European Construction Technology Platform (ECTP). It addresses research needs in the field of ICT supported processes in the European construction sector over the coming years and sets out directions for research, development and innovation.

FA PICT was initiated on 19 September 2005 by the ECTP Support Group. The kick-off meeting was held on 21 October 2005. At that time the 6 other previously established FAs were already completing their SRAs which were then consolidated into an overall ECTP SRA, issued in December 2005. PICT started to prepare its SRA in March 2006. This was done in parallel with contributing to a follow-up document of the ECTP SRA, the Implementation Action Plan (IAP). The IAP included suggestions from all FAs for inclusion of priority topics into research programs, especially intoFP7, and was released in June 2007. The elaboration of the PICT SRA continued until the end of 2007. The outcomes were published in the final report of the Strat-CON project at the end of 2007. This document is edited to be consistent with the other ECTP documents.

From March 2006 to the end of 2007 the activities of PICT were supported by the Strat-CON project "Strategic Actions for Realising the Vision of ICT in Construction" (www.strat-con.org/) under the ERABUILD programme (www.erabuild.net). The Strat-CON Consortium constituted:

- VTT - Technical Research Centre of Finland (www.vtt.fi); supported by TEKES, the Finnish Funding Agency for Technology and Innovation,
- CSTB - Centre Scientifique et Technique du Bâtiment, France (www.cstb.fr) ; supported by the French Ministry of Equipment (Ministére de l'Ecologie, du Développement et de l'Aménagement Durables) under the CSTB research programme,
- TU-Wien, Vienna University of Technology, Austria (http://www.tuwien.ac.at/); supported by the Austrian Program on Technologies for Sustainable Development, HAUS der Zukunft.

We acknowledge the contributions of numerous experts who participated in workhops and sent suggestions for research topics.

FA PICT is lead by Arup (UK) and VTT (Fi).

Executive Summary

This document presents strategic research priorities in the domain of "processes and ICT" in construction. The SRA addesses 4 key aspects of construction: process, products, projects, enterprises. Each aspect is divided in to 2 complementary themes, altogether 8, as summarised in figure 1 below.

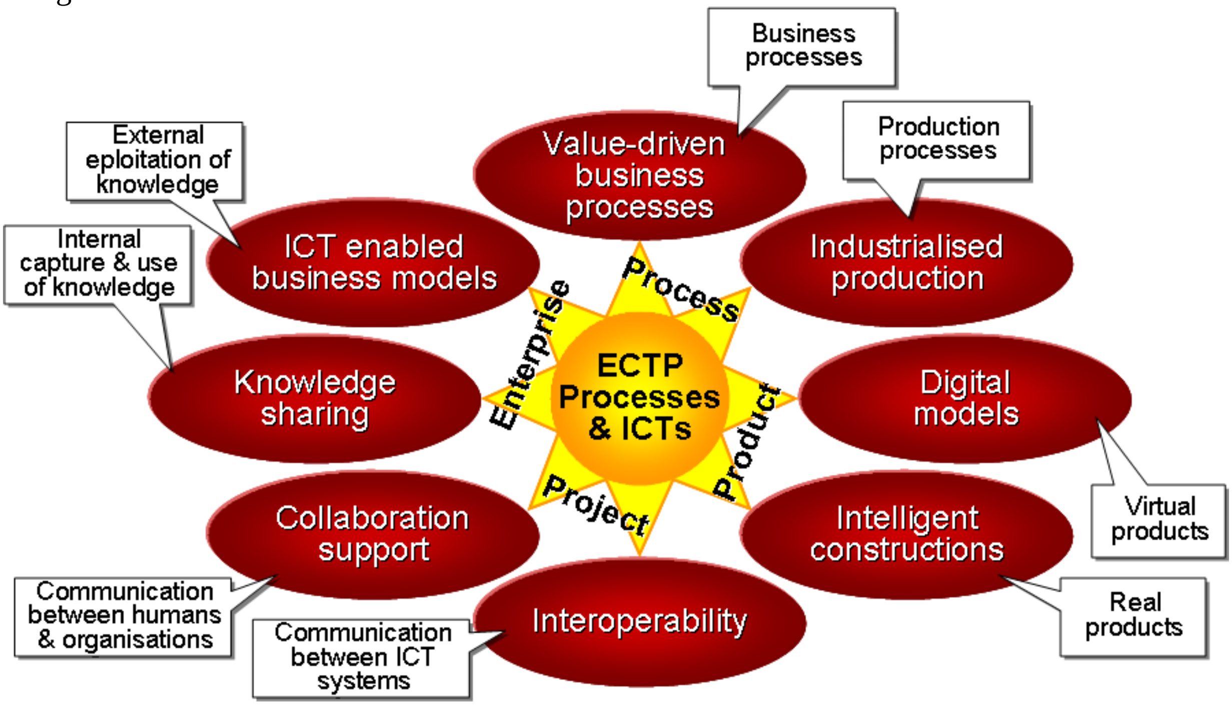


Figure 1. Main themes of the SRA

Within each theme, a set of key business drivers are identified, and are supported by a set of key research topics. The research topics are broken down into a set of short, medium and long term actions in terms of time-to-industry. These are presented as 8 "roadmaps", illustrated graphically and explained in detail section 4 of this SRA. Figure 2 below illustrates the methodoly: generic research priorities and specific research ideas were defined iteratively.

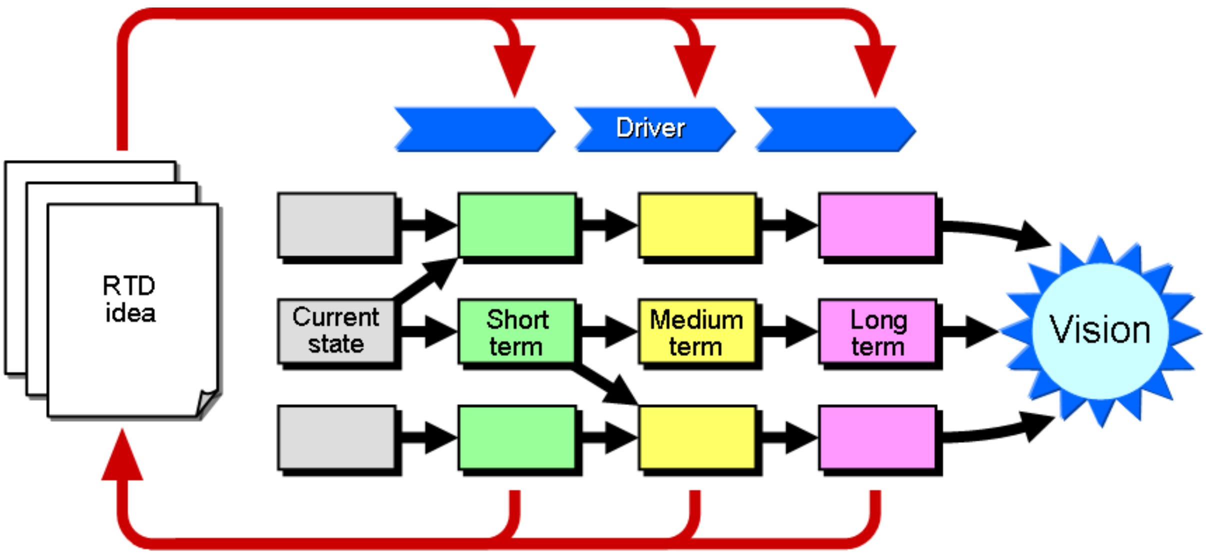


Figure 2. Roadmapping methodology

The contents of the 8 roadmaps is summarised in Table 1 on the next page.

Table 1. Main Themes and Corresponding Business Drivers and Key Research Topics

Main theme	Business drivers	Key research topics
Value-driven business processes	Performance-driven process, value to customer, total life-cycle support, product and service customisation.	Performance-driven processes, process orchestration, metrics, indicators, requirements engineering, mass customisation.
Industrialised production	Supply chain management, just in time logistics => open market, site productivity => ambient manufacturing and construction.	ICT for modular provision of customised constructions, logistics, assembly & services, digital sites.
Digital models	Semantics and interoperability => user and lifecycle orientation => real-time adaptive models.	nD models, access to life time information for all stakeholders anywhere anytime; ICT for design, configuration, analysis, simulation, and visualisation.
Intelligent Costrutions	Integrated automation and control (connectivity) => remote diagnostics and control (serviceability) => context-aware seamless configurability (adaptability).	Smart embedded systems & devices for monitoring and control, embedded learning & user support.
Interoperability	Data/file exchange => data sharing => flexible interoperability.	Model servers, distributed adaptive components, ontologies & open ICT standards for semantic communication, ICT infrastructures.
Collaboration support	Rapid and easy connectivity => robust team interaction => seamless inter-enterprise integration.	ICT tools for information sharing, project steering, negotiations, decision support, risk mitigation, etc.
Knowledge sharing	Access to knowledge => sharing structured knowledge => context-aware knowledge.	ICT for transforming project experiences into corporate assets. Object repositories, IPR protection of complex shared data, context aware applications.
ICT enabled business models	Business networking, customer orientation & sustainability, system integration, specialisation.	New ways for sustainable exploitation of ICT as a key part of business strategy in the open European / global construction marketplace.

Table of Contents

1. Introduction

1.1 Structure of the SRA

This document presents research priorities in 4 important areas of attention. In each area the priorities are organised into 2 complementary themes, altogether 8 themes:

- Processes: 1. Business processes.
  2. Production processes.
- Products: 3. Digital modelling of products.
  4. Intelligent products.
- Projects: 5. Interoperability between ICT systems.
  6. ICT support for collaborative work between organisation.
- Enterprises: 7. Capturing project experience into knowledge assets.
  8. Exploiting knowledge in new business models.

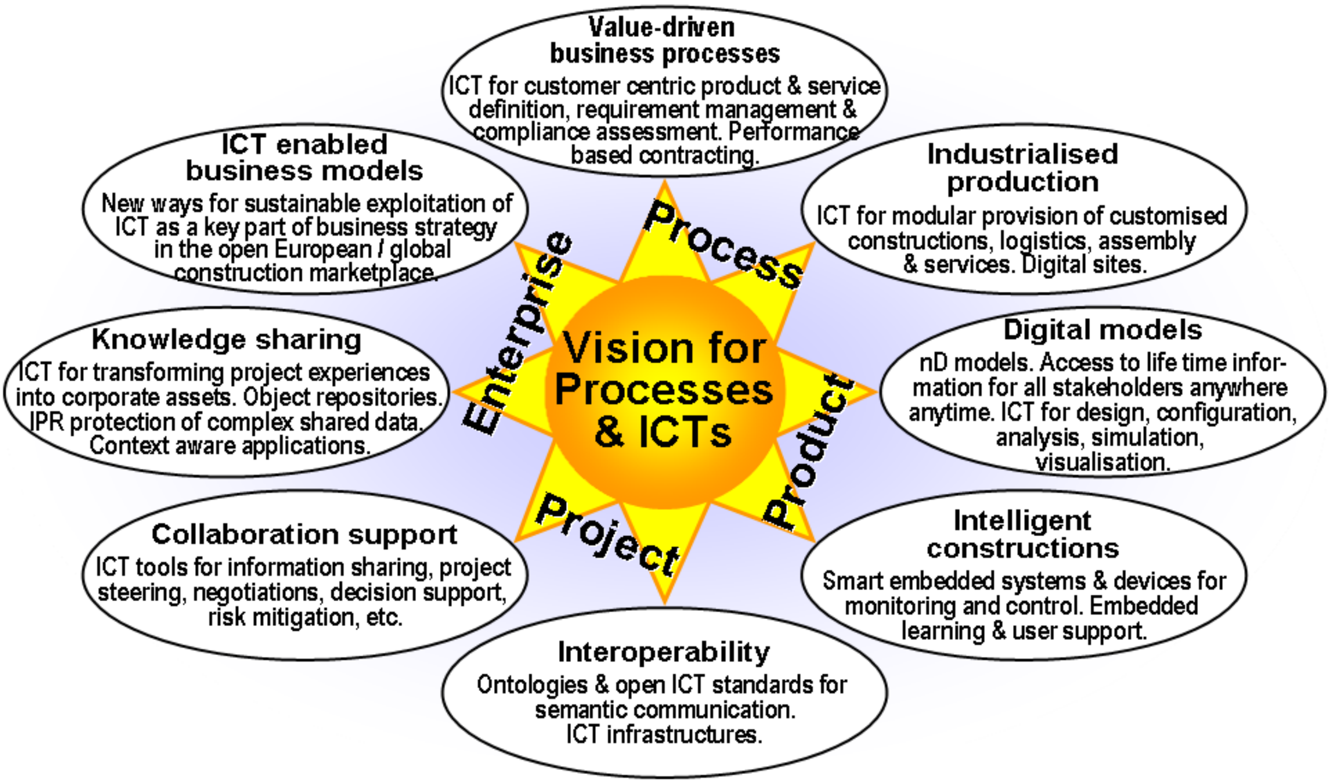


Figure 3. Summary of SRA themes

1.2 Context of Focus Area Processes and ICT

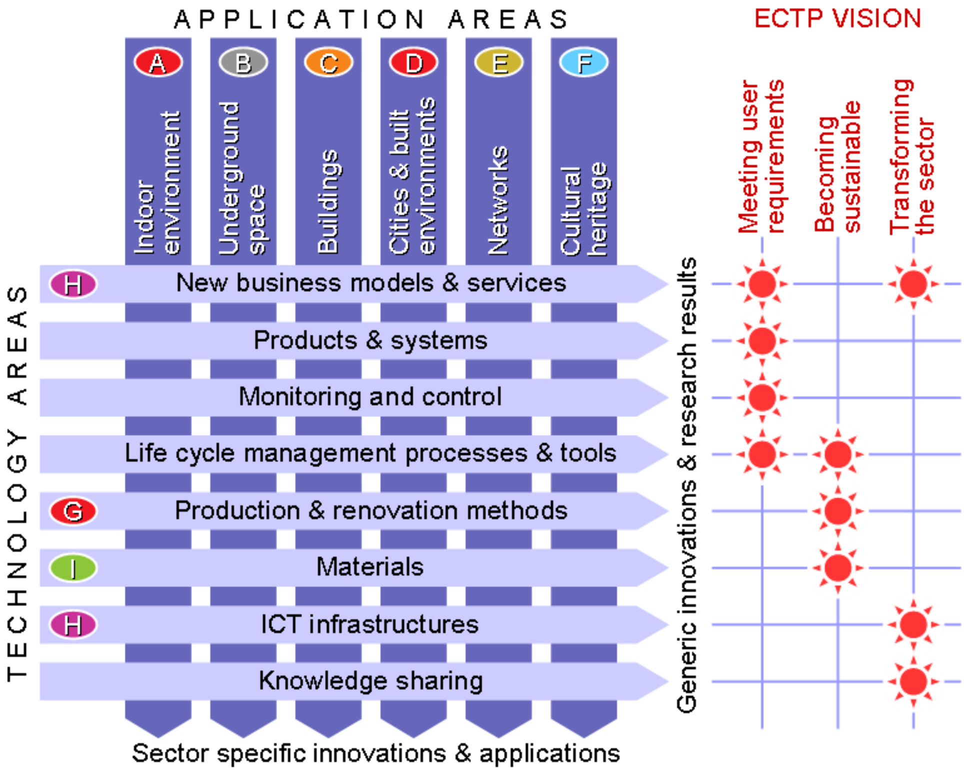
Relation to other Focus Areas

Processes and ICT (PICT) is a cross-cutting technology oriented Focus Area of the ECTP. The Vision & SRA of PICT supports the priorities of the application oriented FAs. PICT links construction specific priorities to generic developments in other industry sectors and especially in ICT.

Figure 4. Focus Areas of the ECTP

In June 2007 the ECTP issued the "SRA Implementation Action Plan" (IAP), including 55 RTD topics suggested by all 7 Focus Areas. The topics are mainly related to applications in different segments of the construction sector (vertical dimension). From a technological point of view, the IAP topics can be categorised into a far smaller number of enabling technologies (horisontal dimension), e.g. into the 8 categories shown in Figure 5. This analysis, done after fixing the PICT SRA structure, confirms good coverage of the PICT SRA with all IAP topics.

Figure 5. Technology areas



Other European Technology Platorms

The ECTP is one out of ~37 European Technology Platforms. Including the ECTP, altogether 19 Platforms address construction related topics.

Being confident that the construction sector will benefit from RTD in these related areas, PICT has considered the SRAs of other ETPs, focusing on topics where specific RTD is necessary for construction.

PICT related ETPs

The following 8 construction related ETPs are deemed to be directly relevant for PICT:

1. ARTEMIS - Advanced Research and Technology for Embedded and Intelligent Systems (ICT)
2. ECTP - European Construction Technology Platform.
3. eMOBILITY - Mobile and Wireless Communications (ICT).
4. EPoSS - European Technology Platform on Smart Systems Integration (ICT).
5. EUROP - European Robotics Platform (ICT).
6. MANUFUTURE - Future Manufacturing Technologies.
7. NEM - European Initiative on Networked and Electronic Media (ICT).
8. NESSI - Networked European Software and Services Initiative (ICT).

Other construction related ETPs

The following 11 construction related ETPs are not deemed relevant for PICT.

9. ERRAC - Rail Transport
10. ERTRAC - Road Transport
11. ESTEP - Steel
12. ESTTP - European Solar Thermal Technology Platform
13. ETPIS - Industrial safety
14. EUMAT - Advanced Engineering Materials and Technologies
15. FTP - Forest-Based Sector Technology Platform
16. PHOTOVOLTAICS
17. SMARTGRIDS - Electricity Networks of the Future
18. SUSCHEM - Sustainable Chemistry
19. WSSTP - Water Supply & Sanitation

ETPs that are not related to construction

The remaining 18 ETPs do not seem relevant for construction:

20. ACARE - Aeronautics and Air Transport
21. BIOFRAC - European Biofuels Technology Platform
22. EIRAC - European Intermodal Research Advisory Council (on transport)
23. ENIAC - Nanoelectronics (ICT)
24. ESTP - Space and Space-Enabled Technology
25. FOOD FOR LIFE
26. FTC - Future Textiles & Clothing
27. GAH - Global Animal Health
28. GAS COOLED REACTORS
29. GMES - Global Monitoring for Environment and Security
30. Hydrogen and Fuel Cells
31. IMI - Innovative Medicines for Europe
32. ISI - Integral Satcom Initiative (ICT)
33. NANOMEDICINE
34. PHOTONICS21 Technology Platform (ICT)
35. PLANTS for the Future
36. WATERBORNE - Advisory Council on Maritime R&D in Europe, ACMARE
37. ZERO EMISSION FOSSIL FUEL POWER PLANTS

FIATECH

The closest activity related to the ECTP outside of EU is FIATECH: The Capital Projects Technology Roadmapping Initiative, that brings together key players in the USA and Canada. While the ECTP is mainly driven by public funding opportunities, FIATECH aims at defining and executing industry-funded RTD and take-up projects. Basically the FIATECH roadmap is an implementation plan.

The FIATECH roadmap, which has basically the scope as the whole ECTP, addresses surprisingly similar topics as FA PICT. There are only two exceptions:

- FIATECH does not address new business models. This can be explained by the somewhat shorter term thinking in FIATECH.
- FIATECH addresses materials while PICT does not. In the ECTP they are addressed by Focus Area Materials.

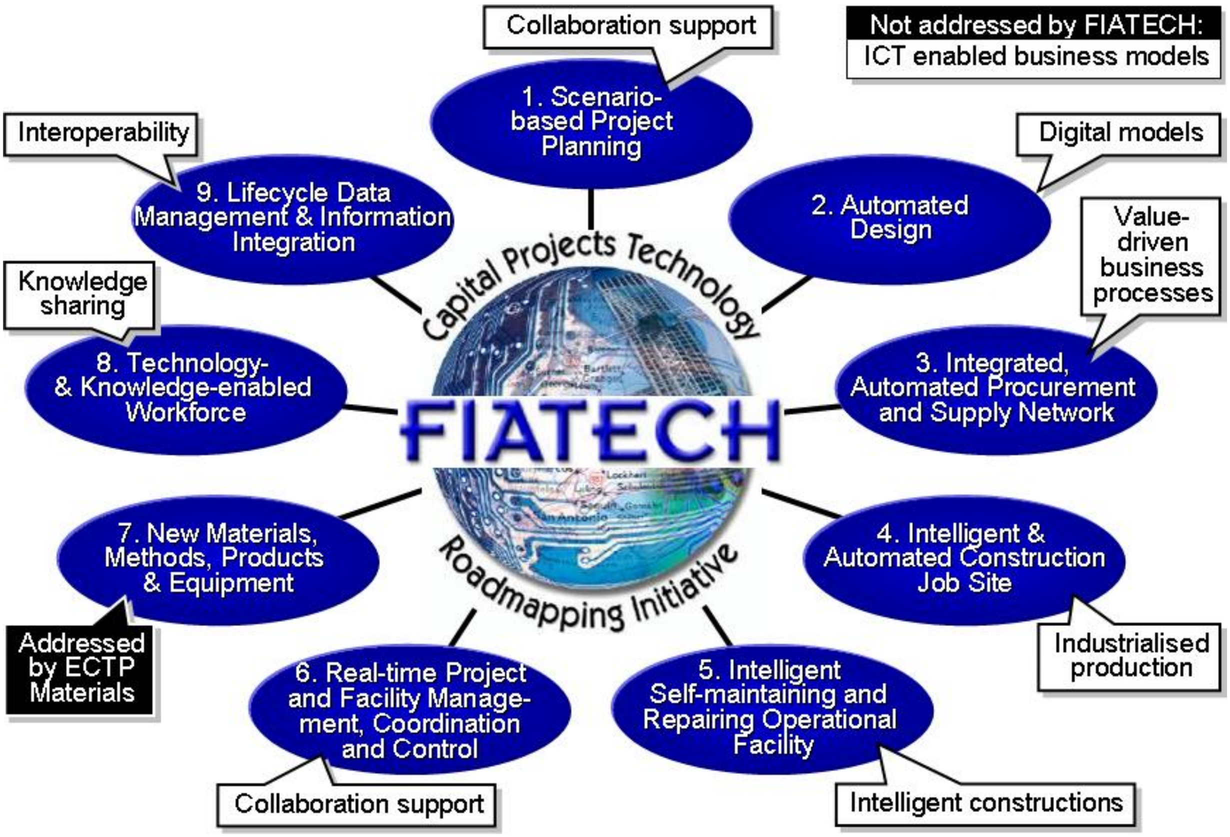


Figure 6. Mapping between the FIATECH Capital Projects Technology Roiadmap and the ECTP PICT SRA

Related RTD initiatives

Besides the European Technology Platforms, also a number of other organisations and initiatives have a strong influence of future directions of RTD: European and national RTD projects, standardisation bodies, industry & research networks etc. Members of FA PICT are involved in many of these initiatives.

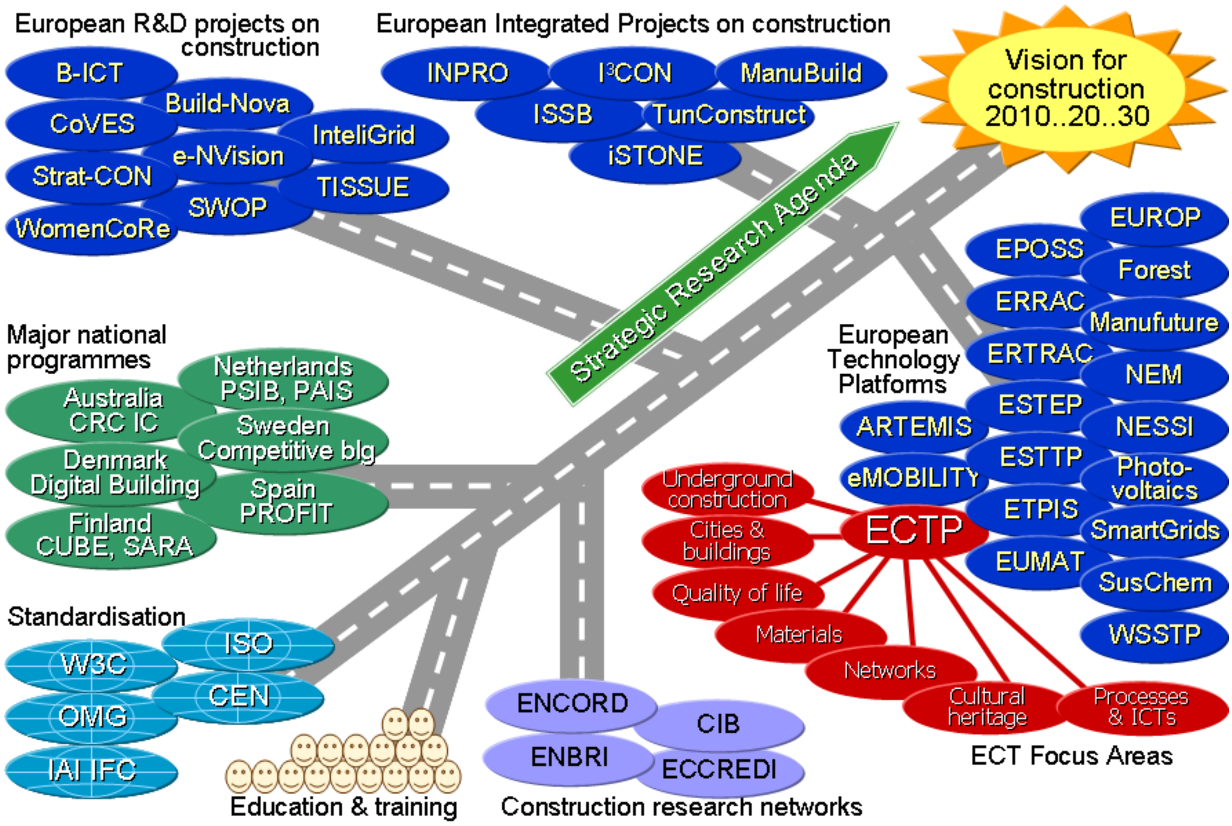


Figure 7. Context map - related activities

Related previous RTD strategies for ICT in construction

Typically at the end of each Framework Program, initiatives are launched to give directions to the forthcoming Framework Program. Key initiatives in the domain of PICT were:

- ELSEWISE project, "European Large Scale Engineering Wide Integration Support Effort". It defined industrial priorities for product data & information technologies. The project was supported by FP4 (just before FP5). Contract: Esprit 20.876; duration 1996-1999.
- ROADCON project, "Strategic Roadmap towards Knowledge-Driven Sustainable Construction". The project was supported by FP5 (just before FP6). It defined RTD priorities in ICT for construction. Contract IST-2001-37278; project duration 2002-2003.

No project for this purpose was supported by FP6 (before FP7). However a directly related project was launched from the multi-national ERABUILD programme:

- STRAT-CON project, "R&D strategies for ICT in construction", supported national funding organisations in Austria, Finland and France (see the Foreword). The project facilitated workshops for the preparation of this SRA and provided expertise and editing.

Some contributors to this SRA were involved in all these efforts being able to build on previous work.

2. Background, present situation and challenges

It is generally known that the construction sector lags significantly behind many other sectors in ICT infrastructures, ICT support for internal processes, supply-side e-business activities, and electronic marketing and sales (e-Business w@tch, 2005). The sector is known for its low investments in RTD.

The reasons are less well understood: project-based operations, locally limited competitive environment, temporary business relationships, complex one-of-the-kind products, non-professional clients etc.

It is anticipated that construction will continue to adopt more industrial modes of operation. The main challenge for the sector is to achieve holistic and integrated ICT support covering the complete project life cycle from conception to demolition.

In the area of managing of projects and dynamic business relationships construction is a leader and can not adopt solutions from other sectors.

2.1 Processes

- Business processes and competition are based on lowest project cost and short term antagonistic relationships rather than knowledge.
- Poor understanding and missing methodologies to assess and change value measurement, incentive drivers and contractual conditions.
- Production processes are dominated by on-site labour and low productivity off-site production.
- Low level of product differentiation makes companies vulnerable to increasing cross-border trade.

2.2 Products

- Current ICT tools in the construction industry are based mainly on application-specific data or are at low semantic level such as (digital) 2D-drawings and textual specifications. This hampers automation and integration of processes.
- Semantic (“nD”) modelling is increasingly supported by proprietary software tools and interoperability standards.
- Sharing semantic data is hampered by insufficient protection of intellectual property.
- Products are designed and delivered to order, with low degree of configurable manufactured components.
- Current constructions are mainly ”dumb”, poorly documented and difficult to use in an optimised way, while becoming increasingly complex due to use of new technologies.
- Existing intelligent (sub)systems are poorly integrated.

2.3 Projects

- Despite promising developments of object modelling and data exchange standards such as IFC, increasing use of semantic (”nD”) applications continues to face huge interoperability challenges.

- Available solutions address static data but not dynamic product behaviour.
- Interoperability problems limit the potential benefits of new and emerging ICT, cause extensive information management overload, limit possibilities for business collaboration between geographically remote partners, and limit the introduction of new and innovative products & services to the market.
- Current collaborative environments ("project web sites") provide basic file/document management and basic collaboration tools.
- Use of advanced collaboration tools is constrained by short project durations and concurrent participation of stakeholders in many projects at the same time. This leads to difficulties regarding costs and learning to use multiple systems.
- A fundamental and growing problem is the disparity of internal enterprise systems and external project environments.
- In addition to CAD/CAE tools product data in other industry sectors is managed by so called PDM systems which are rarely used in construction. Generic PDM addresses document and workflow management for large organisations and their suppliers. Consequently setting up a PDM system is time consuming, expensive and not feasible in a project oriented sector like construction.

2.4 Enterprises

- The sector makes wide use of commonly available knowledge. Few organisations exploit project experiences for developing genuine competitive advantages.
- Current business processes provide low incentives for R&D and knowledge development.
- Current business model are based on lowest cost and capacity provision.
- Enlarging open market, evolving business processes and new technologies in combination open up rewarding opportunities to innovative companies to develop and offer new knowledge based products and services.
- Generic Knowledge Management has been target for exhaustive RTD so far. However, very little has been done for capturing project experiences, formalizing them into corporate assets and exploiting them in new business models. This remains a relevant opportunity for construction and faces little competition on RTD funding from other sectors.
- Enterprise Resource Planning (ERP) is an area where construction seems to be lagging behind other industry sectors. The applicability of mainstream ERP systems has been limited by the project oriented nature of construction.

3. Vision for processes and ICT

The overall vision for the future Processes and ICT in construction is:

Construction sector:

- Achieves sustainability in products and processes.
- Considers whole life cycle of its products and services.
- Applies value / performance driven business processes.
- Meets users' and clients' requirements and aspirations.
- Uses innovation, knowledge and ICTs as key assets.
- Operates competitively in the European wide open market.
- Provides products that offer comfortable and healthy working and living environment.
- Is attractive as a working place.

The main challenge for the construction sector is to achieve holistic and integrated ICT support covering the complete project life cycle from conception to demolition. Figure *8* below illustrates this key driver for most RTD on construction ICT over the past 20 years.

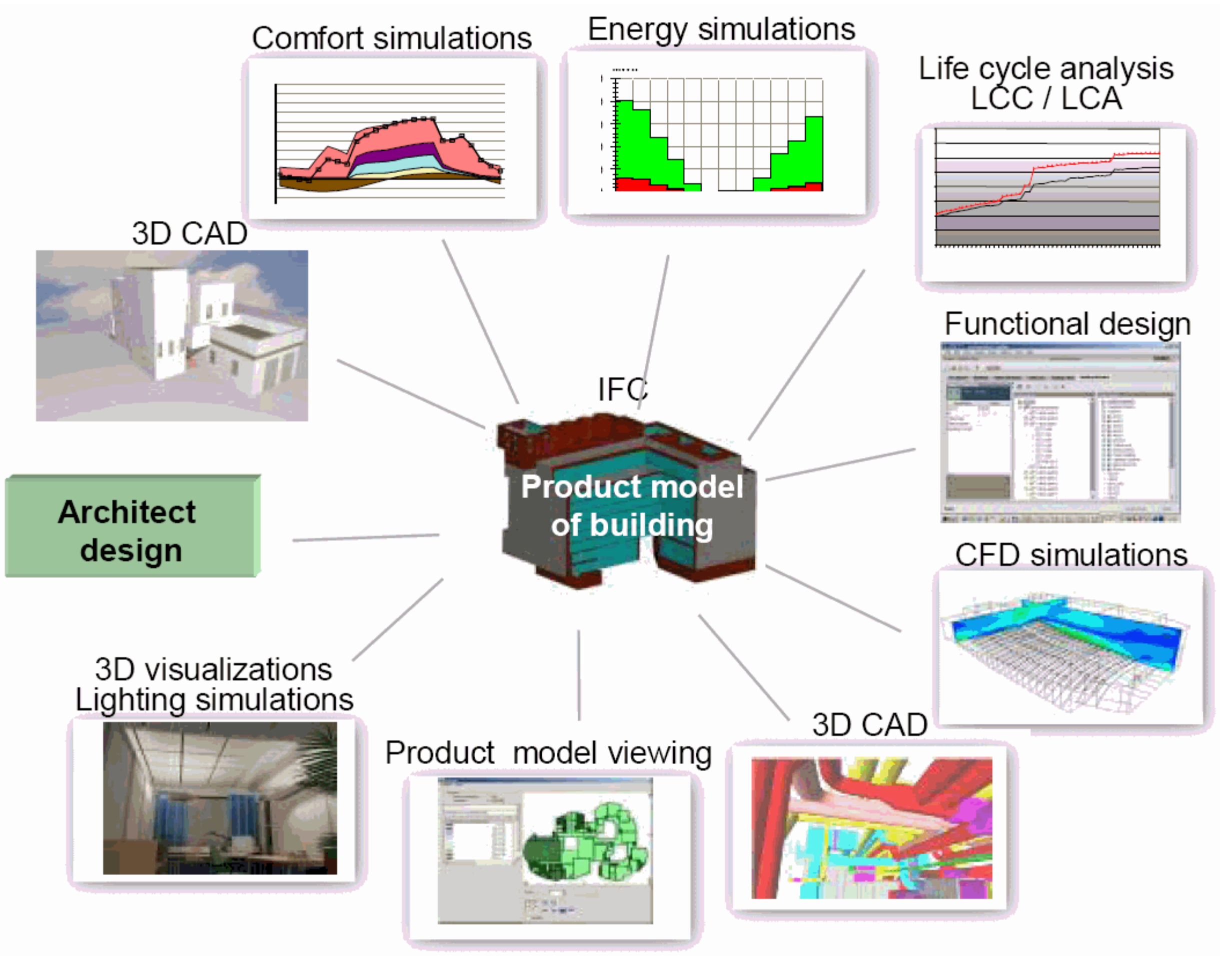


Figure 8: Vision of model based based information integration

4. Strategic Research Priorities

4.1 Value diven Business Processes

Main Business Drivers:	performance-driven process, value to customer, total life-cycle support, product and service customisation
Key Research Topics:	performance-driven processes, process orchestration, metrics, indicators, requirements engineering, mass customisation

Background

Nowadays, actors involved in the construction processes are facing the increasing complexity of projects (e.g. shorter delays, increasing number of actors involved in the design process, high quality requirements, variety of technologies, etc). The one-of-a-kind nature of construction projects adds to this great complexity.

Some relevant characteristics of the construction sector can be summarised as:

- Business processes and competition based on lowest project cost and short term antagonistic relationships rather than knowledge.
- Poor understanding and missing methodologies to assess and change value measurement, incentive drivers and contractual conditions.
- Production processes dominated by on-site labour and low productivity off-site production.
- Low level of product differentiation making companies vulnerable to increasing cross-border trade.
- Customer requirements not necessarily satisfied. Project delivery is based on cost and time optimisation, and not necessarily value to customer.
- Contracts typically awarded to lowest bidder and not necessarily best "performer".
- Product/service customisation is limited and few opportunities exist for product/service re-configuration during product lifecycle.

Client demand for value-adding products/services, customisation, re-configurability, etc. are posing new challenges for contractors. There is a clear paradigm shift towards performance-driven process, value to customer, total life-cycle support, product and service customisation.

Vision

Target State

The vision proposed in this roadmap is based on the fact that today, there are no tangible methodologies, models and tools available to manage performance and business processes in construction. It is advocated that to move from the current state of time and cost driven process towards value driven processes, performance driven processes, value to customer, total life cycle support, and product and service customisation must be supported.

Such a vision also leads to the following considerations:

- Strong stakeholders, like clients, are important agents of change and may provide leadership in the development of a sustainable built environment provided by an integrated supply side.

- Business relationships are based on trust, partnerships and win-win.
- The demands of end-users and society are met while optimising the use of resources; the technology available to achieve sustainable development is integrated in a systematic way, and the integration is site-specific thereby exercising vigilance and meeting local expectations of end-users and achieving performance and 0-accident and health risks.
- The procurement of services or products is done in ways that improve responsibility, reliability, quality, encourage competition and stimulate innovation.

Business Scenario: Performance based Contracting and Conformance to Customer Requirements

Shift of focus is needed; construction service providers have to see themselves as a short but regularly recurring chain of the client's business processes. The companies should be able to provide space for the customer in its entirety; helping client to define the needs, creating the performance brief based on those needs, designing the building, constructing, maintaining and operating it and finally, demolishing it. Performance approach forces the clients to think what is really needed to support their business processes. Performance based requirements give designers and suppliers possibilities to fully exploit their knowledge accomplishing creative and flexible solutions. When requirements are performance based, the variety of procurement methods is larger. The contractors can improve design and also benefit from this. Feedback from other parts of the process enables learning and better buildings in the future. In the future, contracts will be awarded based on the past performance of contractors and/or their potential in terms of performance to deliver a product/service as per customer requirements.

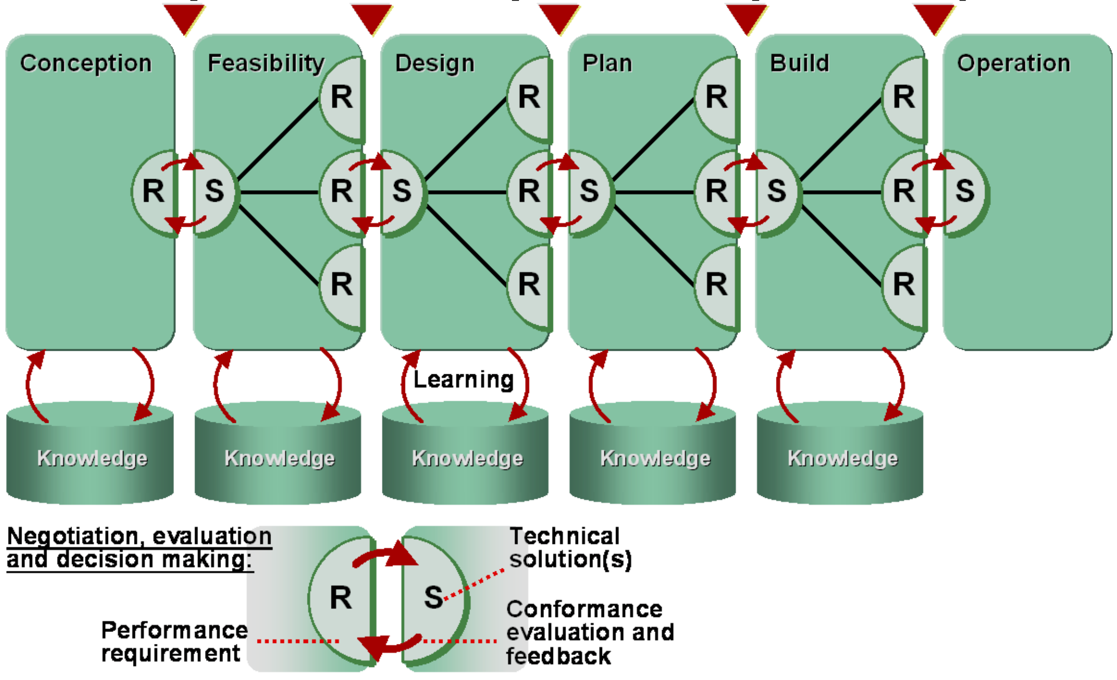


Figure 9: Conformance to Customer Requirements

Business Scenario: On-demand Customisation of Products and Services

Clients require customised products and services that address changing client product/service needs during the lifecycle of the solution (product/service). Modular product and service design alongside mass customisation tools allow this to happen. Rather than select the closest solution available, clients will be able to "pick-and-mix" different product/service modules to design their solutions. As the product/service components will be modular in nature, they will not only be easy to design (modular design), but to also easily manufacture and assemble (industrial production). Once the product/service has served its purpose, rather than being demolished/terminated, and it could be easily disassembled, reconfigured, and re-used.

Roadmap

Objectives

The objectives of the roadmap are to develop an extended approach for Construction re-engineering, revisiting process-chains for conception, achievement, maintenance & restoration of buildings and infrastructures. This re-engineering should rely on knowledge-based paradigms and assessment metrics and methods, related to *value-/performance- driven business models* which can create incentives for better performance, innovation and knowledge creation, and it should include a systematisation of the value analysis over the life-cycle, from inception and design to exploitation and maintenance. This roadmap aims to address four main business drivers:

- Performance-driven process
- Value to customer
- Total lifecycle support
- Product and service customisation

Main Research Areas

ICT should allow dealing with customer-centric definition of products and services, management of requirements being instrumental in providing what the end users want (especially how functional requirements are translated into design and production requirements), support for capturing and fulfilling predefined performance criteria. ICT should also support scheduling & planning with information transfer between applications used in different stages of the construction process. The following roadmap illustrates the main research areas for value driven processes. A set of short, medium, and long-time to industry research areas are identified for performance-driven process, value to customer, total lifecycle support, and product and service customisation respectively.

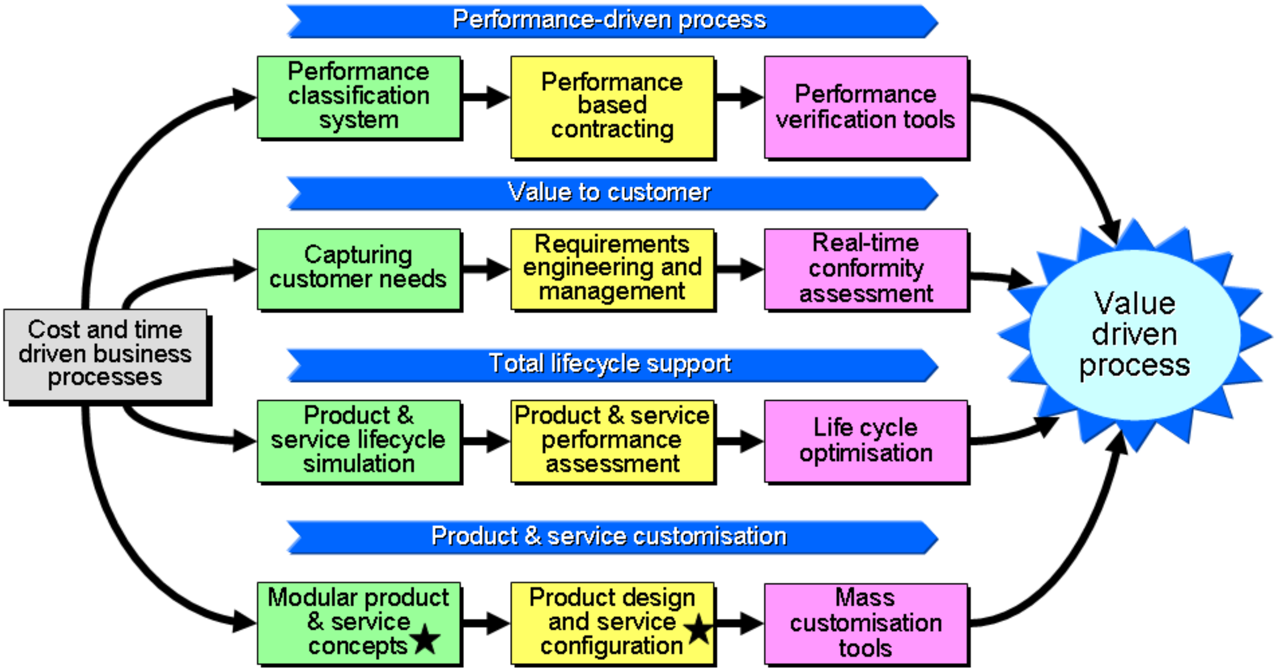


Figure 10: Roadmap for Value Driven Business Processes

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Short term:

- Development of performance classification systems
- Methods for capturing customer needs in "tangible" form (e.g these requirements could be based on product/process performance)
- Methods, models and tools for product and service lifecycle simulation
- Development and use of modular product and service concepts

Medium term:

- Tools to support performance based procurement and contracting.
- Tools for the engineering and management of customer requirements
- Tools for product and service performance assessment
- Tools for customised product design and service configuration

Long term:

- Model based tools for performance verification
- Tools for real-time conformity assessment of customer needs
- Tools for product/service lifecycle optimisation
- Tools for mass customisation of products and services

Current State of the Art

- Cost and time driven business processes: Most business processes within the construction sector are built around the premises of minimisation of cost of production and time of product delivery. They may provide some economical benefits to the client and contractor, but this may be at the cost of non-satisfaction of initial client requirements, and furthermore the quality of the product/service may be compromised.

Time to Industry: Short term

- Performance classification system: A performance classification systems not only serves as an instrument to measure contractor/supplier and or desired product performance, but also serves as a common language through which different actors in the construction sector can understand each other.
- Capturing customer needs: Capturing customer needs and targets at the very beginning of the project is essential for a successful end result. It is also important to bridge the gap between customer terminology (satisfactory lighting in the office rooms) and the domain terminology (750 lux in the working area, no glare, even distribution of light). It is of paramount importance to ensure that the customer needs are captured in a tangible form that is then easily understood both by the customer and the product/service provider.
- Product and service lifecycle simulation: There is a need for tools that not only assist in the design and visualisation of products/services, but also provide a means to assess their respective lifecycles. As an example, how will the foundation of a building react to varying loads (e.g. initially an office building and then converted to a supermarket) over a period of twenty years when.
- Modular product and service concepts: Shorter delivery times are needed so that the structures of the built environment can adapt to the more rapidly changing business environment. Also more reliable and well-performing solutions are necessary. Modular product concept enables variety of end results from a limited number of modules that are effective to realise and easy to maintain. Tools for modular product and service design are essentially model-based and rely in part on object orientation concepts. These modules in fact can be seen as plug-in, self-design, and operate.

Time to Industry: Medium term

- Performance based contracting: There is a need for tools and services that allow analysis of past performance of contractors and suppliers and their competence from a performance based potential for future projects. Performance here is seen as being in conformance to the desired performance (value) of a product or service. Contracts are awarded on the basis of performance and not necessarily lowest bid.
- Requirements engineering and management: Too often the original requirements are lost due to the deficient requirements management. It is important to capture the client requirements at the beginning of the project, but it is equally important to manage the changes, and maintain transparent decision making during the performance driven process.
- Product and service performance assessment: Tools and services that provide the opportunity for regular product/service assessment. Though initially products and service lifecycles may have been visualised and simulated during design and/or construction stages (refer to product and service lifecycle simulation), there is a need for regular product/service assessment once these products (e.g. building or building component) are in use.
- Product design and service configuration: Relying on modular product and service concepts, there is a need for tools that support modular product design and service configuration. These tools will support the “drag-and-drop” of different product/service modules to form and mainly design a complete product or service. As such, the modules will in addition to geometric and material properties also contain behavioural and design information allowing for the design of the interfaces (connections) between different product/service modules.

Time to Industry: Long term

- Performance verification tools: The verification of the performance requirements has to be regular. In all phases of the performance driven process, the technical solutions are (automatically) verified against the set performance requirements ensuring the there are no defects in the final product.
- Real-time conformity assessment: There is a need for tools that allow for continuous verification of conformity to customer requirements. As is known in the construction sector, such requirements may change from one product/service lifecycle stage to the next. The tools will during each lifecycle stage support feedback from the designed, developed, or used product/service solution to the customer requirements.
- Life cycle optimisation: To ensure optimal use and minimal environmental impact (e.g. due to demolition, emissions from heating, air-conditioning, etc.), there is a need for tools and services that support product/service lifecycle optimisation. Lifecycle optimisation tools will support the efficient use of products/services both during and beyond their initial intended lifespan. They will not only provide better value to the customer through more efficient use of the product/service, but also contribute to minimising environmental impacts from the use of the building/service.
- Mass customisation tools: Customers today, typically demand unique products/services. Relying on modular product and service design, customers will be able to receive the product/service that they desire through an assembly of a set of choice products/services. Furthermore, being modular in nature, the products/services will be designed to be changeable when desired as opposed to being built for life. Mass customisation tools support industrialised production and support modular product and service design, operation, and reconfiguration. As an example, when a building needs to serve a new need, it can be reconfigured to do so without having to necessarily demolish and rebuild it, or without massive and time consuming refurbishment.

Business Impacts

There will be a paradigm shift in terms of product/service delivery from lowest investment cost to optimal value to and conformance of requirements of the customer. Both customers and contractors/suppliers will share a common terminology (or interfaces to a common terminology) allowing for better understanding and delivery of customer requirements. Aided by modular product and service design, not only will more solutions be available to customers, but it will be feasible for designers and mainly contractors to deliver them. The products/services of the future will be fully configurable at start and reconfigurable during the lifecycle of the product/service. This will allow for example in the case of a major hazard (e.g. earthquake) to convert an opera house to a fully functional hospital within a matter of days (2-3), and to then re-convert it back to an opera house thereafter. Buildings, infrastructures and urban achievements of the future will integrate all new constraints, including a rational use of energy, minimising risks, trouble and discomfort for the individual users, and minimising pollution and risks of any kinds for all users in general and the society.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• ICT meeting societal challenges: – Health, environment & sustainable development, risk & emergency management, data management for environmental monitoring (contributing to INSPIRE, GMES, GEOSS).

FP7 Nanosciences, Nanotechnologies, Materials & new production technologies	• Developing generic production assets (technologies, organisation, production facilities) meeting safety & environmental requirements.
FP7 Environment	• Impact of buildings & cities: – Identification of pollutions sources, emerging environmental stressors & their potential health effects. – Sustainable management of the urban environment.
ROADCON 2003	• Legal and contractual governance. • Performance driven process. • Total Life Cycle support.
ELSEWISE 1997	• Awareness of technological opportunities. • Functional requirements & conformance assessment. • Decision support. • Demanding client.
FIATECH 2007	Element 3: Integrated, Automated Procurement and Supply Network

4.2 Industrialised Production

Main Business Drivers:	Supply network management; Open market; Effective manufacturing and construction.
Key Research Topics:	ICT support for modular provision of customised constructions; Logistics, on-site production and assembly; Integration of construction site in the process.

Background

Industrialised production in construction means application of modern manufacturing methods in prefabrication, supply network management and on-site assembly. The underlying drivers are safety at work, productivity, time to delivery and predictable quality. Moving site production offsite requires radical shift of thinking construction as one-of-a-kind oriented craftsmanship towards construction as a knowledge based industry. Ad-hoc design and re-invention needs to be replaced by development of modular, re-usable solutions and customer oriented configuration management. Industrialisation will both require and benefit from an EU-wide open market for manufactured building components and services. The required ICT tools will support promotion of manufactured components in the market, customer oriented configuration design & management, effective supply logistics and on-site automated production and assembly.

Vision

Target State

The vision of industrialised construction comprises:

- Construction sector offers safe and attractive high-technology work places.
- Sites, construction machinery and mobile staff are connected to corporate information networks.
- Customised construction products are produced industrially.

- Manufactured construction products are offered on the EU wide open market.

Business Scenario: Mass Customisation

This scenario combines industrialised production with individual design solutions: An essential part of design is done in advance before any specific construction project. The pre-defined solutions provide options for customised configurations for specific situations:

- Building concept is a generic definition of a building type and the range of its possible performances that address the needs of a market segment described in a way that allows conformance assessment. An example of a building concept is "low energy building". Different providers may offer competing proprietary solutions a building concept.
- Product platform is a set of specific, possibly proprietary, re-usable technical solutions for configuring customer specific systems and buildings (layouts, components, modules, connections).

Many building components are available as manufactured components with some degree of customisation. Manufacturers provide information about their products in the web-based intelligent component catalogues which describe relevant data for product selection and customisation. The required design logic and guidance is embedded in the component objects.

Users, e.g. designers, search the web for products that meet specific criteria. Standardised classification schemes and product attributes enable EU-wide access to product information. Selected objects are incorporated to the designers' CAD system by dragging and dropping. Each object is adapted to its environment and function based on its built-in design logic. For instance, a beam can adopt itself to the specific span width and load.

A similar approach is applied on the level of overall design: pre-made "template" designs for rooms, structural frames etc. are available, from internal development by companies or from specialised service providers. The overall design is composed from templates which are configured to fit as partial solutions within a unique overall solution.

Business Scenario: Ambient Manufacturing

This scenario introduces manufacturing-level production methods in factory and on site.

- Factory production uses "normal" manufacturing methods which are adopted from other industries, e.g. FMS and robotics.
- Rapid on-site assembly methods make use of intelligent machinery, high-precision positioning, fast hardening connection materials, customised connection components produced with rapid prototyping technologies ("3D printing"), real-time digital site model which is accessible to site personnel via wearable terminals, etc.
- Special products are pre-assembled / pre-produced in small mobile factories at or close to site or during transport. Examples: ventilation ducts, HVAC-assemblies etc.

Roadmap

Objectives

Develop modular (intelligent & pluggable) products, integrated multifunctional modules and production equipment for industrialized off-site production and methods for rapid on-site assembly and connection. Develop innovative measurement techniques for assessment and quality control of materials in arrival at the construction site. Develop tools for effective logistics management from suppliers to site and ambient/embedded guidance for on-site assembly work.

A second objective, in the specific context of the Construction sector, is related to the operation of the Construction site where assembly of the Construction product is done. This objective is to develop a new approach integrating a generalized use of ambient technologies and semantic knowledge technologies to ensure optimisation of on-site manufacturing, integration, resource management and quality control:

- with secure access to site information to all involved stakeholders,
- while minimising "embodied energy" (which is the sum of all energies consumed for the construction - e.g. adequate production of materials), - and during the construction of the building or infrastructure),
- and ensuring "stealth Construction sites", especially in case of refurbishment or rehabilitation of existing legacies under strong functional, environmental and human constraints: this is to be achieved by low-intrusive renovation techniques with minor impact on public, directed to groups with special needs.

Main Research Areas

The RTD targeting Industrialised Production is driven by two main trends:

- Evolving EU-wide open market in constructions.
- Increasing productivity throughout the supply network including the construction site.

Short term:

- Tools for supply network and logistics management.
- Flexible manufacturing.
- On-site communication.

Medium term:

- Standards for supply network integration.
- Customer oriented configuration design & management using manufactured components.
- On site production and assembly methods.

Long term:

- Customised product & service integration.
- Manufacturing level on-site production and information management.
- Fully virtual production.

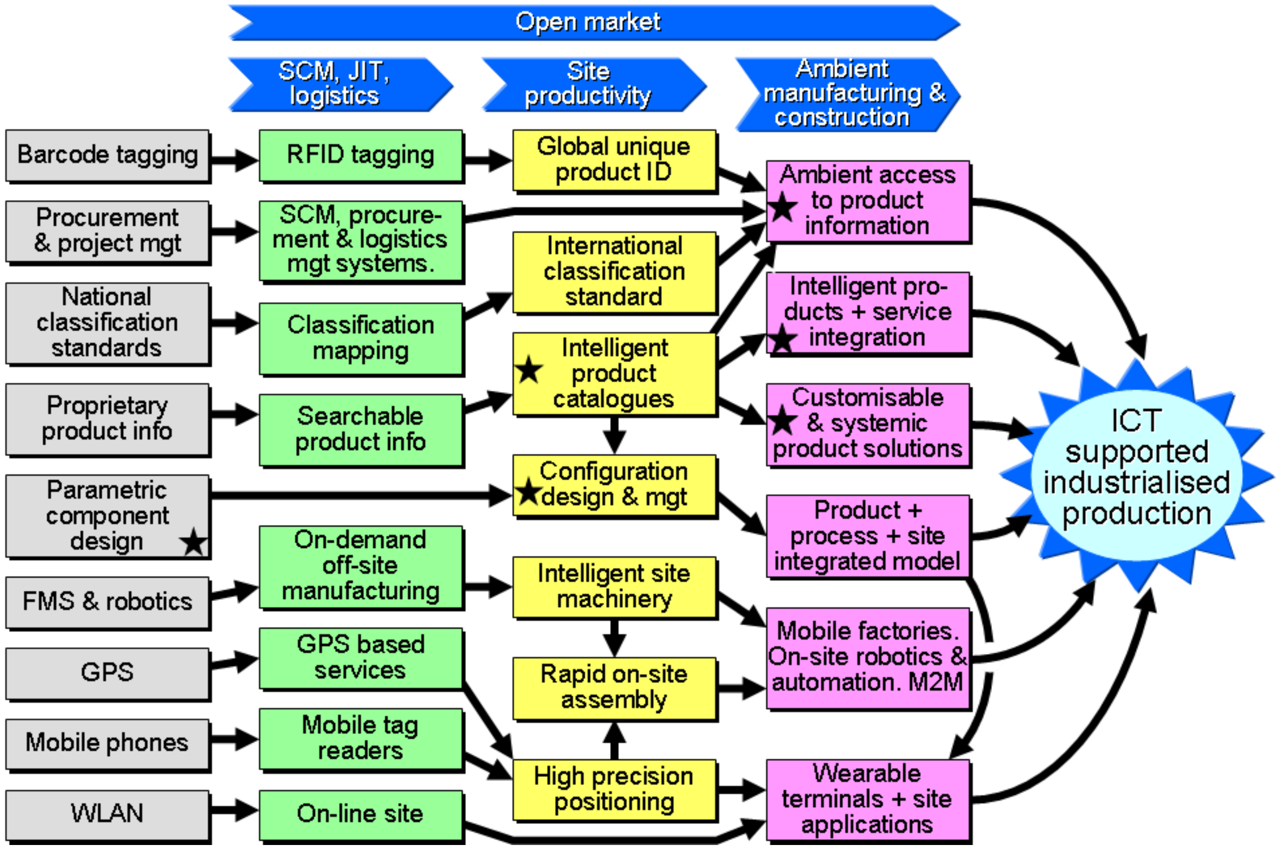


Figure 11: Roadmap for Industrialised Production

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- Barcode tagging: Products are tagged on a category basis. Individual instances of similar products are usually not differentiated. Custom made products are identified with supplier specific codes (human readable only). This limits possibilities for precise logistics management, assembly planning and monitoring over product life cycle.
- Procurement: Procurement is based on annual agreements between the buyer and a few preferred suppliers. This together with dominantly national classification standards limit possibilities for open procurement.
- Project management: All collaborating project partners use ICT-based project management tools but these are not integrated. Project management is largely a human centric activity with intensive personal communications. Web based access to a shared document server is also common but mainly used by office-based personnel only.
- Product information: Suppliers provide product information in proprietary formats with no or low semantics. This limits possibilities for finding the best fitting products and access to product specific information.
- Parametric component design: Manufactured components are often designed with parametric ICT-applications provided by the suppliers / manufacturers. Users and customers have limited access to such applications and need to engage in human centric sales negotiations.

- FMS & robotics: Industrialized construction is in many cases characterised by manual production in indoor conditions (“factories”). Adoption of effective manufacturing methods is limited e.g. FMS and robotics, JIT, Kaizen, lean production.
- Geographic positioning systems: GPS is already used for tracking logistics processes. High precision positioning is not available for on-site conditions, e.g. indoors and underground.
- Mobile phones: Mobile phones are commonly used by most personnel and suppliers, including SMEs, on- and offsite. SMS messaging is used for reporting receipt of deliveries and quality checks. Construction specific mobile productivity applications are rare.
- LAN/WLAN: Site offices are connected to the corporate ICT system of the main contractor. Wireless networks on constructions sites are increasing and provide access to corporate networks and the internet.

Time to Industry: Short term

- RFID tagging, supply chain & logistic management: RFID tags allow wireless reading of product identification and access to product information. ICT applications are needed for component tracing throughout the delivery process.
- Web-based & mobile platforms for computer supported collaborative work (CSCW): Collaboration tools are already commonly used by office based personnel and need to be enhanced to serve mobile and site personnel, too.
- Classification mapping: Building classification systems are deeply rooted in national and regional process practices. A short term strategy in order to promote cross-regional trade is to provide mapping between different classifications.
- Searchable product information: The users often need to find suitable products for specific purposes. Product information is available from manufacturer’s / suppliers catalogues, that are increasingly published on the web. In order to support searching the web based product information should include standardised classification codes, keywords and property attributes.
- On-demand off-site manufacturing: Integration of communication capabilities and flexible manufacturing technologies allow responsive manufacturing of custom components at short notice.
- GPS based services: GPS positioning devices are commonly available and are useful for tracing products in logistics processes.
- Mobile tag readers: Mobile readers are readily available e.g. integrated with mobile phones. Combined with application software, GPS positioning and embedded digital cameras these devices can be used for versatile reporting purposes.
- On-line site model: Digital modelling of products is already common. Enhancing these models with scheduling information leads to “4D” models that are useful for communicating the progress on site. Such models can be made available to stakeholders via web, in addition to documents, digital photos and videos.

Time to Industry: Medium term

- Global unique product identification: All products need to have global identifiers. It is not sufficient to identify the product category only – also the individual instances of similar products need to be identifiable.

- International classification standard: In order to enable fluent international trade of construction products a standardised classification system is needed and reflected in ICT tools for e-procurement and logistics management of manufactured components.
- Intelligent product catalogues: Technologies like semantic web enable implementation of "intelligent" catalogues which are searchable, include embedded knowledge (e.g. design rules & instructions) and provide customised views to different users based on their needs. Exploiting these opportunities needs to be aligned with the marketing strategies of suppliers and manufacturers.
- Configuration design and management: Buildings are individually designed as one-of-a-kind products. Increasing industrialisation leads to platform-based, customisable systemic solutions for construction products and services. Configuration design and management tools are needed for customisation.
- Intelligent site machinery: On-line connectivity of site machinery for monitoring of capacity utilisation and condition, maintenance needs etc.
- Rapid on-site assembly: Increasing off-site production necessitates just-in-time deliveries, elimination of storage on-site and rapid assembly methods. Efficient site operations need to be supported by enhanced planning and monitoring.
- High precision positioning: High precision measurement and positioning methods are needed to support assembly of manufactured components.

Time to Industry: Long term

- Ambient access to product information: Widely accessible communication infrastructures and embedded intelligence (identifier tags and sensors) allow ambient access to published product information as well as real time product status anywhere anytime.
- Intelligent products + service integration: Embedded sensors and intelligence in products support related services like remote control, condition monitoring and maintenance.
- Customisable & systemic product solutions: Self-configuring intelligent products adopt themselves to new usage scenarios and system solutions.
- Product + process + site integrated model: All production related information will be modelled.
- Mobile factories, on-site robotics & automation, M2M: Construction sites make use of manufacturing level production methods like robotics and automated and remotely controlled machinery. Flexible production is distributed in factories, on-site and mobile production cells ("mobile factories").
- Wearable terminals + site applications: Mobile terminals hosting various context & location aware applications are integrated in the apparel of site personnel.

Business Impacts

The solutions shall radically improve safety at working place and offer attractive knowledge intensive employment opportunities and shall also address retrofitting.

Construction sites will be safer, better organised (and therefore less expensive) and optimising refurbishment, while at the same answering to a strong societal demand of minimising discomfort of people living around, or being customers of the building or infrastructure.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• ICT supporting business & industry: – *Manufacturing:* rapid and adaptive design, production and delivery of highly customised goods; digital and virtual production; modelling, simulation and presentation tools; miniature and integrated ICT products;
FP7 Nanosciences, Nanotechnologies, Materials & new production technologies	• Developing generic production assets (technologies, organisation, production facilities) meeting safety & environmental requirements. – *Materials* – *New production:* development and validation of new industrial models and strategies; adaptive production systems; networked production; rapid manufacturing concepts for small series industrial production. – *Integration of technologies for industrial applications:* Sectoral applications e.g. in construction.
FP7 Environment	• Technologies for managing resources or treating pollution (e.g. on Construction sites) more efficiently.
ROADCON 2003	• Digital Site. • Ambient access.
ELSEWISE 1997	• Manufacturers' product catalogues. • On-line site • Process models.
FIATECH 2007	Element 4: Intelligent & Automated Construction Job Site

4.3 Digital Models

Main Business Drivers:	semantics and interoperability => user and lifecycle orientation => real-time adaptive models.
Key Research Topics:	nD models, access to life time information for all stakeholders anywhere anytime; ICT for design, configuration, analysis, simulation, and visualisation.

Background

Electronic business activity is less developed in the construction industry than in manufacturing sectors. There are a multitude of standards, technical specifications, labels, and certification marks. Electronic business activity in construction is very limited compared to the other sectors studied by e-Business W@tch. Many companies prefer to be re-active rather than pro-active in their use of ICT. The construction industry has yet to show the same level of ICT driven improvement of productivity as in other industries. This can partly be explained by the nature of the work and the type of production involved in construction processes. It is also related to slow uptake of ICT in a sector which is dominated by SMEs. Large enterprises in the industry and new sector entrants have adopted ICT based production methods. However, there is still great potential for further ICT uptake, for example: production planning systems, ERP-systems with financial components, inventory management systems, supply chain management (SCM) and mobile solutions. Business process integration may be a key driver for ICT adoption in the future. Most companies in the sector tend to organise work around individual construction projects which has led to a fragmentation in ICT use and e-business activity, characterised by a lack of commonly accepted standards, technical specifications and labels. (Source: e-Business Sector Studies – Construction, http://www.ebusiness-watch.org/resources/construction/construction.htm)

The current situation can be summarized as follows:

- Current ICT tools in the construction industry are based mainly on application-specific data or are at low semantic level such as (digital) 2D-drawings and textual specifications. This hampers automation and integration of processes.
- Semantic ”nD” modelling is increasingly supported by proprietary software tools and interoperability standards.
- Sharing semantic data is hampered by insufficient protection of intellectual property.
- Products are designed and delivered to order, with low degree of configurable manufactured components.
- Current constructions are mainly ”dumb”, poorly documented and difficult to use in an optimised way, while becoming increasingly complex due to use of new technologies.
- Existing intelligent (sub)systems and tools are poorly integrated.
- Exchange of geometry is manageable, but further related information (“intelligence”) has to be recreated.

Vision

Target State

The vision of future digital models in the Construction Industry is as follows:

- All systems in constructions share common platform, network and protocols, with secure external connectivity via the internet enabling local, remote and mobile monitoring, diagnostics, reporting and operation.
- These systems provide optimised control and intelligent services to users and operators.
- The life cycle of construction products is supported by applications using semantically rich models that contain all relevant information without need for human interpretation.
- Digital models are accessible anywhere and anytime.
- Future digital models providing easy access.

Business Scenario: The Annotated "Planners"- Knowledge Base

Architectural practice shows frequently a high fluctuation in terms of the average duration of employment and this within miscellaneous planning offices. Especially team-members and -partners are changing during the repeatedly drawn-out planning process. A fact that leads to a loss of knowledge in cohesive planning processes and in understanding previous working steps. Short-term employment therefore leads to a high risk of direct loss of accumulated knowledge. It has furthermore to be considered that it is hard for new employees to orient themselves in an ongoing project and to take over the assigned planning tasks. How can novice employees orient themselves in a complex planning process? Is there a way of directly reading into the past activities? Therefore a knowledge base is to be developed minimising that specific knowledge loss. The vision is to create a digital data model environment, which at the same time allows the user to access additional knowledge about the planning-status and annotated information of a diverse planning content. Structured information has to be collected in during the process of planning and directly linked with the digital model. It is urgent to create an easy access for new employees for getting in touch with the far reaching information of complex planning. The structure of this model basement has to be quickly readable and allows for uncomplicated learning. Using the annotated *Planners Knowledge Base* will minimise the loss of specific planning-knowledge and open the gateway to an easy accessible working platform for novice employees.

Business Scenario: The Easily Accessible "Virtual Building Model"

Normally, enormous amounts of 2D-representations of a (future) building are constituting the planning basis for managing the construction-site and later on the conservation of the building during the whole lifecycle. Understanding and relating different sources of 2D-information is a complex task, inactively and usually connected with the problem of spatial representations in case of complex geometry. Instead of collecting loosely coupled 2D-documents with a high demand for "correct" human interpretation, the "Virtual Building Model" is offering a database driven model (combination with a structured project database). One of the features of the "Virtual Building Model" is the generation of representations on demand. Offering such a set of features means setting up the foundations for a complex 3D-model at an early stage of design. Necessarily the digital model receives continuous refinement. During the ongoing planning process the digital model gets more and more detailed. Subject to the user, specific information is opened on different levels to the diverse planning partners. Access-keys are allowing to implement and change 3D-information subject to declared points of time. The 3D-model contains any collected relevant information about the real-scale building. After finishing the construction work it serves as an easily accessible 3D-representation of the 1:1 building providing efficient conservation and monitoring data.

Business Scenario: Building Information Models on Digital Maps

The use of online map services is now gaining wide usage by both individuals and corporations. However, in many case the accessible information is limited to geographical coordinates and images of e.g. buildings. This scenario builds upon providing access to a given building (or infrastructure element's) relevant information through a building information model. Buildings are no longer seen as static pictures or geographical coordinates, but as digital information rich models of the building. They can provide on demand (and upon authentication) information on the type of material used within the building, relevant dimensions of rooms, doors, windows, etc. This should actively support facilities management firms in supporting and actively monitoring all the buildings that they are managing within a given geographical space (neighbourhood, city, or even country). Furthermore, based on the information provided through a building's information model, user could be able to identify relevant service providers within the vicinity of the building for a given service or to for example acquire a particular component. For example, when a user needs to replace a particular door, then based on the information from the building's information model, the user should be able to search for vendors nearby with a capability to provide replacement doors.

Roadmap

Objectives

Generalise the development of translators and interfaces between applications and standard data presentations (e.g. IFC), object databases (e.g. product / component libraries) and Model servers for sharing product model data, and models and ontologies to cope with any levels of semantics. Research should be pursued on the fields of:

- Model mappings & generalized ontology interoperability;
- increased intelligence of applications and interfaces for communication with other applications;
- Extensible models through metamodels enabling flexible extensions to standard models based on specific needs not covered by the standards;

- Model checking for validating model data against standards, regulations, design rules, contracts etc., with possible notification of identified conflicts and, when possible, suggesting corrective measures.

Models are key underlying assets for shared information between architecture and engineering based on simulations and visualisations:

- *Performance Simulation*: generalise and deploy the use of "single-simulation" tools (structural, lighting, thermal, acoustics, safety, schedules, construction tools, etc.) for engineering and construction processes, moreover with integration of these simulation tools with other Lifecycle tools;

- *Visual Simulation*: 3D visualisation of the geometry of the building and real-time "walk-throughs" allowing to inspect the building from the inside and to visualize its integration in the neighbourhood, 4D simulations (4D is 3D geometry added by time information enabling e.g. simulation of assembly process on site), interference checking, etc.

- *Generation of manufacturing information on demand*. Accessing Rapid prototyping, CNC and Computer aided manufacturing.

Main Research Areas

ICT should support scheduling & planning with information transfer between applications used in different stages of the construction process.

Short term:

- Take up of existing process paradigms: performance based procurement, open building etc.
- Development and standardisation of value metrics and indicators.

Medium term:

- Methods and tools for capturing value requirements, and transforming and validating them between stakeholders throughout the process.
- Re-engineering business processes for dynamic supply networks, driven by customer-perceived value and sustainability.
- Models and tools for performance-based contracting, customer involvement, partnering and system integration.

Long term:

- Integrated theory and related methodologies for modelling and rapid engineering of dynamic project-based business processes and networks.
- Configuration tools for consortium formation, contract preparation and ICT integration.

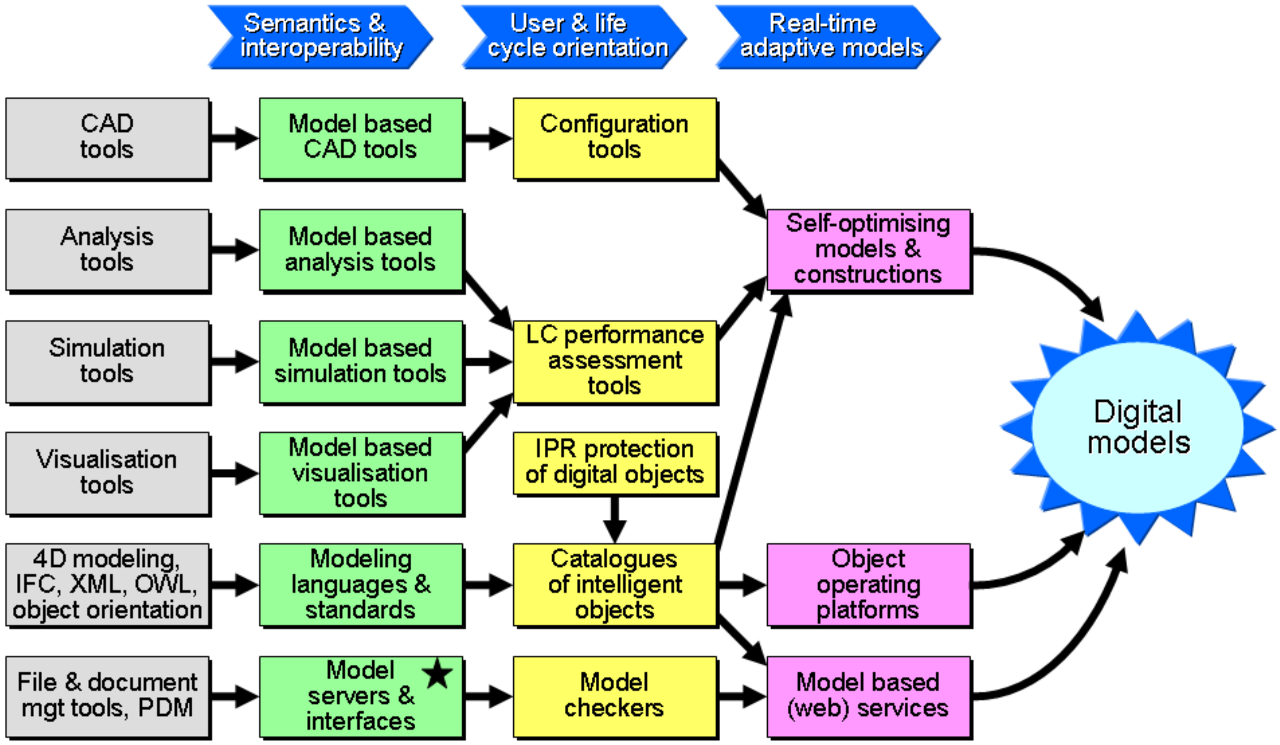


Figure 12: Roadmap for Digital Models

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- CAD-tools: Different packages serve the professionals with a varying set of (dis-)advantages. Basic visualization tools are incorporated.
- Analysis and simulation Tools: In some cases to be regarded as "stand-alone tools", partly highly specialised; only covering a smaller part of a range.
- Visualisation tools: By means of imported modelling data further processing can follow, such as advanced texture mapping leading to high end visualization (photorealism, ray tracing) and animation.
- 4D- Modelling: linking of 3D (CAD) geometry to one or more schedule activities. Tools for project organisers and project team members to better communicate and analyze schedule information.
- File + Document mgt tools: System mainly used for exchanging and storing files (documents).

Time to Industry: Short Term

- Model based CAD tools: Fading away from plain (digital) 2D-drawings and isolated textual specifications towards a higher semantic level of building information, database driven model basis.
- Model based analysis tools: Effective reuse of already created CAD-geometry, possibly as plug-in or add-on (eventually within the CAD-environment); intuitive handling supported and less education required, leading faster to valuable results.

- Model based simulation tools: Effective reuse of existing CAD-geometry. Possibly as plug-in or add-on (eventually within the CAD-environment); intuitive handling supported and less education required, leading faster to valuable results.
- Model based visualisation tools: Improved (re-) use of existing geometrical data for representation issues, minimal conversion work and subsequent post-editing efforts.
- Modelling languages & standards: Efficient handling of variety with avoidance of repeated loss of information; uncomplicated implementation of well-functioning conversion tools and coherent standards.
- Model servers & interfaces: Support of collaborative working attitudes; handling without delaying synchronization issues; viable solutions for the maintenance of versioning aspects.

Time to Industry: Medium Term

- Configuration tools: Tools for customer-centric holistic definition, configuration and optimisation of products. User friendly interfaces with visualisation, augmented/virtual reality, context- and location-awareness, to support communication and decision making by stakeholders. Progressive use of pre-modelled building parts/components and subsequent assemblage.
- LC performance assessment tools: Semantic based ICT tools for various engineering applications of different actors at all life cycle stages. Tools for assessment and simulation of product life cycle performance: aesthetics, comfort, costs, energy usage, environmental impacts, flexibility, functionality, serviceability etc. Integration of simulation, visualisation and analysis tools, allowing for the assessment of the expected performance.
- IPR protection of digital objectives: Clarified legal handling when using/accessing object catalogues.
- Catalogues of intelligent objects: Object catalogues of products, services etc. supporting e-commerce of manufactured products and specialized services.
- Model checkers: Automation of control and verification of formal specifications. Compliance with specified computational modelling rules. Checking consistency of data entered (conflicts, collisions, ...). Indication of changes to underlying data (for example: imported geometry) before and after feature recognition.

Time to Industry: Long Term

- Self optimising models & constructions: As ongoing planning and building execution work may cause changes and alteration, consequences in all directions should be controlled. Handling of contextual information; responsiveness to changes occurred by iterative design processes.
- Object operating platforms: Distributed computing, including a delivery of interactive services, without limitation accessible by all stakeholders.
- Model based (web)-services: In a complex web-based system a model can be used as unifying framework in which each component finds its place. Therefore a distributed ICT infrastructure is needed. Using model servers enabling sharing of information at high semantic level by all stakeholders throughout product life time and including open access to information of built environment and cultural heritage. Furthermore the protection of intellectual property in digital object models has to be ensured.

Business Impacts

Pervasive use of ICT-based models will deeply improve quality control, assessment, monitoring and measurement of project progress and performance, especially based on the identification of quality repositories and performance indicators and standards, and will be the support for development of methodologies and procedures to effectively manage productivity and quality. It will allow the development and adoption of high sustainability standards (eco-labelling, certification, performance-based standards, etc.) related to protection of environment, saving of natural resources, health and safety, safety of workers, etc.. It is also a key instrument for:

- the adoption of a *product* total lifecycle approach, including all management aspects at various stages of the product lifecycle, including pre-construction, construction and post construction (e.g. development management, project management, resource management, design management, etc.).
- the improvement of the *process* efficiency and effectiveness (including feasibility, planning and scheduling of activities). This includes means to analyse and measure productivity, analyse risks, allocate resources, plan sites etc.).

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• Simulation, visualisation, interaction & mixed reality.
FP7 Energy	• Smart energy networks. • Energy efficiency & savings.
ROADCON 2003	• Collaboration support for distributed virtual teams. • Flexible interoperability. • Model-based ICT.
ELSEWISE 1997	• Decision support. • Internal & external libraries. • Legacy applications. • New applications. • Object-oriented tools. • Product models. • Total life cycle management.
FIATECH 2007	Element 2: Automated Design

4.4 Intelligent Constructions

Main Business Drivers:	Integrated automation and control (connectivity) => remote diagnostics and control (serviceability) => context-aware seamless configurability (adaptability)
Key Research Topics:	Smart embedded systems & devices for monitoring and control, embedded learning & user support.

Background

Intelligent Constructions and Smart Home Environments indeed correspond to needs already expressed in various other FAs of the ECTP. The current state is that of final constructions containing various and increasingly versatile control and service systems, which are not (or very few and in scarce cases) standardised, and not interconnected among themselves. Moreover, they are currently based on vendor-specific technologies using "dumb" devices, proprietary software platforms and wired connections and protocols. Monitoring, maintenance and services are done by specialised companies, each responsible of different systems, which are relying on customised ICT (to meet specific needs of users) and are based on monolithic applications that require manual configuration for specific uses, maintenance and support.

Vision

Target State

The vision proposed in this roadmap is that in the future, all objects[1] *within the home, the office or potentially any building will communicate and provide information ubiquitously, and will be able to "understand" people circulating or living in the built environment so as to answer to their needs at any time.*

To achieve such a desired state, it is required that:

- ambient intelligence is kept and managed within chips, sensors, actuators,… embedded in objects that are able to dialog thanks to wireless communication techniques;
- all systems in constructions share common platform, network and protocols, with secure external connectivity via the internet enabling remote and mobile monitoring, diagnostics, operation and self-reporting, and provision of innovative interactive services to people at home or in their working environments.

Typical fields of applications of these R&D developments are for instance solutions related to Ambient Assisted Living (AAL), especially for disabled and ageing people, or in another field, Positive Energy Buildings (PEB - and also energy self sufficient buildings), with a new vision for tomorrow building energy performance to solve the huge global problem on sustainable energy uses at world-wide scale, with Europe having a leadership in this action.

Typically, this should be supported, among others, by technologies for ambient access[2] to all building information that should be made available to all stakeholders anytime and anywhere, and regardless of physical location: office, construction site, home, etc. ICT systems have to be intimately integrated with everyday environments and supporting people in their activities

[1] including objects as simple ones as doors, windows, etc., potentially communicating with furniture like chairs, ovens…

[2] Ambient access stems from the convergence of 3 key technologies: 1) ubiquitous computing, 2) ubiquitous & secure communication, and 3) intelligent user-friendly interfaces.

or their daily life. Wireless and powerless sensors should support interactive spaces providing personalised, location and context aware services[3], and in an ultimate visionary future of the "smart, self-configuring and self-adapting home / building", users needs and requirements (including evolution of users' profiling) will require special attention, based on advanced technology like pattern recognition and uncertain reasoning (e.g. fuzzy or probabilistic logic, or neural nets).

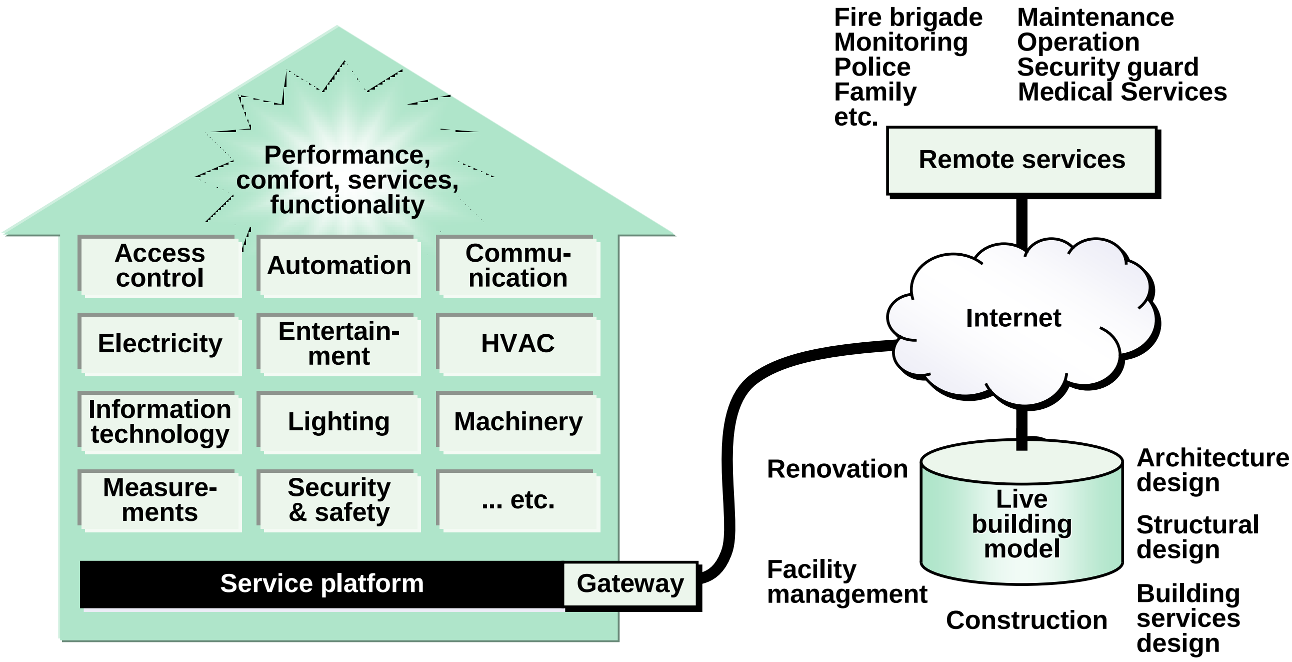


Figure 13: A Potential (non exhaustive) View on "Intelligent Constructions" Services

Business Scenario: Ambient Assisted Living for the Elderly

This scenario springs from a societal objective to assist elderly people to remain in their familiar home surroundings, prolonging independent living and postponing their need to move into institutional care. Age is beginning to affect wider society in very challenging ways. According to the UN report World Population Ageing: 1950-2050, **ongoing demographic change is unprecedented** and profound. It may lead to a restructuring of Society "as social and economic forces compel us to find new ways of living, working and caring for one another". Everybody will be affected – young or old – and it is likely that never again will societies be shaped demographically as in the past with more young than old. In 2002, the number of persons aged 60 years or older in the world was estimated by UN to be 629 million. That number is projected to **triple** to 2000 million by 2050, when the population of older persons will be larger than that of children (0-14 years) for the first time in human history.

Old age is usually accompanied by physical and/or mental impairment (e.g. Alzheimer, Parkinson, etc.), observable in limitations and behaviours particular to each person. Assistance must therefore take account of individuality in terms of ameliorating the impairment and enhancing capability whilst ensuring safety, comfort, autonomy and due privacy. So, **the issue is very important to individual elderly people** but also to **family members and social agencies** that have a responsibility for arranging care for them, especially in a context where, in many parts of the world, including Europe, family structures are becoming much looser because, for instance, of higher mobility in the workforce. Often there is a stark choice be-

[3] It is worth noticing that the previous comments are also applicable to the "tools" and systems used during the construction process itself.

tween an elderly person moving to a new location with, or close to, their family or being placed in institutional care. The costs of care are high both in the commitment of family effort or in hard € for institutional care paid for by agencies, relatives and the elderly themselves. The question is: **"Is there a viable, ethical 'care at home' middle way?"**. Note that the question includes role of national instances in charge of privacy of data and life, to be key in future scenarios so as to avoid negative reactions of targeted people (and public in general) towards deployment of such innovations in the future.

This scenario leads to some real **innovative role that ICT** will have in tackling the demographic and personal needs challenges for quality care viably provided. Objectives and targets are abundant and diverse, but one key problem domain largely deals with healthcare, as exhibited in the figure below. It may allow dealing with "preventative care" (portrayed in red in the figure) that takes account of medical, physical and mental states to safeguard an individual and intervene/warn before "crisis intervention" is required, as well as to deal with "reactive care" and crisis management.

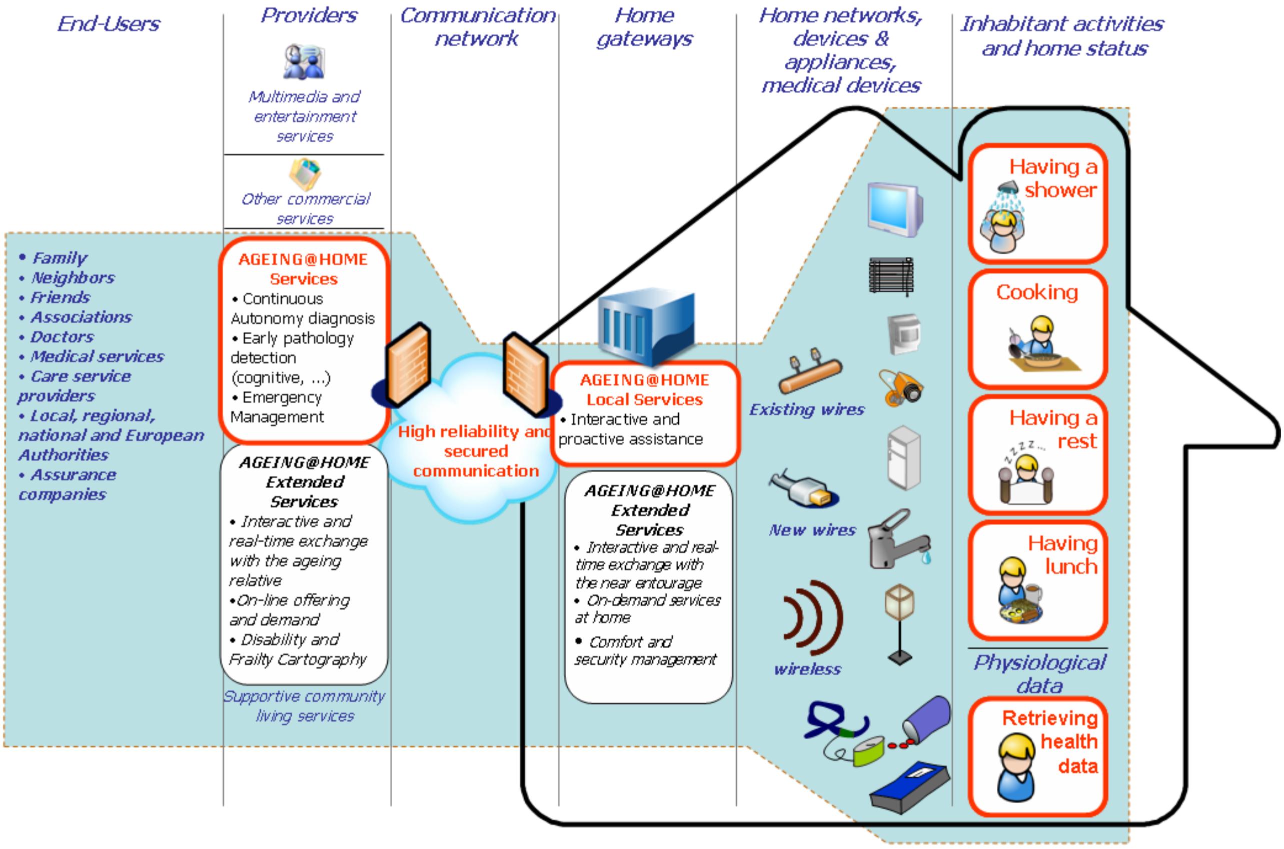


Figure 14: Ambient services targeting the elderly in the smart house of the future

Business Scenario: Positive-Energy Buildings

In front of the global warming and the risks of shortage of fossil energies, the European Construction area is in directly concerned. Indeed, the housing is responsible for +40% of the power consumption, and +25% in France, for example, of the gas emissions for purpose of greenhouse effect. With a regular increase in the requirements in energy, stimulated by an always increased demand of comfort within the individual residences even more roomy, the building industry must implement corrective actions, as regards consumption, without degrading the levels of comfort, quality and safety desired by the end users.

Precursors on the matter, e.g. countries like Germany, Switzerland and even the United States[4], developed new models of sparing homes in energy, even self sufficient and producers of energy towards outside. These models, called Passivhaus®[5] in Germany, Minergie®[6] in Switzerland or Zero Energy Homes® in the United States, use renewable energies (as wind, sun, geothermics, biomass...) for the needs for the house, and restore the energy not consumed on a network which becomes a wide energy co-operative store. These models allow, for example for Minergie, to use only 1/3 of the power usually consumed by a traditional house. They recommend to improve in priority the insulation of the building (windows with double/triple glazings, reinforced insulation of the walls, phase change material...) before optimizing the treatment (production, ventilation..) of the calories in the winter, or the air cooling in the summer thanks to active thermal solutions (more efficient heat pumps, thermal solar collectors, Canadian wells...). As soon as the house become sparing in thermal energy, it can become producer of electrical power using photovoltaic solar panels first of all for the needs for the house, before reselling on the network, the surplus of electrical production.

But the improvement can also progress while equipping the house with "intelligent" solutions (environment sensors, dedicated software...) issued from ICT. Indeed, in addition to the fact that the owner of Positive Energy Building will have to run more and more complicated active equipment, it will be able to activate advanced devices, that will reduce or remove automatically useless consumption of energy, in real time, programmed or by anticipation of the evolutions weather (automatic release of solar blinds, screening of glazings electrochromes...). Conversely, when the user will be outside, these automatisms will allow without manual intervention, to benefit from favourable conditions weather, by storing electric or thermal energy.

Of course, the user will have to operate the same switching/control interface usually used for other applications as for example safety units, of comfort (quality of air, acoustics, infotainment services,...) and be in relation with remote automatic or manual hotline for maintenance

By comparison, a dashboard for energy home as the one supplied today into the hybrid car Prius® [7] becomes a reality thanks to the information technology. This equipment will permit soon to manage consumption and the storage of energy at home. Thanks to such equipment, it will be easy to decide, according to the instantaneous cost of energy, to sell or purchase electricity and to select different levels or strategy of consumption (economic, normal, forced, stand-by...) in real time or in anticipation.

[4] Even if the United States did not sign the agreements of Kyoto
[5] www.passiv.de
[6] www.minergie.ch
[7] Manufactured by Toyota Company.

Roadmap

Objectives

The roadmap is to identify the various R&D axis required to transform the today living and working environments (houses, offices, buildings, etc.) in future smart environments and their innovative services, with a focus on all ICT artefacts that may support such an evolution. This includes:

- Developing integrated system architectures, innovative sensors and sensor networks, and models sustaining solutions for communication, operation and control, including ambient user interfaces, context awareness and embedded support for virtual working environments.
- Developing monitoring and assistance of the home, buildings and public spaces, with seamless interoperability and use of all devices taking account of cost efficiency, affordability, usability and safety;
- Developing new services and new forms of interactive digital content and services including entertainment, access to information and management of knowledge. Such services should allow, for instance, the control and optimisation of energy fluxes and production over a full life-cycle operation of the building, or provide continuous support to people living or working in the building (e.g. elderly / disabled people, see scenario 1).
- In parallel, consolidating international experiences from intelligent constructions and suggest best practice, improved regulations and standards covering new constructions and retrofitting, and develop dissemination, experimentations, evaluations, training and certification around products and services for the smart houses.

Additional considerations are related to, on one hand, the acceptance of such ambient ubiquitous interactive services (which seems highly connected to the levels of both security and pervasiveness that such communicating objects and services may provide), on the other hand, the economic viability of services that could be imagined and further deployed.

Main Research Areas

The R&D targeting the intelligent constructions and smart houses is to be developed around three fundamental pillars:

- The ***"intelligent" objects***: these objects must have embedded electronic chips, as well as the appropriate resources to achieve local computing and interact with the outside, therefore being able to manage appropriate protocol(s) so as to acquire and supply information.
- The ***communications***: these must allow sensors, actuators, indeed all intelligent objects to communicate among them and with services over the network. They have to be based on protocols that are standardised and open.
- The ***multimodal interactive interfaces***: the ultimate objective of those interfaces is to make the in-house network as simple to use as possible, thanks to a right combination of intelligent and interoperable services, new techniques of man-machine interactions (wearable computing, robots, …), and learning technologies for all communicating objects. These interfaces should also be means to share ambient information spaces or ambient working environments thanks to personal advanced communication devices.

Time-wise, the following need to be developed:

Short term: the R&D is devoted to achieving full integrated automation and control, leading to the ***e-HOME*** – the "electronic HOME". This is mainly about:

- All objects / components in the built environment integrating elements for a given degree of intelligence: RFID tags, chipsets, embedded micro-systems, etc., including the opportunity for humans to wear such devices or chips with embedded intelligence.
- Application of sensor technologies for distributed monitoring, control, end-user support and services, thanks to all "intelligent" communicating objects being able to mutually identify in the network, connect and interact with each other according to various communication models and channels.

Medium term: the R&D is devoted to the generalisation of network-based services accessible from home, leading to the ***i-HOME*** – the "interactive HOME". This is about considering the built environment being naturally considered as a node (or set of nodes) of the Internet backbone, therefore providing and requesting services over the network:

- Smart products and systems with embedded devices, and embedded learning support to users, operators and maintenance staff.
- Software tools for tracking, logistics, diagnostics, monitoring and control.
- Modular integrated automation, monitoring and control of all subsystems with holistic optimisation and support to service provision.

Long term: the R&D eventually is targeting a full understanding and adaptability of the home as regards people living in it, leading to the ***u-HOME*** – the "ubiquitous HOME". This includes:

- User and context aware, self-optimising intelligent built environments, with potential for dynamic re-configuration, and providing access to interactive spaces and personalised services.

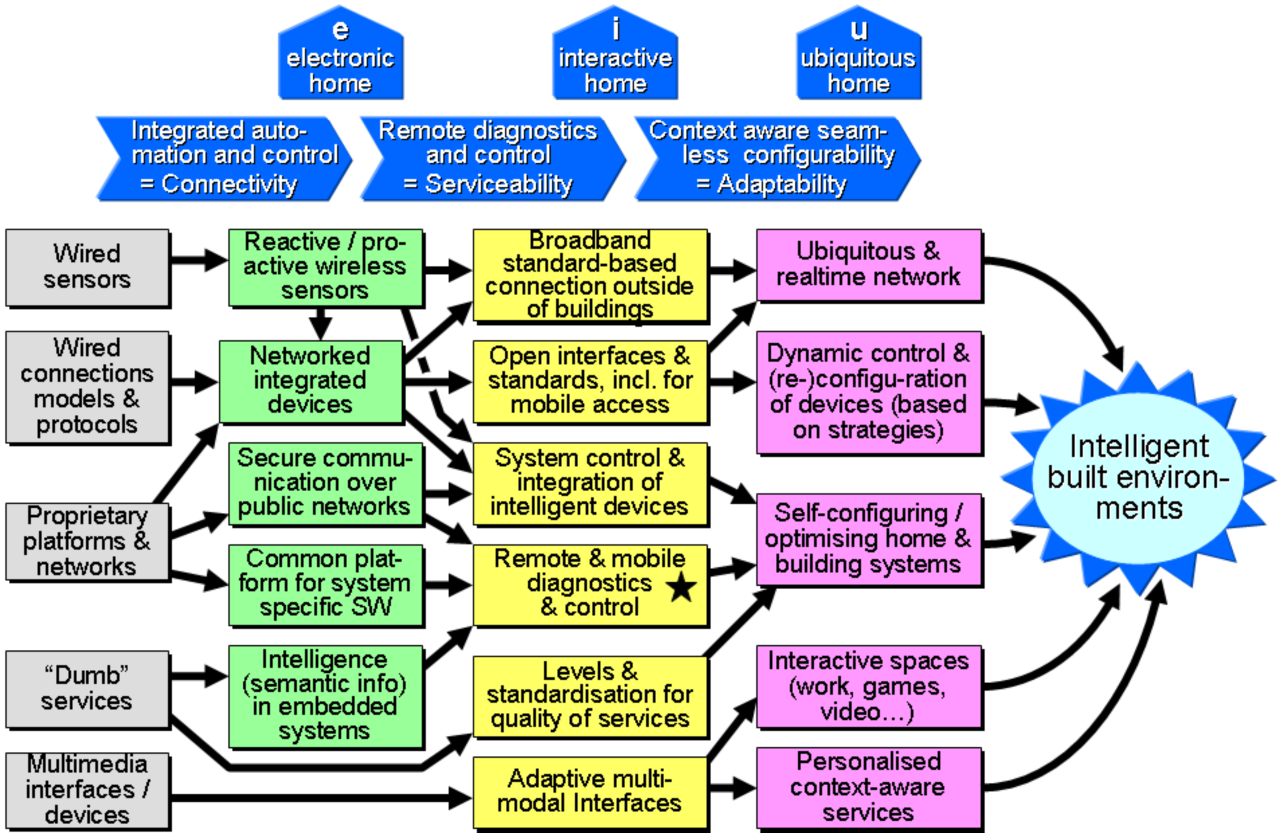


Figure 3: Roadmap for Intelligent Constructions

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- Wired sensors: lots of various remote controlled devices, with the use of such devices (HVAC, lighting, audio-video equipments…) being currently investigated in the built environment through preliminary deployment and experimentations.
- Wired connection models & protocols: still under development and even more looking for harmonisation and standardisation (NFC - Near Field Communication, Bluetooth, Wi-Fi, RFID, ZigBee, etc.), they aim at establishing and managing communication between objects.
- Proprietary platforms & networks: current platforms implementing connected objects are mainly experimental platforms, with no standardisation of management of and communication between any kind of "intelligent" objects.
- "Dumb" services: all services provided by the industry so far are specialised / dedicated services that ensure one given function, without providing interoperability, and no capacity to "talk" with other services or to take into account the full environment.
- Multimedia interfaces / devices: still few intelligent objects that are not intrusive and offer appropriate interfaces to allow the final user to seamlessly integrate the ubiquitous network.

Time to Industry: Short Term

- Reactive / proactive wireless sensors: sensors that are able to integrate a set of contextual data and compute them before providing information corresponding to any request. As a potential chain in an overall process, they should also integrate behaviour patterns to proactively fill in a given mission.
- Networked integrated devices: the achievement of such network integrated devices (such as home appliances and site equipments) should allow the development of new applications seamlessly and dynamically integrating through the network any autonomous device, based on its universal ID, its dedicated API, and its capacity of active / reactive behaviour.
- Secure communication over public networks: this should allow exchanging any type of information, including private information whenever required, between smart components and/or houses, and e-services over any type of networks, including the Internet. This means both in terms of reliability of the transport (i.e. no loss of alteration of the data), than in terms of privacy and security of conveyed information.
- Common platform for vendor/system specific SW: must allow the integration of any devices / components (sensors, actuators, transmitters, chips in building components and furniture, …) so that these objects can collect data, compute them, send them, thanks to standardised operating systems and platforms. This is also related to specifying format of objects for distributing the middleware. Such systems/platforms must form the ground for "spatial information systems" able to link objects in a physical space.
- Intelligence in embedded systems: Embedded systems should make their (Construction) containers "smart" by being able to deal with semantic information (query and get) and to manage it (locally analyse, compute, and provide output - in case according to pre-defined or dynamic strategies) so as to integrate a network of smart sub-systems that form the smart house / building.

Time to Industry: Medium Term

- Broadband standard-based connection outside of buildings: need for environments subject to automation to be integrated in networks and systems that provide proved and reliable communicating channels, including for large in and out data streams.
- Open interfaces & standards, including for mobile access: coherency between information managed by the "intelligent" ambient objects…They are a key angular stone to the Software interoperability which still remains an issue in a context where all the intelligent objects have to organise themselves and communicate spontaneously over the network.
- System Control & integration of intelligent devices: specify and develop enhanced products characterised not only by improved features (e.g. optimising the equation quality/duration/cost) and capabilities (e.g. smart buildings), but also shipping with e.g. fully digitalised, unique and personalised, universal electronic cards or digital mock-ups, that could manage the information structuring and integration for the product, allowing traceability of all parts of the final end product (so as to provide all guarantees of quality and safety to the client), and long-term memory of end products for maintenance, enhancement, refurbishment, and even the demolition process (in terms of potential reuse of parts of the building). Such products / devices will communicate by embedding appropriate tags (RFID, etc…), and will allow to improve global monitoring of complex systems in the built environment.
- Remote & mobile diagnostic & control: achieving diagnostic / control and indeed leading to decision-making systems will require semantic based content integration (including data fusion), i.e. specify and develop algorithms and solutions that will achieve syndication of information from a semantic point of view leading to a seamless integration of data from disparate and multiple data sources. This will especially rely on BIM[8] in the context of the built information.
- Levels & standardisation for Quality of home services: identify and classify different levels (defined by some sets of indicators and parameters) for Quality of services in smart homes and buildings. Such levels should provide Quality repositories for service developers and providers to target a given level (as a level of service ensured to the end user), as well as to achieve tests and evaluation and deliver certification for new home services.
- Adaptive Multi-Modal Interfaces: this is about the achievement of intelligent user-friendly interfaces, i.e. identify, specify and develop systems allowing context-based multiple modes of interaction, augmenting human to computer and human to human interaction (including potential interaction with robots), adapting to the devices, user preferences and contextual conditions, and available / accessible to all. One step is the evaluation, adaptation to the Construction processes, and integration of such systems (currently developed in research centres and laboratories), including speech recognition interfaces, rollable & foldable displays, head-mounted display devices, and holographic applications.

Time to Industry: Long Term

- Ubiquitous and realtime network : develop solutions and systems exploiting the 4th Generation Broadband Mobile Network that will provide the best interactive and intuitive collaboration / communication services than any alternative networks, including high-level security, better QoS, mobile and audio / video conferencing enabled, improved wireless data protocols, etc. → ***achievement of Ubiquitous & secure communication***

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[8] Building Information Models (a typical example of such a BIM is the IFC model).

- Dynamic control & (re-)configuration of devices (based on strategies): develop algorithms and architectures for any configuration of smart devices (i.e. any set of such devices being inter-connected) to be able to dynamically evolve according to the environment or change in a choice of a global strategy. This includes as well individual “roaming” profiling, allowing configurations to follow users, related to a wide variety of applications.
- Self-configuring home & building systems: develop architectures where Component-based in-house systems learn from their own use and user behaviour, and are able to adapt to new situations, locating and incorporating new functionality as required. Situations are automatically tracked and significant events flagged up. Intelligent assistant maintains a view of the users responsibilities, finds needed resources as required and priorities events and tasks, making relevant services available as needed. This included use of pattern recognition to identify and prioritise key issues to be addressed, and to identify relevant information.
- Interactive spaces: develop architectures and systems that offer smart audio, video, leisure and working environments that must be adaptive and “immersive”. This includes agent-based user interfaces adaptation to suit user preferences and profile inferred from usage habits, and Advanced Identity Management (based on a follow-up of the progress in current research in this field, e.g. biometrics), to identify and assess the potential of integration of these technologies in services dedicated to Construction.
- Personalised context-aware services: identify, specify and develop smart systems that easily integrate or connect to the house or building, and that are Context aware systems providing services to support personalisation and context data processing, and interpretation of information on the user and his environment in order to provide seamless information access and gathering for each stakeholder, as well as value-added information dependent on the context.

Impacts

These solutions shall increase comfort, security and safety at working and living place and reduce energy consumption, and needs for travelling and transports.

Such a roadmap supports the policy priorities for the Information Society as highlighted in the i2010 initiative. As regards all the services for the inhabitants, it is worth noticing that Viviane Reding[9], in a keynote speech at the i2010 Conference in London in September 2005 set out pillars of activity instrumental in taking forward policy and research programmes on e-Health, e-Government and e-Learning. She said ***“****these continue to be pivotal to the agenda for ICT-enabled public services, but very often all the efforts we have been making in these areas have not received the attention they merit. That is why in i2010, I have proposed three ICT flagship initiatives to give critical mass to our work in three important and visible areas where ICT has a positive impact on citizens: the first flagship aims to make our ageing society a better place to grow older with independence and dignity. The flagship will build on our research initiatives on assistive living, eHealth and eAccessibility and be used as a basis for prioritising both research and policy in the coming years.”*

Considering the case of PEB, there are of course evident social impact: reducing (and in a more long-term inversing) buildings consuming of energy, reducing buildings pollution (i.e. reduction of CO2 and other gas emission), provide alternatives to energy production as regards current classical production (petrol, fossil, nuclear…), with overall reduction of nuclear-based production, overall reduction of petrol/fossil production, etc.. But impact is at level of the Building industry too, with control and optimisation of energy fluxes and production over

[9] EC Commissioner for Information Society and Media.

a full life-cycle operation of the building. The technologies developed at level of each component should also allow 0-default “knowledge-embedded” building components to be immediately assembled on Construction sites – with assembly done easily, even with low-level human power.

Indeed, emergence of new concepts like energy self sufficient buildings or Energy positive buildings connected to energy distribution networks might become a common practice in a sustainable economy. A local market of energy exchanges between buildings in micro urban area should become a common situation. Developing technologies and practices will not only improve sustainability and competitiveness of Europe, but also offer possibilities of transferring technologies to developing countries, contributing to solve the great global problem on sustainable energy uses. Experimental and demonstration buildings in the last two decades proved the technical feasibility of such concepts. Some European countries or regions of these countries entered the process of progressively generalizing such practices.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• Home environments. • Embedded systems, computing & control: − Open composable architectures & scale-free platforms. • ICT meeting societal challenges: − Health (personal non-obtrusive systems, autonomous systems).
FP7 Health	• Innovative therapeutic approaches & interventions. • Translating clinical research into clinical practice.
FP7 Energy	• Smart energy networks. • Energy efficiency & savings.
FP7 Environment	• Technologies for managing resources or treating pollution (e.g. while operating buildings) more efficiently.
ROADCON 2003	• Adaptive and self-configuring systems. • Ambient access. • Smart buildings and embedded systems.
FIATECH 2007	Element 5: Intelligent Self-maintaining and Repairing Operational Facility

4.5 Interoperability

Main Business Drivers:	Data/file exchange => Data sharing => Flexible interoperability
Key Research Topics:	Model servers; Distributed adaptive components; Ontologies & open ICT standards for semantic communication; ICT infrastructures.

Background

The current state of interoperability in the construction sector today can be summarised as follows:

- Despite promising developments of object modelling and data exchange standards such as IFC, increasing use of semantic ”nD” applications continues to face huge interoperability challenges.

- Available solutions address static data but not dynamic product behaviour.
- Interoperability problems limit the potential benefits of new and emerging ICT, cause extensive information management overload, limit possibilities for business collaboration between geographically remote partners, and limit the introduction of new and innovative products & services to the market.

Vision

Target State

Interoperability encompasses several aspects, should they be mainly technical (e.g. related to networks or software applications) or more linked to organisational and process issues (thus in relationships with the "Collaboration support" roadmap). For instance, the European Interoperability Framework (EIF) for eGovernment services for EU citizens (as proposed for development in the eEurope 2005 Action plan) describes three aspects of interoperability: technical, semantical, and organisational. Quite synthetically:

- Technical interoperability is about linking up computer systems through network and data transport protocols and standards;
- Semantic interoperability is about same meaning / understanding of data semantics between systems to process received information in the right way;
- Organisational interoperability is about modelling and harmonising business processes and their organisation, while ensuring their availability to end users.

The vision proposed in this roadmap is that in the future, relying on interoperable and standardised data transfer protocol, semantically rich information will be shared by the Construction Sector throughout the whole life-cycle of buildings and the built environment by means of integrated information systems and services encompassing all processes and their interactions. To achieve such a desired state, it is required that:

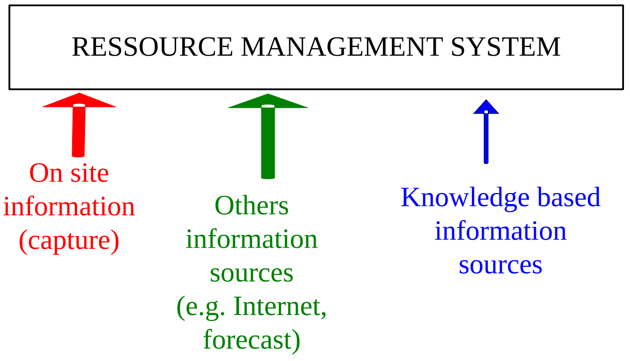
- Any of two or more IT components or systems have the ability to communicate and jointly utilise the information, especially thanks to the definition of its semantics;
- Communication of information semantics is effective thanks to international or industry standards (rather than proprietary standards), and preferably thanks to open standards, which are to be product, services and systems-independent, background technology agnostic, and having their specification freely available to all interested parties.

Fields of applications of R&D developments in Interoperability have quite a large spectrum: we shortly introduce to some of them in the scenarios below, without any pretension in terms of exhaustivity.

Business Scenario: Resource Management System in the Construction/ Manufacturing phase

The construction site of the new Hospital of MYTOWN has started for 5 months. It should finish in one year. After earthwork and foundation phases, the first floor of the main building is above ground and the floor slab (flagstone) of the second floor is now under construction.

BARBENDER company was informed (the week before) by email/SMS that its "window" of reinforcements delivery was to take place at 2PM tomorrow. This information is made possible thanks to the Resource Management System which takes into account the needs for materials of the building site (management of the stock of materials), the availabilities of the lifting equipments, the availability of storage areas and human resources availability to achieve the unloading and the reception of the delivery.



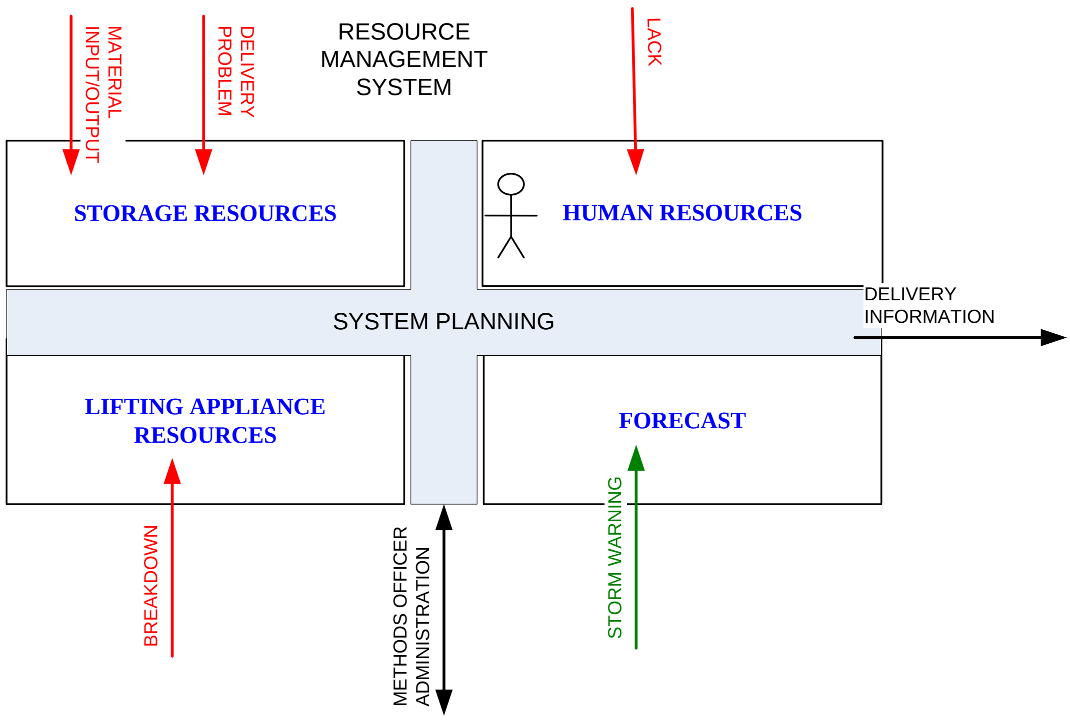


Figure 15: Resource Management System

Two days before the delivery, the company delivery manager receives a message indicating to him to postpone (defer) its delivery to the following day under the reason that the crane requires an intervention of maintenance following a breakdown.

A new generation of Resource Management Systems should allow to manage events (in real time) which occur on the building site: breakdown of a machine, forecast weather, absence of manpower etc.

All this information “is collected” in real time by “ad hoc” communicating equipment adapted to the constraints of robustness, minimal size, reliability and ergonomics of the interface.

Methods officer was of course immediately informed of the breakdown, he is then able to reorganize the continuation of the work to avoid the layoff and the delay in planning. He is in addition informed of the inventory position of materials on the site, thanks to the identification (tagging) procedure (bar code, RFID) of all entry or export of the merchandise toward a storage area of the construction site or a straightforward use on the construction site.

The Resource Management System takes into account the delivery management: date, place, hour, expected (awaited) data-processing marking (tagging) (on the delivery order, or the RFID chip), route to follow taking into account the volume or the tonnage of the merchandise, site storage location and also the events relating to non conformity of the delivery or bad delivery condition.

Business Scenario: Smart Building in the Service Phase

This scenario illustrates a typical use case of new equipment to be integrated in an operational building. This equipment is intended to contribute to the overall strategy for building operation: saving energy, improving brightness control, increasing thermal comfort etc.

Mr. Smith has bought a motorised rolling shutter. The shutter is fully compliant with CSTBATCommunic® standard recommendations which refer to semantic networked computing. Typically the recommendations are based on interoperability standards such as OSGi Alliance, IPV6, UPNP, W3C-DI and FIPA. In addition the equipment is compliant with HQE standard (High Environmental Quality) and generally contributes to the sustainable International policy.

Mr. Smith has fixed the shutter over a window on the outside south wall of his house and connected it to the power supply. The shutter is immediately automatically identified and authenticated on the network since the electricity network supports IPV6 and is compliant with HomePlug Alliance recommendations. Hence immediately the communicating store sends signals to other communicating building components providing information to them such as: its name, function and features. At this point no human parameterisation is needed: this is plug-and-play building equipment.

Then the store searches on the network to find some central controlling “assistant or manager” to specify its behaviour according to the selected global strategy of the controlled building (energy, comfort etc). However the shutter cannot find any such information support and so adopts a basic default strategy based on the weather forecast. On its own initiative the equipment look for a local forecast station or a specific sensor such as a wind gauge or a rain gauge.

But it cannot find such an information service on the building network, and so looks for a local Internet forecast service. This service aids it in its simple strategy:

- roll down the shutter when local forecast information indicates: "sun shines";
- roll up the store when local forecast information indicates: "rain or high wind" etc..

The communicating shutter is now a component of the building network – a power and knowledge network. However, if a manager component is introduced to take control of the building network, the shutter becomes a servant of the strategy set by the manager.

Mr. Smith is no longer involved in configuring the shutter, especially in the integration of the new equipment in his house. But in case communicating equipment requires a decision from Mr. Smith, a display resource (like a terminal, TV, PDA) can be used. Moreover equipment choice is widened, since interoperability of new equipment is guaranteed whatever the manufacturer or trademark.

Roadmap

Objectives

The roadmap is to identify the various R&D axis required to transform the current eBusiness processes environment(s) into fully integrated / interoperable innovative semantical eServices supporting structured and harmonised processes in Construction, with a focus on all ICT technologies and tools that may support such an evolution. This includes:

- Providing seamless semantic (forward and backward) communication (object exchange and sharing), to support both interfacing and synchronisation between actors;
- Integrating (open and standardised) nD modelling technologies, Semantic Knowledge Technologies (SKT), Grid-based Computing, and Global Optimisation methods, along with intuitive visual and interactive user interfaces;
- Developing and refining architectures for construction product/service life-cycles and their associated supply chains, that are adapted to the Construction sector (especially SMEs), with easy methods and techniques for specialisation;
- Offering flexible access to IT-based business services, semantic information resources and Content repositories / libraries of re-usable solutions, with standardized global identification of construction objects;
- Offering capability to provide services for installing, maintaining and monitoring these advanced systems (strengthening the role of system integrators in construction).

Main Research Areas

The R&D targeting the Interoperability issues is to be developed covers:

Short term:

- Development and use of enhanced standards scope consolidation.
- Take-up of solutions supporting dynamic linking of documents to different model elements

Medium term:

- Development of model-based applications and agents
- Development of model APIs, model servers, and object-based ontologies to support semantic web services

Long term:

- Web-based logic and reasoning supporting self organising context aware systems
- Open object oriented ontologies to support semantic based content integration
- Object servers and distributed adaptive components

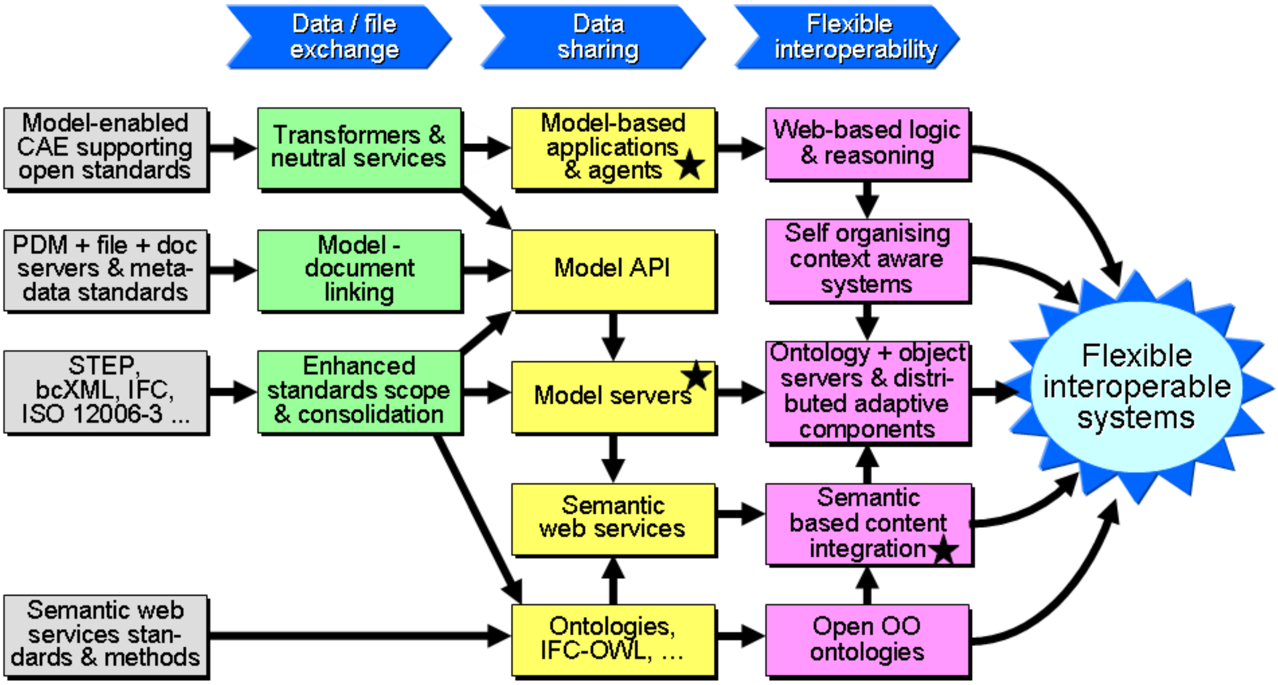


Figure 16: Roadmap for Interoperability

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- Model-enabled CAE supporting open standards: Computer-aided engineering (often referred to as CAE) support engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis and repair. Software tools that have been developed for providing support to CAE encompass simulation, validation and optimization of products and manufacturing tools. Already today, and even more in the future, CAE systems have to support design teams in decision making, based on data and information coming from multiple sources and multi-disciplinary simulation, relying on formal modelling and already existing open standards.

- PDM, file, doc servers & meta-data standards: technologies allowing enterprises to establish business process relations and cooperate with other enterprises, and to increase their co-operations during the entire product life cycle, are the ones mainly based on product data modelling (*see also next bullet*) leading to potential product data management through file exchange between applications, or access to data servers through APIs relying on models / meta-models. Additional meta-data may already facilitate the search for specific types of data.

- STEP, bcXML, IFC, ISO 12006-3: In the past 15 years, standards and norms have already been developed, with tangible progress (even if still under development), like the STEP norm (ISO 10303, introducing a set of norms for the modelling, exchange and management of product data), or the IFC standard, a comprehensive model for the formal and structured description of buildings through objects and Property sets, the latter dealing with extensions to the Core model. Another example is the ISO 12006-3 standard, that defines a schema for a taxonomy model, which provides the ability to define concepts by means of properties, to group concepts, and to define relationships between concepts, with objects, collections and relationships being the basic entities of the model, and the set of properties associated with an object providing the formal definition of the object as well as its typical behaviour.

- Semantic web services standards & methods: Service Oriented Architectures (SOA) form a computing paradigm that has emerged from Object and Component based approaches, so as to organise and access distributed resources thanks to on-the-fly service creation and use, based on loosely coupled, reusable software components. Well developed forms of SOA are the Web Services relying on XML standards to provide a coherent platform for building loosely coupled distributed applications. Semantic Web Services aim to combine concepts of the Semantic Web with Web Services technologies. The Semantic Web intends to create a universal medium for information exchange by putting documents with computer-interpretable meaning (semantics) on the Web. The key standards and tools of the Semantic Web are XML & XML Schema, Resource Description Framework (RDF), RDF Schema, and Web Ontology Language (OWL).

Time to Industry: Short term

- Transformers and neutral services: Transformers (Mappers, Translators, Convertors) for "beyond-CAD" support and neutral services/utilities (viewers/browsers/editors like IFC browsers). Where standards do not exist, they act as “interfaces” that support interoperability across standards and proprietary applications.
- Model-document linking: Natural links between different model objects and relevant documents/drawings/CAD files, etc. These could as an example be based on “association and/or derivation”.
- Enhanced standards scope & consolidation: The scope of standards should not be restricted to a particular project phase or actor. Rather, standards should be enhanced and broad to cover the complete product/project lifecycle, supply chain, all process and all actors. Where possible, standards could be enhanced through consolidation of different “parts” of different standards to form a “whole” standard.

Time to Industry: Medium term

- Model-based applications and agents: Model-based applications & Smart agents that can work with open grammar/syntax, ontologies and corresponding content. This would lead to new business opportunities enabled by model based data e.g. analysis, estimation, visualisation, multi-disciplinary simulation, etc.. Thanks to computer-interpretable information highly specialised services using sophisticated software become feasible.
- Model API: Open model-level API allowing for flexible communication across applications manipulating different product and/or process models. This could exist in the form of a metamodel enabling flexible extensions to standard models based on specific needs which are not covered by the standard.
- Model servers: Object Oriented (distributed) model servers that may reside in different organisations and yet have the capacity and capability to communicate with each other. Grid technology may be one solution to support distributed model servers in terms of service discovery, interoperability and mainly security. It should be noted that while a specific model server (e.g. within an organisation) may contain a relevant part (or view) to the overall product/process model, these parts should through the distributed model servers be mergeable to form the complete model (containing all parts, and of course views).
- Semantic web services: Semantic Web Services (SWS) methods and tools supporting fully integrated semantic web services technologies to support and enable increased intelligence of applications and interfaces for communication with other applications.

- Ontologies, IFC-OWL: (Actual) Semantic Web-based Ontologies (global, detailed, generic, specific) and Web Services (WS) services supporting a digital framework for developing engineering models, and offering a basis for high-level functionality on top of existing model servers.

Time to Industry: Long term

- Web-based logic and reasoning: Open Web-based Logic & Reasoning (on top of semantic web services) supporting distributed service integration and interoperability, as well as dynamic composition of services
- Self organising context aware systems: Systems that are self-configurable upon demand for a given purpose or project. These systems are expected to support the ICT operations of a virtual enterprise. It is the scope, purpose, and needs of modus operandi such as that of a virtual enterprise that determine and lead to the self-organisation (configuration) and optimisation of such systems.
- Ontology + object servers and distributed adaptive components: Ontology/Object servers supporting distributed and context aware adaptive ICT components that are responsive to given user/organisational requirements for a given purpose (task) or project.
- Semantic based content integration: Use of semantic technologies (semantic web + ontologies) to inter-relate different forms of content and media to form a whole.
- Open Object Oriented Ontologies: Open Object Oriented Ontologies (not just data-driven) to support definition, configuration, and visualisation of different instances of product/process components. The key points here are openness and object orientation. These ontologies are not necessarily domain specific; rather they offer the capability for convergence of different domain ontologies to serve a given instance/purpose and rely on semantic technologies for this convergence. The convergence itself may be seen as an operational meta-ontology.

Business Impacts

ICT-based interoperable service platform(s) and system(s) that will allow a full-fledged *Business Service oriented* approach, allowing to move from “design for the customer” to “design by the customer”, and making possible the quick delivery to all Construction stakeholders of new products and service concepts for the entire life span of the buildings / infrastructures and for its various functions, and the creation of new service markets.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• Software, GRID: − Services-based infrastructures. − Open platform. • ICT supporting businesses and industry − collaborative work environments

FP7 Nanosciences, Nanotechnologies, Materials & new production technologies	• Networked production – Supply Chain Integration and Real-Time Decision Making in Non-hierarchical Manufacturing Networks. – Interoperability of technical business solutions in production networks. • Rapid transfer and integration of new technologies into the design and operation of manufacturing processes – Knowledge Based Manufacturing – Integration of Heterogeneous Data and Enhancement of Human Interactions in Manufacturing Environment. • Integration of knowledge for sectoral and cross-sectoral applications – Industrialised interoperable production systems for off-site and on-site production.
ROADCON 2003	• Flexible interoperability. • Model-based ICT.
ELSEWISE 1997	• Data exchange. • Distributed object oriented databases. • Open interfaces. • Shared project database. • Standards.
FIATECH 2007	Element 9: Lifecycle Data Management & Information Integration

4.6 Collaboration Support

Main Business Drivers:	rapid and easy connectivity => robust team interaction => seamless inter-enterprise integration
Key Research Topics:	ICT tools for information sharing, project steering, negotiations, decision support, risk mitigation, etc.

Background

Electronic business activity is less developed in the construction industry than in manufacturing sectors. A multitude of standards, technical specifications, labels, and certification marks is dominating. Many companies prefer to be *re-active* rather than *pro-active* in their use of ICT. The construction industry has yet to show the same level of ICT driven improvement of productivity as in other industries. This can partly be explained by the nature of the work and the type of production involved in construction processes. It is also related to slow uptake of ICT in a sector which is dominated by SMEs. Large enterprises in the industry and new sector entrants have adopted ICT based production methods. However, there is still great potential for further ICT uptake for instance in the field of *collaborative working environments*. Most companies in the sector tend to organise work around individual construction projects which has led to a fragmentation in ICT use and e-business activity, characterised by a lack of commonly accepted standards, technical specifications and labels. (Source: e-Business Sector Studies – Construction http://www.ebusiness-watch.org/resources/construction/construction.htm).

The current situation can be summarized as follows:

- Current collaborative environments ("project web sites") provide basic file/document management and basic collaboration tools.
- Use of advanced collaboration tools is constrained by short project durations and concurrent participation of stakeholders in many projects at the same time. This leads to difficulties regarding costs and learning to use multiple systems.
- There is no legal framework to support the introduction of ICT tools (and especially such as collaborative tools) in project management.
- Despite promising developments of object modelling and data exchange standards such as IFC, increasing use of semantic ”nD” applications continues to face huge interoperability challenges.
- Available solutions address static data but not dynamic product behaviour.
- Interoperability problems limit the potential benefits of new and emerging ICT, cause extensive information management overload, limit possibilities for business collaboration between geographically remote partners, and limit the introduction of new and innovative products & services to the market. Especially, *a fundamental and growing problem is the disparity of internal enterprise systems and external project environments*.
- In addition to CAD/CAE tools, product data in other industry sectors is managed by so called PDM systems which are rarely used in construction. Generic PDM addresses document and workflow management for large organisations and their suppliers. Consequently setting up a PDM system is time consuming and expensive, and not feasible in a project oriented sector like construction. Furthermore, construction is already moving from documents to modelling.

Vision

Target State

The vision of future collaboration support in the Construction industry is as follows:

- Internal enterprise systems are connected to external collaboration environments with project partners in a transparent way.
- International standards enable fast set-up of collaboration platforms for new project consortia.
- Collaboration environments support social cohesion and trust among geographically distributed, cross-organisational teams with multidisciplinary skills, multiple cultures and multiple languages.
- Collaborative environments support mobility in a seamless way, covering all the phases of the construction process including construction sites.
- Advanced collaboration tools are easy to use without system specific training.
- Virtual meeting spaces enable (a-) synchronous communication.

Business Scenario: An “Intelligent” Virtual Project Space

Different companies are working on a large scale building project. The specific handicap thereby is the fact that they are dealing with an enormous amount of information that has to be controlled. Therefore, the in- and outgoing data has to be processed. In terms of internal and external communication the participants are sharing a web-based platform, which is able to structure and administrate all incoming and outgoing data. The virtual project space allows “strategic” data exchange between all participants. A system of access codes allows regulating access and manipulation of deposited data in a useful manner. In that case it is rather useful to predefine a hierarchy that regulates the rights to handle, bring in, change and exchange data. Furthermore, the assigned time of manipulating the data is well-defined.

The system itself works as a real-time based shared data-platform, which is collecting and preserving all relevant building-information. It is shared between all relevant members of the team. It provides and offers all necessary information during the process of planning, construction and ongoing during the whole lifecycle of the building. The cumulative information is interconnected to a three-dimensional model of the building. Diverse interfaces allow access to relevant information from any point in the world.

Business Scenario: “e-House” – A Web-based Collaborative Design Process

Miscellaneous small companies are offering a common service: A single-family house (”e-house”) that could be described as a prefabricated structure made out of, for example, wooden-elements. The design and the production process is a collaborative one. Therefore a virtual working environment is created. The participants inside the collaborative working group are the members of the design and manufacturing group.

The client, who is willing to order and buy the “e-house” is entering a web-based platform, which is connecting him to all members of the group. Specific tools are providing the possibility of easily creating a three dimensional structure, which is at the same time ”visible” to all involved participants of the future building-process. Client and group members meet each other at the virtual working environment. Additional participants in the construction process will get in touch with the team via a virtual conference-room for ongoing exchange of information. When the design process is completed, the three dimensional information is going to be converted and split into single information packages allowing to calculate and manufacture the construction and cladding parts for the house. All assembly and finishing works are connected to the originally created model of the house. Entering the virtual working environment, the client is able to control the design, the timetable as well as the building-costs.

Business Scenario: A “Collaborative Remote Decision System”

The remote decision system is about problem solving directly at the construction site. It provides the possibility of digital-communication between diverse participants. For example: Mr X (site manager) is responsible for the refurbishing of an office building. During one of his periodic visit at the construction site, he identifies an unexpected structural problem that requires the advice of a technical expert. Using his PDA (or smart phone), he launches his favourite collaborative tool (for PDA) and, through the presence search service, gets in touch with the architect of the project (Mr Y) and one person of the structural team (Mr Z) at their respective office, both equipped with desktop computers and the same collaborative platform (for PC). The system establishes a virtual meeting between all of them.

Mr X exposes the problem (audio communication), takes a photo (or a video) with his PDA and sends it to Mr Y and Z. At the office, Mr Z asks the project server (seamlessly accessed from the collaborative environment) to download from the project repository all the documents related to the location where the problem occurs (detailed plans of the existing building and of the new project, technical documents…). Comparing the data for the existing building, and the photo sent by Mr X, he concludes that the data were not up to date, and that the new project should be modified. Having no personal solution to the problem, Mr Z questions a best practice database (through appropriate metadata or by submitting the photo for searching similar problems). This database is operated by the “Structural Engineers Community” he is belonging to. Having an answer to the problem, Mr Z asks the system to share his graphic viewer with Mr Y in order to show him the proposed solution. At the same time, consequences on site organisation and work scheduling can be analyzed through appropriate web services that are called on demand and shared between Mr Y and Z (including advanced 3D and 4D visualisations). Any interaction made by Mr Y or Mr Z with the shared applications can be seen simultaneously by both actors. The decision is made on the agreed solution. New plans are drawn; timetables are updated, and transferred to Mr X in a "lighter" version automatically built by the system accordingly to the display capabilities of Mr X's device. The communications are finally switched down.

Roadmap

Objectives

Develop services and ICT tools to support optimised and dynamic steering of projects and decision support, both for management of construction processes (e.g. decision support system for priorities and impacts of risk mitigation) or for complex engineering problems (e.g. prediction and simulations tools for hazard impacts to the built environment in various conditions). These will rely on knowledge representation (models & standards for knowledge sharing like ontologies and semantic graphs), embedded learning support & training tools, Intelligent design & configuration tools, analysis, simulation & visualisation tools.

Develop new concepts and tools for Communities of Practice (CoPs) and Communities of Interest (CoIs) for Semantic Collaborative design and engineering established on common ground and shared understanding in the context of complex design and engineering tasks. The objective is the elaboration of ICT-based parametric open platforms offering knowledge semantic information space for communities at the crossing of design & architectural domain, engineering domain, semantic knowledge technology, promoting a better understanding, a closer dialogue and active cooperation between end-users/practitioners and solution/technology-suppliers through community building activities, and leading to reduce the concepts formalisation phase and improve considerably trade-off and decision support by a semantic based reasoning approach.

Therefore the development of translators and interfaces between applications and standard data presentations (e.g. IFC) has to be generalised, object databases (e.g. product / component libraries) and Model servers for sharing product model data, and models and ontologies to cope with any levels of semantics. Research should be pursued on the fields of:

- Model mappings & generalized ontology interoperability[10];
- Increased intelligence of applications and interfaces for communication with other applications;
- Extensible models through metamodels enabling flexible extensions to standard models based on specific needs not covered by the standards;
- Model checking for validating model data against standards, regulations, design rules, contracts etc., with possible notification of identified conflicts and, when possible, suggesting corrective measures.

[10] Also in relationships with the "*Knowledge sharing*" roadmap.

Main Research Areas

Short term:

- Take up of existing collaboration tools (CSCW, EDM/PDM).

Medium term:

- ICT infrastructures and tools to support project collaboration of temporary multi-organisational teams.
- Integration of (internal) engineering & enterprise systems (CAE, ERP etc.) with (external) project collaboration environments in a transparent way including authentication, authorization and audit trail.
- Collaborative inter-enterprise ICT infrastructures including model and catalogue servers.
- Standardisation of the interfaces between enterprise systems and project collaboration environments.
- Collaborative ICT tools for information sharing, change management, project steering, negotiations, decision support, risk mitigation, on-site monitoring etc.
- Low entry tools for efficient integration of SMEs in project collaboration.

Long term:

- Ubiquitous access interfaces for communication and information sharing with all stakeholders towards the merging of: "digital site" + "virtual project office" + "virtual control room" + "virtual service centre".
- Legal & contractual governance of shared object data.

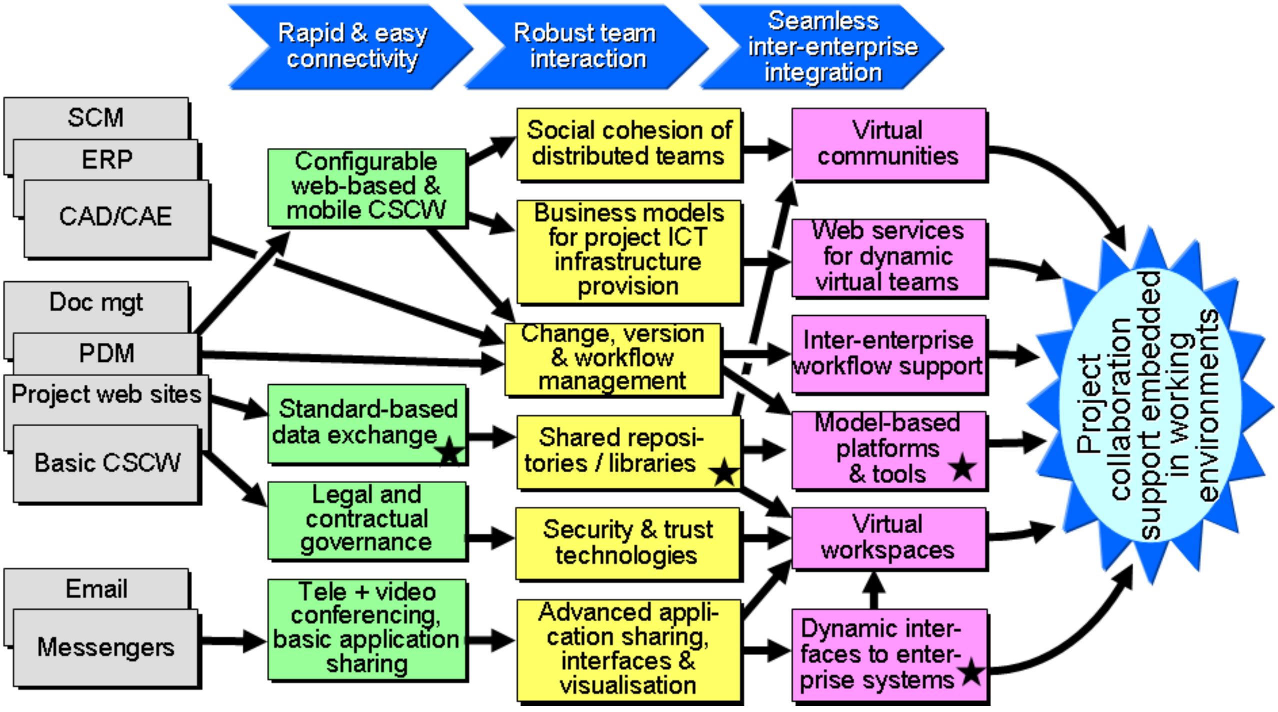


Figure 17: Roadmap for Collaboration Support

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- Email: Transmission of messages (text and files) over communication networks, mostly Internet. Very popular and the main information exchange in the Construction industry.
- Messenger: Synchronous mailing service that mainly provides instant transfer of messages and voice chat service. Still limited but spreading use.
- Document Management Server: System mainly used for exchanging and storing files (documents).
- Project Web Site: besides providing a place for exchanging and storing project-related documents, a Project Web Site includes other functionalities for asynchronous collaboration between distributed teams, e.g. (limited) workflow management, visualization of documents, actors' profile management, scheduling management, events follow-up, etc. However, its use is still limited to large projects because of the learning and parameterisation costs.
- PDM (Product Data Management): systems allowing the management of thousands of heterogeneous data (CAD/CAM data, Bills of Materials, etc.) related to products. In particular, technical data management permits the management of the all-informational patrimony of a product starting from its design until its discharge. Today, in the construction industry, the use of PDM systems (with the meaning it has in the mechanical industry) is very limited. But CAD systems (especially with import/export functionality in STEP/IFC format) can be seen as a kind of (partial) implementation of PDM for the purpose of concurrent engineering.
- Basic CSCW (Computer-Supported Cooperative Work): groupware-like systems that provide basic groupwork support services like file repositories, calendars, discussion forums, email distribution lists, partner contact information…
- ERP (enterprise resource planning): A business management system that integrates all facets of the business, including planning, manufacturing, sales, and marketing. As the ERP methodology has become more popular, software applications have emerged to help business managers implement ERP in business activities such as inventory control, order tracking, customer service, finance and human resources.
- SCM (Supply Chain Management): The control of the supply chain as a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management does not involve only the movement of a physical product (such as a microchip) through the chain but also any data that goes along with the product (such as order status information, payment schedules, and ownership titles) and the actual entities that handle the product from stage to stage of the supply chain. There are essentially three goals of SCM: to reduce inventory, to increase the speed of transactions with real-time data exchange, and to increase revenue by satisfying customer demands more efficiently.

Time to Industry: Short term

- Tele and video-conferencing: teleconferencing tools with audio and video using medium to high speed data connections (over Internet) allowing to develop shared multimedia communication environments between distant users.
- Configurable web-based & mobile CSCW: CSCW environments that support advanced cooperation functionality (e.g. application sharing, virtual meeting room) between distributed users, including mobile users, by taking advantage of the increasing bandwidth of

communication channels. Seamless integration with user applications tends to develop (e.g. "Collaborative" AutoCAD).

- Standard-based data exchange: problems of interoperability tend to disappear thanks to a widespread use of data exchange standards such as IFC. This also allows to go beyond exchange of drawings and to foster the use of the digital mock-up.
- Contractual governance: contract-based mechanisms/procedures to practically set up the ways of ICT-based collaboration between partners. Need for contract models agreed by the construction industry.

Time to Industry: Medium term

- Social cohesion of distributed teams: methods and tools to support the emergence of communities of practices (for instance SME networking), e.g. thanks to shared/distributed authoring using tools such as WIKI and the maintenance of emerging, specialized ontologies. Emergence of collective knowledge.
- Business models for project ICT infrastructure provision: new organisation patterns to support temporary, distributed, cross-organisational project teams with an economic viability.
- Change, version & workflow management tools: to allow the follow-up of the history of a project (successive versions, events, decisions, etc.), including the traceability of decisions with an objective of knowledge capitalisation, decision support and risk mitigation.
- Shared repositories / libraries: information/knowledge repositories that are not only internal to enterprises but shared (and above all updated and improved) between several stakeholders. (Linking to "knowledge sharing").
- Security & trust technologies: advanced communication technologies that allow trusted relationship through authentication, security and confidentiality of information exchanges over all types of communication networks.
- Advanced application sharing interfaces & visualisation: communication tools that allow common use and exchange of data, including a suitable representation, continuously synchronizing the actual standard of knowledge of involved project partners.

Time to Industry: Long term

- Virtual communities: Methods & tools to support more dynamic collective innovation of organisations relying on community-based forms of collaboration, e.g. using sophisticated applications based on WebDAV (Web-based Distributed Authoring and Versioning).
- Web services for dynamic virtual teams: ICT collaborative environments that allow to control and coordinate resource and service sharing to enable dynamic networking of virtual teams (presence, awareness, service discovery, …) and provide adaptive context-aware and construction-specific web services that foster collaboration over time and space within and between organisations or communities. Include service composition.
- Inter-enterprise workflow support: solutions to achieve dynamic ("on-the-fly") inter-enterprise workflow management based on business process models. Typically workflow applications/services are provided by the collaborating enterprises and can be accessed in the form of web services.
- Model-based platforms & tools: all data exchanges, processes and decisions are based on a shared building information model that covers all AEC/FM areas and enables process automation, systems integration, many different computer simulations & analysis, and

user/context specific presentations/views. RTD in construction should skip over the existing PDM generation (which are rarely used today in construction), and focus on developing the next level technology, i.e. model servers that support collaboration, flexible work flows, change management, etc. in dynamic project consortia. Useful lessons can still be learned from current PDM as a baseline and for developing the migration strategy. Other industry sectors are moving from rigid supply chains to flexible & networked organisations. They are approaching a similar situation as construction from the opposite direction. This ongoing transformation of EU industries gives opportunities for cross-sectorial RTD where construction can provide added value and play a significant role.

- Virtual workspaces: advanced ICT-based environments that allow distributed team members to fully collaborate across organizational, geographical and time boundaries as if they were co-located. It implies excellent audio and video quality in communication for any kind of device and network, excellent presentation techniques, images and visualizations, intuitive interfaces and also expressive human interaction.
- Dynamic interfaces to enterprise systems: solutions to achieve dynamic exchange of information/data between miscellaneous enterprises and their individual systems.

Business Impacts

ICT-based services and applications aiming at supporting BPM & BAM (Business Process Management & Business Activity Monitoring) in the Construction sector, through their various integration and the specific use of Dashboards (managing indicators, events, rules and administration of profiles) along with common repositories / Master data management. The use of such services / applications should first be experimented before generalisation / customisation and deployment.

As regards *Communities for Semantic Collaborative Design & Engineering*, the ambition is to develop and sustain a movement throughout Europe towards more dynamic collective innovation of European organisations and SMEs relying on revolutionary community-based forms of collaboration. The expected impact is an improved participation, and effective involvement and collaboration of industrial organisations (both institutes/academia and companies – especially small and very small – in closer relationships) in semantic collaborative modelling, design and engineering research activities, in the context of semantic rich environments with shared semantically described engineering concepts in the Construction industry.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	Software, GRID: • Collaborative approaches. • Simulation, visualisation, interaction & mixed reality: • Tools for innovative design & for creativity in products and services. • Knowledge, cognitive & learning systems: • Interpret, represent & personalise knowledge.
FP7 Nanosciences, Nanotechnologies, Materials & new production technologies	• Integration of technologies for new applications & solutions responding to major challenges, as well as RTD needs identified by ETPs.
ROADCON 2003	• Adaptive and self-configuring systems. • Collaboration support for distributed virtual teams.

ELSEWISE 1997	• Communication network. • Coordinated ICT management in projects. • Groupware. • Multiple views. • Shared project database. • Workflow management.
FIATECH 2007	• Element 1: Scenario-based Project Planning • Element 6: Real-time Project and Facility Management, Coordination and Control

4.7 Knowledge Sharing

Main Business Drivers:	access to knowledge => sharing structured knowledge => context-aware knowledge
Key Research Topics:	ICT for transforming project experiences into corporate assets. Object repositories, IPR protection of complex shared data, context aware applications.

Background

Experience and previous solutions are available in personal and departmental archives but new solutions are regularly re-invented in every project. The current background concerning the creation, capitalisation and use of "knowledge" can be mainly described as follows:

- Most information is stored in scattered archives, mainly paper-based, but in some cases digital. Content is not annotated, and is extremely difficult to find. Experiences from projects are not captured or retained efficiently and in most cases reside in the minds of those involved in the project. There is little, if any sharing or propagation of knowledge.
- The current collaborative environments ("project web sites") provide basic file/document management and basic collaboration tools. These kinds of tools / environment become more and more used, and can be considered as a very preliminary level of knowledge access and sharing.
- Even if the sector makes wide use of commonly available knowledge, few organisations exploit project experiences for developing genuine competitive advantages.
- Generic Knowledge Management has been a target for exhaustive RTD so far. However, very little has been done for capturing project experiences and targeted best practices, formalizing them into corporate assets and exploiting them in new business models. This remains a relevant opportunity for construction and faces little competition on RTD funding from other sectors.

Vision

Target State

There will be a capability to support the sharing of previous experiences, good practices and knowledge within and, increasingly, between organisations. The aim is to have (transparently) immediate access to the right information, at the right time, in the right format, and from the right sources (both internal to an organisation and external). This encompasses also the achievement of tools / services and environment allowing sharing previous experiences, best practice and knowledge within and, increasingly, between organisations. The ultimate objective is access to and sharing of semantic information resources, with:

- Knowledge embedded in management systems, products, services, software, digital models and catalogues;
- Automatic indexing of both textual and non textual content (e.g. multimedia resources, like photos or video);
- Search engine able to take into account the implicit knowledge / implicit environment of the users to enrich his search and gave him only the most relevant information according to his profile.

Business Scenario: Sharing Knowledge across Industrial Sectors

An individual faces a problem (e.g. leakage through the roof of a concrete basement due to excessive rainfall). His/her KM environment should be able to search across multiple data repositories, mine the relevant information (e.g. from potential similar problems or occurrences) and return the potential solution(s) and relevant contact people. At the same time, it should have the capability through a combination of ontologies (or a meta-ontology) to exploit relevant content for identification through the semantic web and retrieval of the same into end-user applications using intelligent knowledge agents. The retrieved content may come from a different domain (e.g. aerospace) and relate to a different problem whose solution may yet be relevant and adaptable to the problem in context.

Business Scenario: Intelligent e-Catalogues for Design and Sales

This scenario is focused on e-procurement of construction products. It allows the use of intelligent electronic catalogues to support both design and sales process. In the first case the designer wants to try different products in his/her project. In the second case, the salesman uses the catalogue to show different alternatives to his clients. The catalogues are compliant to a given standard (e.g. XML, RDF, OWL) and a given software tool is used to support all interactions. Tools that can be considered here are the following: catalogue server and taxonomy server. The former helps publishing the respective catalogues of product (standard-compliant); the latter supports the specification of the products and helps treating the queries properly.

Business Scenario: Conformance to Industrial Regulation

This scenario focuses on Knowledge Management practices related to conformance to industrial regulation. It relies on a Knowledge Management tool which can use services provided by an Ontology Server. For instance, the project manager feeds the system with knowledge about regulations (for instance, the “url” of regulatory bodies). During a project, he is informed about the publication of new regulations and then he uses the KM tool to verify if his on-going projects have to be changed in accordance with the new regulations regarding accessibility matters for disabled people. The Ontology server can be used to represent, classify, index, retrieve, and update the knowledge about regulations.

Roadmap

Objectives

A key objective is the development of a comprehensive methodology, with an iterative and incremental approach driven by well-defined industry requirements, which can be utilized by Construction organisations to define a full-fledged KM strategic vision, including development of semantic information spaces. As a stepped process, the methodology will encapsulate:

- the analysis of recognised current KM (best) practices and the identification of KM requirements within an organisation and between several organisations;
- mechanisms to identify informal KM processes and practices;
- modelling techniques to represent both formal and informal KM processes and knowledge items;
- identification of both socio-organisational techniques and ICT supported techniques to stimulate a knowledge sharing and dissemination culture – with the view that incremental evolution of ICT solutions to provide KM enabling functionality is required rather than step change;
- delivery of appropriate KM evaluation metrics dependent on the socio-technical solutions selected.

Information or knowledge should be available anywhere and at anytime. This will be achieved through the development of ICT-based information repositories and services (including information retrieval and semantic search engines, as well as administration of profiles and access control conventions) providing ubiquitous access to both explicit *corporate* knowledge, and *domain* knowledge (e.g. standards, regulations, specifications, etc.), as well as to some explicit representation of tacit knowledge and skills of the company's experts. This should be achieved through experimentations on top of various well-defined scenarios and with a constant will for adaptation to users practices and needs, including multi-modal interfaces (voice, 3D, immersion, etc.) allowing to get rid of complexity of ICT systems.

Main Research Areas

A wide range of different ICT based tools and services necessary for moving an organization towards a dynamic knowledge management will be developed in the next years. ICT should be essential not only for the storage of tacit and explicit knowledge in web based repositories but also as a communication device allowing ubiquitous access to organizational knowledge anywhere, anytime.

Short term:

- Online knowledge repositories
- Shared ontologies
- Distributed content management systems

Medium term:

- Knowledge/best practice repositories
- Semantic tools
- Knowledge management services, models, and frameworks
- Advanced decision support systems

Long term:

- Knowledge mining and semantic search services and tools
- Adaptive and context aware applications

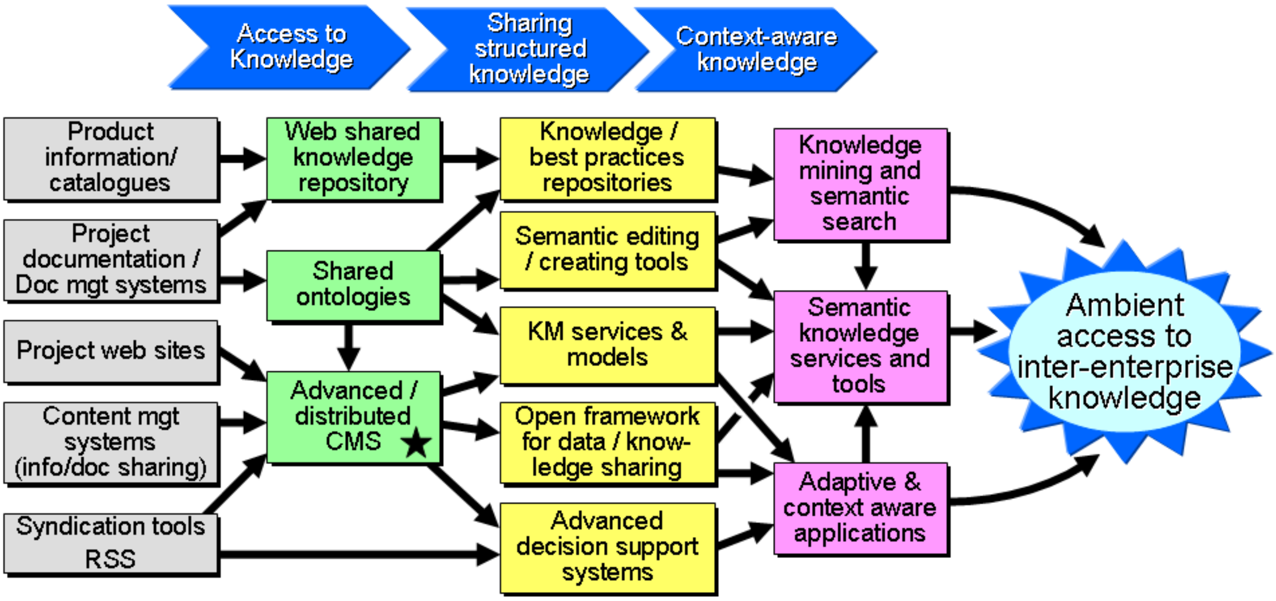


Figure 18: Roadmap for Knowledge Sharing

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Current State of the Art

- Product information: Product catalogues (electronic & paper based) mainly containing static textual information on products/services.
- Project documentation: Simple document management systems for archiving project documentation.
- Project web sites: Quasi static websites of a given project with limited groupware functionality.
- CMS: Content Management Tools: Content management systems are the next generation of simple document management systems. They offer the possibility for publishing information and sharing it across organisational units. Some groupware functionality is usually offered.
- Syndication tools (RSS): Aggregation of news flows on one single page, dynamically refreshed. This is just a tool to concentrate several information sources. A good example is “My yahoo”.

Time to Industry: Short term

- Web shared information repository: Web space accessible to all through given rules (user rights management mainly), where information/knowledge can be stored / retrieved.
- Shared ontologies: Identification of key concepts and their inter-relationships. Ontologies should not be too generic or too large. Rather, lifecycle phases, or topic specific (e.g. facilities management) should be developed in detail. A meta-ontology should be built on top of these to allow for interoperability and mapping between these ontologies when and where needed.
- Advanced/distributed CMS: Dedicated solution, providing advanced services (profile and context based information push for instance). These solutions will also rely on open common agreed standards to exchange knowledge across different CMS.

Time to Industry: Medium term

- Knowledge /best practices repository: Methods and tools for the identification, capture, consolidation, and dissemination of best practices. These should contain tools that enable the search and retrieval of past experiences, good (to-do) and bad (not-to-do).
- Semantic editing/creating tools: Tools that allow for automatic on-the-fly tagging of not only content (documents, drawing, media, etc.), but also parts of content (paragraphs, objects, etc.) based on shared ontologies. These should also support user-creating semantic links between different objects. Furthermore, based on a search, these tools should support content classification based on on-the-fly ontologies created through concept analysis from the searched content.
- KM services & models: These services should facilitate inter-enterprise knowledge management through provision of simple services such as searching, and sophisticated services such as e-Tendering. Models through the support of shared ontologies should support the classification and tagging of relevant content to projects, products, services, etc.
- Open framework for data/ knowledge sharing: Development of platforms and services dedicated to the knowledge sharing in inter-organisational environments. They are dedicated to knowledge sharing based on user profiling, and push of adapted/relevant information to each profile. These should ideally be transparent to the users and be accessible by different applications and search services. Furthermore, they should provide relevant groupware functionality at an industry (e.g. network of experts) level.
- Advanced decision support systems: The focus should be on support for real-time decision support as compared to decision support during planning phases only. Advanced decision support will be possible through a consolidation of the expertise (relevant experts) and various analytical tools based on past project performance. These tools should furthermore be supported by syndication services acting on business intelligence applications and sources.

Time to Industry: Long term

- Knowledge mining and semantic search: Development of new searching methods and tools aiming at reducing the "noise" of the answers by taking into account the implicit environment in which the query has been submitted by the user. Searching capabilities will be extended to non textual content (multimedia formats). Tools for the retrieval of knowledge, business logic, and rules from different information sources and applications. This should be automated, with the captured business logic and rules made reusable in the form of application components.
- Semantic knowledge services and tools: Development of both meta repositories (that will provide definitions of, and relationships, and mappings between different information repositories, knowledge sources and ontologies) and semantic technologies being able to modify / adjust / enhance user's queries so as to retrieve the required information from the relevant sources (taking into account, the implicit context of the query). As an example, knowing that the calling user/application is from the construction domain, when a search on "knowledge management" is done, the system would search for "knowledge management + construction industry". Furthermore, the results may be ranked and categorised (automatically) based on the typical preferences of the user/application. One promising way to implement such tools is based on the agent technology.
- Adaptive & context aware applications: Development of self adapting tools anticipating user's needs and actions (anticipation based on the treatment of information flows and in-

ternal knowledge and process models and rules) and presenting the "right functionality at the right moment". They rely on user profiles, roles, etc. Ubiquitous, personalized and context-dependent access to knowledge is necessary and will be provided through ambient access technologies. These technologies will be based on an integrated use of ontologies, semantic web, context aware applications, knowledge processes, personal usage patterns, mobility, etc. This will enable a paradigm shift in the way individuals and mainly applications solicit information from the Internet. As opposed to human interpretable and computer un-interpretable web content, annotations and intelligence will be added to content to all for ease of retrieval and interpretation by different applications.

Business Impacts

Intra- and Inter-company Knowledge Management will:

- Allow digital capitalisation of knowledge and experiences generated on construction projects to avoid repeated errors and increase quality of construction;
- Improve companies' productivity and skills based on knowledge capture and transmission processes.
- Improve sharing of knowledge between enterprises involved in the building process, especially for the supply chain management, while preserving individual competitiveness.

Ambient access should allow a generalized use of digitalized information and knowledge throughout the whole company, allowing re-use of information and seamless access to the full expertise within the company, anywhere, anytime.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	Knowledge, cognitive & learning systems.
FP7 Energy	Knowledge for energy-policy making.
FP7 Environment	• Assessment tools for sustainable development (assessment of impacts of current trends in production & consumption patterns related to Construction).
ROADCON 2003	• Adaptive and self-configuring systems. • Ambient access. • Knowledge sharing.
ELSEWISE 1997	• Enterprise models. • Learning organisation. • Re-use of prior knowledge.
FIATECH 2007	Element 8: Technology & Knowledge-enabled Workforce

4.8 ICT Enabled Business Models

Main Business Drivers:	business networking, customer orientation & sustainability, system integration, specialisation
Key Research Topics:	new ways for sustainable exploitation of ICT as a key part of business strategy in the open European / global construction marketplace; management tools and services to support inter-organisational collaboration across products and services

Background

- The sector makes wide use of commonly available knowledge. Few organisations exploit project experiences for developing genuine competitive advantages.
- Current business processes provide low incentives for R&D and knowledge development.
- Current business model are based on lowest cost and capacity.
- Enlarging open market, evolving business processes and new technologies in combination open up rewarding opportunities to innovative companies to develop and offer new knowledge based products and services.

Vision

Target State

- Innovative companies offer new knowledge based products and services in the construction sector based on: branding, business networking, ICT, innovation, knowledge, specialisation, system & service integration etc.
- New ICT enabled business models support advanced: business networking, customer orientation and sustainability, system integration, and specialisation allowing for on-demand customisation of products and services.

Business Scenario: Inter-organisational Competence Network

Organisations are part of a network that agrees upon certain rules for inter-organisational collaboration including shared standards, common or interoperable ICT tools, collaboration platforms etc. Participation in the network is based on complementary competencies and not necessarily capacity. When a client approaches one organisation with a request for a unique product or service, the organisation using an intelligent competency search and assimilation tool, relies on the network to build a consortium based on required competencies. The consortium can be self-configured in terms of participants, competencies, roles, etc. and a collaboration solution configured based on the unique needs of the project. A virtual enterprise is created, configured and put in operation to deliver the product/service. When the product/service is delivered, the virtual enterprise is decommissioned (or a new one formed to provide lifecycle support for the product/service).

Business Scenario: Plug & Play Building Design

A user would like to design his/her dream home. Through plug and play product/service components, the user can design and digitally assemble the home based on a set of generic components. For each of the components, relying on searchable and comparable product catalogues, a user can select different product component solutions from different manufacturers/suppliers. The home is automatically designed based on smart connections between the different components. A cost and schedule estimate is also generated on the fly within a margin of error of 15-20%. The user can furthermore based on the design and selected components identify relevant contractors to build the home.

Business Scenario: Total LC Mgmt. from Conception to Demolition

Clients' expectations and needs are captured and validated very early in the process. Visual information is used to inform the client about the project and also on previous similar developments. The expected TLC performances are defined at the beginning of the design phase and used, as inputs, to optimise different technical domains. Optimisation uses on-line information about building components. On-line geographical information is accessed to test implementation options and to require planning permission from authorities. During the design phase, simulation is used extensively to test "what-if" scenarios and to assess feasibility and buildability. Planning and cost estimations are conducted concurrently with the design. Long term partnering relations allow to simplify the procurement phase and to start the construction phase. The "design product model" is used on site through wearable and wireless computing and is updated regularly (along with planning and cost estimates) with "as built" information. Delivery information of components and materials is accessed on-line and in real-time to prepare site for deliveries. "How to build" information is checked on site through visual displays by subcontractors in order to avoid errors. At the end of the construction phase, an "as built" model is handed over and used for FM and for automatic generation of maintenance schedules. After demolition of the building, dangerous materials are tracked and oriented toward adapted facilities.

Roadmap

Objectives

Develop:

- Model based services offering new business opportunities enabled by model based data e.g. analysis, estimation, visualisation, simulation etc. Thanks to computer-interpretable information highly specialized services using sophisticated software become feasible.
- Model driven process / workflow management, leading to intelligent workflow aid combining product model with scheduling, resource planning and progress monitoring.

Main Research Areas

The ICT-based solutions should be, among others:

- Innovative e-Business solutions, especially for SMEs, supported by open, interoperable, modular and adaptive ICT-based platforms that would also allow integration of enterprise applications.
- Pan-European multi-lingual "information resource points" accessible and "valuable" all across Europe. This will be done through the promotion of the semantic web and its related technologies applied to the Construction needs.
- Solutions for Sustainability management, through optimised management of multi-constraints systems, and improved cooperative development towards "sustainable construction model(s)".

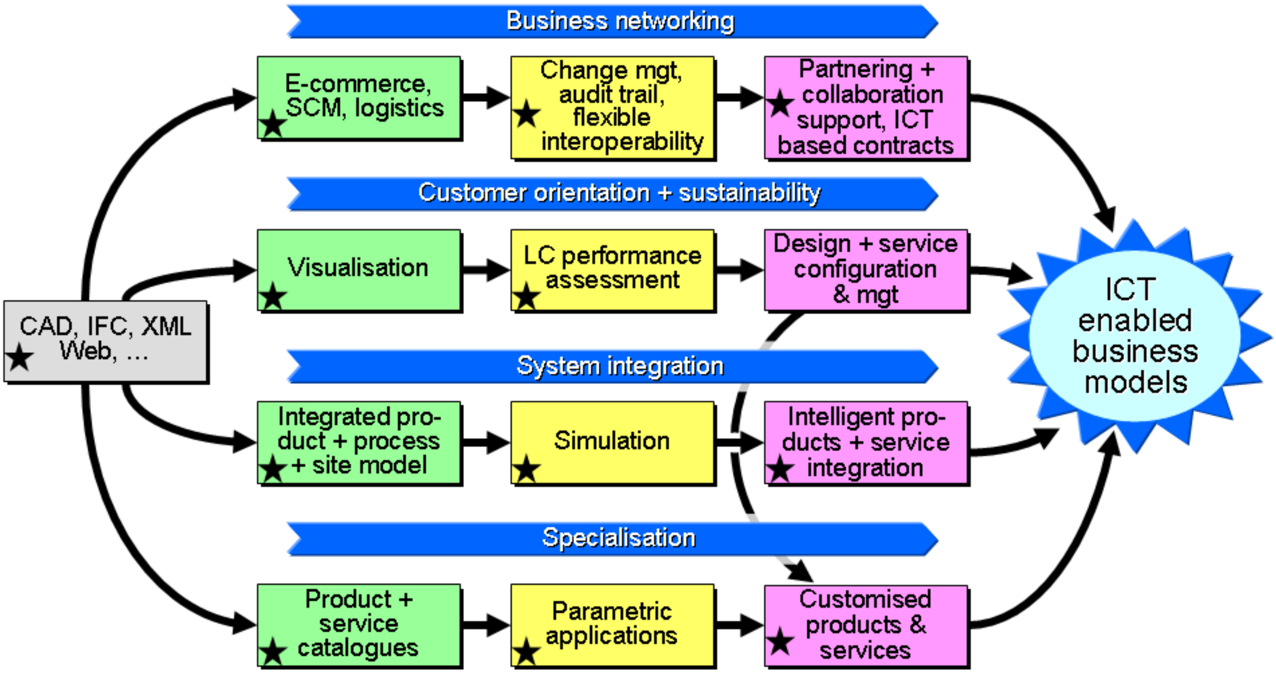


Figure 19: Roadmap for ICT enabled business models

Legend: State of the art | Short term | Medium term | Long term | Driver | ★ Link to other diagram

Short term:

- Tools for managing inter-functional and inter-organisational e-Commerce, supply chain management, and logistics
- Tools that support product, process and service visualisation
- Tools that support management and integration of products, processes, and site models
- Tools for managing (digital) product and service catalogues

Medium term:

- Tools for managing change management, audit trailing, and flexible interoperability in inter-organisational settings
- Tools for managing life-cycle performance assessment
- Tools for managing product and process simulation
- Tools for managing parametric products and services

Long term:

- Tools for managing partnering, collaboration support, and ICT based contracts in inter-organisational settings
- Tools supporting both design and service configuration and management
- Tools for managing intelligent product and service integration
- Tools supporting product and service customisation.

Current State of the Art

- CAD, IFC, XML, Web, etc.: Technologies currently used are most of the time CAD tools and Office tools, with limited integration and interoperability (even if some of those tools provide file exchange mechanisms, e.g. the IFCs, and/or APIs for integration), and very few of them really object-oriented. These tools typically support a particular operational phase or product/process domain.

Time to Industry: Short Term

- e-Commerce, SCM, logistics: e-Commerce, supply chain management and logistics is typically limited to uni-directional flow of products and related information. New business models should concentrate on multi-directional flow of information throughout a given product or services life-cycle. While a product or service may flow from one organisation to the next, and then yet to another within a typical supply chain, there is a need for information relay across all organisations involved in the chain. Tools that support the management of inter-functional and inter-organisational e-Commerce, supply chain management, etc. need to be developed.
- Visualisation: Product (and increasingly service) visualisation is allow to support customers' understanding of the product/service that they desire. A simple example is a 3-D walk-through a to-be-built building. In addition to product geometry visualisation tools will support visualisation (e.g. in the form of a management dashboard) of schedules, cost, product performance, etc. at any given point in time (before, during, and even after construction of the physical product).
- Integrated product + process + site model: Management tools that will support visualisation and management of different building model views such as product, process, and site views (models). These could be in the form of visual information layers that provide related information on an object (e.g. a beam) from a product, process, or site perspective at a given time. Such tools will (at least in part) rely on the IDM (information delivery manual) work being done by the IAI (More information available at http://www.iai.no/idm/.)
- Product + service catalogues: Product and service catalogues will allow provide product and service information in a digital form. This will allow for use of this information in different design/management applications and furthermore allow for comparison of similar products and services from different manufacturers and suppliers.

Time to Industry: Medium Term

- Change mgmt, audit trail, flexible interoperability: Business models and tools supporting inter-organisational change management, audit trailing, and flexible interoperability across distributed applications. These will allow organisations to monitor and track how their products/services may have been changed/modified through a typical supply chain. Accordingly, organisations will be in a better position to learn from the experience of others on "their" products and thereby present an opportunity for providing better, more configurable products and services in the future.
- LC performance assessment: A product or service can be best optimised in terms of value to the customer if its performance during different project life-cycle stages is assessed. This assessment can allow for product/service reconfiguration and optimisation for that particular lifecycle stage based on the stage's requirement and the then state of the product/service.
- Simulation: Product/service simulation for different project lifecycle stages under varying boundary conditions can support better understanding of product/process/service behaviour and thereby offer opportunities for improvement in real-life settings. It is important to note here that they key point is simulation under "different" boundary conditions which is a reflection of product/service behaviour under different usage scenarios.

- Parametric applications: Parametric applications will support the design, assembly, configuration and management of products/services through their product and service catalogues. These parametric applications will increasingly rely on ontologies and semantic services for assembly, configuration, and management of different components (possibly dissimilar and from different manufacturers/suppliers) of products/services.

Time to Industry: Long Term

- Partnering + collaboration support, ICT based contracts: Organisations that are a member of a network that share common standards, interoperable ICT tools, etc. will be able to quickly set-up collaboration spaces to share competencies to deliver unique one-of-a-kind products and services. Increasingly, based on the product/service components provided by the different organisations and the nature of the project at hand, ICT based (electronic) contracts will be negotiated through applications with final endorsement from the participant organisations. Legal barriers such as legal admissibility of emails, CAD drawings, use of ASPs, ownership of information, company vs. project information and legal issues of objects (such as IFCs) are overcome by specifying an ICT-related contract governing these issues. E-contracting, contract configuration and on-line negotiation tools**Error! Hyperlink reference not valid.**) are used to develop such ICT-related contracts.
- Design + service configuration & mgmt.: Relying on lifecycle performance assessment (possibly through visualisation and simulation), new business models and supporting tools will allow for design optimisation, service configuration (based on optimal state of product or service at a given lifecycle stage based on functional needs of client), and management.
- Intelligent products + service integration: Intelligent products will be linked to relevant services based on semantic product definition allowing for look-up of related services, service providers, etc.
- Customised products & services: Product/service catalogues parametric applications will open new forms of business allowing customisation of products and services based on specific client needs. Relying on modular product and service design, customers will be able to receive the product/service that they desire through an assembly of a set of choice products/services. These can be designed, assembled and configured on demand based on intelligent connections connecting different product/service modules. Being modular in nature, the products/services can be changeable when desired as opposed to being built for life.

Business Impacts

ICT-based services will enable companies to create competitive advantage through new operating models in several key areas. Some examples are:

- Logistics services focused on creating new operating models in the network level.
- Structured recording of experience and knowledge in order to improve information management, workflow management, interface management and document management.
- Risk management system including diagnostic and decision support tools that enable the identification, analysis, tracking, mitigation, and communication of risks in software-intensive programs.
- Design, configuration, and life-cycle management of one-of-a-kind products and services
- Real-time identification and assembly of competencies across organisations to support inter-organisational collaboration to deliver a customised product or service.

Thematic Mapping and Further Information

FP7 Information & Communication Technologies	• ICT for trust and confidence. • ICT supporting business & industry: − Dynamic network-oriented business systems for product & service creation and delivery.
FP7 Nanosciences, Nanotechnologies, Materials & new production technologies	• Develop/validate new industrial/business models & strategies for whole Construction LC.
FP7 Environment	• Assessment tools for sustainable development (assessment of market-based & regulatory approaches).
ROADCON 2003	• ICT skills and awareness. • Legal and contractual governance. • Total Life Cycle support.
ELSEWISE 1997	• Demanding client. • Differentiation. • Dynamic virtual enterprise. • Enterprise models. • Life cycle view. • New business concepts. • Total life cycle management.

5. Implementation

5.1 Organisation

5.1.1 Leadership

The leadership of this FA is ensured by an Industry member of the ECTP, with the support of a co-leader from industry/research, and support from 2 research centres:

- ARUP (UK), leader.
- Bouygues Construction (France), co-leader until March 2006.
- VTT (Finland), RTD support, co-leader after March 2006.
- CSTB (France) RTD support.

5.1.3 Core group

The Core Group of the FA is formed by the four leaders of the FA and the leaders of the 4 Working Groups that are formed within the Focus Area. This Core Group is in charge of a continuous management of the FA and through this group the coordination of the work done in the different Working Groups takes place. The Core Group is responsible for the final documents and other output of the FA.

Members of the Core Group are:

- ARUP: Jeremy Watson, Marta Fernandez, leader
- Bouygues Construction: Claude Dumoulin, co-leader until March'06
- CSTB: Alain Zarli, Marc Bourdeau
- SBi: Lone Moller Sorensen, Kresten Storgaard, WG1 convener
- VTT: Matti Hannus, Abdul Samad (Sami) Kazi, WG2 convener, co leader after March'06
- TNO: Peter Bonsma, Michel Böhms, WG3 convener
- Acciona: Jose Javier de las Heras Bueno, WG4 convener

5.1.4 Working groups

FA7 PICT consists of 4 Working Groups:

- WG1 Process
- WG2 Product
- WG3 Project
- WG4 Enterprise

5.1.5 Membership

Membership of the FA is open to all European interested organisations, and is accepted after a written request to the FA leader, with:

- the nomination of a liaison person;
- the express commitment to participate in the working group activities;
- a clause to support the level of dissemination of the information received accordingly;
- with the rules established in the group.

The members mainly come from:

- research community - public and private; technical and socio-economic;

- industry (incl. SMEs) - embracing the whole production, supply chain, and life-cycle;
- public authorities - European, national, regional, local;
- Software editors, vendors and IT companies, either with a general profile or with a specialisation in IT for Construction.

The FA will greatly encourage the participation of SME's and organizations from the EU25 countries, as well as it will encourage the participation of women in the group's activities.

FA PICT members (162 persons as of 19 may 2008: contact details are available on the ECTP intranet at www.ectp.org):

5.2 Workplan

5.2.1 Deliverables

Actions for the FA Processes & ICT are:

- Development of Vision 2030 (this document).
- Development of Strategic Research Agenda (completed in June 2007).
- Presentations of Vision 2030 & Strategic Research Agenda.

At the time of writing the ECTP is preparing its action plan for 2008-2009.

5.2.2 Interfacing with other FAs

The FA Processes & ICT has reviewed the SRA documents of all other FAs and indentified their priorities in the domain. A overview of the analysis is presented in the Appendix.

5.2.3 Calendar

2005-09-21 ....Setting up of FA PICT at the Support Group meeting.

2005-10-20 ....Kick-off meeting of PICT, London.

2006-01-29..30 ...Core group meeting, Brussels.

2006-03-20..21 ...Strat-CON kick-off meeting, VTT, Espoo, Finland. Participants: VTT, CSTB, TU Vienna, TEKES.

2006-09-14 ....RTD strategies for ICT in Construction. Workshop hosted by the Strat-CON project and the ECTP Focus Area "Processes and ICT" in the context of the ECPPM 2006 conference "e-Busines and e-Work in Architecture, Engineering and Construction", Valencia, Spain, 14-16 September 2006. About 60 participants.

2006-10-17 ....ECTP FA Processes & ICT workshop of RTD topics, Arup, London. Organised by Arup, Strat-CON and FA PICT. About 30 participants.

2006-11-21..23 ...IST Conference, Helsinki, Finland. Introduction of the IST program in FP7.

2006-11-21..22 ...Nov 2006 ECTP Conference, incl. brokering session on "ICT-supported new integrated processes for the construction sector". Versailles, France.

2007-03-09 ....Meeting of BuildingSmart, FA PICT and the CIP programme.

2007-08-22..24 ...Workshop of FIATECH, Strat-CON and FA PICT, Aavaranta, Finland.

2007-11-19..20 ...3rd ECTP Conference Amsterdam. Brokerage session 1: Industrialisation through new integrated construction processes (NMP-2008-3.4-2)

5.2.4 Contributions

The resources for the implementation of work come from the organisations present in the Focus Area.

Contributions of some members are partially based on funded work in related RTD projects:

- BICT: Evaluation of benefits of ICT for the industrialization of project and product processes in the construction industry (ERABUILD).
- BUILDNOVA: Building innovation in the European Construction Sector (Innovation).
- COVES: Collaborative Virtual Engineering for SMEs (NMP+IST, *started in summer'06*).
- I3CON: Integrated, Intelligent & Industrialized Construction (NMP, *started in Oct'06*).
- INPRO: (NMP, *started in Sep'06*)
- INTELIGRID: Interoperability of Virtual Organizations on Complex Semantic Grid (IST).
- MANUBUILD: Open Building Manufacturing (NMP).
- STRAT-CON: R&D strategies for ICT in construction (ERABUILD).
- SWOP: Semantic Web-based Open engineering Platform (IST).
- TUNCONSTRUCT: (NMP).

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Appendix 1: RTD idea proposal form

RTD ideas within the scope of this SRA were identified in several workshops using the below template. The received ideas are downloadable from the internal web site of ECTP PICT.

Table 2. RTD idea proposal template

RTD idea proposal on Processes & ICT in construction						
Title (max 10 words)						
Keywords (max 5)						
Time to industry		Short term		Medium term		Long term
Topic area	Process :		1. Value-driven business processes			2. Industrialised production
	Product :		3. Digital models			4. Intelligent constructions
	Project :		5. Interoperability			6. Collaboration support
	Enterprise :		7. Knowledge sharing			8. ICT enabled business models
	Other :					
Industrial problem / relevance: Why is this action important? What are the main business drivers?						
Technological objectives: What is the aimed measurable achievement / RTD innovation / progress beyond the state of the art?						
Approach: How will the problem be solved: baseline technology + methodology / approach + necessary competencies?						
Results: What tangible, applications / tools, methods etc. will be developed / extended?						
Exploitation: How will the results be provided to users? Who will use the results and how?						
Impacts: What potential benefits will follow from the use of results?						
Follow-up actions: What else is required to achieve the benefits?						
Proposer	**Name** (First, Last)					
	Organisation					
	Email					