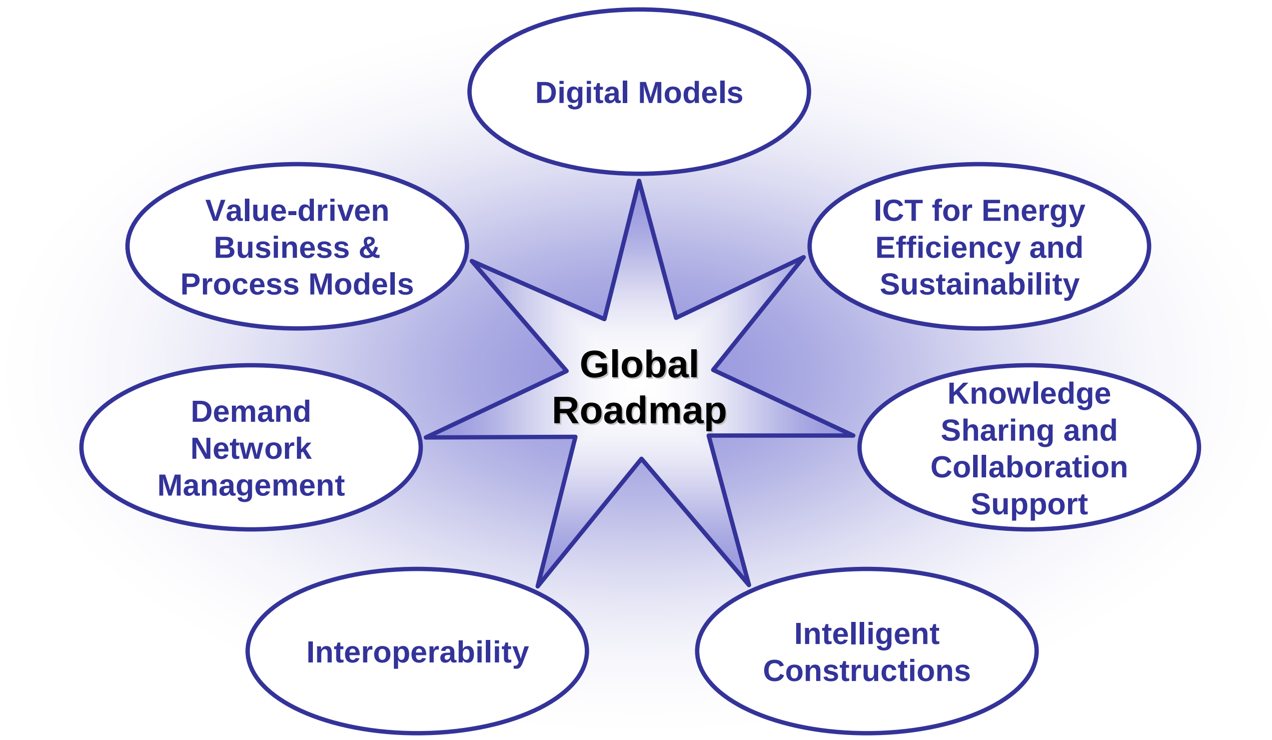
International Workshop on Global Roadmap and Strategic Actions for ICT in Construction

(August 22-24, 2007 | Finland)



Workshop Report and Summary of Key Findings

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Executive Summary

During August 22-24, 2007, a joint global workshop on roadmaps for ICT in Construction between FIATECH and Strat-CON was held in Finland. Through active participation of more than 30 international experts the workshop aimed to develop a series of thematic roadmaps based on common topics of interest of the FIATECH and Strat-CON roadmaps. Focusing on information and communication technologies (ICT) and value driven processes supported through these technologies seven main thematic areas and their respective visions were identified (Figure 1):

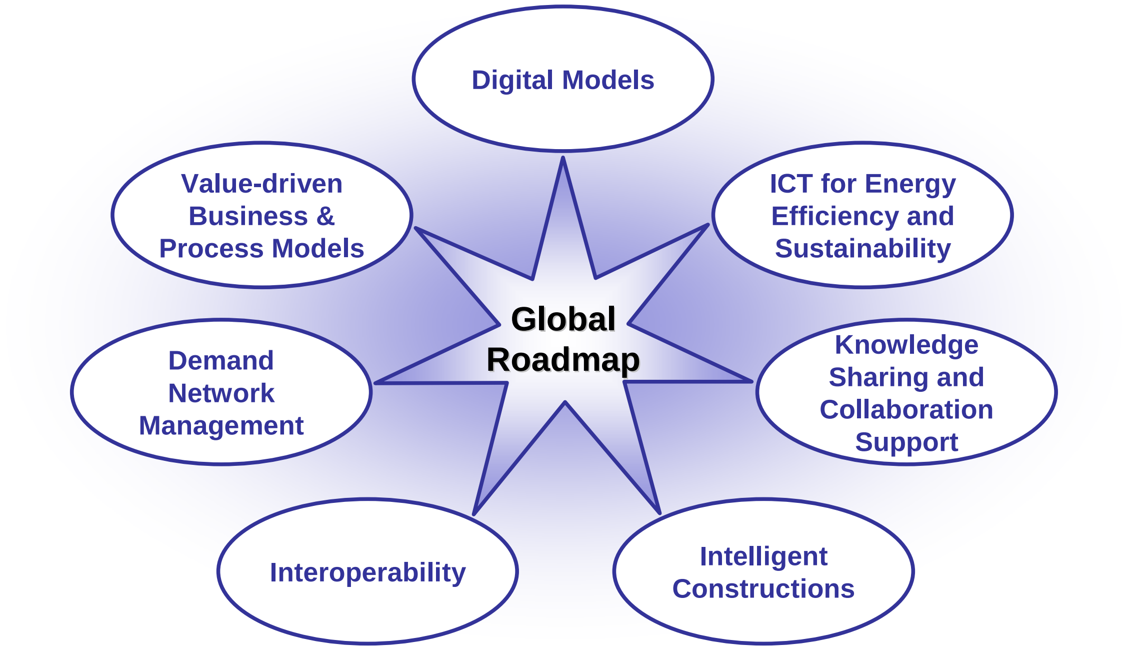

Figure 1: Main Thematic Areas

Digital Models: Digital models are the key enablers for integrating, managing, and sharing multi-disciplinary views and perspectives of the built environment's lifecycle information.

ICT for Energy Efficiency & Sustainability: Delivery and use of sustainable and energy-efficient facilities through ICT-based informed decision-making (both human and automated)

Knowledge Sharing & Collaboration Support: Seamless and instant access to the right information/knowledge at the right time and in any place

Intelligent Constructions: Ubiquitous B2P (B=Building, P=People)

Interoperability: Information sharing without concern of the creating system; Interoperability independent of source, life cycle stage and type; Information to be securely accessible and interpretable across the life of the asset

Network Demand Management: Customer aware and informed of status at all times and receives on-time delivery; supplier aware of customer and project demands and potential barriers as soon as they arise; environmental requirements included in all future transactions

Value Driven Business & Process Models: What You Feel Is What You Get

For each of the seven thematic areas, key industrial problems, and current research/technological gaps were identified. These were followed by definition of the vision, main objectives, current state of the art, and roadmaps covering topics for short, medium, and long term delivery to the industry. Furthermore, for each theme, a set of strategic actions (project ideas) to serve as building blocks for projects were identified.

Table of Contents

Introduction

Background/Overview

The value-adding role of information and communications technologies (ICT) in the facilitation of information exchange across software applications and organisational boundaries is widely acknowledged. However, the construction industry at large has been slow compared to other manufacturing industries in the adoption of ICT solutions.

In response to industrial needs, several initiatives have been setup to develop roadmaps providing pathways to accelerate the adoption, take-up, development, and research of emerging and new technologies that may revolutionise the construction sector. FIATECH Capital Projects Technology Roadmap and Strat-CON Thematic Roadmaps (see Figure 2 for complimentarity and basis for this workshop; and Figure 3 for comparison between the two initiatives) were seen as a relevant basis for initiating the dialogue. The relevance, timeliness, and richness of information contained in each of these roadmaps have warranted a desire to first review, and then consolidate this information in the form of a common global roadmap for ICT in construction.

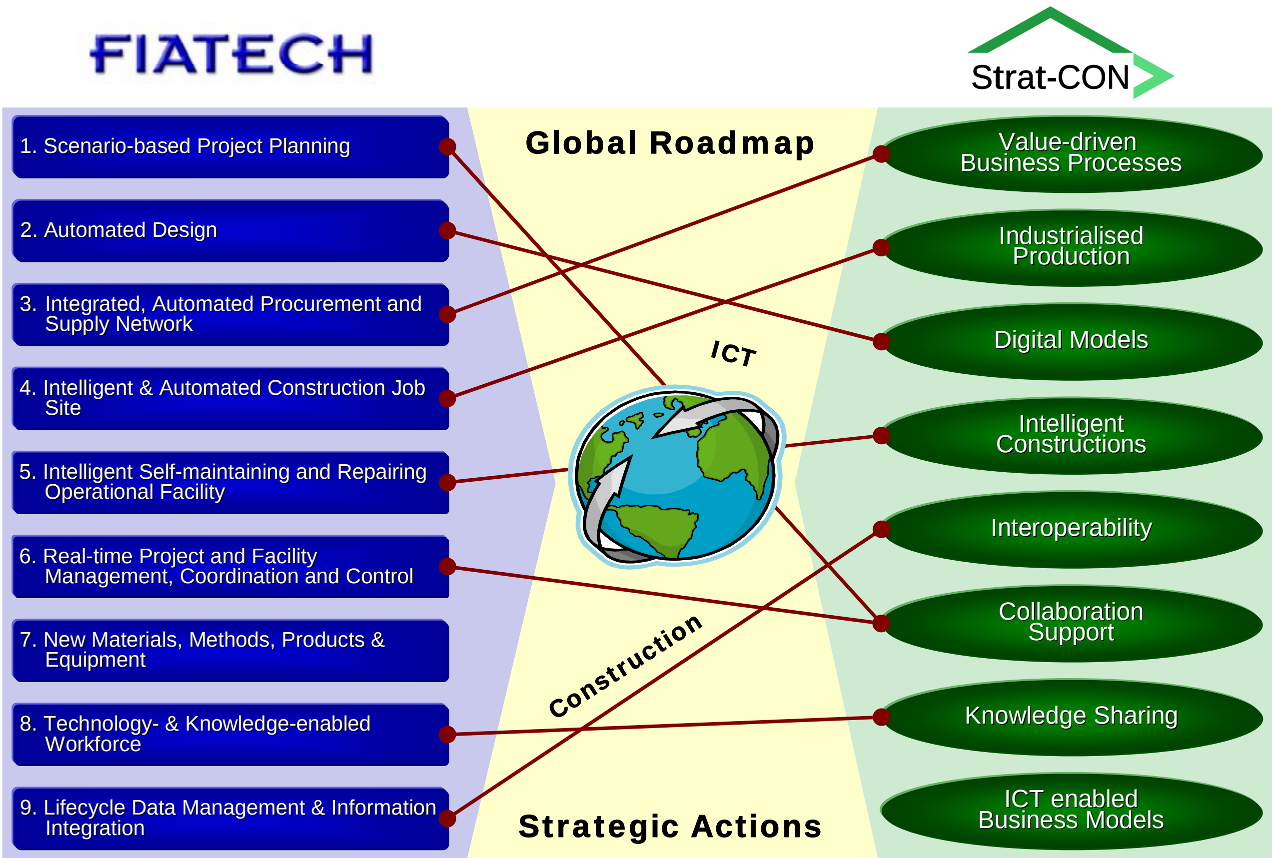

Figure 2: Complimentarity between FIATECH and Strat-CON Roadmaps

	FIATECH	Strat-CON
Approach	9 roadmap elements	8 thematic roadmaps
Focus	Projects	Research topics
Time to Industry	Short & medium	Short, medium & long
View	Process	Technology
Offering	Projects for take-up	Topics for research funding
Main Audience	Industry	National funding bodies
Proposition	Stakeholder benefits	Business scenarios

Figure 3: Comparison between FIATECH and Strat-CON Roadmapping Approaches

It is also of interest to note that together, both FIATECH and Strat-CON roadmaps contribute to completing a typical innovation cycle from vision to research topics to research projects and finally industrial implementation as illustrated in Figure 4.

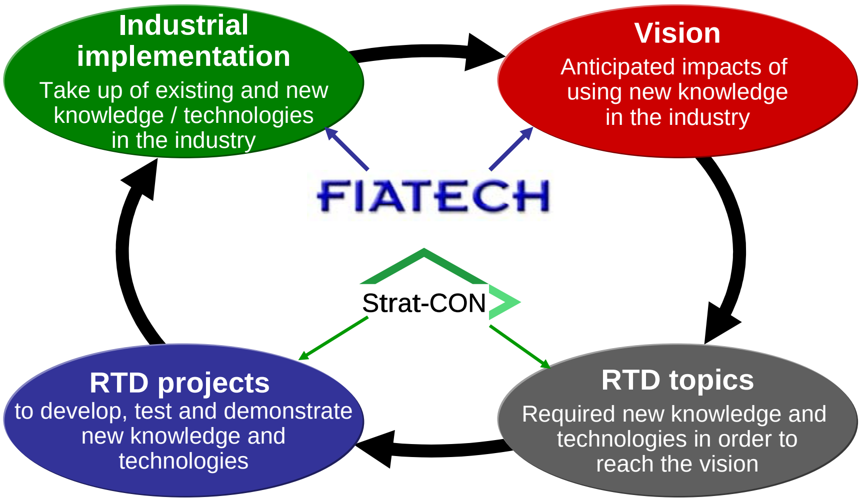

Figure 4: Closing the Innovation Loop

FIATECH (www.fiatech.org), CIB (www.cibworld.nl), on behalf of the Strat-CON project consortia (www.strat-con.org), VTT (www.vtt.fi) and CSTB (www.cstb.fr), and TEKES (www.tekes.fi) organised an international workshop on August 22-24, 2007 in Finland. The 34 participants in this invitation-only workshop represented 12 countries and had extensive experience in roadmap development. About one third of the participants represented organizations that are members of FIATECH, and half represented organizations that are members in CIB.

Scope /Objectives

This international workshop concentrated primarily on information and communications technologies (ICT) and value-driven business processes supported through the use of technologies. The FIATECH and Strat-CON roadmaps were used to provide a strong foundation and baseline for the work done in the workshop. The main objectives of the workshop were:

- Review of FIATECH and Strat-CON roadmaps
- Identification and selection of 8-10 thematic areas for roadmapping
- Development of roadmaps based on time-to-industry for selected thematic areas
- Identification and definition of a set of strategic actions/projects to support realisation of roadmaps

Expected Tangible Outcomes

By the end of the workshop, it was expected for participants to have:

- Co-developed a series of thematic roadmaps
- Identified a set of strategic actions (project ideas) to support realisation of the roadmaps
- Agreed upon common follow-up actions to refine and document the roadmaps and strategic actions

These expected outcomes have been achieved and are summarised in this report.

Content Structure

This report presents some of the key findings from the International Workshop on Global Roadmap and Strategic Actions for ICT in Construction that was held during 22-24 August, 2007 in Finland. The contents of this workshop report are structured as follows:

- **Introduction:** This section presents the background/context, main objectives, and expected outcomes of the workshop.
- **Approach:** This section presents the workshop programme. The seven main identified thematic areas around which group sessions were held are presented along with the approach used for roadmapping and capture of strategic actions (project ideas).
- **Theme:** Each of the identified seven themes is presented within an individual section with each section containing most of the following sub-sections:
    - Overview and Industrial Context
    - Industrial Problems Addressed
    - Current Gaps and Foreseen Technological Challenges
    - Vision
        - Business Scenario(s)
    - Main Objectives
    - Roadmap
        - Key Enablers
        - Key Barriers
        - Main Topics
            - Current State
            - Short-Term to Industry
            - Medium-Term to Industry
            - Long-Term to Industry
    - Project Ideas
    - Related Initiatives and Further Reading
- **References:** Pointers to roadmaps used as baselines for this workshop and the methodology used for roadmap development and strategic action/project idea development.
- **Appendices:**
    - Appendix A: Workshop Participants
    - Appendix B: Strat-CON Thematic Roadmaps
    - Appendix C: FIATECH Capital Projects Technology Roadmap Elements
- **Contact Information:** Information on workshop sponsors and organiser contact information.

Approach

To continuously evolve and innovate, organisations and industrial sectors need to set clear evolutionary paths facilitating a transition from a "current" state to an envisioned "future" state. Within this workshop, the Strat-CON approach to roadmapping was used. It is a simple and visual methodology for developing strategic roadmaps supplemented with a set of strategic actions (project ideas) that support realisation of the elements of the roadmap. Using a futuristic visionary state as the goal, a set of short, medium, and long-time to industry actions are defined.

When developing the roadmaps and supporting strategic actions, some key assumptions were made:

- Visions serve as the basis for continuous evolution and innovation
- Clear roadmaps define the path from today (as-is) to the desired vision (to-be)
- Strategic implementation actions provide the means to follow the roadmaps to achieve the vision

For more information on the overall approach, please refer to Kazi (2007).

Workshop Programme

The workshop programme was purposely designed to allow enough time for comprehension of existing FIATECH and Strat-CON roadmaps, development of thematic roadmaps and strategic actions (project ides) through interactive group work, result sharing in plenary sessions, and interactive dialogue. Both FIATECH and Strat-CON roadmaps served as the baseline for the workshop.

Tuesday, 21 August 2007	
19:00	Informal Get-together and Welcome Reception (Dinner)
Wednesday, 22 August 2007	
08:30	Registration, Coffee, and Meeting Participants
09:00	Welcome, Introduction to Workshop, and Programme Overview
09:30	Re-Cap I: Overview of Capital Projects Technology Roadmap – FIATECH
11:30	Lunch and Enjoy the Nature
13:30	Re-Cap II: Overview of Strat-CON Roadmap & Strategic Actions
15:00	Coffee Break and Nature Stroll
16:00	Setting the Scene: Identification and Selection of Thematic Priorities for Roadmapping
17:00	Understanding the Approach: Common Approach to Roadmapping and Team Building
18:00	Free Time
20:00	Sauna (including light dinner)
Thursday, 23 August 2007	
09:00	Re-Cap: Roadmapping Approach, and Objectives for the Day
09:30	Break-Out I: Roadmapping (One Team per Thematic Priority)
12:00	Lunch and Enjoy Nature
13:30	Roadmap Tours (see what others have done)
14:30	Break-Out II: Roadmapping (One Team per Thematic Priority)
16:00	Coffee Break
16:30	Feedback: Presentation of Each Thematic Roadmap
18:30	Free-time
19:00	Bus Departs to Helsinki for Dinner
20:00	Dinner
Friday, 24 August 2007	
09:00	Breakout I: Identification & Definition of Strategic Actions for Each Thematic Roadmap
10:30	Coffee Break
11:00	Breakout II: Identification & Definition of Strategic Actions for Each Thematic Roadmap
12:00	Lunch and Enjoy Nature
13:30	Feedback: Presentation of Strategic Actions for Each Thematic Roadmap
15:30	Forward Planning: Next Steps and Follow-up Actions
16:00	End of Workshop

Thematic Priorities

When selecting the main thematic priorities for the workshop, the FIATECH CPR elements and Strat-CON thematic roadmaps were used as a baseline for thematic priority selection.

FIATECH Capital Projects Technology Roadmap Elements	Strat-CON Roadmap Themes
Scenario-based Project Planning Automated Design Integrated, Automated Procurement & Supply Network Intelligent & Automated Construction Job Site Intelligent Self-maintaining & Repairing Operational Facility Real-time Project & Facility Management, Coordination & Control New Materials, Methods, Products & Equipment Technology- & Knowledge-enabled Workforce Lifecycle Data Management & Information Integration	Value-driven Business Processes Industrialised Production Digital Models Intelligent Constructions Interoperability Collaboration Support Knowledge Sharing ICT enabled Business Models

During the first round of thematic priority selection, a total of 19 themes were identified as follows:

1. Collaboration support
2. Interoperability
3. Value Driven Process
4. Business Models
5. Digital Models
6. Intelligent Constructions
7. Industrial Production
8. Energy Efficiency & Sustainability
9. Knowledge Sharing
10. Life-cycle management
11. Materials
12. Knowledge sharing & collaboration support
13. Digital models
14. Intelligent constructions
15. Energy efficiency & sustainability
16. Supply chain management
17. Value Driven Business & Process models
18. Interoperability
19. Life cycle management

These 19 themes were later reduced to 11 to include:

1. Collaboration support
2. Interoperability
3. Value Driven Process
4. Business Models
5. Digital Models
6. Intelligent Constructions
7. Industrial Production
8. Energy Efficiency & Sustainability
9. Knowledge Sharing
10. Life-cycle management
11. Materials

In the final round, seven main themes were selected for the workshop. These themes and their respective team members (those who elaborated on the theme, developed the roadmaps, and identified project ideas) are presented below.

Theme	Team Members
Digital Models	M. Halfawy, P. Lukkarinen, H-J Jun, A. Kaka, T. Froese
Energy Efficiency & Sustainability	J. Vanegas, V. Bazjanac, M. Hannus, J. Watson, J. Karlshoj
Knowledge Sharing & Collaboration Support	C.B.B. Tatum, S. Kubicki, B-C Björk, H. Bell, A. Koskinen
Intelligent Constructions	A. Zarli, A. Vialle, F. Rabuck
Interoperability	A. Laud, A. Kiviniemi, R. Amor, F. Matthewson, H. Wanpyo, K. Reed
Supply Chain (Demand Network) Management	H. van Tellingen, M. Kokkala, N. Testa
Value-driven Business & Process Models	I. Moltke, J.J. Kim, T. Mäkeläinen, E. Nykänen, S. Nissinen

(Note: During breakout group sessions, the theme of “Supply Chain Management” was renamed to be “Demand Network Management”)

Roadmapping

When developing roadmaps, it is essential to consider radical innovation as the means to transform from the current state (as-is) to the vision (to-be). At the same time, it needs to be understood that to achieve the vision, incremental innovation is required. This serves as the basis for migration from a current state to short, then medium, and finally long-term implementation and deployment plans.

The visual representation of a typical roadmap is illustrated in Figure 5. It should be clearly noted that a roadmap (e.g. the one in Figure 5) is a snapshot at a given moment in time. This can be understood as follows:

- Current state: what is available and in use in the industry today
- Short time to industry: what is near ready for take-up and use by industry
- Medium time to industry: what is currently being developed
- Long time to industry: what is currently being researched or explored (emerging technologies)

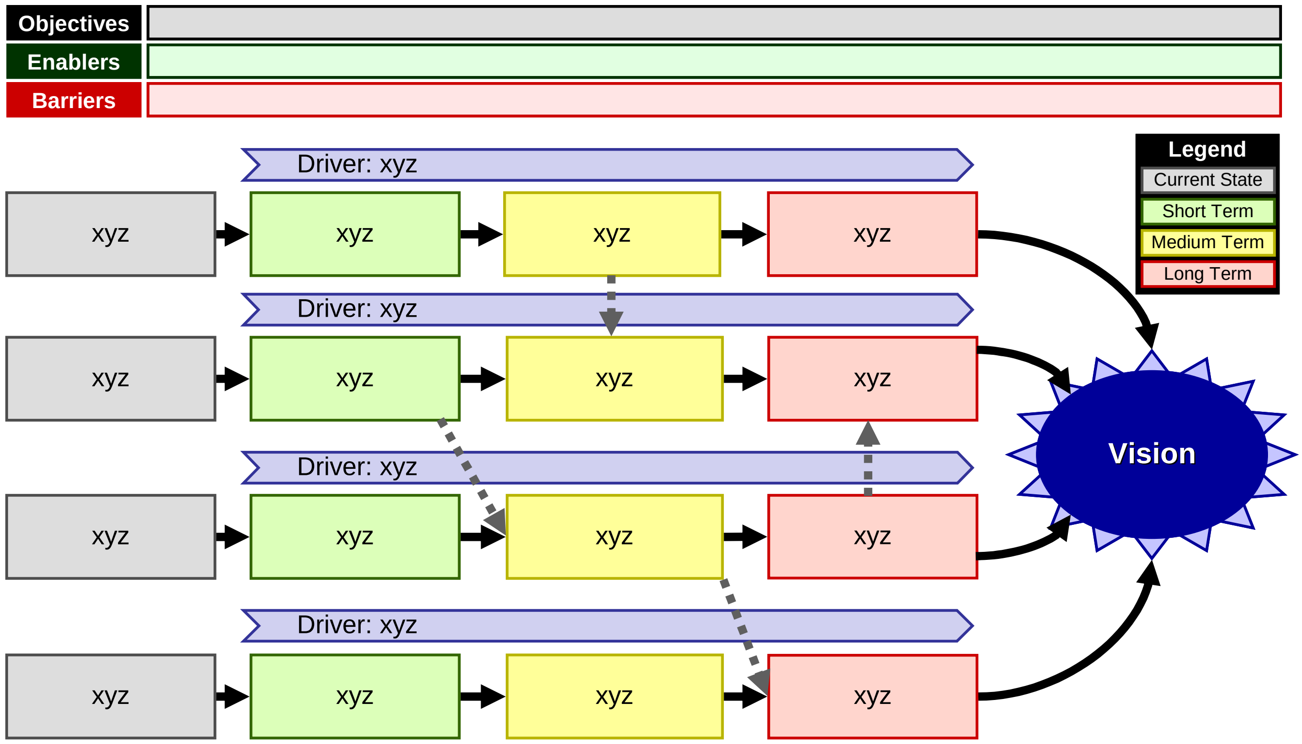

Figure 5: Visual Representation of Roadmap

Definition of Strategic Actions (Project Ideas)

Once the roadmaps have been finalised, the next step is the identification of strategic actions / project ideas (building blocks for projects). These actions may cover one element (e.g. one yellow box) of a given roadmap or span several elements where relevant.

For the sake of simplicity, the template shown in xyz was used during the workshop for strategic action / project idea definition.

Title	*Title of project idea*
Keywords	*5 keywords describing the project idea*
Industrial Problem	*Industrial problem addressed.*
Technological Objectives	*Main technological objectives*
Approach	*Approach to be used to achieve objectives*
Results	*Key results expected (e.g. a software tool)*
Time to Industry	*When can the industry expect to receive and use the results?*
Main Actors & Expertise	*Main participants and their required expertise*
Main Beneficiaries	*Main beneficiaries and their benefits*
Industrial Impacts	*Foreseen industrial impacts (e.g. time savings of 10%)*
Follow-up Actions	*Follow-up actions expected once the objectives are reached*

Figure 6: Simplified Template for Strategic Action / Project Idea Definition

Theme: Digital Models

Overview and Industrial Context

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 generally related to the slow uptake of ICT in the construction sector, which is primarily dominated by SMEs.

Digital models (e.g. Building Information Models) can serve as an efficient means for integrating, managing, and sharing semantic-rich model-based project lifecycle information across different functional disciplines (e.g. planning, design, construction, operation and maintenance, etc.) and corresponding software applications.

Industrial Problems Addressed

Interoperability Problems

- Data sharing/exchange is very inefficient
    - Model-based representations do not span all project disciplines.
    - Use of model-based data for facilities lifecycle management is almost non-existent.
    - Limited capabilities for software interoperability and data/knowledge sharing.
    - Currently limited to file-based data exchange.
    - Most data models and model-based approaches focused on the building industry and did not extend to address other critical construction sectors (e.g., infrastructure).
- Collaboration/communication/work concurrency is ineffective
    - Need to support objectives of Concurrent Engineering
    - Across project; across industry/segments, etc.
    - Different industries/segments have developed overlapping approaches

Tools Problems

- Model-based tools throughout project life-cycle (need to share models)
- Model-based tools should provide platforms for linking multi-disciplinary views.
- Model-based representations should become the main vehicle for information delivery, sharing, and management.
- Tools should support model-based project submissions (owners/operators are demanding such submissions).
- There is a lack of automation
    - Need more automation to support project planning/design/analysis/simulation/project management & control/operation & maintenance.
    - Little automation of production/fabrication (should also be model-based)

Information Management Problems

- There is a lack of guidelines
    - How to efficiently use the digital models; information handover protocols
- Managing data throughout project lifecycle
    - Life-cycle data management
    - Model-based representations are still not used to support operation and maintenance processes (e.g., to date, no facility management software can use BIM to populate building inventory databases, without the need to manually re-enter the data).

Current Gaps & Foreseen Technological Challenges

Limitations of Digital Modelling Technology

- Harmonization across different modelling approaches
- Modelling non-standard objects (through generic constructs for geometry & properties representations)
- Tools for working with/managing the models are weak (large models, model servers, …)

Data Standard Gaps

- Not widely adopted in practice
- Some construction segments currently have industry-standard data models (e.g., AEC), others lack standard data models (eg., infrastructure).
- Coverage of scope (only few project phases are typically supported by a standard model)
- Not well or fully supported by existing tools
- Usability (e.g., data standards are often tool large, not modular)

Model-based Tools

- Lack of tools to support entire project lifecycle.
- Visualization of information-rich n-D models (not just 3D models).

Work Processes

- Need formalized processes and information flows (i.e., standard process models).
- Need to switch to "Model-Thinking"
- Too few project participants may be able to use models at present.
    - "Limited" and "sparse" user-base
- Lifecycle information/model management work processes need to be implemented in a transparent and mostly automated ways.

Legacy Data

- Need tools for mapping legacy data to standard models (e.g., 2D drawings in proprietary format to product models).
- Don't have models of existing facilities for refurbishment/building control, etc.

Model Content

- Having good data to populate models (e.g., lifecycle performance data)
- Having product data/libraries linked to or referenced from models
- E-Catalogues, etc.

Vision

- The model is the universal delivery vehicle for the built environment's information.
- The Model is to the building/built environment as the Internet is to knowledge
- Key characteristics:
    - Integrated (all data elements come together in the model) / Lifecycle continuity
    - Quality/semantically rich/usability
    - Efficient model utilization by tools/work processes
    - Spans physical scope from building components, to structures, to regions
    - Well managed, shared, easily accessible, ubiquitous
    - Streamlined processes and formalized process models.

Main Objectives

1. Models: expand scope (to entire lifecycle and to other construction disciplines), extend semantics and intelligence, establish standards, modularization, extensibility.
2. Tools: model-based platforms, tool interoperability, improved usability, improved data management processes.
3. Processes: information management practices, model-based & integrated practices, supporting knowledge sharing

Stakeholder Roles and Benefits

- Building owner
  - Role: Beneficiary of process/product improvements
  - Foreseen Benefits: better (including reliability), cheaper, faster project delivery
- Operator/manager/occupants
  - Foreseen Benefits: Uses model for facilities management, "owner's manual", more efficient maintenance planning and management.
- Operational service providers (maintenance/emergency services, etc)
  - Foreseen Benefits: Efficient and timely access to up-to-date information, use the model to perform various performance assessments.
- Supply chain (designers, constructors, suppliers)
  - Foreseen Benefits: Streamlined process, improved quality, and reduced delays/conflicts/errors/rework.
- Regulators / permitting, etc.
  - Foreseen Benefits: Faster evaluations/reviews/permitting processes.
- Software companies/tool developers & vendors/researchers/educators
  - Foreseen Benefits: Focus on value-adding processes and technologies.

Roadmap: Digital Models

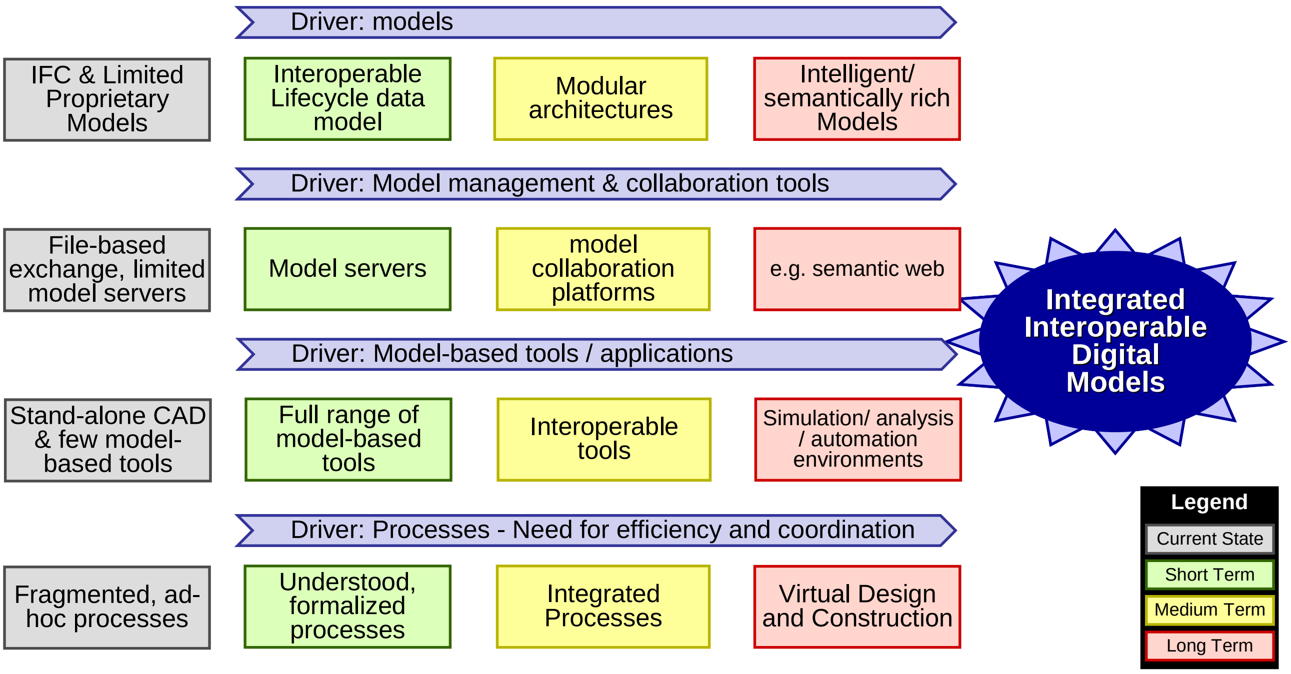

Figure 7: Roadmap – Digital Models

Key Enablers

- More structured and semantic-rich modelling techniques (e.g., XML) and better information modelling tools.
- Existing standard data models (e.g., IFC/CIS2/ISO15926/SDSFIE/….)
- Investigation of various levels within industry as to what is the cost/benefit; how far down can you justify to individual companies, etc.
    - Business Case Studies for Digital Models (to get the industry motivated to adopt these models).
- Leveraging existing work rather than re-inventing
- Software developers
- Availability of funding

Key Barriers

- Old mindset (that hinders the adoption of new technologies)
- Legacy tools (that use proprietary black-box models)
- Incomplete data standards
- Software developers
- Lack of funding

Main Topics

Current State:

- Few data standards (e.g., IFC, CIS2) & Limited Proprietary Models
- File-based exchange, limited model servers
- Stand-alone CAD & few model-based tools
- Fragmented, ad-hoc processes

Short-Term to Industry:

- Interoperable lifecycle data models
- Model servers
- Full range of model-based tools
- Understood, formalized processes and information flows

Medium-Term to Industry:

- Modular architectures
- Model collaboration platforms
- Interoperable tools
- Integrated processes

Long-Term to Industry:

- Intelligent / semantically rich models
- Semantic web-based tools
- Simulation / analysis / automation environments
- Virtual design and construction

Project Ideas

Project: Harmonization of related digital modelling efforts – ISO15926, IFC, etc

Keywords	harmonisation, ISO15926, IFC, building information models
Industrial Problem	Different industry segments have developed similar solutions independently. The technical solutions have significant overlap, but the degree of linkage/commonality is unclear.
Technological Objectives	Compare, map, and possibly harmonize related digital modelling efforts
Approach	Workshops, joint harmonization project,
Results	Mapping mechanisms between ISO15926 and IFC
Time to Industry	1 year (short term)
Main Actors & Expertise	Core technical groups from both ISO 15926 and IFC
Main Beneficiaries	
Industrial Impacts	Harmonization/Interoperability between process industry and building industry Potential for each effort to leverage the work of the other
Follow-up Actions	Follow-up workshop at FIATECH annual member meeting; on-going liaison

Project: Business Case for Digital Models

Keywords	digital models, industry, business benefits, case study
Industrial Problem	Business justification is not well understood or quantified. Linkage between different industries is not
Technological Objectives	Definition and quantifications of opportunities and benefits
Approach	Case studies, formal business case models
Results	Building Industry is more aware of successes in the process industry (and possibly vice-versa)
Time to Industry	
Main Actors & Expertise	Universities, industry champions & pathfinders
Main Beneficiaries	Industry
Industrial Impacts	Drive industry uptake and demand
Follow-up Actions	Identification of business cases

Project: Raising Awareness and Skills

Keywords	dissemination, enlightenment, training material
Industrial Problem	Lack of engagement
Technological Objectives	Increase use of digital models
Approach	Web-based training and education
Results	Training material
Time to Industry	
Main Actors & Expertise	Universities, research institutes, FIATECH, government, industry
Main Beneficiaries	Industry, operators
Industrial Impacts	Wider applications
Follow-up Actions	

Related Initiatives and Further Reading

- FIATECH: Element 9 (1,2,3,4,5)
- Strat-CON: Digital models, (Interoperability, Collaboration support, ICT-enabled business processes)
- Data standardization initiatives

Theme: ICT for Energy Efficiency & Sustainability

Overview and Industrial Context

With increasing global populations and consequent implications of increased energy consumptions having a detrimental effect on the environment, there is a need to ensure energy efficiency and sustainability of existing and future buildings. Different information and communications technologies (ICT) can play an influential role in supporting energy efficiency and sustainability of buildings through better knowledge of, access to, and use of related data supported by new methods, processes and tools.

Industrial Problems Addressed

- Inadequate ICT-based informed decision-making (both human and automated) in the current delivery and use of sustainable and energy-efficient facilities:
    - Availability of Data/Information (D/I)
    - Appropriateness of D/I Source
    - D/I Collection Methods
    - Integration of D/I
    - Reliability of D/I
    - Application/Use of D/I
    - D/I Transfer
    - D/I Transformation
    - Explosive size of databases
    - Delivery of D/I to stakeholders
- Current delivery and use of facilities does not necessarily lead to sustainable and energy-efficient buildings
    - There is no agreement of what sustainable and energy-efficient buildings are
    - Too many standards regulate buildings that affect delivery and use, and some are in conflict with each other towards achieving sustainability and energy-efficiency
    - There is no agreement on holistic and systems-based view of buildings
    - There are too many options to choose from regarding environmental systems and their configurations
    - Decision-making is not supported by adequate information
    - There is no industry agreement on measurement and control
    - Automation is complex and difficult
- There is a need for post-occupancy feedback to user to enable behaviour modification towards sustainability and energy efficiency
    - Definition of user requirements and preferences
    - Dynamic and personalized environmental controls
    - Visualization of data associated with energy use
- Management of energy types and distribution in buildings and urban areas
    - Integration of sources of energy
    - Balancing and optimization of energy sources and uses
- Inadequate D/I on, and methods for establishing, sustainability, energy efficiency, and other attributes of materials and products used in facilities
    - Assessment
    - Smart labelling
    - Logistics

Current Gaps & Foreseen Technological Challenges

- Systems-thinking, multi-stakeholder, and multi-disciplinary design and construction of sustainable and energy-efficient facilities (A/E/C)
- Pre-designed/engineered, replicable, and flexible environmental systems solutions
    - Optimization, adaptation, and scaling to specific context applications
    - Configuration tools to do so
- Cost-effective deployment of specific ubiquitous sensing networks
- Incorporation of the human dimension (as end-users) in ICT
- Understanding and development of quantitative tools that match reality
- Scaled and selective mining of D/I within enormously large databases
- Visualization of D/I within enormously large databases
- Integration of disparate databases
- Development of mature, fully functional, and robust domain and cross-domain software tools for industry
- Development of performance metrics for sustainability and energy-efficiency in buildings and urban areas

Vision

Delivery and use of sustainable and energy-efficient facilities through ICT-based informed decision-making (both human and automated)

Main Objectives

1. Stimulate government and industry investment in research related to delivery and use of sustainable and energy-efficient facilities (through ICT-based informed decision-making)
2. Conduct research focused on ICT-based informed decision-making for delivery and use of sustainable and energy-efficient facilities
3. Deploy and implement research results throughout government and industry (achieve wide-spread adoption)

Stakeholder Roles and Benefits

- Financial/investment institutions
    - Role: Demand, champion
    - Foreseen Benefits: Significant risk reduction, Higher ROI
- Insurance companies
    - Role: Demand, champion
    - Foreseen Benefits: Significant risk reduction, Higher ROI
- Building owners
    - Role: Adoption, Demand, Champion, Demonstration
    - Foreseen Benefits: Significant risk reduction, Higher ROI, Easier
- National, regional, and local levels policy-makers
    - Role: Leadership, Champion, Foster,
    - Foreseen Benefits: Better evidence for policy development and implementation
- National, regional, and local levels regulators
    - Role: Compliance
    - Foreseen Benefits: Quantifiable regulatory framework, Objective metrics for verification of compliance
- Research funding agencies
    - Foreseen Benefits: Better understanding of research priorities, Quantifiable framework for measuring research effectiveness

- End users
    - Foreseen Benefits: Better understanding of research priorities, Quantifiable framework for measuring research effectiveness
- Utility companies (e.g., water, energy, sewage, waste)
    - Foreseen Benefits: More informed planning, More effective operations and efficient use of resources, More influence/control on the demand, New business models and opportunities, More responsive pricing structure, More informed capital investments
- Construction Firms
    - Foreseen Benefits: More profitable selection of construction solutions, Expedite construction processes, New business models and opportunities for services, Better evaluation of construction alternatives
- Manufacturers and suppliers
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, Risk reduction, D/I for better products
- Hardware (e.g., appliances, building elements, equipment), vendors
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, Risk reduction, D/I for better products
- Software developers
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, Risk reduction, D/I for better products
- A/E design professionals
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, More informed selection and optimization of design alternatives, Expedite design processes, Faster delivery to client
- Professional specialty consultants
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, More informed provision of services, Expedite consulting processes
- Building operators
    - Foreseen Benefits: More informed day-to-day decisions, More informed long-term decisions, More cost-effective operations, Better monitoring of end user behaviour, Better understanding of building performance
- Maintenance and service providers
    - Foreseen Benefits: New business models, Opportunities for collaborations, Extended market penetration, Enabling new Markets, More informed planning, More informed day-to-day decisions, More informed long-term decisions, More cost-effective maintenance and service, Better understanding of building performance
- Primary energy providers
    - Foreseen Benefits: More informed planning, More effective operations and efficient use of resources, New business models and opportunities, More responsive pricing structure, More informed capital investments

Roadmap: ICT for Sustainability and Energy Efficiency

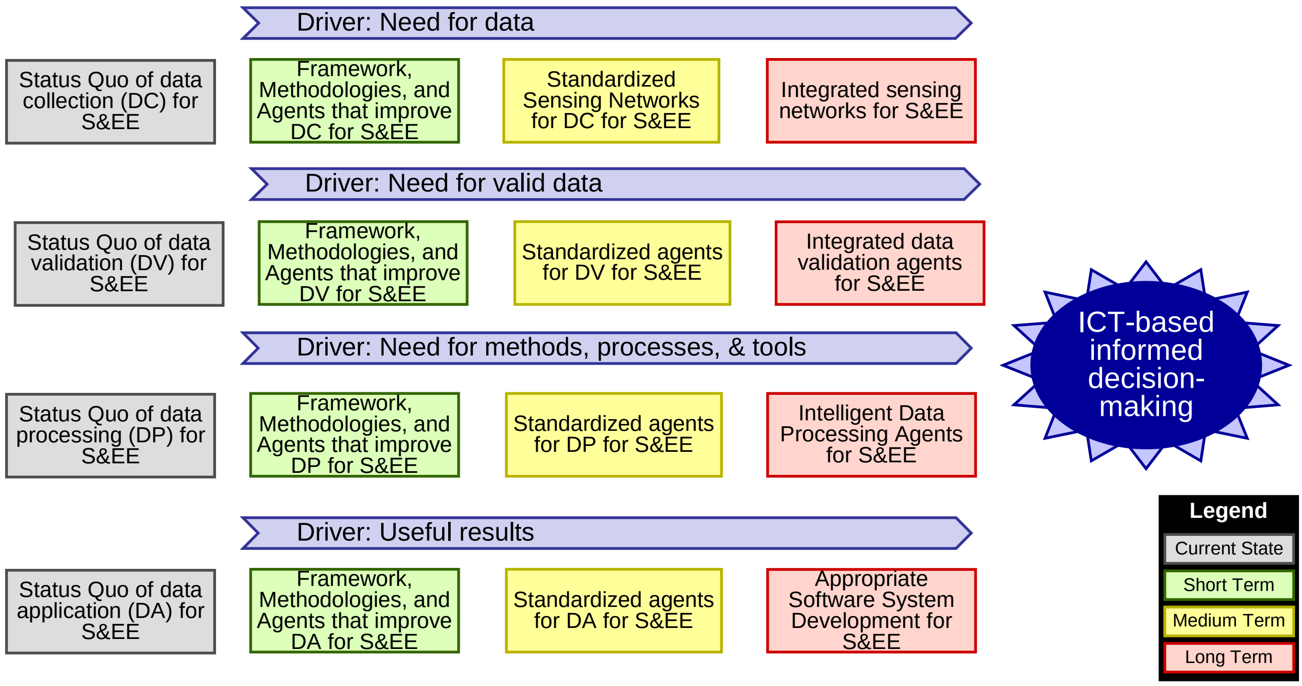

Figure 8: Roadmap – ICT for Sustainability and Energy Efficiency

Key Enablers

- Government agencies, policy makers, regulators, funding institutions, research bodies
- Availability of funding

Key Barriers

- Lack of timely action
- Lack of funding

Main Topics

Current State:

- Status Quo of data collection (DC) for S&EE
- Status Quo of data validation (DV) for S&EE
- Status Quo of data processing (DP) for S&EE
- Status Quo of data application (DA) for S&EE

Short-Term to Industry:

- Framework, Methodologies, and Agents that improve DC for S&EE
- Framework, Methodologies, and Agents that improve DV for S&EE
- Framework, Methodologies, and Agents that improve DP for S&EE
- Framework, Methodologies, and Agents that improve DA for S&EE

Medium-Term to Industry:

- Standardized Sensing Networks for DC for S&EE
- Standardized agents for DV for S&EE
- Standardized agents for DP for S&EE
- Standardized agents for DA for S&EE

Long-Term to Industry:

- Integrated sensing networks for S&EE
- Integrated data validation agents for S&EE
- Intelligent Data Processing Agents for S&EE
- Appropriate Software System Development for S&EE

Project Ideas

Project: Predict Environmental Impact

Keywords	impact design, lifecycle
Industrial Problem	Too difficult today to evaluate / predict environmental impact. Lack of data
Technological Objectives	Standardize data; Interoperable ICT solutions
Approach	Define framework, make standards, implement solutions in industry
Results	Better knowledge/predictions. Possible to make demands.
Time to Industry	5 years
Main Actors & Expertise	Research; Software companies; Industry; Regulators
Main Beneficiaries	Greener world, less consumption
Industrial Impacts	New processes, new products
Follow-up Actions	Improve on results

Project: Improve Energy Efficiency

Keywords	reduced consumption, integrated design
Industrial Problem	Too difficult to test alternative solutions. Analyses are made too late.
Technological Objectives	Improve interoperability
Approach	Validate/modify existing standards; Implement solutions in the software; Implement interoperable solutions in the industry
Results	Better predictions; Better solutions during the design
Time to Industry	3- 5 years
Main Actors & Expertise	research, software, A/E firms
Main Beneficiaries	building owners; regulators; politicians; energy providers
Industrial Impacts	Changes in the design process
Follow-up Actions	Extend the area to include life cycle approach, monitoring consumption, etc.

Project: Data Transformation Methodology

Keywords	data set reduction, data set simplification, data translation, data interpretation
Industrial Problem	Objective definition of information; Subjective results of use.
Technological Objectives	Rules of data transformation per topic
Approach	Analysis; Definition of differences; Rules/algorithms
Results	Rules and Algorithms
Time to Industry	1 year
Main Actors & Expertise	Domain experts; Software developers
Main Beneficiaries	Designers (A/E); Specialty consultants; Building operators/users/owners; Insurers; Government bodies
Industrial Impacts	Reproducible analysis
Follow-up Actions	Implementation per discipline; Application

Project: Building Monitoring Systems Consistency

Keywords	Sensors Systems, Collection, Transmission, Recording consistency
Industrial Problem	Measured & predicted data do not match; Inconsistency
Technological Objectives	Synchronize data collection with what can be predicted
Approach	Analysis of predictive systems; Specifying collection systems
Results	Specifications for monitoring systems
Time to Industry	2 years
Main Actors & Expertise	Measuring systems hardware/software vendors ; Building operators; Systems scientists
Main Beneficiaries	Building operators/users/owners; A/E Designers; Government
Industrial Impacts	Better buildings; Better user comfort; Lower operating cost
Follow-up Actions	Development; Manufacturing; Installation; Verification

Project: Metrics for Sustainability & Energy Efficiency (S & EE)

Keywords	sustainability, energy efficiency, indicators
Industrial Problem	Lack of common/standardized indicators
Technological Objectives	Standardized indicators which can be derived from (easily) available data
Approach	Collaborative
Results	Standardized indicators which can be derived from (easily) available data
Time to Industry	Medium (after glossary)
Main Actors & Expertise	Regulators & the whole sector
Main Beneficiaries	Owners/users
Industrial Impacts	Easiness of S&EE assessment
Follow-up Actions	

Project: Catalogues of Products and Materials

Keywords	Intelligent catalogues, Sustainability, Energy efficiency
Industrial Problem	Lack of data for S&EE
Technological Objectives	Definition of standardized attributes for S&EE (+whatever); Tools & platforms for authoring, delivery
Approach	
Results	(See objective) Standards, tools, platforms, e-service
Time to Industry	Short-medium
Main Actors & Expertise	Manufacturers
Main Beneficiaries	Owners/operators/service providers
Industrial Impacts	Open market
Follow-up Actions	

Project: Multi-Domain Design Tools for Building Energy Optimization

Keywords	energy optimisation, design tools
Industrial Problem	Building design across discipline
Technological Objectives	Development of integrated methodology
Approach	Collaborative
Results	Demonstrator tools
Time to Industry	< 10 yrs
Main Actors & Expertise	S/U Building Eng;
Main Beneficiaries	Building designers; Users; Owners
Industrial Impacts	Energy; Cost savings
Follow-up Actions	State of art review; Collaborators identification

Project: Development & Demonstration of Self-Organizing Wireless Sensor Networks (Ambient Powered)

Keywords	sensor networks, ambient power, demonstration building
Industrial Problem	Cast of deployment; Inflexibility
Technological Objectives	Integrative & pure R&D
Approach	Collaborative A&I
Results	Demonstration building
Time to Industry	<3 yrs
Main Actors & Expertise	H/W & S/W COS; Computer Science Departments
Main Beneficiaries	Building users & owners
Industrial Impacts	Market development
Follow-up Actions	Planning; Support; Coordination

Project: Self-Optimizing Building Controls with Occupant ID Sensing

Keywords	optimisation, occupant sensing, energy consumption
Industrial Problem	Energy consumption
Technological Objectives	Development of concept; Integrative & pure R&D
Approach	Collaborative; Platform technology identification & use
Results	Demonstrator control systems
Time to Industry	<10 yrs
Main Actors & Expertise	H/W & S/W COS; Mobile (cell) SPS; Academic Computer Science Departments
Main Beneficiaries	Building users & owners
Industrial Impacts	Energy saving; New markets
Follow-up Actions	Scoping research; Coordination

Project: S & EE Lexicon (Glossary)

Keywords	sustainability, energy efficiency, glossary
Industrial Problem	Too many definitions and interpretations of terminology associated with S & EE
Technological Objectives	Development of a taxonomy and a lexicon of terminology associated with S & EE
Approach	Extensive literature review and compilation; Multi-stakeholder consensus building on a global scale; Use of Wiki technology
Results	A global consensus taxonomy and a lexicon of terminology associated with S & EE (a structured "Wikipedia")
Time to Industry	<2 yrs
Main Actors & Expertise	Academia; Industry (AEC, ICT & Manufacturers/Vendors/Suppliers; Government
Main Beneficiaries	All stakeholders in the capital projects industry
Industrial Impacts	Avoidance of confusion
Follow-up Actions	Develop a plan; Seek funding; Establish collaborative alliances and partnerships

Project: S & EE Demonstration Building Prototype

Keywords	sustainability, energy efficiency, demonstration building
Industrial Problem	There are no current prototypes or examples of facilities that are fully ICT-enabled/supported for S & EE
Technological Objectives	Planning, design, procurement, construction, commissioning, and use of a facility of adequate scale (a house) that is fully ICT-enabled/supported for S & EE, to demonstrate and validate the vision, framework, and objectives developed by this team
Approach	Global, multi-disciplinary, and open-source approach to the planning, design, procurement, construction, commissioning, and use of the facility; Use the TAMU Architectural Ranch for the location of the prototype; Provide global connectivity access to researchers from academia and practitioners from industry during the process followed, for the product developed, and to the results obtained
Results	A replicable and scalable prototype of a facility that is fully ICT-enabled/supported for S & EE, developed and owned as a shared global asset
Time to Industry	<3 yrs
Main Actors & Expertise	Academia; Industry (AEC, ICT & Manufacturers/Vendors/Suppliers); Governments; Funding agencies
Main Beneficiaries	All stakeholders in the capital projects industry
Industrial Impacts	A new model for global collaboration in S &EE
Follow-up Actions	Develop a plan and seek funding; Establish collaborative alliances and partnerships, and execute

Project: Global Collaboratory for S & EE

Keywords	sustainability, energy efficiency, collaboratory
Industrial Problem	There are no current mechanisms within the global capital projects industry or examples of facilities that are fully ICT-enabled/supported for S & EE
Technological Objectives	Create a new networked organizational form of a centre without walls (a collaboratory): (1) In which global researchers can perform research in ICT-enabled/supported S & EE, without regard to physical location, allowing interaction with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries (Based on Wulf); and (2) That combines social processes; collaboration techniques; formal and informal communication; and agreement on norms, principles, values, and rules (Based on Cogburn)
Approach	Adapt the best practices and lessons learned of existing collaboratories in various fields of science and engineering to the nature and needs of S & EE within the capital projects industry; Use the FIATECH & STRATCON roadmaps as the foundation of the collaboratory; Establish a cyber infrastructure to support the collaboratory; Leverage the resources and talents of the partners in the initiative
Results	A collaboratory and its associated cyber infrastructure to support research, development, demonstration, deployment, evaluation, and dissemination activities in S & EE for the capital projects industry
Time to Industry	<5 yrs
Main Actors & Expertise	Academia; Industry (AEC, ICT & Manufacturers/Vendors/Suppliers); Governments; Funding agencies
Main Beneficiaries	All stakeholders in the capital projects industry
Industrial Impacts	A new infrastructure for global collaboration in S &EE
Follow-up Actions	Develop a plan and seek funding; Establish collaborative alliances and partnerships, and execute

Related Initiatives and Further Reading

- FIATECH elements: #1, #2, #3, #4, #5, #6, #7, #8, #9
- Strat-CON roadmaps: value-driven business processes, digital models, intelligent constructions, collaboration support, knowledge sharing, ICT enabled business models

Theme: Knowledge Sharing and Collaboration Support

Overview and Industrial Context

Recent and expected advances in ICT tools offer significant potential to improve collaboration and knowledge sharing within project teams and improve their performance in meeting quality, safety, sustainability, schedule, and cost objectives. Market forces in many segments and locations are demanding improved project results related to each type of objective.

Industrial Problems Addressed

Many types of obstacles create substantial difficulties in realizing the potential of ICT to improve collaboration and project results. The study team identified two main types: knowledge content for tool development and implementation of advanced tools. The knowledge to share for effective collaboration includes many diverse types, some of which are difficult to capture, represent, and retrieve. The types of implementation obstacles include market, competitive, contractual, organizational, social, personal skill, language, incompatibility of tools, and lack of standards.

Current Gaps & Foreseen Technological Challenges

Each type of obstacle identified by the study team creates a gap and research need. For knowledge content, the major challenges are to model process knowledge and translate technical information and knowledge for use in multiple languages. Overcoming gaps concerning implementation of advanced ICT tools for collaboration will require increased understanding of related economic, contractual, and motivational factors.

Vision

For effective knowledge sharing and collaboration support we envision seamless and instant access to the right information and knowledge at the right time and at any place. This will require advances in knowledge capture and representation, along with removal of contextual and individual obstacles to provide user-centric ICT services.

Business Scenario: Models and Services for Knowledge Sharing and Collaboration

A team of industry and university researchers select generalisable project activities and develop the structure of models that satisfy the knowledge requirements for these activities. Using tools based on these models, projects can better meet objectives through increased collaboration and companies have complete re-use of knowledge from one project to another. The ICT services providing this capability also support on-going organizational learning.

Business Scenario: Strategies to Overcome Obstacles to Knowledge Sharing

Research projects involving industry and universities identify the major obstacles limiting knowledge sharing and collaboration and develop strategies to overcome these obstacles. Within the supportive context resulting from implementation of these strategies, Company A in country 1 shares all relevant information with company B in country 2.

Business Scenario: Research Funding for Collaboration Tools & Results

Research roadmaps allow agencies to set priorities for a comprehensive global research program and these priorities include knowledge sharing and collaboration support. Collaborate research, including the projects identified in this section of the report, proceeds and produces results that change work processes to realize the opportunities for improvement.

Business Scenario: Successful Implementation of Advanced ICT tools for Knowledge Sharing and Collaboration Support

Globalization of the market drives change for adaptation of networks and organizations involved in delivering constructed facilities. All culture and language barriers are removed. Improved work-practices include extensive collaboration and knowledge sharing, and are easily adaptable to fit the requirements of individual projects.

Main Objectives

1. Develop realistic, comprehensive and flexible process modelling capability;
2. Allow simple and fast context-aware visualization for collaboration;
3. Foster effective dissemination and implementation of ICT tools for knowledge sharing and collaboration to provide IT services that are independent of culture and language

Stakeholder Roles and Benefits

- Building owner, Project manager
    - Role: Define tenant requirements for the facility; facilitate collaboration; provide finance and enforce project requirements (ICT-tools, standards, as-built).
    - Foreseen Benefits: Improved performance of the project and the facility over its life-cycle.
- Designers
    - Role: Provide and use the technical definition of the facility.
    - Foreseen Benefits: Better design coordination, easy-access to information, higher quality for less time and money.
- Suppliers
    - Role: Supply product models and physical products.
    - Foreseen Benefits: Quicker approval of their product models, foster product innovation.
- Infomediaries
    - Role: Help in knowledge and information transfer between producer and end-user.
    - Foreseen Benefits: More informed decisions (products, materials).
- General contractors, construction managers, design-build contractors, or coordinators
    - Role: Complete design for fabrication if required; coordinate/manage construction phase.
    - Foreseen Benefits: Improved performance relative to cost, schedule, quality, safety and sustainability.
- Speciality or sub-contractors
    - Role: Detail fabricate, install materials/components for assigned scope of work.
    - Foreseen Benefits: Improved performance relative to cost, schedule, quality, safety and sustainability.
- Commissioning agencies
    - Role: Verify and document system operations per design.
    - Foreseen Benefits: Increased information availability for planning.
- Facility users
    - Role: Occupy space, use facility per program.
    - Foreseen Benefits: Improved facility performance; higher occupant satisfaction.
- Operations and maintenance staff
    - Role: Operate and maintain active systems; monitor structural and architectural systems.
    - Foreseen Benefits: Increased information availability.

- Building authorities and public representatives
    - Role: Approve site selection and design, verify facility conformance.
    - Foreseen Benefits: Increased understanding of design rationale and availability of detailed technical information for decision making.

Roadmap A: Dev. of Advanced ICT Tools for K-Sharing & Collab. Support

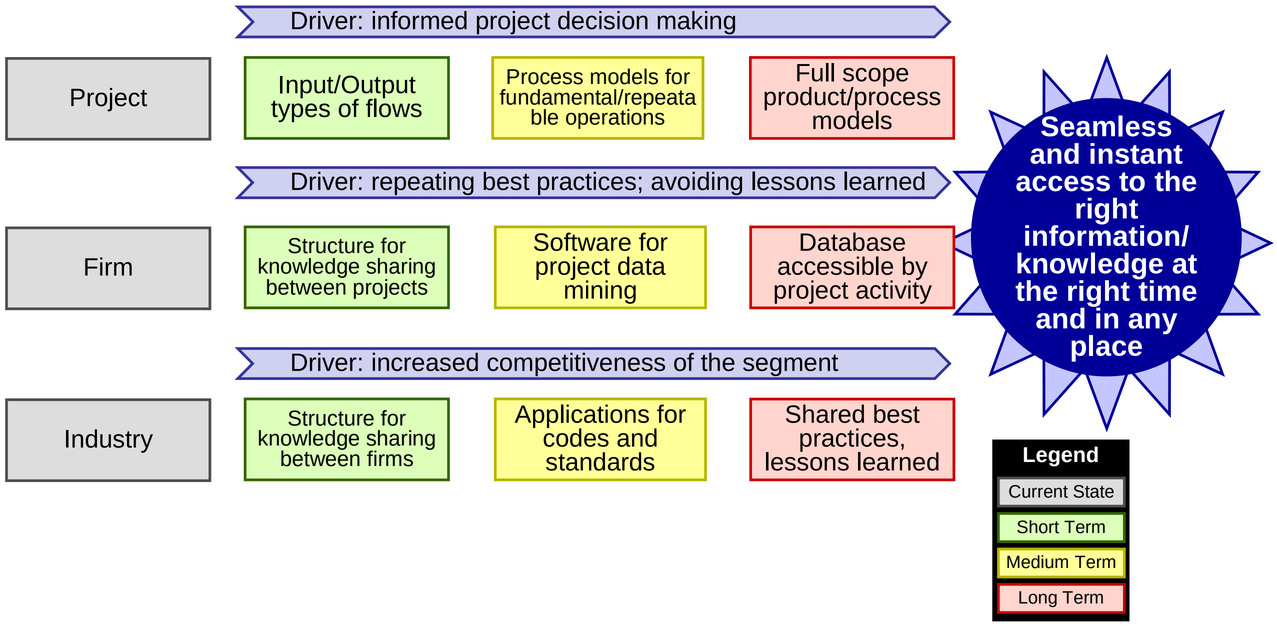

Figure 9: Roadmap – Dev. of Advanced ICT Tools for Knowledge Sharing & Collaboration Support

Key Enablers

Process description platforms, software products and international open-standards

Key Barriers

Comprehensive models, knowledge to populate and proprietary formats

Main Topics

Advanced ICT tools for collaboration support and knowledge sharing at the project level

Advanced ICT tools for collaboration support and knowledge sharing at the firm level

Advanced ICT tools for collaboration support and knowledge sharing at the industry level

Current State:

- Project level: collaboration focused on human initiation and interaction, typically using information and knowledge retained by humans or available in paper documents
- Firm level: written reports documenting best practices and lessons learned; difficult to retrieve and access by potential users with specific needs
- Industry level: very limited sharing of information or knowledge; typically through professional organizations

Short-Term to Industry:

- Project level: manual activities for knowledge sharing; individually initiated collaboration and input/output access to project databases
- Firm level: development and initial use of standardized structure for knowledge representation and sharing between projects
- Industry level: limited extension of project structure to foster knowledge sharing between firms

Medium-Term to Industry:

- Project level: initial standardization of structure for process models of fundamental and repeatable operations
- Firm level: limited capability of ICT tools for project data mining
- Industry level: initial development of ICT tools for collaboration support and use in the development and interpretation of codes and standards

Long-Term to Industry:

- Project level: availability of proven full scope product and process models that support collaboration and knowledge sharing
- Firm level: availability of ICT tools that allow capturing all transferable project knowledge and making it available to all functional activities and projects within the firm
- Industry level: standardized ICT applications that fully support sharing best practices and lessons learned across all types of organizations that include project stakeholders

Roadmap B: Impl. of Advanced ICT Tools for K-Sharing & Collab. Support

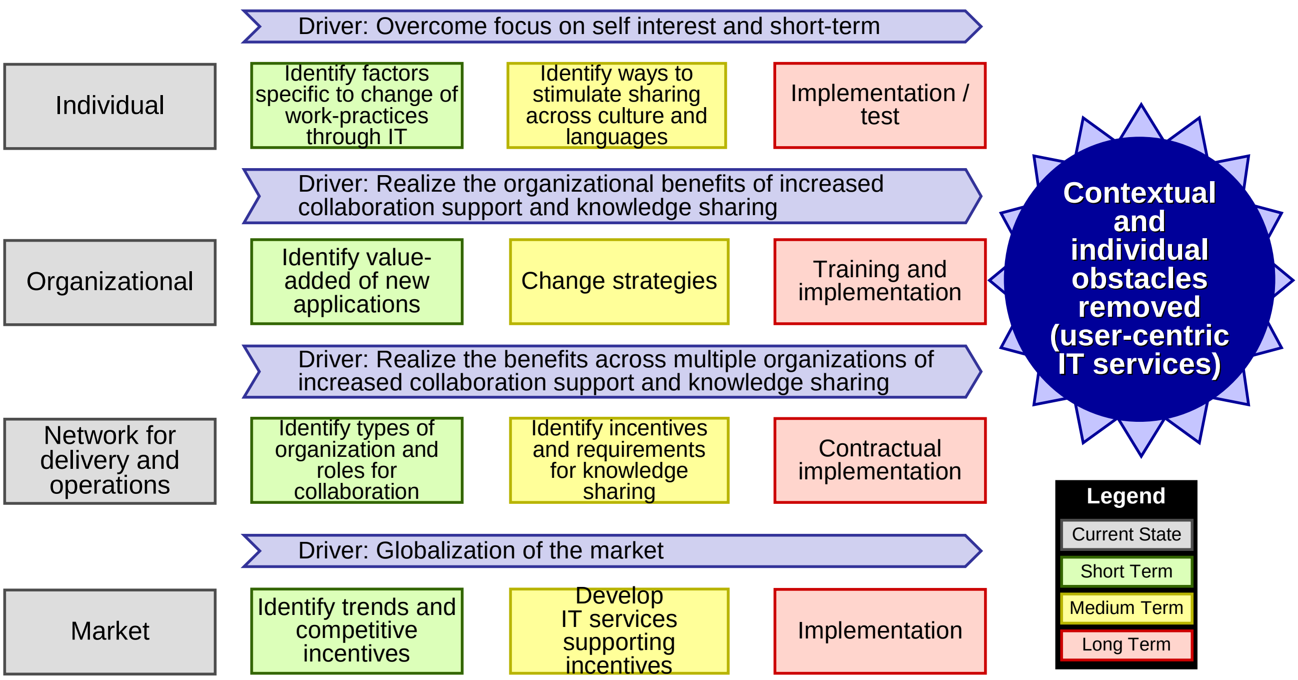

Figure 10: Roadmap – Implement. of Advanced ICT Tools for Knowledge Sharing & Collab. Support

Key Enablers

Necessity to share information across cultures, networks, organizational entities

Key Barriers

Resistance to change (at multiple levels)

Main Topics

Collaboration support and knowledge sharing at the individual level

Collaboration support and knowledge sharing at the organizational level

Collaboration support and knowledge sharing at the level of the network for delivery and operations

Collaboration support and knowledge sharing at the market level

Current State:

- Individual level: ICT tools for collaboration and knowledge sharing are quite basic and do not take into account the user-context in the interaction (e.g. there is no link between user interface and the process in which he is involved).
- Organizational level: ICT tools for collaboration and knowledge sharing are under-used because the real added-value is not clearly identified.
- Network level: ICT tools for collaboration are basic, often un-adapted because inspired from very different industrial fields. ICT tools for knowledge sharing not available, especially because of cultural, language, process differences from a country to another, or from an industrial field to another.
- Market level: ICT tools for collaboration and knowledge sharing not available

Short-Term to Industry:

- Individual level: research results identify factors specific to change of work practices through ICT. Best work-practices of collaboration and knowledge sharing between individuals are highlighted through implementation and experiments with "prototype ICT tools" in the framework of "prototype projects".
- Organizational level: research results identify value-added of new applications implemented inside an organization, i.e. in terms of quality compliance, resource allocation optimization and schedule respect.
- Network level: identify types of organizations and roles for collaboration. Experiments highlight the responsibilities of each organization in the project and how ICT tools implement it and facilitate project monitoring.
- Market level: identify trends and competitive incentives

Medium-Term to Industry:

- Individual level: research results describe ways to simulate sharing across culture and languages. ICT tools favour trust level in relationships between individuals through awareness improvement.
- Organizational level: feasible change strategies to overcome obstacles to implementation
- Network level: identify incentives and requirements for knowledge sharing, through an improved cooperation based on trust between individuals. ICT is an enabler of best practices of cooperation.
- Market level: develop IT services supporting incentives

Long-Term to Industry:

- Individual level: successful implementation and testing of strategies to overcome obstacles
- Organizational level: training and implementation
- Network level: contractual implementation
- Market level: implementation in design, construction, supplier, and services segments

Project Ideas

Project: Formalize project knowledge for sharing

Keywords	Models, knowledge sharing
Industrial Problem	Existing models do not capture full range of knowledge required.
Technological Objectives	Comprehensive and accessible structure
Approach	Examples from projects; test cases
Results	Preliminary structure for product and process models
Time to Industry	2 years
Main Actors & Expertise	Academic/industry research team
Main Beneficiaries	All previously identified stakeholders
Industrial Impacts	Initial steps in meeting vision
Follow-up Actions	Additional development and population of models

Project: Obstacles and strategies for increased collaboration and knowledge sharing

Keywords	Obstacles, collaboration IT services, change management
Industrial Problem	Many types of obstacles limit effectiveness of collaboration and knowledge sharing
Technological Objectives	Identify obstacles; develop strategies to overcome
Approach	Project case studies; data analysis and synthesis.
Results	Definition of obstacles and strategies
Time to Industry	2 years
Main Actors & Expertise	Industry/university research team
Main Beneficiaries	All previously identified stakeholders
Industrial Impacts	Initial improvements in overcoming obstacles
Follow-up Actions	Additional work on obstacles with greatest impact.

Project: Define research program and resources for knowledge sharing

Keywords	Research program, research funding, lobbying
Industrial Problem	Uncertain funding and potential collaborators
Technological Objectives	Define and pursue a research program and identify industrial collaboration
Approach	Define a scope and requirements to identify potential sources
Results	Successful research program
Time to Industry	3 years
Main Actors & Expertise	Government and industry, university researchers, KM vendors
Main Beneficiaries	All the stakeholders
Industrial Impacts	Improved performance in collaboration support and knowledge sharing
Follow-up Actions	Extend the implementation

Project: Change work practices to increase collaboration and knowledge sharing

Keywords	Change management, multiple levels, semantics, service
Industrial Problem	Reluctance and difficulty of change at different scales
Technological Objectives	Culture and language-independent IT services
Approach	Further develop strategies, actions and incentives, develop metrics, implement
Results	Improved work-practices
Time to Industry	5 years
Main Actors & Expertise	Individual / organizational / network / market scales
Main Beneficiaries	All previously identifies stakeholders
Industrial Impacts	Improved performance in collaboration support and knowledge sharing
Follow-up Actions	Expand the scope of work-practices applications

Project: Develop context-based visualization in IT services for cooperation and knowledge sharing

Keywords	Context-aware IT services, user-centred visualization, AEC cooperation context
Industrial Problem	Visualization of information in IT-based cooperation tools is often generic and based on a classical approach of computing (e.g. hierarchical views are predominant, views are often limited to one document). But actors need cross-linked information to better understand the context of a problem/information.
Technological Objectives	A framework for developing context-adapted views in AEC-software design: from HCI design to implementation techniques.
Approach	Distinguish between types of contexts to take into account (user-related, activity-related…), experiment it in test-developments.
Results	Modelling context, guidelines for designer and developers of applications
Time to Industry	3 years
Main Actors & Expertise	Researchers (computer scientists and AEC experts), application developers, practitioners
Main Beneficiaries	All practitioners of the AEC sector using cooperative IT service
Industrial Impacts	Improved performance in collaboration support and knowledge sharing especially through a better comprehension of the project context by the individuals
Follow-up Actions	Transfer of these guidelines to the AEC software industry

Related Initiatives and Further Reading

- FIATECH: # 1 Scenario-based Project Planning # 6 Real-time Project and Facility Management, Coordination and Control # 8 Technology- & Knowledge-enabled Workforce
- Strat-CON: # 6 Collaboration Support, # 7 Knowledge Sharing

Theme: Intelligent Constructions

Overview and Industrial Context

This strategic roadmap paves the way towards future R&D in terms of ICT support for building, using, maintaining, and exploiting Intelligent Constructions. What is meant here by Intelligent Constructions refers to:

- The "intelligent" way of building the future constructions, should it be houses, buildings, cities or large infrastructures;
- The Smart Home Environments, with reference to Home automations;
- The Smart (office) Buildings, with reference to Building Automations;
- The Smart civil large infrastructures and Capital Projects facilities, with reference to Facility Automations.

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.

Typically, the industrial context is progress and achievement towards full sets of (ICT-based) eServices in the context of Intelligent Constructions. The figure below synthesises the vision of the ZigBee Alliance about the various functionality provided in the context of the Smart Houses.

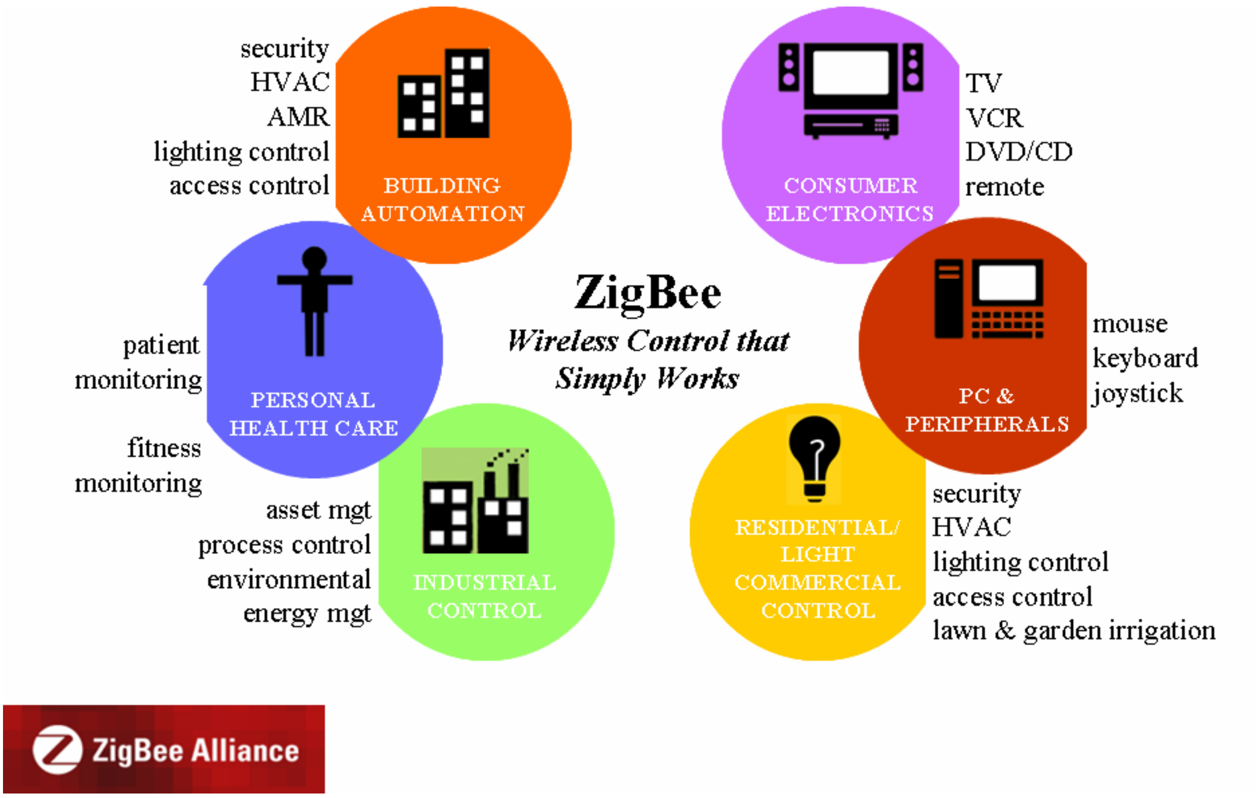

Figure 11: ZigBee Alliance Vision for Functionality Provided by Smart Houses

Industrial Problems Addressed

The addressed industrial problems may be synthesised as follows:

- Lack of real-time information for builders, in terms of tracking of resources (materials, components, people…), optimisation of SCM, optimisation of Construction site (organisation, security, safety);
- Lack of real-time information for owners, e.g. for intelligent monitoring, maintenance, etc.;
- Need for generalisation of smart / high-level services for occupants in houses, office buildings, in terms of comfort & leisure, security, optimised use of energy, safety & health.

Typically, this should be supported, among others, by technologies for ambient access[1] to all Manufacturing, Construction site and 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 or their daily life. Wireless and powerless sensors should support interactive spaces providing personalised, location and context aware services[2], 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).

Current Gaps & Foreseen Technological Challenges

The most fundamental current gap (and consequently foreseen Research/ Technological Challenge) is definitely the lack of standardisation, interoperability and “intuitive” interfaces. There is a need to:

- (builders) develop tools for automated information gathering, processing & transfer into construction field functions;
- (owners) generalise interoperable monitoring, maintenance and services – overcoming shortcoming of today tools and services done by specialised companies, each responsible of different systems:
    - relying on customised ICT (to meet specific needs of users);
    - based on monolithic applications that require manual configuration for specific uses, maintenance and support.
- (occupants) outstrip today (final) constructions containing various and increasingly versatile control and service systems:
- not (or very few and in scarce cases) standardised;
- not interconnected among themselves;
- currently based on vendor-specific technologies using "dumb" devices, proprietary software platforms and wired connections and protocols;
- Not taking into account occupant profiles & habits;

And where a given system/equipment is dedicated to one identified function (1 hardware = 1 function…), and not adaptable to various functions

[1] Ambient access stems from the convergence of 3 key technologies: 1) ubiquitous computing, 2) ubiquitous & secure communication, and 3) intelligent user-friendly interfaces.
[2] It is worth noticing that the previous comments are also applicable to the “tools” and systems used during the construction process itself.

Vision

*The vision proposed is that in the future, most (if not all) objects[3] on a Construction site, or within the home, the office or potentially any building, facility or infrastructure, 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: this is the concept of "**Ubiquitous B2P**" (B=Building, P=People).*

According to the main family of stakeholders, this vision can be translated as follows:

- For builders: continuously orchestrated, monitored, integrated & automated construction sites thru fully sensed, networked (wireless) environment providing information real-time / on-demand;
- For owners & occupants: all objects within the home, the office or potentially any building / infrastructure 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. Moreover, alll systems in constructions will have to 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. This has 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.

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.

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[3] including objects as simple ones as doors, windows, etc., potentially communicating with furniture like chairs, ovens…, but also more complex objects like appliances, equipments, systems, etc..

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 between 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 <u>before</u> "crisis intervention" is required, as well as to deal with "reactive care" and crisis management.

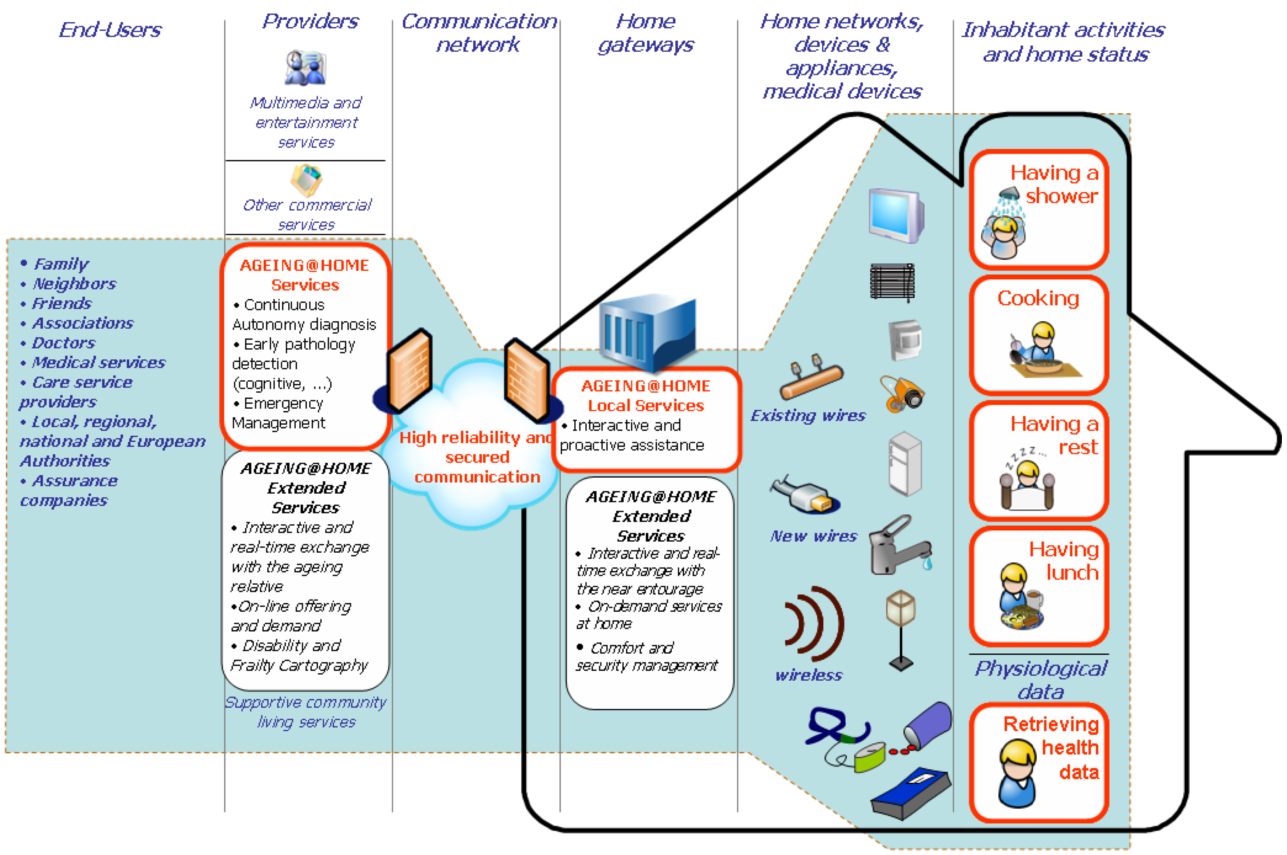

Figure 12: Innovative ambient services targeting the elderly in the Smart house of the future

Main Objectives

The roadmap is to identify the various R&D axis required to transform, on one side the current (off-site) manufacturing, SCM[4], and Construction site into an integrated, coordinated and continuously assessed process, on the other side the today living and working environments (houses, offices, buildings, facilities, etc.) in future smart environments and their innovative services, with a focus on all ICT artefacts that may support such evolutions. The focus is on the specification, development and deployment of smart[5] eServices relying on most recent undergone ICT. This encompasses:

- Smart services for continuous monitoring of construction process – off-site & on-site, including:
    - Continuous assessment of component/system production *versus* functional requirements
    - Coordination of SCM, with Construction site too;
    - Field workers security, safety on Construction site.
- Smart services for Building owners, including:
    - integrated automation and control;
    - remote diagnostics and control.
- Smart services for Building occupants, especially with respect to context-aware and user-aware seamless adaptability / configurability, self-optimising intelligent built environments, with potential for dynamic re-configuration, and providing access to interactive spaces and personalised services.

From an ICT point of view, the generalisation of such eServices requires:

- Developing integrated system architectures, innovative sensors and sensor networks, and models sustaining solutions for communication, operation, monitoring, assistance and control: such architectures shall provide seamless interoperability, ambient user interfaces, context awareness and embedded support for virtual working environments.
- Developing new services and new forms of interactive digital content and services including access to information and management of knowledge, and potentially entertainment (in homes and offices). 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 Business 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 and regulatory viability of services that could be imagined and further deployed, including the fact that they should lean on all devices taking account of cost efficiency, affordability, usability and safety.

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[4] Supply Chain Management.

[5] Smart is to be regarded here in a broad sense, i.e. “Digital”, “Connected”, “ICT-based”, …

Stakeholder Roles and Benefits

- Builder/Contractor
  - Foreseen Benefits: control of cost & schedule, improved construction assembly, improved management of sites, continuous visibility.
- Material/Equipment/System Supplier
  - Foreseen Benefits: improved collaboration & procurement, JIT delivery.
- Building Owner/Operator
  - Foreseen Benefits: proactive & easier maintenance, reduced costs & risks, improved asset management, reduced cost of insurance, higher ROI.
- Occupant
  - Foreseen Benefits: improved customer satisfaction, access to new value-added / entertaining services.
- Utilities Provider (e.g. energy provider, telephone operator, etc.)
  - Foreseen Benefits: new billing models, decrease manual workforce, opportunity for on-demand provision of services
- Service Provider
  - Foreseen Benefits: opportunity for provision of various classes of on-demand services, improved security services, improved healthcare services.
- Insurer
  - Foreseen Benefits: improved visibility/perception on assets risks, opportunity for custom insurance policies.

Roadmap

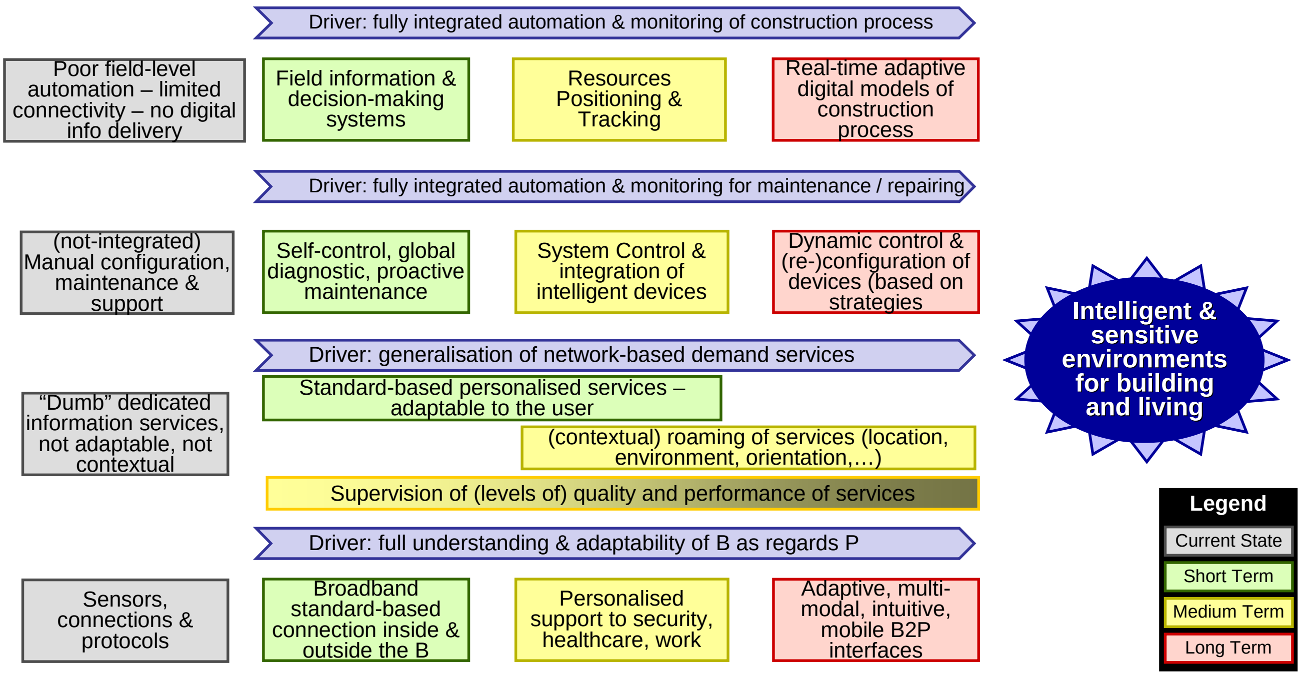

Figure 13: Roadmap – Intelligent Constructions

Key Enablers

RFID, Wireless connectivity, sensors & actuators, embedded processing power, regulations, awareness of societal issues.

Key Barriers

Disparate / legacy systems, lack of standards & gateways, business incentives (related to client demand).

Main Topics

Current State:

- Poor-field-level automation – limited connectivity – no digital info delivery
- (not-integrated) Manual configuration, maintenance & support
- Dumb dedicated information services, not adaptable, not contextual: all services provided by the industry so far are specialised / dedicated services that ensure one given function only, without providing interoperability, and no capacity to "talk" with other services or to take into account the full environment There is no standardisation of management of and communication between any kind of "intelligent" objects supporting those services. In terms of multimedia interfaces and devices, there are still quite few intelligent objects that are not intrusive and offer appropriate interfaces to allow the final user to seamlessly integrate the ubiquitous network.
- Sensors, connections & protocols: there are 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. *Future proactive/reactive (wireless) sensors* should be 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. Wired connection models & protocols are still under development and even more looking for harmonisation and standardisation (NFC - Near Field Communication, Bluetooth, Wi-Fi, RFID, ZigBee, Z-Wave, etc.), they aim at establishing and managing communication between objects.

Short-Term to Industry:

- Field-information & decision-making system
- Self-control, global diagnostic, pro-active maintenance: Develop systems and tools achieving remote & mobile 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[6] in the context of the built information.
- Standard-based personalised services – adaptable to the user: develop architectures where Component-based in-house or on Construction sites 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.
- Supervision of (levels of) quality & performance of services: identify and classify different levels (defined by some sets of indicators and parameters) for Quality of services in Manufacturing & Logistics, Construction sites, and smart homes, buildings and facilities. 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 construction or homes/buildings services.
- Broadband standard-based connection inside & outside the B(uilding): development of 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. They

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

should allow secure communication over public networks, 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. Solutions and systems should exploit 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. to achieve *ubiquitous & secure communication.*

Medium-Term to Industry:

- Resources positioning & tracking:
- 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 enhancing global monitoring of complex systems in the built environment. As a generalisation, 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.
- (Contextual) Roaming of services (location, environment, orientation,…): these services will rely primarily on 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. Such systems/platforms must form the ground for "spatial information systems and services" able to link objects in physical "interactive" spaces that will offer smart audio, video, leisure and working environments that must be adaptive and "immersive". Especially, these systems/services will have to manage agent-based user interfaces adaptation to suit user preferences and profile inferred from usage habits, and to deal with 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.
- Supervision of (levels of) quality & performance of services: <<*extension Short-Term* >>;
- Personalised support to security, healthcare, work: 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. This should apply to various functionality for the end-customer in terms of security, safety, comfort, health, entertainment, improved management of the house or the office, etc.

Long-Term to Industry:

- Real-time adaptive digital models of Construction process:
- 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, putting to the extreme the concept of roaming of services in the context of automation for maintenance / repairing.

- Supervision of (levels of) quality & performance of services: <<*extension Medium-Term* >>;
- Adaptive, multi-modal, intuitive mobile B2P 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.

Project Ideas

Project: Sensors

Keywords	Sensors, actuators, cameras, wireless networks
Industrial Problem	Sensors e.g. embedded in concrete; curing, monitoring, controlling
Technological Objectives	Design of sensors able to integrate into current infrastructures, and to be able to communicate over a given period of time
Approach	
Results	
Time to Industry	3 to 5 years
Main Actors & Expertise	Traditional wired sensing vendors (Siemens, GE, Honeywell, Johnson Control,…), wireless sensor vendors / organisations (ZigBee, Zwave, Insteon, …)
Main Beneficiaries	Builders
Industrial Impacts	Sensors, actuators, cameras, wireless networks
Follow-up Actions	Sensors e.g. embedded in concrete; curing, monitoring, controlling

Project: Detailed study and evaluation of wireless standards and protocols

Keywords	802.11n
Industrial Problem	Need for more adaptable wireless standards for greater speed
Technological Objectives	Test and deploy on site 4th generation wireless hardware to move to 802.11n. Implementation tests could include: 1. Wireless Voice over IP 2. Mobile devices (Rugged Handheld, mobile devices, tablets, smartphones) 3. Mobile Bar code/RFID readers 4. Location Based Services based on WiFi?? 5. Wireless Security standards and backward compatibility 6. Backward compatibility with 802.11 a/b/g 7. Backhaul reconfiguration of antenna arrays for larger bandwidth 8. Point-to-point, Point-to-multipoint models Ease of setup, installation 9. Understand Globalization Issues
Approach	Setup and testing of 4th Generation Wireless Network
Results	
Time to Industry	Next 6 months
Main Actors & Expertise	FIATECH and probably Target using Xirrus Vendor and Equipment
Main Beneficiaries	Engineering and Construction, Building Owners
Industrial Impacts	
Follow-up Actions	Project Plan for Site Test

Project: Digital modelling of people behaviour and needs

Keywords	Machine learning, sensor networks, data processing
Industrial Problem	Lack of proper interface between in Building services and the user
Technological Objectives	Being able to understand user behaviour by analyzing the patterns of habit
Approach	Gather data, extract pattern of behaviour, analyze variations to this pattern
Results	Modeling of the user behaviour as a control of the building automated machines (HVAC, lighting…)
Time to Industry	3 years
Main Actors & Expertise	Software vendors
Main Beneficiaries	Users, building owners
Industrial Impacts	Change control systems inside the building… ?
Follow-up Actions	Machine learning, sensor networks, data processing

Project: Smart services for digital housing

(e.g. advanced and intelligent control system that was able of self-adapting the HVAC system taking into account the users preferences and the context)

Keywords	Digital housing, smart home technologies, …
Industrial Problem	Customers with different type of general and personalized needs: safe and secure living, productivity and expandability of user activities, and efficiency of building services (costs). The service of these needs can be promoted and enabled by means of smart home technologies. Main challenge: experiment & deploy technologies – develop products, supply chain and services should leading to new solutions beneficial to the users – investigate opportunities / potential of mass customisation of product & systems.
Technological Objectives	Develop new Digital housing service concepts and models – e.g. intelligent space management, technical systems solutions for house LC management Develop new appropriate business models for the future digital housing Develop proof the concept via demonstrations and experiments.
Approach	Project to be carried out by a multidisciplinary project team. Prioritisation of the alternative development options based on the stakeholders' requirements. Use case and scenario analysis, usability studies using demonstrators, and piloting.
Results	Models, services & reference solutions for the future housing enabled by digital home platform. Reference model and implementation of Digital Home Platform. Modular mass customable product and production technologies. Models and methods for knowledge based design methodology and tools. New business models and process definitions of mobile FM and LC services.
Time to Industry	3 to 5 years
Main Actors & Expertise	
Main Beneficiaries	
Industrial Impacts	Improved performance, energy economy, home safety and security. New life cycle and maintenance services. Promotion of the breakthrough of smart home technologies
Follow-up Actions	

Related Initiatives and Further Reading

- FIATECH: Element 4 - Intelligent & Automated Construction Job Site, Element 5 - Intelligent Self-maintaining & repairing Operational Facility
- Strat-CON: Intelligent Constructions (#4)
- CABA
- Technology roadmap for Intelligent Buildings
- IEA – International Energy Agency
- Intelligent Buildings Initiative

Theme: Interoperability

Overview and Industrial Context

Interoperability addresses the ability of software tools to seamlessly exchange pertinent information with each other. The information that is exchanged is that which is used in the profession across the whole life-cycle of a building project to support existing, and evolving, business processes. A core aspect of the information exchange process is that the context of the information being exchanged is clearly understood so that the semantics of the information is maintained during exchange. Interoperability ensures the integrity of the exchanged information and that only the necessarily required information is shared amongst professionals. True interoperability would dispel the enormous range of inefficiencies which exist in the A/E/C-FM industries and lead to more accurate and reliable understandings of the building being addressed.

Industrial Problems Addressed

- Poor or no interoperability between existing systems and across the whole life cycle
- Rework and errors in reproduction of information
- Inefficiency which the NIST report categorises as: avoidance, mitigation and delay

Current Gaps & Foreseen Technological Challenges

- Lack of vendor participation, proprietary systems
- Lack of alignment in approach (bespoke solutions)
- Scalability of current approach (point to point transfer, ownership, security) to all domains
- Publishing approaches to information management

Vision

- Information sharing without concern of the creating system
- Interoperability independent of source, life cycle stage and type
- Information to be securely accessible and interpretable across the life of the asset
- Enable an environment that encourages collaboration

Main Objectives

- Reduce life cycle cost of the asset
- Improve the quality of the asset
- Render information open and accessible
- Maintain information independent of any authoring system

Stakeholder Roles and Benefits

- System Vendors
    - Role: Developers of interoperable systems and components
    - Foreseen Benefits:
        - Growth of market share
        - Plug and play software ability (componentisation)
    - Foreseen Issues:
        - Competition in the marketplace
        - Return on investment across many possible choices
        - Dependence on quality of information of up-stream systems
        - Driver from marketplace
- Asset Owners
    - Role: Developers of interoperable systems and components
    - Foreseen Benefits:
        - Growth of market share
        - Plug and play software ability (componentisation)
    - Foreseen Issues:
        - Competition in the marketplace
        - Return on investment across many possible choices
        - Dependence on quality of information of up-stream systems
        - Driver from marketplace
- Asset Creators
    - Role: Design and construction of the asset
    - Foreseen Benefits: Faster, better, cheaper
    - Foreseen Issues:
        - Uneven distribution of benefits of interoperability
        - Requires change of contractual models
- Suppliers
    - Role: Supply of construction products
    - Foreseen Benefits:
        - Lowered cost of business
        - Integral part of the team
        - Deeper market penetration
    - Foreseen Issues:
        - Proprietary approaches to dissemination
        - Quality/accuracy of information provision
- Regulatory Bodies and Public Agencies
    - Role: Review and approval of plans
    - Foreseen Benefits:
        - Facilitates review and speeds the process
        - Accuracy of information transfer and provision
        - Supports performance based codes
        - Global overview
    - Foreseen Issues:
        - Requires complete uptake of interoperability
        - Requires changes to regulations/laws/provisions

Roadmap

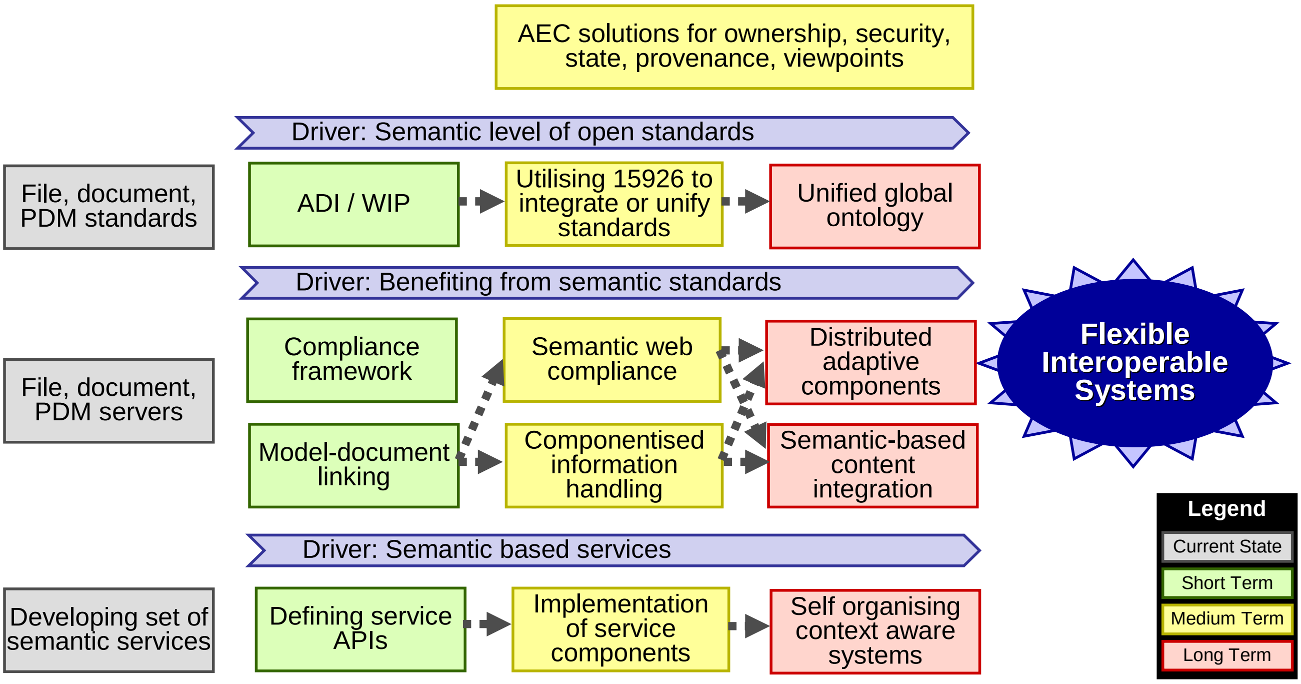

Figure 14: Roadmap - Interoperability

Key Enablers

- Standards development and adoption.
- Push by govt, major owners, etc.

Key Barriers

- Equipment manufacturers/suppliers ability to deliver.
- Plethora of standards.
- Bespoke solutions.

Main Topics

- Standardisation
- Servers
- Semantics

Current State:

- Standardisation: A wide range of file, document and PDM standards
- Servers: A wide range of file, document and PDM servers
- Semantics: An evolving set of semantic services

Short-Term to Industry:

- Standardisation: ADI / WIP
- Servers: Compliance framework
- Servers: Model-document linking
- Semantics: Defining service APIs

Medium-Term to Industry:

- AEC solutions for ownership, security, state, provenance, viewpoints
- Standardisation: Utilising 15926 to integrate or unify standards
- Servers: Semantic web compliance
- Servers: Componentised information handling
- Semantics: Implementation of service components

Long-Term to Industry:

- Standardisation: Unified global ontology
- Servers: Distributed adaptive components
- Servers: Semantic-based content integration
- Semantics: Self organising context aware systems

Project Ideas

Project: Enlightenment of owner-operators

Keywords	business cases, implementation guidelines
Industrial Problem	Owner doesn't see the benefit of interoperability and does not demand an interoperable approach
Technological Objectives	Better promotional material such as case studies, success stories, implementation guidelines
Approach	Identify the decision maker in regards to interoperability. Find the 'pain points'. Better metrics for showing business value. Reduce cost of handover.
Results	Quantitative business cases, use cases
Time to Industry	Ongoing, but frequent updates
Main Actors & Expertise	Contracted academic team (e.g., through CII, FIATECH)
Main Beneficiaries	Owner-operators
Industrial Impacts	Creating owner demand for interoperability
Follow-up Actions	FIATECH led

Project: Support infrastructure for system developers/vendors

Keywords	middleware, toolkit, open source
Industrial Problem	High cost of entry to market and complexity of implementation of interoperable solutions.
Technological Objectives	Suite of middle-ware support tools for deploying interoperable components (e.g., ADI project), supporting information transformation, etc
Approach	Developers and vendors collaborating on infrastructure or e.g., NIST open source developments
Results	Open source tools
Time to Industry	Ongoing
Main Actors & Expertise	System developers and vendors
Main Beneficiaries	System developers and vendors, ultimately the AEC community
Industrial Impacts	Quality of tools, wider choice of tools, faster/cheaper development
Follow-up Actions	Define specification/requirements

Project: Conformance testing and certification for interoperable systems

Keywords	compliance, certification, standards
Industrial Problem	Definition of compliance and strength/quality of the testing procedures
Technological Objectives	What constitutes compliance
Approach	Determining needs, surveying other successful industries approaches
Results	Certification process and methodology. Certified software.
Time to Industry	Timed for standard releases
Main Actors & Expertise	System developers and vendors, System users, Standards bodies, Consortia
Main Beneficiaries	System users
Industrial Impacts	Efficiency of workflows
Follow-up Actions	Identify success in other disciplines (e.g., ICT). Certification framework. Plan of action.

Project: Harmonisation of standards

Keywords	IFC, ISO 15926, building information models
Industrial Problem	Multitude of standards and uncertainty over coverage. Decision as to which standards to implement.
Technological Objectives	Guidance on standards to use. Driving alignment of related standards.
Approach	Pairing standards developers
Results	Successful and utilised standards
Time to Industry	Ongoing
Main Actors & Expertise	Standards bodies; Industrial consortia
Main Beneficiaries	System developers and vendors; Owner-operators; AEC industry
Industrial Impacts	Enabling industry to efficiently communicate (c.f. automotive industry). Expanded interoperability by growing coverage of industry.
Follow-up Actions	Workshop at FIATECH members meetings

Project: Contractual models supporting new workflows

Keywords	contracts, workflow, conflict management
Industrial Problem	Change in responsibilities forces new methods of work
Technological Objectives	Match contractual structures to modernised workflows. Assessment of progress
Approach	Identify the schedules, tasks and milestones in new workflows. Match to new contracts
Results	Advice on contracts and contracting strategy. Contract which match the work.
Time to Industry	Ongoing
Main Actors & Expertise	Owners; EPC / AEC; Legal profession
Main Beneficiaries	Owner, AEC
Industrial Impacts	Deployment of new workflows. Improved workflows and results. Reduction of conflict and litigation.
Follow-up Actions	Govt, FIATECH, CII, Universities, NIBS and other professional organisations

Related Initiatives and Further Reading

- FIATECH: #9 (and across all initiatives)
    - Interoperability framework
        - Transport mechanisms
        - Ontologies
    - Accelerating the Deployment of ISO 15926 (ADI)
- Strat-CON: Roadmap on Interoperability
- NBIMS / BuildingSMART
    - Information Delivery Manuals (IDM)
    - Model View Definitions (MVD)
- POSC/CAESAR
    - Intelligent Data Sets (IDS)
- CIB
    - Integrated Design Solutions (IDS)

Theme: Demand Network Management

Overview and Industrial Context

Just-in-time delivery, not only of materials and equipment, but also of labor and information, becomes more and more a determinative factor in the planning (both schedule and finances) of capital construction projects, both in the building and industry sector. Reasons for this are a more demanding market and the development of new market locations (Middle-East, China, Africa)

Industrial Problems Addressed

- Not having on-time deliveries
  - Too early delivery results in double handling and storage
    - Costly storage
  - Too late delivery results in waiting time
    - Costly labour and installation material (cranes) – downtime/delays
    - Overall schedule disruptions
- Lack of standardisation/interoperability from design to operations
  - Tailor-made materials and equipment limit the supplier market and is costly and time consuming
- Globalisation compliance
  - Global Environment demands most effective use of mineral materials, energy and emissions (CO_2).

Current Gaps & Foreseen Technological Challenges

- Fragmentation is bad and getting worse
- Information security – accessibility to data
- Demand for information needed now; not just materials and goods
- Global perception that this issue is passé
- Basic theoretical work is missing
- Meet changing demands of customers
- Global demand of materials resulting in rising prices (i.e. steel)

Vision

- ***Customer*** aware and informed of status at all times and receives on-time delivery.
- ***Supplier*** aware of customer and project demands and potential barriers as soon as they arise.
- ***Environmental*** requirements included in all future transactions.

Business Scenario: FedEx

Our industry needs technology applied similar to the FedEx model where a customer can ship a package, which is tagged and then track it any where in the world and know where it is at any given time.

Business Scenario: Aerospace

Boeing effectively mandated to their supply chain who, what, when, how and where product will be delivered. We need a streamlined and organized supply network that delivers just-in-time.

Business Scenario: Wal-Mart

RFID technology is used to track goods and products throughout their lifecycle and the company continues to expand the information that is collected and tracked. This model could be used in construction where inventory, materials, equipment, labour, etc is tracked electronically.

Main Objectives

- Fair-sharing and distribution of all value created.
- Less waste (time, material, labour, money, CO2, etc.)
- New and/or enhanced business opportunities.
- Fair distribution of liability
- *Make more money*

Stakeholder Roles and Benefits

- Public Consumer
    - Role: defining requirements
    - Foreseen Benefits: healthy, safer, and therefore happy people
- Construction Owner (developer, operator)
    - Role: boss, in charge, accountable
    - Foreseen Benefits: profit, better quality, less stress- no surprises; safer and more secure job site
- Contractor (EPC, construction companies and contractors)
    - Role: project manager, responsible; delivers project to customer
    - Foreseen Benefits: keep customer happy, resulting in more business which makes him more money, fair distribution of the liability, safer and more secure job site
- Designer
    - Role: most knowledgeable subject matter expert within the network
    - Foreseen Benefits: increased pay, greater control, increased business, gatekeeper to all information within the network
- Manufacturer
    - Role: supplier
    - Foreseen Benefits: better quality, less stress- no surprises, able to meet demands, more profit.
- Logistics Companies
    - Role: transportation from manufacturer to owner’s job site
    - Foreseen Benefits: better planning and preparation, less stress- no surprises, more profit

Roadmap

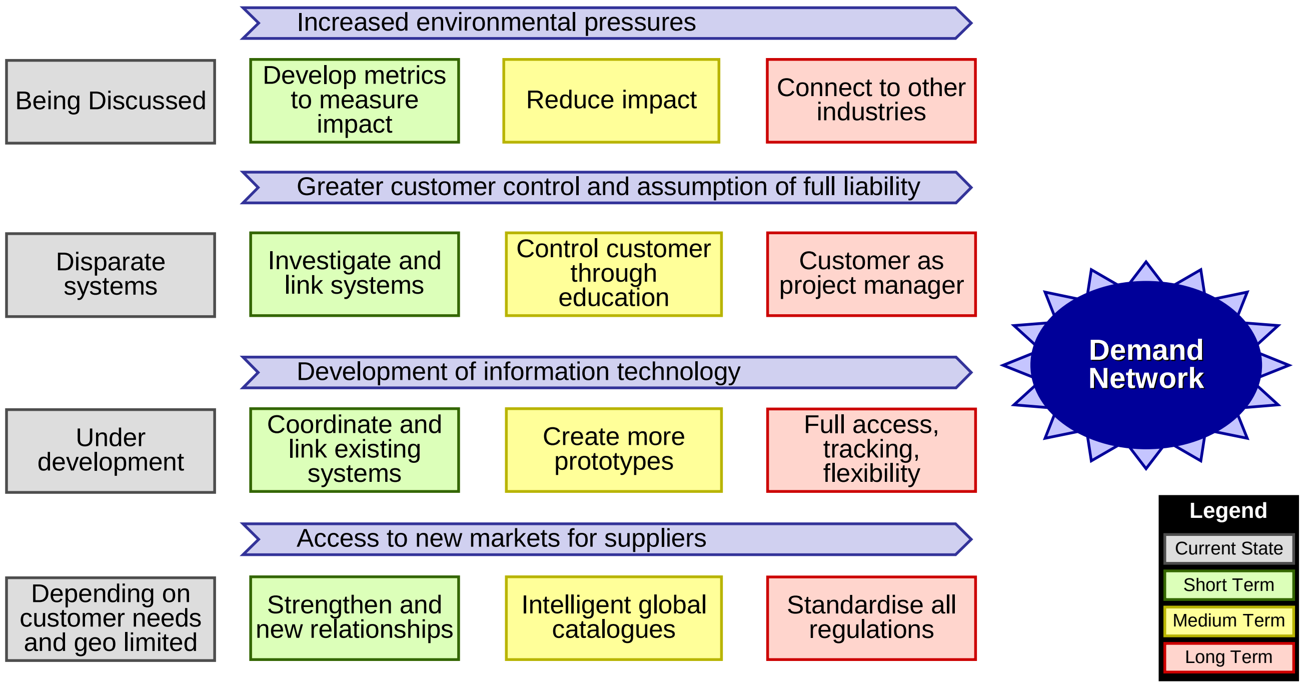

Figure 15: Roadmap – Demand Network Management

Key Enablers

- Global Public demand (both opinion and laws) require fast actions
- New market situation demands a more (read most) effective process to control increasing cost and timing

Key Barriers

- All stakeholders should believe in a new approach and should be convinced of the benefits for themselves
- Some stakeholders represent a great variety of companies
- Solutions require investments (of all stakeholders)
- Change in liability chain

Main Topics

Current State:

- Being Discussed: issue is considered as being discussed before and not being an issue anymore. Changed market situation learns different.
- Disparate Systems: each stakeholder has its own “best practice” as seen from his role in the process
- Under Development: each stakeholder develops from his point of view his step(s) in the process
- Depending on Customer needs and Geo limited: changed demands from customer as result from expanding market

Short-Term to Industry:

- Develop Metrics to measure Impact: identify and quantify the issue, collect data to analyze, and determine possible and probable root causes, barriers, and solutions. Data should be available in the (many) different databases of stakeholders
- Investigate and link Systems: investigate and collect all possible systems and define common platform
- Coordinate and link existing systems: systems are available on the (developing) market and need to be aligned to get quick results
- Strengthen and new Relationships: new developing market requires different needs

Medium-Term to Industry:

- Reduce Impact: after analyzing data find solutions and implement
- Control customer through education: make customers aware of shared liability and common interests
- Create more prototypes: test and prove functionality to get 'Most Effective Technology'
- Intelligent Global Catalogues: new market demand also means new market supply; a intelligent global catalogue will be required to cross-reference between all different descriptions and to make requirements clear to new suppliers market

Long-Term to Industry:

- Connect to other Industries: topic Once implemented and controlled that modified process enables the needs, leverage solutions to other businesses
- Customer as Project Manager: customer who is accountable also takes responsibility
- Full Access, Tracking, Flexibility: each stakeholder will be able to track materials, equipment, or labour at all times. 'Long-Term to Industry' should be read as in the near future for this topic.
- Standardize all regulations: a great variety exists in regulations from governments and institutes, resulting in many different types of the same equipment or material, not forgetting the variety in certificates and tests.

Project Ideas

Project: GPS Open-based Services

Keywords	GPS, RFID, Sensors
Industrial Problem	Hardware exists but not open software system using the internet to make available to smaller companies
Technological Objectives	Software developed from design to implementation
Approach	Look at shipping and aviation examples where this info is available on the internet. Link to google map? Map flow of materials
Results	Customer and contractor has access and new suppliers can join the network easily
Time to Industry	now
Main Actors & Expertise	Large contractors
Main Beneficiaries	Suppliers, owners, contractors
Industrial Impacts	
Follow-up Actions	

Project: Intelligent Warning System

Keywords	Weather, traffic , holidays
Industrial Problem	Unplanned delays and lack of dependability of transports of goods
Technological Objectives	Intelligent warning system
Approach	Signal process, pattern recognition
Results	Predictable online transport system
Time to Industry	Start now
Main Actors & Expertise	Universities, NSF, Homeland Security, NIST, VTT
Main Beneficiaries	everybody
Industrial Impacts	Quick, on-time efficient delivery; no delays and dependable schedule and planning
Follow-up Actions	

Project: Evaluation of Global Scenarios and develop Contingency Plans

Keywords	Business intelligence
Industrial Problem	When unexpected events happen, industry can not respond quickly and can have rippling and devastating results
Technological Objectives	
Approach	Creation of a technology scenario system that allows companies to plan and prepare for unexpected events
Results	Industry can adjust quickly to new situations
Time to Industry	Short: -1 year
Main Actors & Expertise	Research institutes, academe, industry
Main Beneficiaries	
Industrial Impacts	
Follow-up Actions	Business intelligence

Project: Existing Technology Application Project

Keywords	Best practice
Industrial Problem	Existing technology is not being effectively optimized and used on job sites
Technological Objectives	Investigate current technology and find suitable applications to deploy these technologies in new ways on the job site (i.e. display models on windows and walls on sites with projectors and mobile phones)
Approach	Mention here the approach to be used.
Results	New, easy applications of technology. Low hanging fruit with large returns?
Time to Industry	now
Main Actors & Expertise	Owners, workers, contractors, technology suppliers, researchers
Main Beneficiaries	Contractors, owners, workers
Industrial Impacts	List here the foreseen industrial impacts (e.g. time savings of 10%)
Follow-up Actions	Individual innovation awards at Finlandia Hall annually

Related Initiatives and Further Reading

- FIATECH Roadmap Elements: #3: Integrated, Automated Procurement and Supply; #1: Scenario-based project planning; #7: New Materials, Methods, Products & Equipment
- Strat-CON Roadmaps: #1: Value-driven Business Processes

Theme: Value-driven Business & Process Models

Overview and Industrial Context

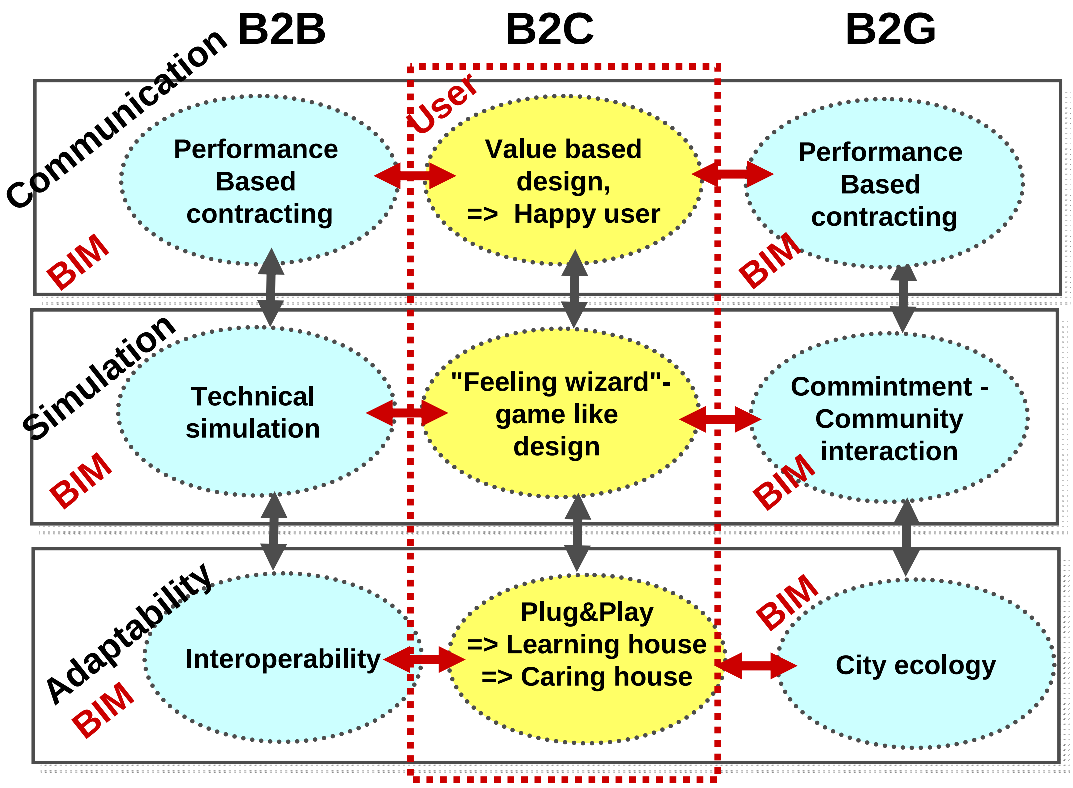

Figure 16: User-centric Business and Process Models through BIM

There is need to have a user-centric view to new value-driven business and process models. In short, a user could "feel" what they want in addition to simply "seeing" what they want through a BIM (building information model).

Industrial Problems Addressed

- User/client/society value not in focus in processes (Values: money, time, convenience, comfort, durability, happiness, culture, artistic, safety, health, sustainability…..)
- Conflict of interest
- Communication barriers between stakeholders, shared understanding is missing because meaning and context is different for different stakeholders

Current Gaps & Foreseen Technological Challenges

- Users and clients can't fully interpret 3D renderings
- Communication methodology with 3D technology is not yet developed
- Evaluation tools and criteria to measure the values above
- Insufficient psychological knowledge about bridging the communication barriers

Vision

- Expanding BIM from design phase to include both user dialog before design, production, and user dialog after design. The Challenge is to communicate between different stakeholders with different interests and professional backgrounds. The User should always stay in "spotlight".
- What you "feel" is what you get.

Business Scenario: What You Feel is What You Get

This fantastic house is build by a family just outside Copenhagen. We ask Anette and Peter how they designed the house:

"We had this dream for a long time to build our own house, maybe a nesting instinct" say Peter laughing, "we have searched through a lot of housing companies without finding that love at first sight emotion we were looking for". "One day we entered the website of www.googlebim.com and tried this kind of "20 questions to the professor" game where they show us a lot of beautiful architecture and we mark up everything we particularly love. All these favourite pictures are sampled into an entirely visual specification, no words, no number, just pictures of all the rooms and spaces and facades and components we like". "Something happened to us looking at all these master pieces. We never knew that there was so much beautiful architecture around"

The picture analysis software at GOOGLEBIM *) database already contains 3D scanning of these buildings. The collage of pictures is linked to this database in order to create a virtual toolbox of spaces. It is furthermore linked to the website of the suppliers of the components shown on the photos.

"Surfing the pictures we build up a catalogue of spaces and components. We could even get a estimate of cost for the spaces and a list price of the components. We went through the pictures several times and had some difficulties deciding our favourites. The kids had of course their favourites too"

The picture analysis software at GOOGLEBIM look the family "over the shoulder" to make a pattern of their search on the pictures and the spaces and components they ask prices for. This is a generic algorithm software learning from the users preferences. The more the family returns to the items, the more these spaces and components will be in focus in the design proposal.

"When we clicked on "Proposal" the computer starts showing us a number of fantastic 3D pictures of houses like nothing we have ever seen"

They are designed by the computer using generative art software merging and mutating the spaces the family has chosen. It is a second generation version of the tool Suddo made back in 2002 (http://www.argenia.it/)

"We are not used to look at drawing so we use our 3D goggles (www.microvision.com) to enter into this virtual world"

Again the computer notice the eye movements of the user in order to learn what they focus on and read brainwaves, pulse, iris and face expression to se if they like the design or not. And all this feed back is re-entering the generative art software in order to regenerate the next design.

"We entered one virtual house after the other and every time it was magically a little closer to our dream. When we were happy with the general impression, we wanted to move into this virtual world with our furniture. We went randomly through the house with a video cell phone and transmitted the video live to GOOGLEBIM where the furniture was transformed into 3D objects www.debevec.org .and returned to our virtual world. We could walk around and place the furniture and painting and sculptures and put up curtains. This was like playing with the dolls house as kids. We all enjoyed it. Serious play, as we actually had to correct a lot of things to make our dream house functional"

The software is 3D parametric. The users can ask to se nodes with handles and can then just push or pull in these handles in order to increase or decrease space.

“We decided that this is for real and the next day wee had the most delicate 3D model delivered by the mail man”

GOOGLEBIM prints their BIM model using a small 3D printer www.zcorp.com

”In the next weeks we had our friends over for house warming in our virtual house. Their first reaction was “wow”, but of course they had all kind of suggestions and critics and unlike real houses we could still change some of these things”

Business Scenario: 3D Printer (follow-up to previous scenario)

All along this process GOOGLEBIM has placed an option on all components and systems. This works C2C (computer to computer” via web portals and semantic web systems where the computers exchange information in a formal language that computers can understand. It is a juridical exchange of information.

“We changed a few components to something looking almost the same but with significantly less cost or with a shorter delivering time and received a movie showing the entire construction process piece by piece, layer by layer”

The idea of this building process simulation is to make sure, those components, tools and materials are delivered just in time.

“We had come to the point of no return. Pressing “Accept” at the GOOGLEBIM contract web page was the decisive moment.

After the accept all options are changed into orders and GOOGLEBIM returns with a confirmation that the building process will start October 21 st.2013 at 7 AM .

“It was great to se the large truck enter our building site and unfolding like the transformer the kids used to play with. In a matter of minutes the huge machine was ready to build our house. I was a great moment to watch our dream become true, virtual reality becoming reality”

Large milling machines have been in use for decades and the only new thing is that this one i mobile. GOOGLEBIMs “3d printer” is much more than a milling machine. It starts spaying PUR in much the same manner as http://www.contourcrafting.org/ . The process starts with the insulation core for several reasons. It is a very fast curing material, with low weight so it is good for the unsupported shaping. It is furthermore a guarantee for perfect insulation without thermal bridges.

“We paused the robot for a short tour through the real house to experience the real rooms and it was exactly like the virtual one, just more impressing”

Next step is milling this insulation core to make sure the dimensions are perfect and that there are cavities for wires, pipes, electrical sockets etc. right where they are supposed to be. The amazing thing is that this operation almost eliminates the need for further geometrical information or drawing in the remaining process.

In a short pause the construction site in invaded by a truckload of humanoid robots http://world.honda.com/ASIMO/ installing all wiring and piping to be hidden in the construction. All these installations are of course within an extra pipe to ensure that they can easily be replaced. Everything is made to measure as Plug&Play components. No measuring or cutting on side. Just clicking on it.

After this interruption the robot goes on spraying fibre reinforced shotcrete on the foam creating a uniform layer on both sides. The shotcrete is absolutely water and airtight and covers seamless the entire house. Is also fire protect the house, and is stable enough to endure hurricanes and earthquakes. Inside the robot spay a finishing layer of the most advanced nano-concrete to obtain a gentle surface as we know it from Greek island villages where painting with chalk for centuries has made everything pleasant to touch.

Outside the surface is painted with photovoltaic nano coating polymer so the entire house is producing much more energy than consumed

The truck folds and leave. The humanoid robots return to the montage of windows, sockets, and all kind of finishing work. As the house is exactly to BIM specified dimensions the wooden floor planks are cut exactly to measure and the robot has an easy task installing them on the floor. Each component is tagged with RFID and the robots are connected wireless with GOGGLEBIM. The robots are furthermore guided by a local x-y-z GPS system. So they know beyond any benefit of the doubt exactly where to put the components.

Business Scenario: Caring Building

"We realise that our life has changed when we got kids and we imagine they will keep changing so we choose a theatre like layout with the entire private roof surrounding the family arena. The division between the centre and periphery is made up by movable objects like sliding doors, closets, bathrooms etc. They are all moveable inspired by Shigura Ban's "Naked house" http://www.designboom.com/history/ban_naked.html)"

The central computer is turned on and it takes a few hours to recognize and install all the light, radiators, smart windows, energy installations, water automatics, central locking system, and white goods. It is like when you get a new computer and install USB components. Next the computer connects to all the smart RFID like sensors embedded in the entire construction monitoring humidity, structural load, temperature, fire etc. This is so to speak BIM real time because all this information is stored in relation to the objects. This way the operational history is available for the component industry in order to improve their life time performance. It is like when your mechanics plugs his laptop to you cars computer. Just real-time and web connected

The central computer connects to the building authority portal and the BIM model of the actual house with the actual installed components and systems is run through the approval software. Better safe than sorry. There is full compliance and the permission to move into the house is mailed to the owner.

"We got exactly what we have dreamed of and we got it fast, without discussion about extra price. The quality is remarkable. Everything works perfect. We are happier every day we live in this house. It is our house"

It took a few weeks for the generic algorithm software to figure out what the user habits are.

"We never think of the house being intelligent or automatic. We hardly notice what it is doing because it supports our life in a gentle caring un-intrusive way".

The central computer is guided by transponders in the user's wrist watch sending information about physical activity, pulse, sweat, skin temperature, and of course a personal ID. The information is used to provide a personal climate adding heating and cooling right where you are instead of adding it in the entire room. When you get so close to other persons in the room that personal climate is impossible, some mediated average climate is opted for.

"I have even heard that such a house once called an ambulance when the occupant had a hart attack. The transponded pulse was way out the normal"

"We still need to tidy up the place but cleaning is automatic"

The mobile industrialised bathroom module is cleaning all the internal surfaces automatically and drying them, just like a giant dishwashing machine. Robots are driving around cleaning the floor and the humanoid robots are cleaning the rest. Self cleaning nano-surfaces on windows makes it even easier. The nano concrete surfaces are even cleaning the indoor air in a catalytic process.

"We don't pay for energy. Our photovoltaic surface produces energy for my electric car (see www.teslamotors.com).

"First time something broke down the central BIM computer turned the device off, change to a plan b operation procedure and ordered a replacement. I installed the Plug&Play replacement following the instructions in my augmented 3D goggles. No problem"

Main Objectives

- Convergence between design and serious/innovation gaming industry
- Evaluation tools and criteria to measure the values above

Stakeholder Roles and Benefits

- User
    - Role: Co-designer
    - Foreseen Benefits: Satisfaction (more value for user)
- Client
    - Role: Co-designer
    - Foreseen Benefits: Satisfaction (more value for money for client)
- Society
    - Role: Town-and city planning
    - Foreseen Benefits: Satisfaction (more site value)

Roadmap

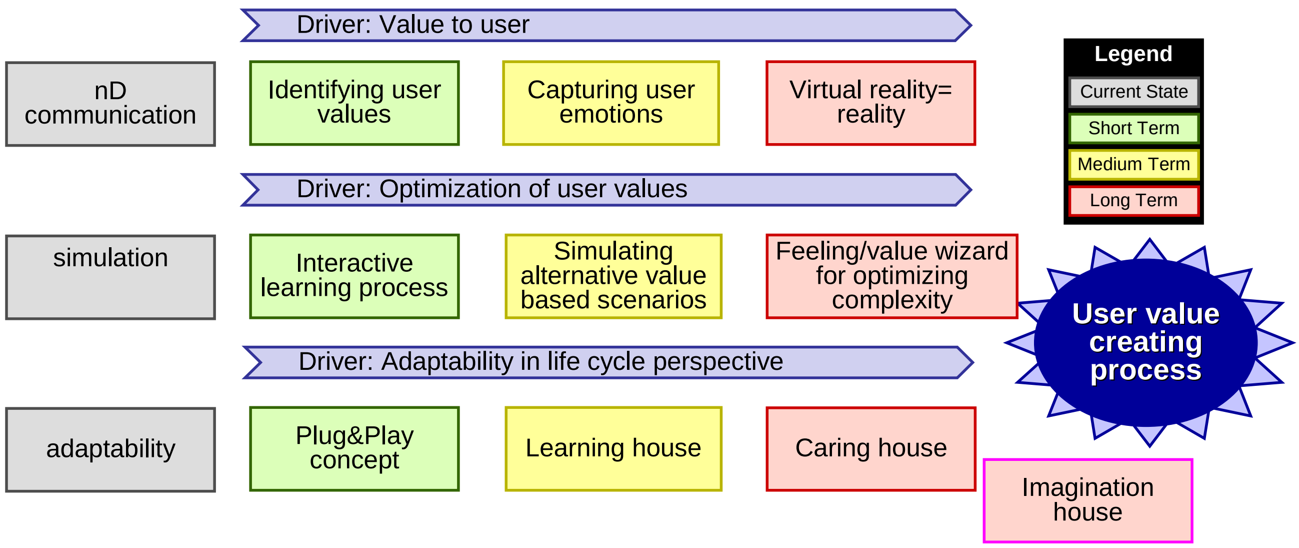

Figure 17: Roadmap – Value-driven Business and Process Models

Key Enablers

- Value to users
- Optimisation of user values
- Adaptability in life cycle perspective

Key Barriers

- Lack of ICT tools for user interaction
- Lack of knowledge about user dreams, feelings and visions
- A lot of missing links in BIM between user and use of building

Main Topics

Current State:

- nD communication: Communication is primarily 2D drawing, text and list on paper as there is a lot of missing links in BIM
- Simulation: Simulation of indoor climate, fire and production is used but most other areas are virgin territory
- Adaptability: Old houses had large multipurpose rooms. Adaptability is however in it infancy

Short-Term to Industry:

- Identifying user values: We can't just ask in a question airy because that is not a tool to neither ask nor answer about tacit knowledge
- Interactive learning process: In the work with new user tools the developers of the tool, the interactive tools and the users all learn from the interaction
- Plug&Play concept: The building should be adaptable to changing users need through Plug&Play components

Medium-Term to Industry:

- Capturing users emotions: The extreme difficult part of it is to capture the emotions involved in choosing, designing and developing a tailor made building
- Simulating alternative value based scenarios: Giving the users a real choice
- Learning house: The house is actually learning from the users

Long-Term to Industry:

- Virtual reality=reality: Going directly from users dream to actual building without loss of information
- Feeling Value wizard for optimising complexity: Developing a tool that can interpret the tacit knowledge, emotions and intuition of users and clients
- Caring house: A house taking care of you as good parents, however without the ruling attitude of parents.

Project Ideas

Project: What You Feel Is What You Get

Keywords	Visual Tacit Knowledge Specification and Simulation Wizard
Industrial Problem	In this post-industrial knowledge and experience society relation to the clients and users are essential, while the actual production is a commodity. BIM has so far failed in making a difference to the clients and end users. It is considered a tool for architects and engineers but should be developed into a hub for all stakeholders It has proved very difficult to specify architectural, emotional and intuitive qualities with words and fit them into a word and number based data processing. But when 100 million people proposed the new 7 building wonders of the world http://www.new7wonders.com/ there is not one single modern box-shaped building among the nominees. People go on holiday to view buildings in places like Mt Saint Michelle, Venezia, Praha. Old house are more expensive than new ones. The problem is that people do not have a choice. They are only offered no frill square buildings. Einstein: “You cannot solve a problem within the paradigm that created it” So why would anyone want to transform something visual into words and numbers when we want to end up with a visual result in a 3D BIM? Why not keep it BIM from day one?
Technological Objectives	Development of an end-user client allowing visual interaction with building using BIM technology. Visual tool allowing for “what you feel is what you get” supporting building/home customisation by end user. Development of a simulation wizard to simulate user interaction and behaviour within virtual building/home.
Approach	Development of concept and specification for tools supporting “user experience” capture. Bundling of toolset based on existing technologies from different domains (e.g. construction, animation, visualisation) and creating interfaces to BIM for user-centric interactive access.
Results	An end user and client specification user interface to BIM
Time to Industry	5 years
Main Actors & Expertise	• Actors: Research institutions; BIM software vendors; CAD and rendering software vendors; Simulation software vendors; 3D on line game industry like SIMs, World of Warcraft; Disney Imagineering; Mobile industry; 3D scanning industry; From 2 to 3D software vendors • Expertise: Generative art network and R&D environment; Architecture; Industrial designers; Anthropology; Psychology; 3D visualisation tools
Main Beneficiaries	Users will get a better building BIM business model with BIM operator as key player
Industrial Impacts	Moving up the Maslow pyramid from the physiological need of shelter, and safety to belonging, esteem and self actualisation. From commodities to premium value design products due to • Enhanced and extended emotional value for users • Building beautiful at no extra cost • Focusing on value and benefit rather than cost • Plan for adaptability and change over time The same software could be used in any other visual design business like industrial design, graphics, movies etc
Follow-up Actions	Establishing a European and global R&D network about this project covering a feasibility study and software prototype

Project: 3D Printer

Keywords	BIM, robot, automated construction
Industrial Problem	The movie makers can design fantastic buildings on a computers but the construction industry cannot build them. So in real life BIM is only a kind of logistic and inventory tool. The process of transforming BIM into 2D drawings and lists is like reading a graphic PDF document over a phone line. BIM is restricted to geometrically very simple messages until the computer is connected directly to the production. Boeing 787 is woven directly by robots, car bodies are pressed in moulds milled directly from computers, and steel plates on ships are cut and folded directly by computers. The building industry needs something that works like a giant 3D printer using the BIM to control an automatic production process.
Technological Objectives	Specification of an automated industrial production solution to develop customised buildings/homes. Feasibility analysis of a possible “3-D” printer like concept to automatically build a building/home based on a BIM.
Approach	Review of available technologies and especially automated robotic technology for building large-scale products. Definition of software tools allowing for configuration of robots to build a building/home based on BIM.
Results	Direct transformation from BIM to building. The key results are expected to be: 3 stage 3D printer for buildings; Software to confine shape and space; Design and validation of process
Time to Industry	5 Years
Main Actors & Expertise	• Actors: R&D institutes; Robot manufacturers; Fibre reinforced concrete producers; PUR foam producers; Milling tool producers; Spray nozzle producers; CAD/CAM vendors • Expertise: FEM calculation; PUR foam expertise; Concrete expertise; Robot software; Robot construction
Main Beneficiaries	• The operator of the robot will be a new construction business just like concrete elements were 50 years ago. • The driving force at this stage is the providers of the robot • The beneficiaries will be the users of the building you can get the design they want, even with complex geometry, beautiful spaces and rich decoration
Industrial Impacts	A 3D printer will completely alter the construction business. It is like when desk top publishing completely altered the typographic industry.
Follow-up Actions	Establishing a European and global R&D network about this project covering a feasibility study and software prototype

Project: Caring Building

Keywords	Plug&Play, Intelligent installations, Computer assisted maintenance, Comfort, Safety
Industrial Problem	Buildings usually have a life time of 100+ years. The real advantage to the users is what difference BIM does to the owner and users within these 100 years. A key challenge is to integrate BIM and building automation.
Technological Objectives	Identification of products and services for on-demand building automation. Specification of solutions to support integration of building automation with BIM.
Approach	Analysis of user behaviour patterns. Development of tool to allow configuration of home installations (lights, heating, energy, windows, locking, etc.) based on user behaviour.
Results	The development from intelligent to caring buildings signals a change in mindset from the technology to the difference it makes to the user.
Time to Industry	5 years
Main Actors & Expertise	• Actors: R&D institutions; RFID producers; Window producers; Cell phone producers; BIM vendors; Genetic Algorithm software vendors; Intelligent building control vendors • Expertise: Intelligent installations; Architecture; Industrial designers; Anthropology; Psychology
Main Beneficiaries	Users, particular elder and disabled user plus the component industry /as almost all components will be smart components in the future
Industrial Impacts	The key result is that caring will have user attraction while intelligent buildings obviously didn't
Follow-up Actions	Establishing a European and global R&D network about this project covering a feasibility study and software prototype

Related Initiatives and Further Reading

- Strat-CON: value driven business processes; ICT enabled business models
- ERABUILD Plug&Play
- NICe Adaptable house
- TEKES: LIITO

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Appendix A: Workshop Participants

This by invitation only workshop was attended by 34 participants representing 12 countries. Each participant, their organisation, country, and role(s) in the workshop is presented in this appendix.

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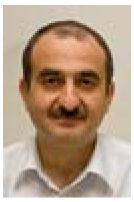

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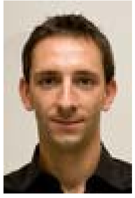

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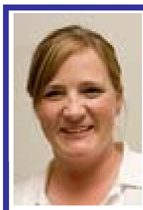

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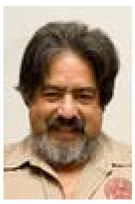

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Appendix B: Strat-CON Thematic Roadmaps

Overview

The construction sector is characterised by delivery of one-of-a-kind product and service delivery through competence sharing between different organisations (some of which may be unknown to others). ICT usage in the sector is limited and lags far behind other manufacturing sectors. The ROADCON project offered a vision for ICT in construction in addition to a set of roadmaps across 12 thematic areas. It did not however provide a means (in terms of research plans) for realisation of the vision. This report presents the Strat-CON project which was initiated to align the ROADCON roadmaps with the main thematic areas addressed by the European Construction Technology Platform's focus area on processes and ICT. Strat-CON furthermore through stakeholder interaction, has identified and developed a set of strategic actions for realising the vision of ICT in construction.

The eight main themes (for whom roadmaps were developed) along with their respective topics are illustrated below.

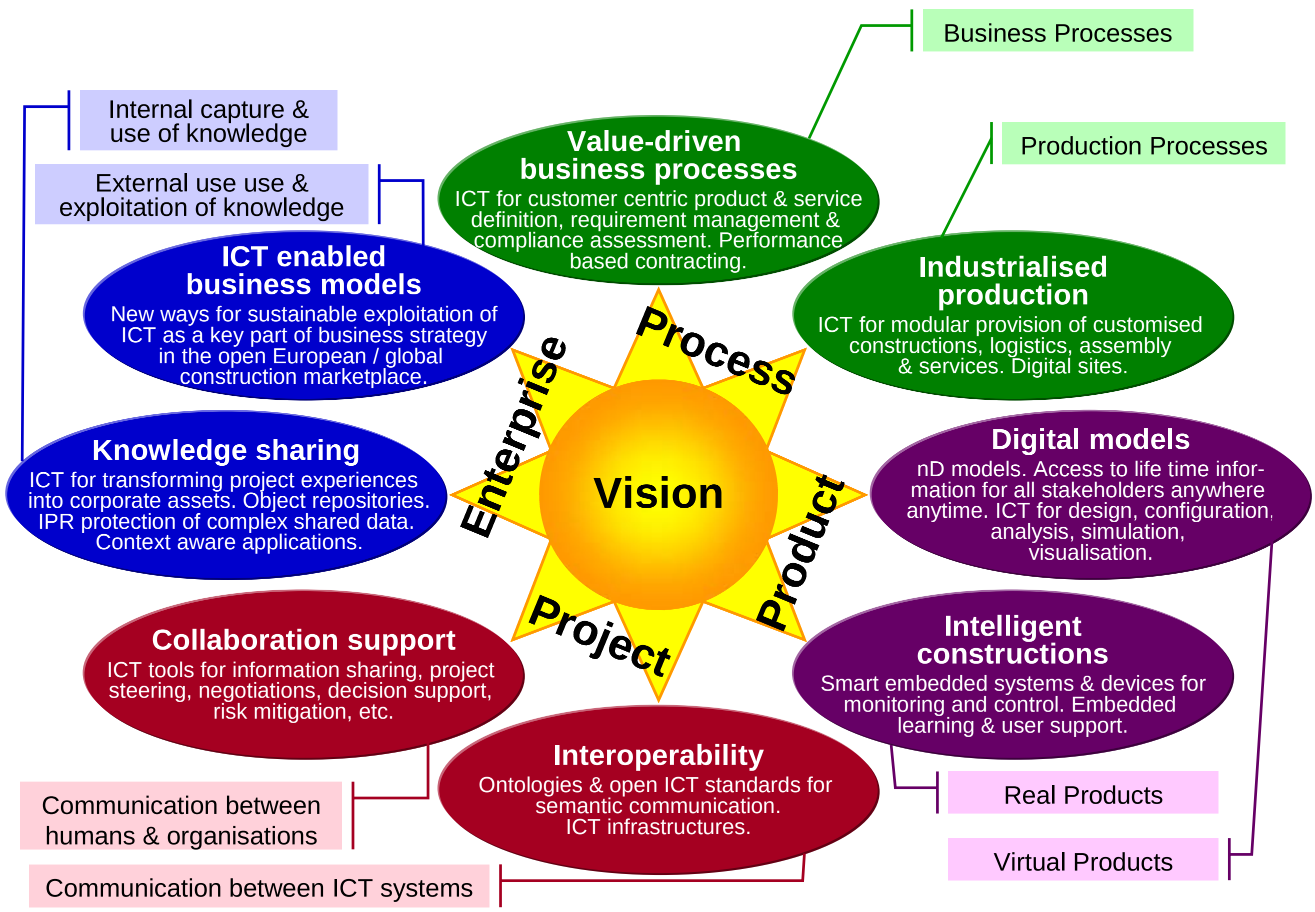


Figure 18: Strat-CON - Main Themes and Corresponding Topics

A set of key business drivers were identified for each roadmap supported by a set of key research topics. Furthermore, a set of short, medium and long term items (research topics) in terms of time-to-industry were identified for each roadmap. Through a series of interactive international workshops for each roadmap a list of strategic actions were identified to support realisation of the short, medium and long term items identified. Furthermore, some of the identified strategic actions were detailed.

ROADMAP: Value Driven Business Processes

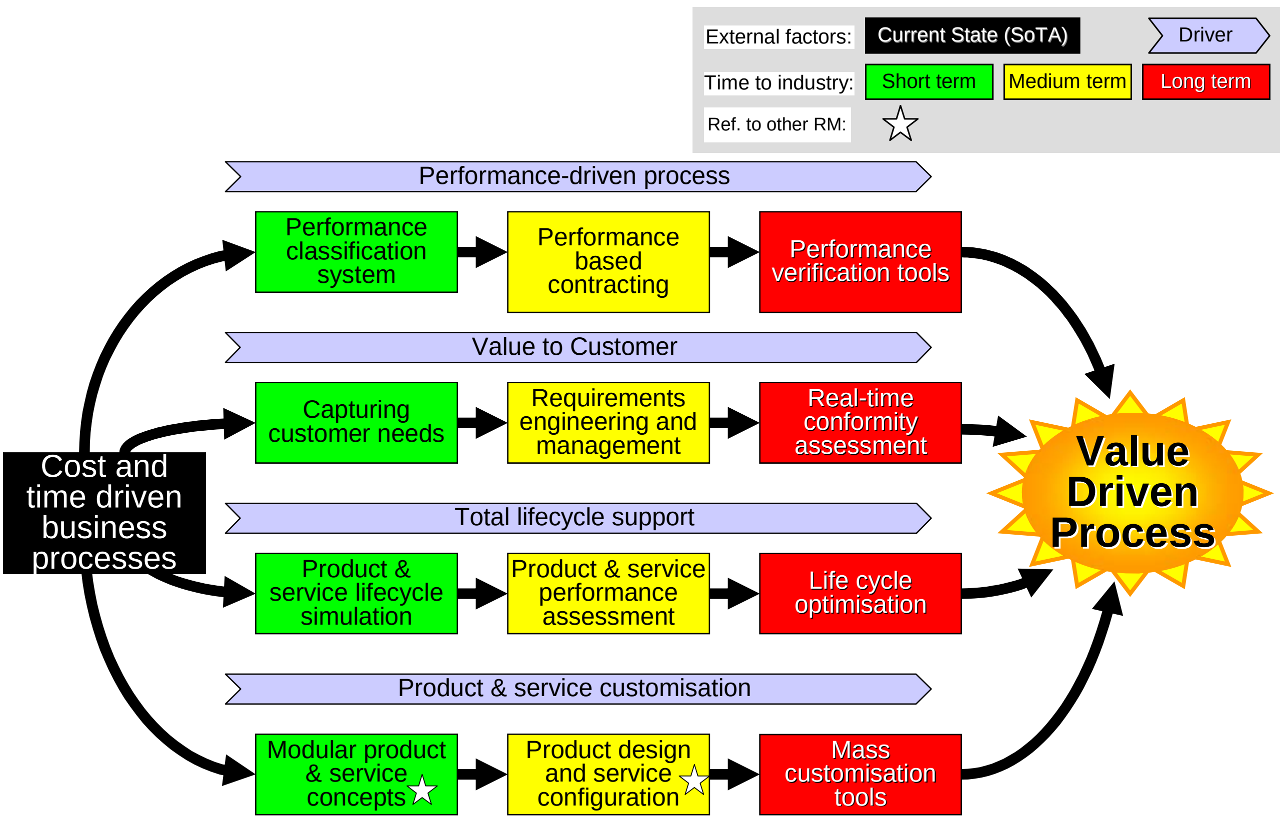
Main Business Drivers:	performance-driven process, value to customer, total life-cycle support, product and service customisation
Key Research Topics:	performance-driven processes, process orchestration, metrics, indicators, requirements engineering, mass customisation

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. 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.

This roadmap aims to address four main business drivers:

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



ROADMAP: Industrialised Production

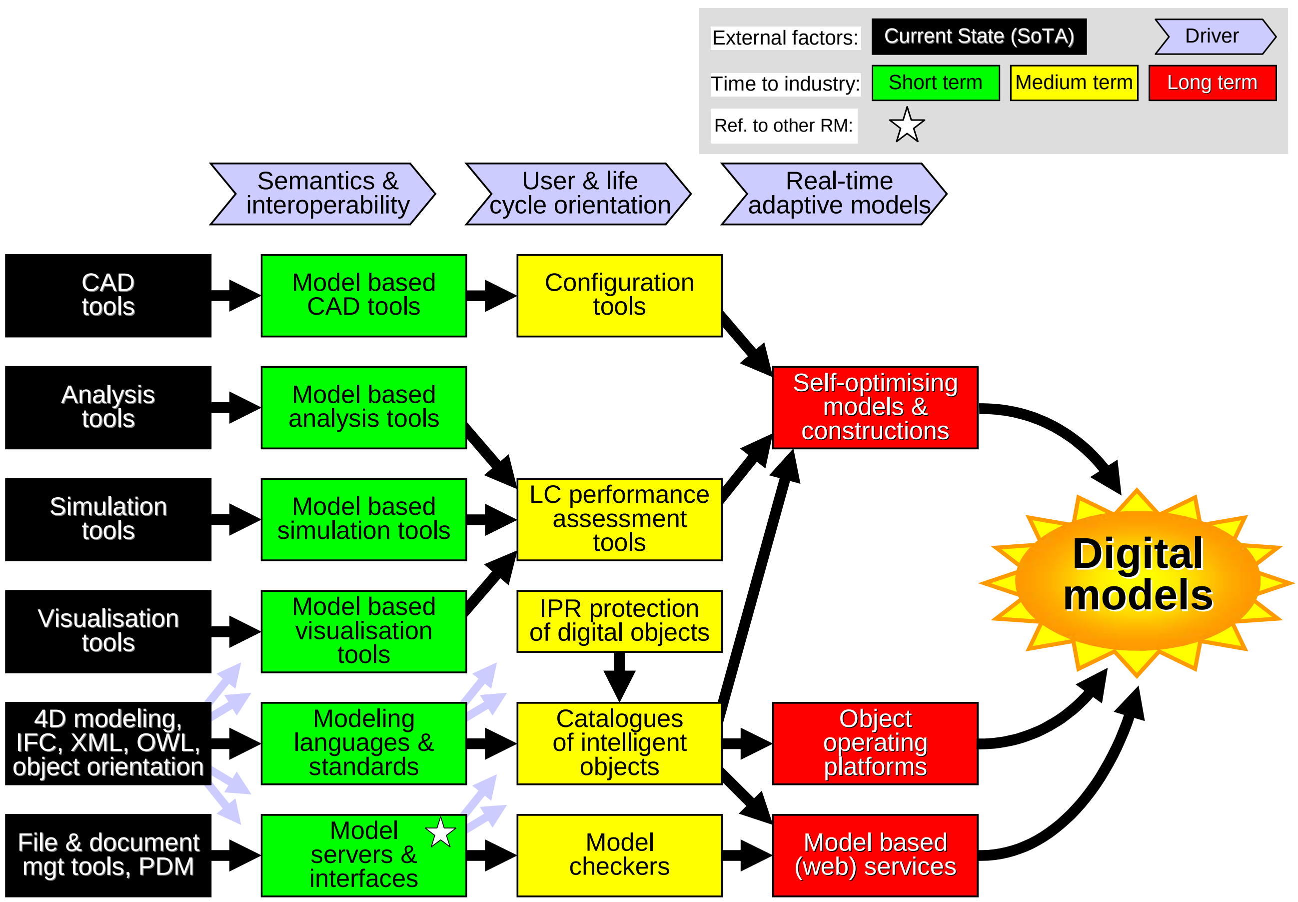
Main Business Drivers:	Supply network management; Open market; Effective manufacturing and construction.
Key Research Topics:	ICT support for modular provision of customised constructions; Logistics, on-site production and assembly; Integration of construction site in the process.

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.



ROADMAP: Digital Models

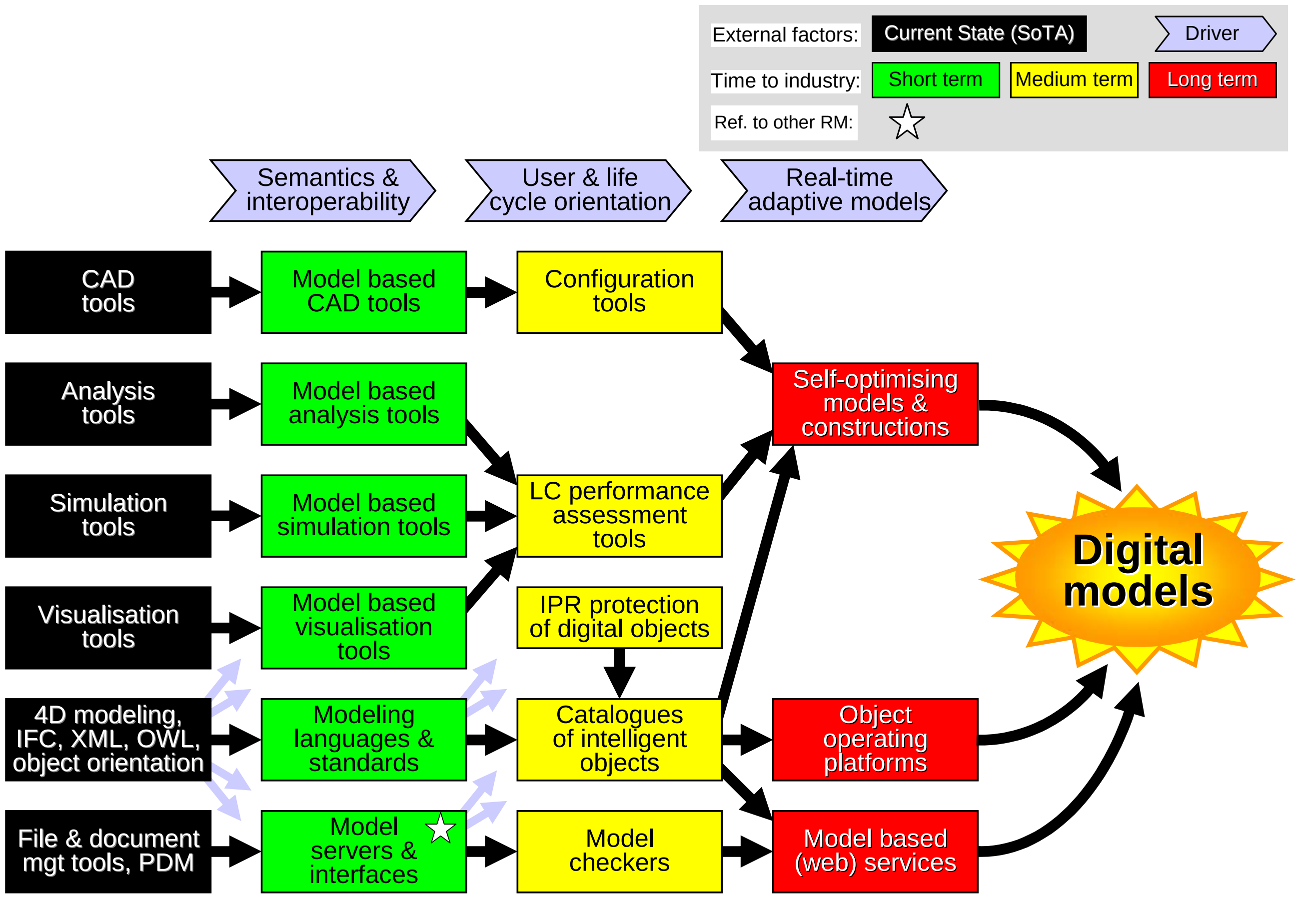
Main Business Drivers:	semantics and interoperability => user and lifecycle orientation => real-time adaptive models.
Key Research Topics:	nD models, access to life time information for all stakeholders anywhere anytime; ICT for design, configuration, analysis, simulation, and visualisation.

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 supporting performance visualisation, visual visualisation, and generation of manufacturing information on demand.



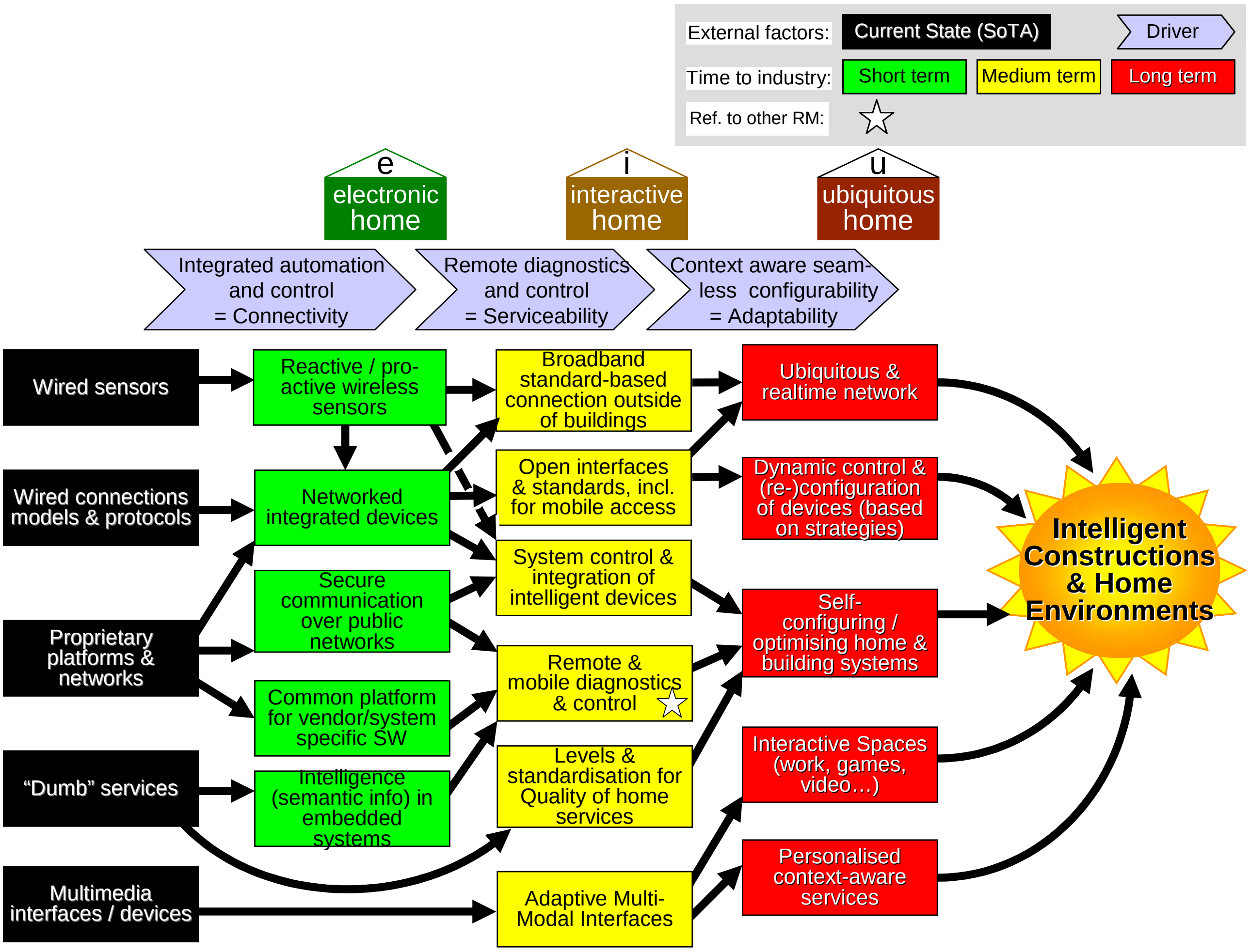
ROADMAP: Intelligent Constructions

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.

<u>Objectives</u>

The roadmap is to identify the various R&D axis required to transform today's 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
- 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.



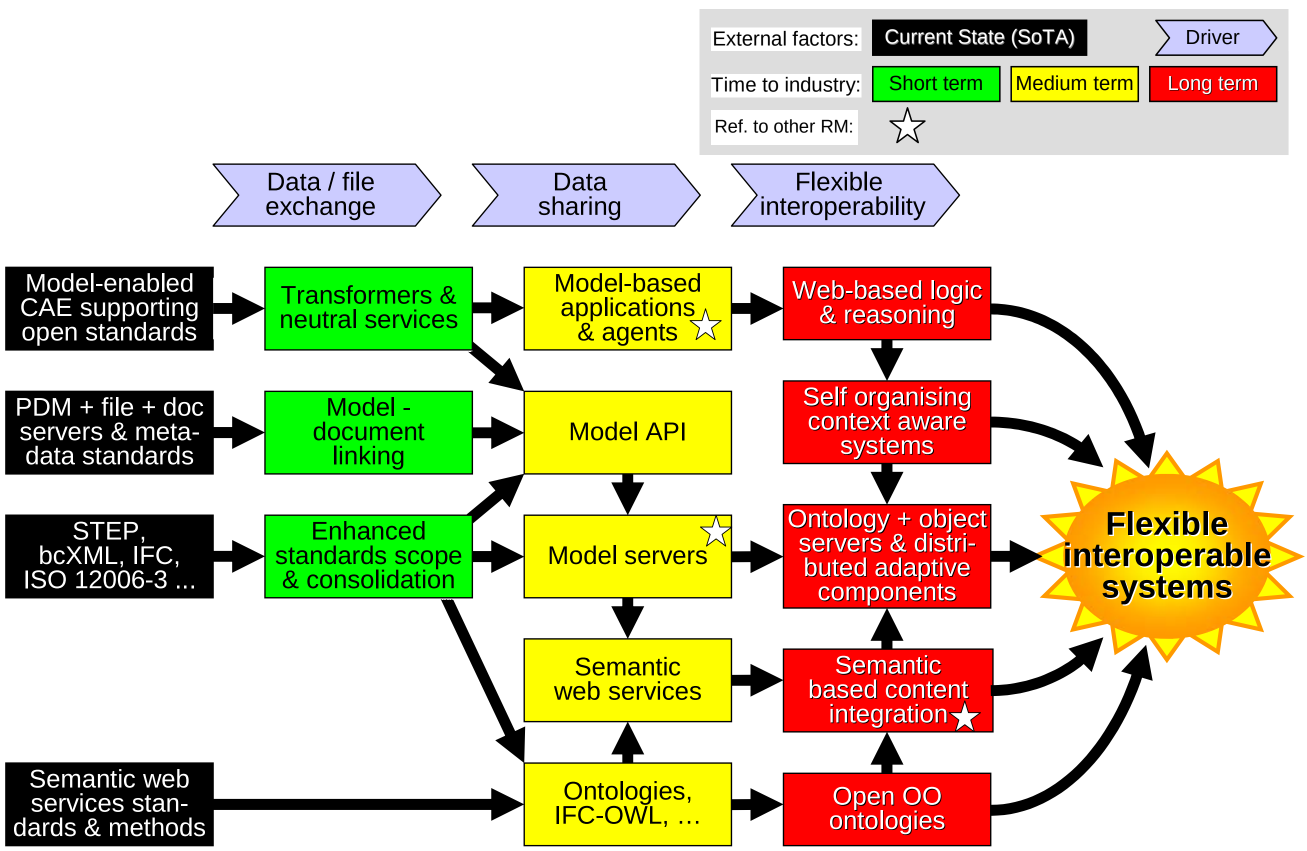
ROADMAP: Interoperability

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.

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)



ROADMAP: Collaboration Support

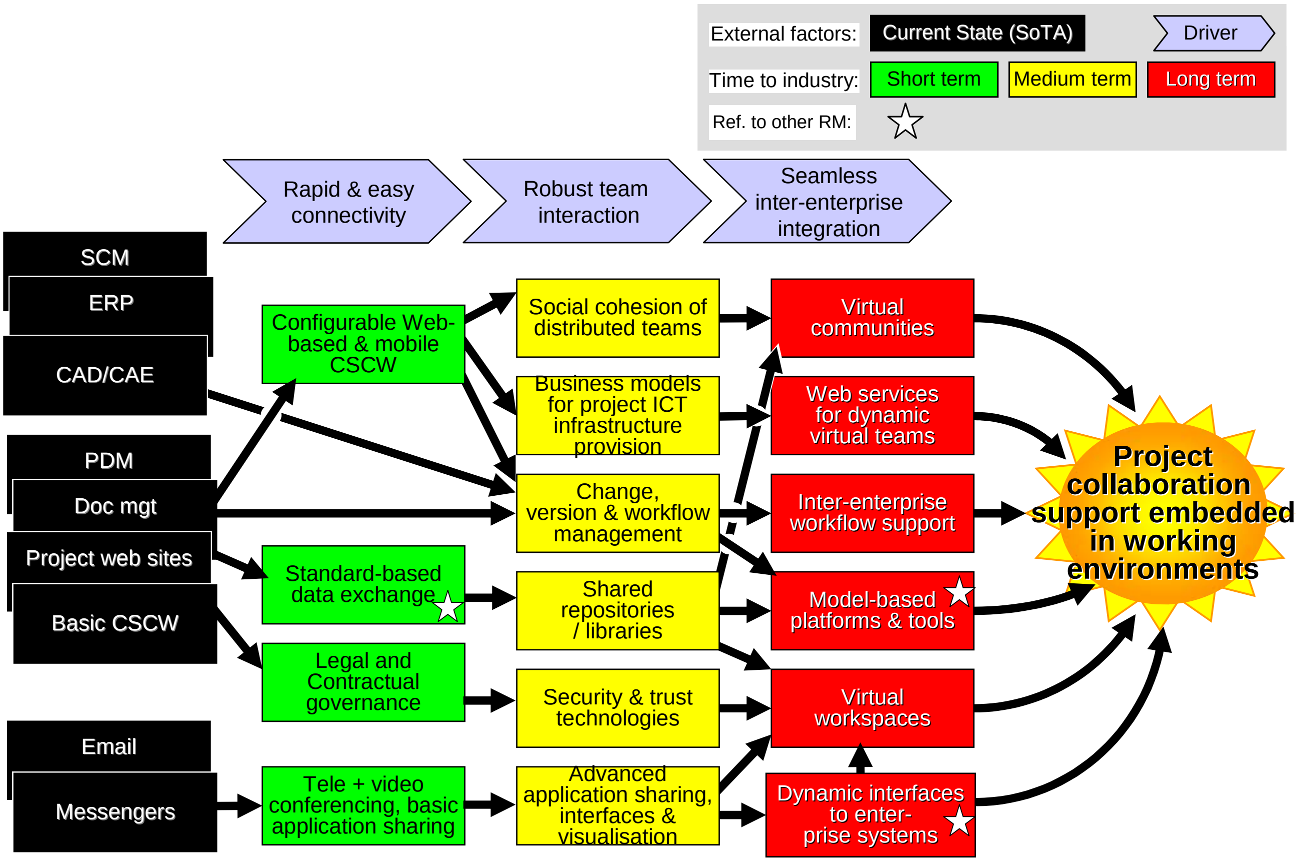
Main Business Drivers:	rapid and easy connectivity => robust team interaction => seamless inter-enterprise integration
Key Research Topics:	ICT tools for information sharing, project steering, negotiations, decision support, risk mitigation, etc.

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 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.



ROADMAP: Knowledge Sharing

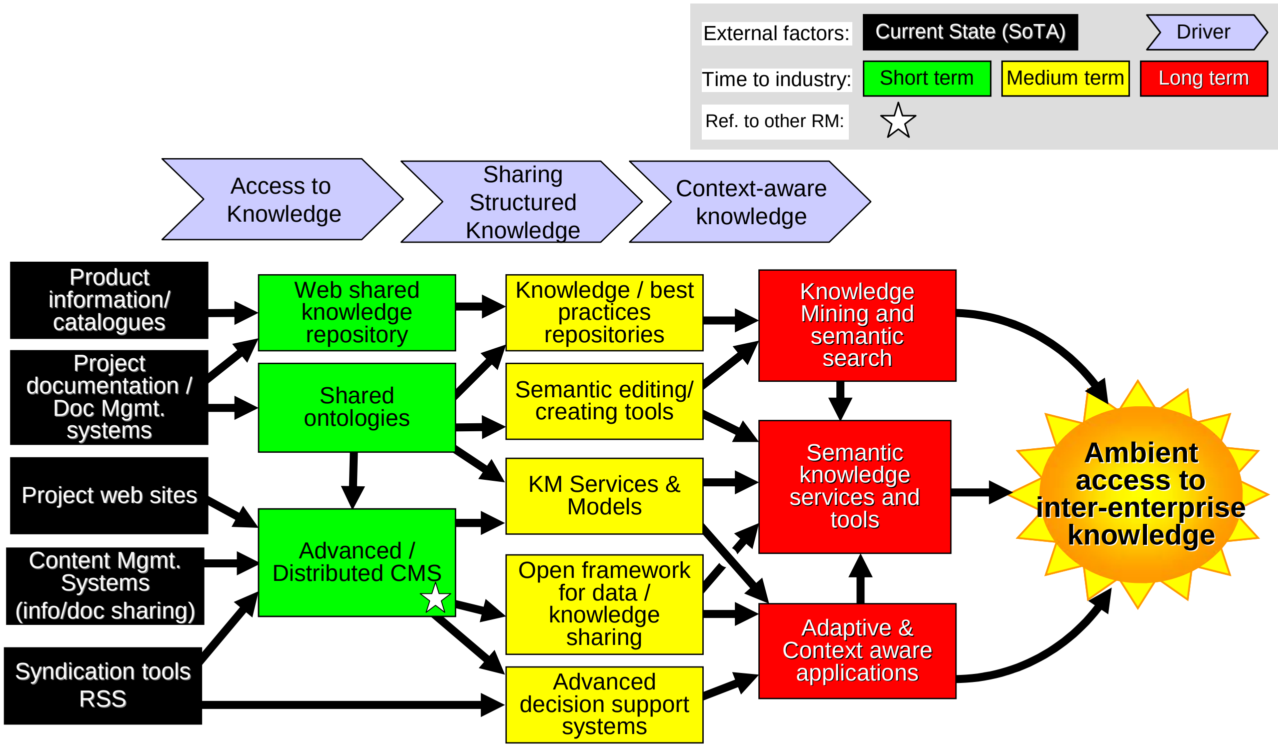
Main Business Drivers:	access to knowledge => sharing structured knowledge => context-aware knowledge
Key Research Topics:	ICT for transforming project experiences into corporate assets. Object repositories, IPR protection of complex shared data, context aware applications.

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.



ROADMAP: 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

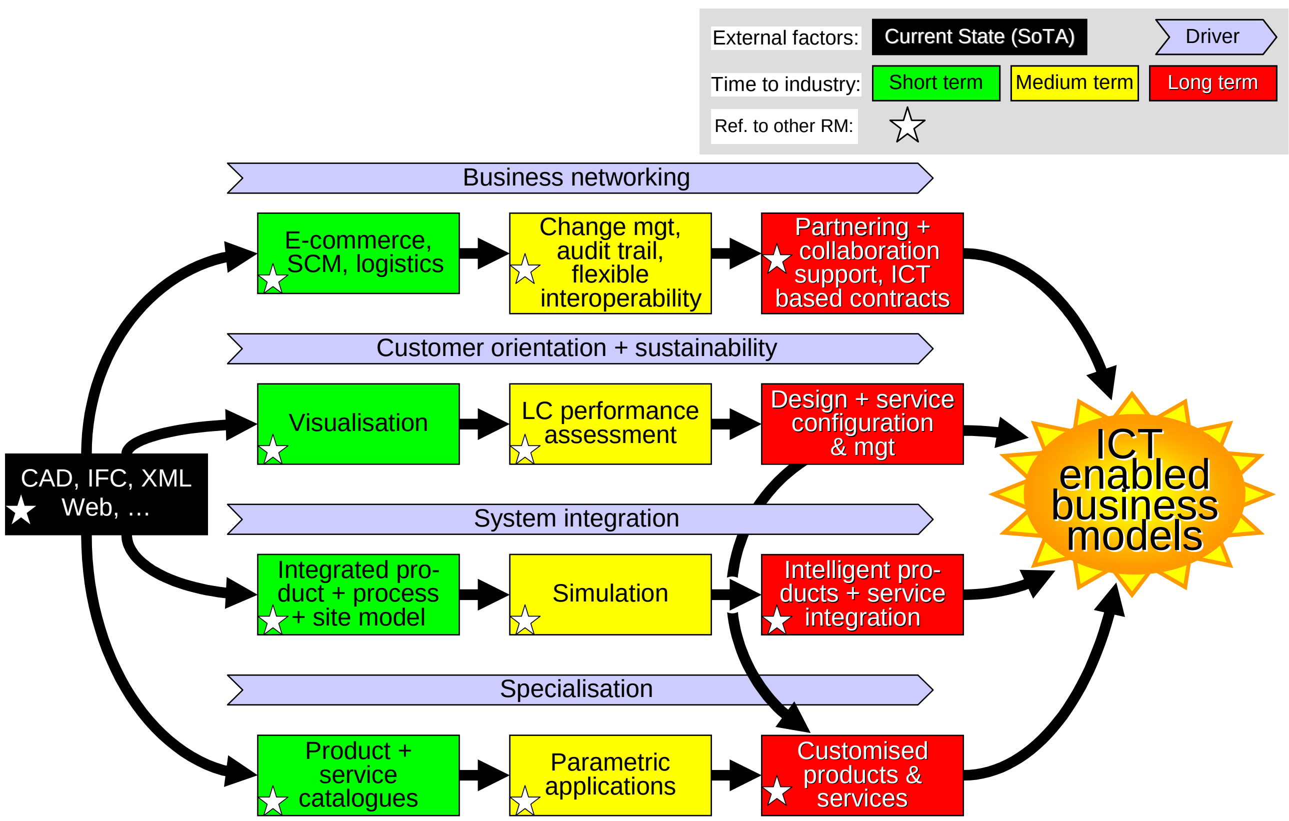
Objectives

The main objectives of this roadmap are to 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.

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)”.



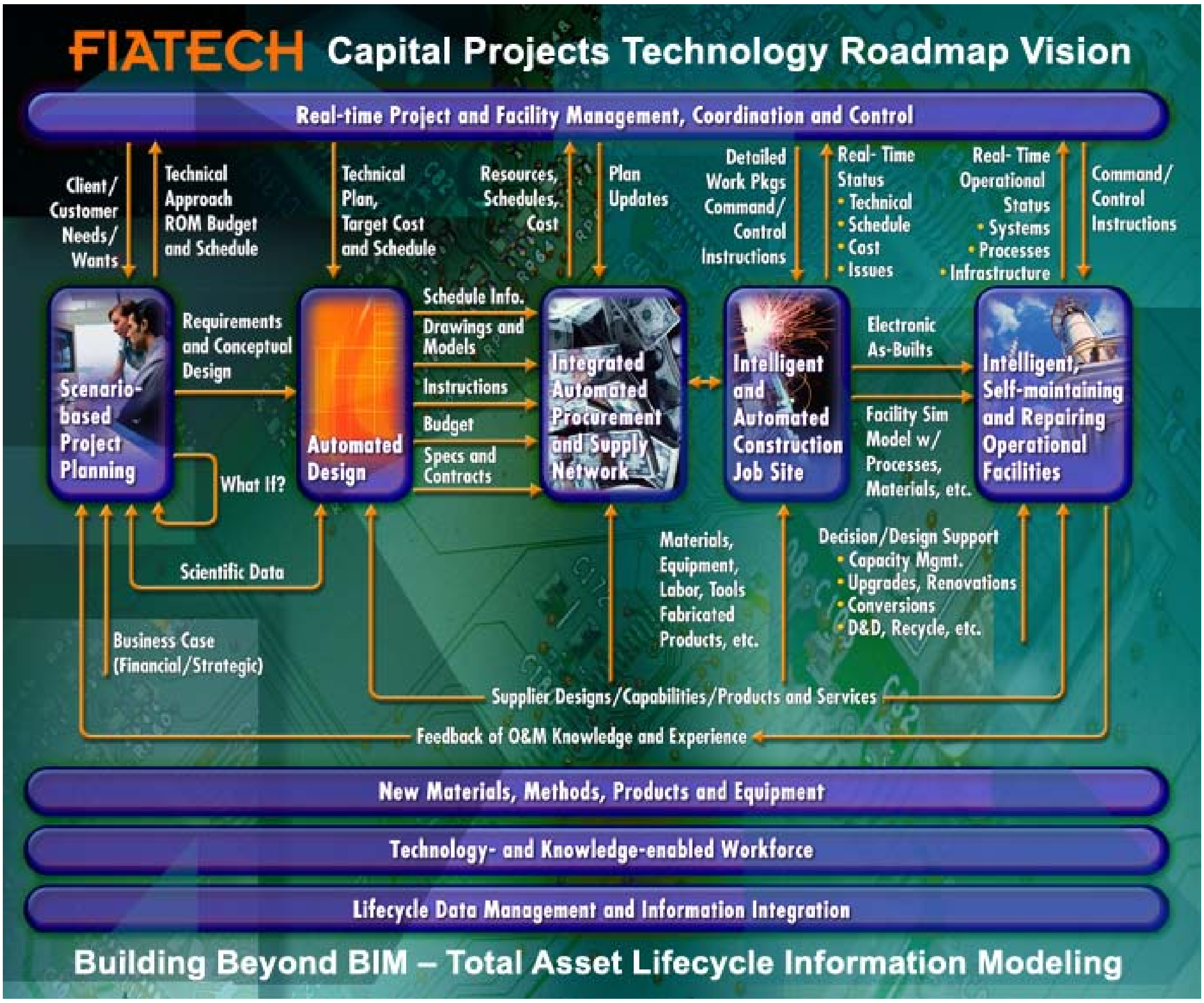
Appendix C: FIATECH Capital Projects Technology Roadmap

Overview

The Capital Projects Technology Roadmap (CPTR or the Roadmap) is a cooperative effort of associations, consortia, government agencies, and industry, working together to accelerate the deployment of emerging and new technologies that will revolutionize the capabilities of the capital projects industry. The initiative is led by FIATECH and is open to all stakeholders who are committed to the future success of the capital projects industry.

The Capital Projects Technology Roadmap presents a vision for the capital projects industry and a strategy and plan for achieving that vision. Representatives from all areas of the industry have come together to create this work. This is their vision, and their foundation for investment in the future.

"Fully integrated and highly automated project processes coupled with radically advanced technologies across all phases and functions of the project/facility lifecycle"



This vision is captured in the guiding model for the Capital Projects Technology Roadmap in the figure above. This model depicts a completely integrated structure composed of nine critical elements and can be thought of as a virtual enterprise for the future.

For more information on the FIATECH Capital Projects Technology Roadmap, its individual elements and their respective projects, visit: http://www.fiatech.org/projects/roadmap/cptri.htm.

Element 1: Scenario-based Project Planning

Vision

The future project planning system will provide interactive evaluation of project alternatives, enabling creation of conceptual designs and project plans that best meet the needs of all stakeholders. This collaborative planning environment will provide full awareness of the impacts of decisions on costs, schedules, and lifecycle performance. The system will provide the initial input to a comprehensive project plan and specifications, ultimately captured in an Asset Lifecycle Information System, to guide subsequent project designs and support downstream project functions.

Scope

Provides a comprehensive, collaborative project planning system that captures and analyzes front end data (including business case, scientific data, what-if scenarios, requirements and conceptual design, customer needs, budget and scheduling, and feedback from operations and maintenance) to assist the planning team as well as to provide the initial data capture to be used throughout the lifecycle of the facility.

Technology

Business Intelligence, Scenario modelling, Knowledge Management, Collaboration, Workflow, Data Mining, Simulation, Process recording, Document Management, Visualization

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefits
Owners/Operators	Rapid and complete agreement on what will be designed, built, and operated - reduces cost, risk, and project cycle time. Considers views of all stakeholders.
Research and Development (R&D) Teams	Seeks alignment on project technology and provides a clear direction on further development required.
Designers/Engineers	Accurate and complete electronic definition of project requirements - reduces design time, eliminates ambiguities, and reduces technical risk.
Constructors	Provides a voice in the early phases to ensure constructability, reduce risks, and eliminate unnecessary challenges - reduces build time and cost
Material/Equipment/Technology Suppliers	Enables early start on long lead items, more cost-competitive solutions through clear specification of requirements, and early mitigation of technical and schedule risks

Focus Areas

- E1-FA1: Work Process Mapping
- E1-FA2: Industry Tool Survey
- E1-FA3: Reference Data Requirements
- E1-FA4: Functional Requirements
- E1-FA5: Data Model Requirements
- E1-FA6: Design & Develop Next Generation Tools and Database

Element 2: Automated Design

Vision

Current and emerging capabilities in 3-D design, analytical modelling and simulation, intelligent systems and distributed information management offer the opportunity to create a truly integrated and automated project design environment. In this environment, all tools will work together as an interconnected system that provides all of the functionality needed to develop and validate detailed designs for every aspect of a project based on the design criteria. This integrated design environment will dramatically reduce the time and cost in moving from concept to construction execution through automation of complex design engineering tasks. It will also greatly reduce errors and liability through comprehensive, automated design optimization and verification. Optimization would include a variety of options including total installed cost, total lifecycle cost, and plant output.

Scope

Provides the forum for an industry-wide set of design automation features and specifications to be created that will be available for software vendors to use when developing improved design automation software. Also provides a design automation information clearing house that will serve as a knowledge management resource. Enables industry stakeholders and software vendors to work collaboratively to develop improved design automation technology for the capital projects industry.

Technology

Knowledge Management, Collaboration, Standards, Simulation, Rules Based Design, Change Management, Risk Assessment

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefit
Owner/ Operators	Full assurance that designs are in direct response to requirements and optimized to meet the needs and constraints of all stakeholders –reducing total cost of ownership over the life-cycle, shortening timelines to completion, mitigating risks, and providing clear visibility of risks.
Architects	Improved efficiency in translating concepts to buildable designs; enhanced ability to translate design capabilities into innovative design solutions Improved ability to integrate the entire design team, including the owner, to reduce changes in scope or design later in the design process and during construction.
Designers/ Engineers	Improved capability and efficiency through built-in analytical and validation tools, automation of all routine tasks, and mathematically accurate visualization of all aspects of the project design with respect to Owner project requirements, building codes, and applicable standards.
Constructors	Delivered contract documents will provide a complete and totally optimized and synchronized build plan. The Building Information Model and related electronic documentation will support fast, flawless execution with zero wasted time, effort, and resources.
Material/ Equipment/ Technology Suppliers	Clear, complete and unambiguous definition of all materials, parts, products, equipment, and other procured resources will enable more cost-effective operations; connectivity to design team will provide streamlining the processes for bidding and construction submittals.
Design software vendors	Vendors need to understand the market benefits associated with developing products that embrace the vision of an automated design environment before they will make decisions to invest in its development. A chorus of clear, concise and unified voices providing a common message will create incentives to the software vendors to enhance their products quickly and support the automated design vision. Regardless of the proprietary software applications, it is imperative that all data can be exchanged between these platforms using open standards for interoperability, so there is no rework or multiple input of data information.

Focus Areas

- E2-FA1: Metrics for proof of concept and demonstration of capabilities
- E2-FA2: Design Viewing
- E2-FA3: Integrated/Interoperable Design Systems
- E2-FA4: Intelligent Design Systems
- E2-FA5: Create and maintain a design automation information clearinghouse

Element 3: Integrated, Automated Procurement & Supply Network

Vision

The procurement system of the future will be seamlessly integrated with the project design system, project management and control system, finance system, field materials management system and the global supply network. This will enable enterprises and project teams to optimize work packages, select products, identify qualified suppliers, and procure the best products at the best prices with complete confidence and ability to deliver on time and within budget. These linked systems will automatically track every order through delivery to the job site, orchestrate the flow of resources for optimal build efficiency and provide instant visibility of progress and variances against technical, schedule, and cost requirements throughout the selection, delivery and payment processes.

Scope

Provide a fully integrated, automated procurement and supply management system (i.e. tools and processes for planning, controlling, including financial controls for the procurement process.)

Technology

Supply Chain, Procurement, Project scheduling and control, Logistics, Materials Handling, Dynamic Mapping and Simulation of Supply Chain, Standards, AEX, Work Process.

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefit
Owner/ Operators	- Reduced efforts in capital project business development and estimating phases - Reduced costs and assured best value in all procurement actions - Faster development/preparation of inquiries - Reduced bid cycle time
Architects	- Easy access to product feature and cost information to enhance innovation and affordability of design concepts.
Designers/ Engineers	- Reduced efforts in capital project business development and estimating phases - Full access to design data for purchased materials, components, and equipment will enable better designs and eliminate disconnects between design specifications and delivered products - Faster development/preparation of inquiries - Reduced bid cycle time - Higher quality specifications (with early owner input), RFQ, BID, POs will help to reduce downstream changes and associated cost - Reduced time for inspection activities
Constructors	- Reduced efforts in capital project business development and estimating phases - Reduced bid cycle time - Higher quality specifications, RFQ, BID, POs will help to reduce downstream changes and associated cost - Reduced time for inspection and on-site receiving activities - On-time delivery of exactly the right resources to point of need, tightly synchronized to the project schedule, will speed construction, eliminate downtime, and drastically simplify site staging requirements.
Material/ Equipment/ Technology Suppliers	- Clear and definitive agreement on cost, delivery, product specifications, and conditions of contracting - Higher quality RFQ, BID, POs will help to reduce downstream changes and associated cost - More efficient sales/business development processes - Reduced bid cycle time - Reduced time for inspection activities

Focus Areas

- E3-FA1: Integration of Engineering and Project Controls with Procurement
- E3-FA2: Supply Chain Information Access and Standards
- E3-FA3: Integration of Procurement with Intelligent Job Site
- E3-FA4: Evaluation of Supply Chain Structures

Element 4: Intelligent & Automated Construction Job Site

Vision

Provides the forum for construction practitioners, material providers and technology providers to make a concerted and systematic effort to identify, develop, deploy and evaluate the impact of the components, systems, standards and deployment strategies that are needed for successful Intelligent and Automated Construction Job Sites.

Scope

Construction sites will become more "intelligent and integrated" as materials, components, tools, equipment, and people become elements of a fully **sensed and monitored environment**. Location and status of all materials, equipment, personnel, and other resources will be continuously tracked on site, thus enabling a "pull" environment where needed resources are delivered on demand. **Automation of construction processes** will augment manual labour for hazardous and labour-intensive tasks such as welding and high-steel work. Construction job sites will be **wirelessly networked** with **sensors** and communications technologies that enable technology and knowledge-enabled construction workers to perform their jobs quickly and correctly.

Technology

Smart Chips (RFID and Sensors), Wireless Technology, Location Based Systems, Mobile Devices, Displays, Work Package Optimization, Construction Automation, Pre-fab/Materials, Survey and Positioning, Modeling and Simulation, Skills Certification, Asset/Site Security

Stakeholders and Foreseen Benefits

Main benefits are to the construction site. Key features and associated business benefits at a site level as are follows:

Feature	Direct Business Benefit
Model-driven, highly sensed job site environment	-Dramatically improves communication between constructors, engineers and suppliers -Delivery of material as needed and reduced costs for storage and lost material -Real-time problem identification and fast resolution -Streamlined workflows reduces build time and cost -Reduce of lost/stolen materials, products, tools, and equipment -Elimination of redundant data entry and entry errors
Continuous visibility of performance vs. plan	-Fast identification and accurate scoping of changes and variances -Accurate capture of costs to improve planning and competitiveness for future projects
Automated, highly accurate capture of as-built data fed to Asset Lifecycle Information System	-Reduces schedule slips due to continuously current visualization aids used for engineering constructability issues in-process -Eliminates cost of "unpleasant surprises" during operational startup -Shortens handover and start-up timelines
Highly visible sequencing and schedules from multiple parallel activities	-Enables increased concurrency of activities to reduce build time
Automatic generation of work orders, resource allocations, and schedule with highly integrated material flow	-Reduces downtime -Reduces time and space requirements for staging and storing material on site -Reduces working capital requirements for held inventory
Technology-enabled workers	-Greatly increases productivity

Focus Areas

- E4-FA1: Standards and Practices
- E4-FA2: Field Information Systems
- E4-FA3: Positioning and Tracking
- E4-FA4: Construction Equipment and Technology

Element 5: Intelligent Self-maintaining and Repairing Operational Facility

Vision

Future capital facilities will be programmed, designed and constructed to be an intelligent integrated system of systems. These intelligent systems will utilize the data flow from self monitored equipment and systems to manage the actions necessary to ensure conditions and performance necessary to enable safe, secure, and continuously optimized facility operations. Facility systems will be totally integrated to utilize data generated during operation to automatically and autonomously activate built-in mechanisms to perform required maintenance and/or repair functions. If necessary, instructions will be automatically communicated to external support systems when the required actions are beyond the capabilities of the built-in mechanisms. A comprehensive network of sensors and decision support systems will provide continuous visibility of operational status and performance, providing trends for systems and flagging problems with recommendations for external intervention. Information from the embedded systems will provide feedback to future programming/design/ construction operations in support of the business and/or regulatory environment to ensure optimal facility utilization, even during response to crises.

Scope

Intelligent Self Maintaining and Repairing Operational Facilities provides the mechanisms for utilization of data to manage the actions necessary to ensure conditions and performance necessary to enable safe, secure and continuously optimized maintenance and operations.

Technology

Sensors, GREEN, LEED, BIM, Sustainability, Automated/Integrated Decommissioning and Demolition, Real Time data, Modeling and 4D Simulation, Facility Monitoring/O&M

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefit
Owner/ Operators (including O&M)/ Commercial Real Estate	- Continuous optimization of performance and profitability across the entire facility life - Reduced risk, liability, and total cost of ownership -"Disaster-proof" operations -Improved ability to respond to changes in the business environment -Facility condition assessment will lead to better and more effective use of funds and personnel
Occupants/ Tenants/ Service Providers	-Access to information for optimizing operations and tasks
Architects	-Feedback of O&M experience and lessons learned to continuously improve design of future facilities
Design/ Engineers	-Feedback of O&M experience and lessons learned to continuously improve future facility designs -Enable effective facility upgrades, renovations, and conversions to alternate use
Construction	-Radically reduced time and cost of operational start-up and handover -Accelerated ramp-up to full operating capability
Material/ Equipment/ Technology Suppliers	-Greatly expanded opportunity for product evolution to support next-generation facilities in all sectors of industry
Insurers/ Finance/ Energy Providers	-Reduction and control of risk (perception)

Focus Areas

- E5-FA1: Facility Condition Assessment
- E5-FA2: Facility Performance
- E5-FA3: Information Exchange
- E5-FA4: Intelligent Materials
- E5-FA5: Catastrophic Event Mitigation and Recovery Technologies
- E5-FA6: Automated/Integrated Decommissioning and Demolition Techniques & Technologies

Element 6: Real-time Project and Facility Management, Coordination and Control

Vision

Future management systems will empower integrated orchestration and control of Project and Facility processes, and will be a tool that provides continuous visibility to all plans and tasks throughout the planning, design, construction and facility lifecycle. The result will be a well-orchestrated series of interrelated tasks and activities optimized for efficiency and results, coordinating resources and plans in an error-free fashion, radically reducing the time and cost required to move from planning to design to construction to operation.

Scope

Provides a fully integrated facility planning and management system (i.e. tools and processes for planning, control, and review, including financial controls - of design, construction, and ongoing facility management). While Project and Facility Management are classically treated as separate and distinct sets of processes with a discrete handoff point, this Element treats them as a single set of processes covering the continuum from initial planning to the end of life of the facility.

Technology

Project Management, Data Information Repositories, Real Time Information, Process Models, Performance Management and Assessment, Change Management, Quality Metrics, Financial Standards, Decision Support Tools, Standards for Project Data, Workflow, Cost Models.

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefits
Owner/ Operators Facility Managers	- Full and continuous awareness of project status enables fast, sure response to issues, leading to more effective facility turnover and operation. - Better knowledge management will lead to project efficiencies, multiple plant efficiencies, and reduced design, construction, and operating costs resulting from shared maintenance and operations procedures, parts, and reduced costs from prototypical upgrades.
Design Firms	- Feedback of comprehensive information will enhance conceptual design capabilities, reusable designs, and the process of issuing the design to users. - Extensive feedback loop (constructability, etc), will lead to reduced errors and omissions and field rework/redesign
EPC Firms	- Highly responsive and efficient change management - Early and accurate feedback on design performance and compliance.
Project/ Construction/ Program Managers	- Clear and current visibility of status and progress of all tasks, early warning of problems, and quick access to information and resources for problem-solving.
Material/ Equipment/ Technology Suppliers	- Instant access to information concerning their obligations to the project and an ability to mesh materials and technologies in a just-in-time environment. - More rapid pay cycles

Focus Areas

- E6-FA1: Intelligent Project Management System
- E6-FA2: Streamlined, knowledge-driven approval processes
- E6-FA3: Optimized Construction Sequence and Schedule
- E6-FA4: Real-Time, Model Based Project and Facilities Control
- E6-FA5: Automated, Distributed Change Management
- E6-FA6: Automated Quality Assurance and Quality Control
- E6-FA7: Integrated Stakeholder Business Systems
- E6-FA8: Verification of Financial performance

Element 7: New Materials, Methods, Products & Equipment

Vision

New materials, methods, and equipment will enable rapid, low-cost construction of modularized, lightweight structures in a fraction of current time spans by applying highly engineered fabrication and assembly methods. Flexible and "programmable" properties will enable new generations of stronger, lighter materials to be easily transported, placed, formed, cured, and attached with little or no temporary support. New and improved processes engineered for efficiency will radically reduce labour and material costs. Self-assembling robotically controlled, and automatically activating components will replace the most troublesome of today's processes.

Scope

Provide an industry-focused Clearing House for New Materials, Methods, Products and Equipment. Also, identify and manage the content to go into one or more of the shared or common knowledge bases. For example, identify common industry-adopted methods or practices as well as materials and equipment information.

Technology

Knowledge Base, Smart Materials and Components/Assemblies, Reconfigurable Materials, Automation Integrated into Materials, Model-driven Construction Systems, Engineering for Automated Construction, New Connection Technologies and Methodologies, Standardized Construction Components, Low-impact Site Prep, Improved Joining, Zero Temporary Structures, Intelligent/Interactive Construction Equipment and Systems, Programmable Nanomaterials and Nanoconstructors, Biomimetic Materials/ Structures and Facility Systems, Non-intrusive Autonomous Effectors, Legacy Integration and Emulation Technologies, Advanced Materials for Reinforcement and Resurfacing, Lean Construction, Autonomous Robots.

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefit
Owner/Operators	Better facilities at lower cost.
Architects	Specification and utilization of new materials and processes enables innovation in facility design.
Designers/Engineers	An expanded array of better options.
Constructors	More efficient processes. Elimination of the time and cost of temporary fixtures, wait times, etc.
Material/ Equipment/ Technology Suppliers	New opportunities to develop products and services - especially for global markets.

Focus Areas

- E7-FA1: Establish and maintain the new materials and methods coordination role
- E7-FA2: Establish and maintain a knowledge base of new materials and methods

Element 8: Technology- & Knowledge-enabled Workforce

Vision

Skilled and committed workers, enabled by technology and empowered by "knowledge at their fingertips" will perform to new levels of productivity. Workers in all functions of the capital projects enterprise will be enabled by technology that assists them in doing their jobs more effectively. Traditional divisions of labour and skills will be redefined, from the top floor to the trenches, to broaden the capabilities and value of every worker in the emerging team-based project environment. Redefined organizational allegiances and incentives will result in a more stable and reliable labour supply for all of the industry. A "knowledge supply chain" will assure the ready and consistent supply of the right workers with the right skills.

Scope

Provides a focus on the human implications of technology for the capital projects industry. Properly trained and skilled labour supply. Improved skills and knowledge empowerment. Improved productivity and employment security, safety, health, and environmental compliance

Technology

Knowledge base, Collaboration, Knowledge Supply Network, Incentives and Rewards, On-demand training, Interactive Work Instructions, Rugged Information Systems, Worker Certification and Verification Systems.

Stakeholders and Foreseen Benefits

Stakeholder	Specific Benefit
Owner/Operators	Ready supply of skilled and trained workers invested in enterprise success; greatly improved flexibility to respond to changing business requirements.
Architects	Confidence in ability of workforce to execute designs, particularly in complex project environments.
Designers/Engineers	Reduced learning curves for leading-edge tools; higher confidence in ability of workforce to translate designs to reality.
Constructors	Greatly improved skills and labour flexibility; assured compliance with HSE and technical requirements; improved workforce stability.
Material/Equipment/ Technology Suppliers	Significant reduction in problems at end user level.

Focus Areas

- E8-FA1: Skilled and Committed Workforce
- E8-FA2: Knowledge Management for Capital Projects Industry
- E8-FA3: Collaborative Business Process Management and Workflow

Element 9: Lifecycle Data Management & Information Integration

Vision

The long term vision of Element 9 of the Capital Projects Technology Roadmap (the Roadmap) is that the execution of future capital projects and operation of capital facilities will be radically enhanced by seamless access to all data, information, and knowledge needed to make optimal decisions in every phase and function of the capital project/facility lifecycle. Element 9 (Lifecycle Data Management and Information Integration) provides a foundation layer for the highly automated project and facility management environment envisioned in the Roadmap.

Scope

Provides the standards, models, classifications and other mechanisms for both data management and information exchange for the industry. Includes the foundation for and programs to create and maintain shared or common knowledge-bases. Enables and motivates individual organizations to accelerate the process to create and deploy an Asset Lifecycle Information System: i.e. a fully integrated solution in which the standards, models, classifications and other mechanisms are implemented for a specific project or facility.

Technology

Data transfer standards, interoperability, knowledge bases, asset life cycle information system, model-based information management, ontologies, digital models, expert rule-based systems, object repositories, process simulation, lifecycle data management system, reference data libraries, ISO 10303, ISO 15926, ISO 12006, IAI/IFC, FIATECH/cfiXML, W3C XML, FIATECH/AEX, etc.

Stakeholders and Foreseen Benefits

Stakeholder	Benefits
Owner/Operators	True integration of business and technical systems across all functions, all phases of the lifecycle, and all members of the supply chain will reduce capital costs and operating expenses, enable real-time responsiveness, and eliminate sources of error and problems.
Architects	One time data entry; seamless integration with design/engineering functions.
Designers/Engineers	Instant access to accurate data for design, analysis, engineering, and requirements management; transparent integration of all applications.
Constructors	Right knowledge and data available on demand to accomplish every task quickly, surely, correctly - and solve problems before they impact performance.
Material/Equipment/ Technology Suppliers	Seamless integration into any supply chain, with direct linkage to customers; eliminate need to support multiple systems (design, purchasing, etc.) for multiple customers.
Information Technology Groups	Reduced focus on inventing ways to store and exchange data. Increased focus on supporting the business needs of their clients

Focus Areas

- E9-FA1: Requirements and Feasibility
- E9-FA2: Technical Framework
- E9-FA3: Shared or Common Data
- E9-FA4: Asset Lifecycle Information System Deployment

Sponsors and Contact Information

Sponsor Profiles

FIATECH www.fiatech.org

FIATECH is a consortium of leading capital project industry stakeholders. It provides global leadership in identifying and accelerating the development, demonstration and deployment of fully integrated and automated technologies to deliver the highest business value throughout the life cycle of all types of capital projects.

CIB www.cibworld.nl

CIB is the International Council for Research and Innovation in Building and Construction. It provides a global network for international exchange and cooperation in research and innovation in building and construction, in support of an improved building process and of improved performance of the built environment.

VTT – Technical Research Centre of Finland www.vtt.fi

VTT Technical Research Centre of Finland is an impartial expert organisation. Its objective is to develop new technologies, create new innovations and value added thus increasing customer's competitiveness. With its know-how VTT produces research, development, testing and information services to the public sector and companies as well as international organisations.

CSTB – Centre Scientifique et Technique du Bâtiment www.cstb.fr

CSTB is a State-owned industrial and commercial corporative, placed under the administrative supervision of the French Ministry of Housing. It assists manufacturers, building contractors, engineering firms, architects and contracting local, regional or national authorities, as well as advising Public Authorities on technical regulations and construction quality.

Strat-CON Project www.strat-con.org

Strat-CON was a research project focussing on the development of thematic roadmaps and supporting strategic actions for ICT in the construction industry. Its focus was on value-driven business processes, industrialised production, digital models, intelligent constructions, interoperability, collaboration support, knowledge sharing, and ICT enabled business models.

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