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# ***A strategic and comprehensive vision for future R&D in construction ICT***

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## ***Abstract***

The tremendous development those ten last years of the Internet and ICT at a large (should it be around general technology like semantic modeling, knowledge mining, or RFID and mobile technologies, or domain-oriented like e-commerce, collaborative spaces, digital mock-ups, etc.) has opened a large spectrum of potential applications of ICT in the Construction sector. The real adaptation and deployment of ICT in Construction has indeed just started, and there is a high need to organize and plan future R&D actions for Construction ICT, while at the same time better evaluating the benefits and therefore convince Construction actors. This is the role of the Strat-CON and BICT projects respectively, which are introduced in terms of aims of major results in this article.

## **1. INTRODUCTION**

Within the framework of the European Construction Technology Platform (ECTP, created in 2004 - see <http://www.ectp.org/>), the goal of which is to work out a vision of future RTD in construction from now up to 2030, a dedicated Focus Area was launched in October 2005, entitled "Processes & ICT" ([http://www.ectp.org/fa\\_pict.asp](http://www.ectp.org/fa_pict.asp)), focusing on future developments and research in the field of Construction processes to be naturally supported by Information and Communication Technologies (ICT). With the ambition of defining a strategic research agenda (SRA), the scope of such a FA is to position, develop and lead to the future execution of an appropriate actions agenda covering items related to processes optimisation, extended smart products and future services for home, buildings, underground constructions and networks, and the appropriate development and deployment of ICT to support these items, along with the development of strong synergies between the whole of the involved actors (universities, research centres, industries and SMEs...) and strategies development of research and innovation.

The work that started beginning of 2006 have led to the definition of a set of 8 (sub)roadmaps, as well as the development of future ideas of RTD. This work is particularly supported by the ERABUILD network (ERA-Net for construction at a European level), which issued in 2005 an invitation to tender on the topic of "Managing Information in Construction". Two proposals, which have both been selected for funding, have led to projects having both begun in Mars 2006 and finishing in April 2007:

- Strat-CON (<http://www.strat-con.org>), is a continuation of the former ROADCON<sup>1</sup> roadmap, with the ambition to refine this roadmap, but also to further define an SRA (R&D identification and priorities scheduling) and to propose “developments” fields of future R&D projects. Strat-CON has three main scientific objectives as follows:
  - o Obj. 1: Refine, validate and if necessary re-develop vision and roadmap for ICT in construction;
  - o Obj. 2: Identify a set of strategic actions for realising the vision of ICT in construction;
  - o Obj. 3: Validate strategic actions and provide guidelines for implementation.
- BICT, which aims at evaluating the possibilities and the potential of ICT in order to increase the effectiveness and the quality of the construction processes, in particular by a greater industrialization of these processes. This project grants a significant place to surveys and the case studies to propose generic models.

This paper introduces to the methodological approaches followed by the two projects to achieve their objectives, and the results from the projects (concluded at time of paper writing) and their impacts on the ECTP FA “Processes & ICT”.

## **2. Strat-CON: A METHODOLOGICAL APPROACH TO DEFINE AN OVERALL VISION AND ROADMAP FOR CONSTRUCTION ICT**

FA7 of the ECTP has identified four main thematic areas of interest for processes and ICT. In addition to the roadmaps offered by ROADCON (2003), Strat-CON makes use of these thematic areas when developing its roadmap(s) and identifying complementary strategic research actions. The thematic areas considered are as follows:

- Processes: business processes and production processes.
- Products: digital modelling of products and intelligent constructions.
- Projects: interoperability between ICT systems and ICT support for collaborative work.
- Enterprises: capturing project experience into knowledge assets and exploiting them in new ICT enabled business models.

Within Strat-CON each of the four thematic groups was broken down into two main themes (strategic research priorities), with each theme addressing one main topic (Figure 1). For each of the main themes, a roadmap was to be developed. When developing the roadmaps, the methodology was industry centric as compared to ROADCON where the roadmapping approach was research and development centric. In Strat-CON, each roadmap was developed bearing in mind key business drivers acting as triggers for development of tools and technologies in a phased approach leading to eventual realisation of the vision within each roadmap. These phases identified items not in terms of research and/or development, but delivery times to industry (short, medium, and long) as illustrated in Figure 2. For each item (or group of items), one or more research and technology development (RTD) ideas were to be identified. It is worth noting here in particular that while the roadmaps are developed mainly from an industry/practitioner perspective, the supporting RTD ideas are the research and development means to achieve these industry targets (items).

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<sup>1</sup> The ROADCON (<http://www.roadcon.org>) 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.

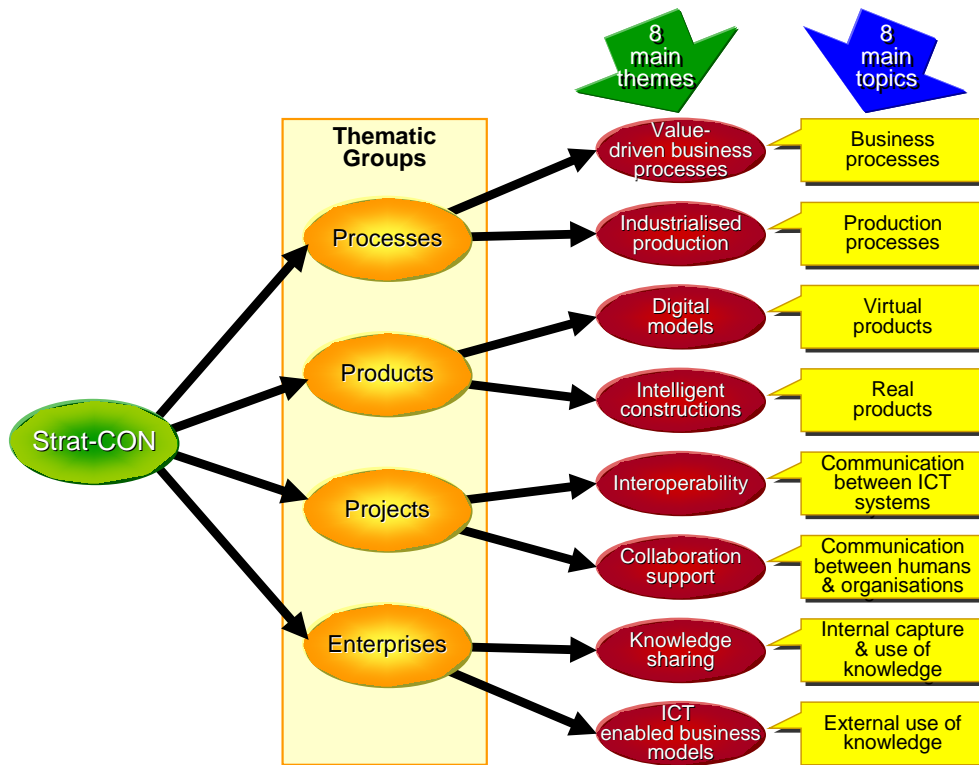


Figure 1 : Thematic Groups and Strategic Research Priorities (Roadmaps)

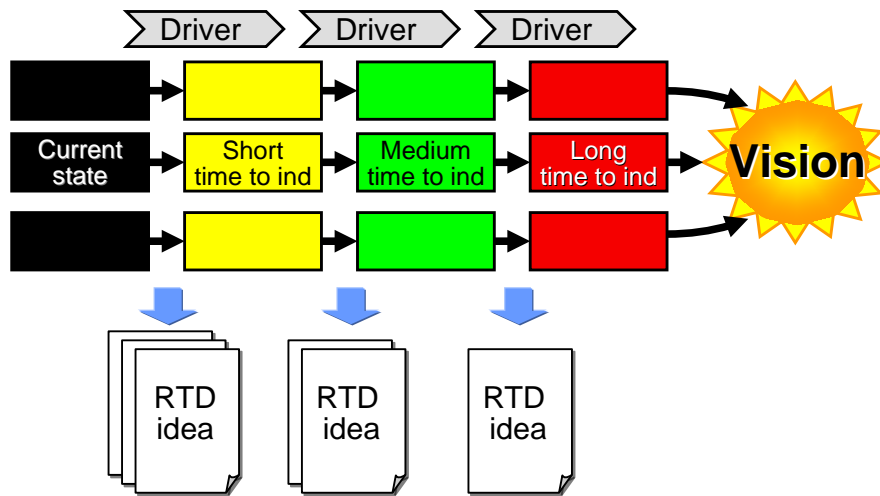
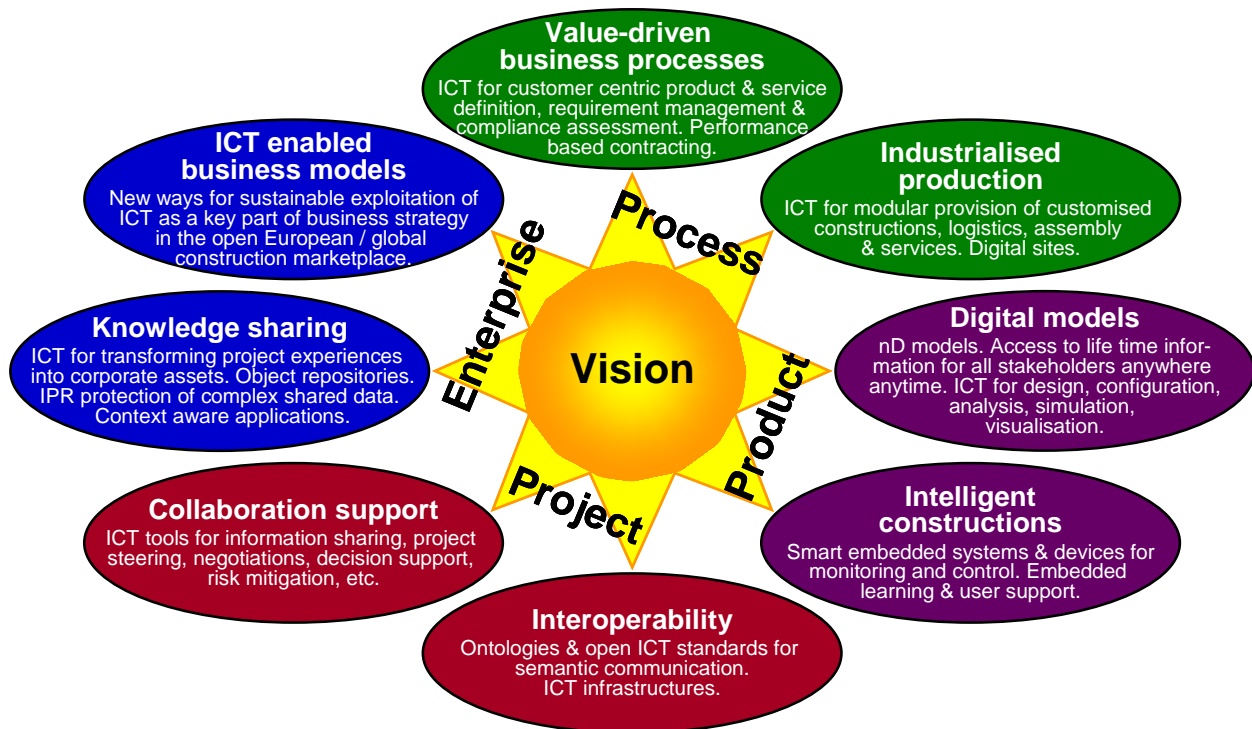


Figure 2 : Roadmapping Approach

### 3. IDENTIFIED VISION AND SCENARIO FOR EACH OF THE 8 Strat-CON ROADMAPS

For each Strat-CON roadmap as initially introduced in the previous section (and developed in the next one), a synthesised vision has been established, which refers as much as possible to a desirable state of the future that could be obtained in terms of achievements realised thanks to future Research developments, especially in Construction ICT. The 8 visions are introduced in the table below and summarised in Figure 3.



**Figure 3 : Thematic Roadmaps and Supporting Visions**

<i>Roadmap</i>	<i>Global vision</i>
Value-driven processes	<p>The vision proposed in this roadmap is based on the fact that today, there are no tangible methodologies, models and tools available to manage performance and business processes in construction. It is advocated that to move from the current state of time and cost driven process towards value driven processes, performance driven processes, value to customer, total life cycle support, and product and service customisation must be supported. Such a vision also leads to the following considerations:</p> <ul style="list-style-type: none"> <li>• Strong stakeholders, like clients, are important agents of change and may provide leadership in the development of a sustainable built environment provided by an integrated supply side.</li> <li>• Business relationships are based on trust, partnerships and win-win.</li> <li>• The demands of end-users and society are met while optimising the use of resources; the technology available to achieve sustainable development is integrated in a systematic way, and the integration is site-specific thereby exercising vigilance and meeting local expectations of end-users and achieving performance and 0-accident and health risks.</li> <li>• The procurement of services or products is done in ways that improve responsibility, reliability, quality, encourage competition and stimulate innovation.</li> </ul>
Industrialised production	<p>The vision of industrialised production in the construction industry is as follows:</p> <ul style="list-style-type: none"> <li>• Construction sector offers safe and attractive high-technology work places.</li> <li>• Sites, construction machinery and mobile staff are connected to corporate information networks.</li> <li>• Customised construction products are produced industrially.</li> <li>• Manufactured construction products are offered on the EU wide open market.</li> </ul>
Digital models	<p>The vision of future digital models in the Construction Industry is as follows:</p> <ul style="list-style-type: none"> <li>• All systems in constructions share common platform, network and protocols, with secure external connectivity via the internet enabling local, remote and mobile monitoring, diagnostics, reporting and operation.</li> </ul>

	<ul style="list-style-type: none"> <li>• These systems provide optimised control and intelligent services to users and operators.</li> <li>• The life cycle of construction products is supported by applications using semantically rich models that contain all relevant information without need for human interpretation.</li> <li>• Digital models are accessible anywhere and anytime.</li> <li>• Future digital models providing easy access</li> </ul>
<p><b>Intelligent constructions</b></p>	<p>The vision proposed in this roadmap is that in the future, all objects within the home, the office or potentially any building will communicate and provide information ubiquitously, and will be able to “understand” people circulating or living in the built environment so as to answer to their needs at any time. To achieve such a desired state, it is required that:</p> <ul style="list-style-type: none"> <li>• ambient intelligence is kept and managed within chips, sensors, actuators,... embedded in objects that are able to dialog thanks to wireless communication techniques;</li> <li>• all systems in constructions share common platform, network and protocols, with secure external connectivity via the internet enabling remote and mobile monitoring, diagnostics, operation and self-reporting, and provision of innovative interactive services to people at home or in their working environments.</li> </ul> <p>Typical fields of applications of these R&amp;D developments are for instance solutions related to Ambient Assisted Living (AAL), especially for disabled and ageing people, or in another field, Positive Energy Buildings (PEB - and also energy self sufficient buildings), with a new vision for tomorrow building energy performance to solve the huge global problem on sustainable energy uses at world-wide scale, with Europe having a leadership in this action.</p>
<p><b>Interoperability</b></p>	<p>Interoperability encompasses several aspects, should they be mainly technical (e.g. related to networks or software applications) or more linked to organisational and process issues (thus in relationships with the “Collaboration support” roadmap). The vision proposed in this roadmap is that in the future, relying on interoperable and standardised data transfer protocol, semantically rich information will be shared by the Construction Sector throughout the whole life-cycle of buildings and the built environment by means of integrated information systems and services encompassing all processes and their interactions. To achieve such a desired state, it is required that:</p> <ul style="list-style-type: none"> <li>• Any of two or more IT components or systems have the ability to communicate and jointly utilise the information, especially thanks to the definition of its semantics;</li> <li>• Communication of information semantics is effective thanks to international or industry standards (rather than proprietary standards), and preferably thanks to open standards, which are to be product, services and systems-independent, background technology agnostic, and having their specification freely available to all interested parties.</li> </ul>
<p><b>Collaboration support</b></p>	<p>The vision of future collaboration support in Construction is as follows:</p> <ul style="list-style-type: none"> <li>• Internal enterprise systems are connected to external collaboration environments with project partners in a transparent way.</li> <li>• International standards enable fast set-up of collaboration platforms for new project consortia.</li> <li>• Collaboration environments support social cohesion and trust among geographically distributed, cross-organisational teams with multidisciplinary skills, multiple cultures and multiple languages.</li> <li>• Collaborative environments support mobility in a seamless way, covering all the phases of the construction process including construction sites.</li> </ul>

	<ul style="list-style-type: none"> <li>• Advanced collaboration tools are easy to use with no specific training.</li> <li>• Virtual meeting spaces enable (a-) synchronous communication.</li> </ul>
Knowledge sharing	<p>There will be a capability to support the sharing of previous experiences, good practices and knowledge within and, increasingly, between organisations. The aim is to have (transparently) immediate access to the right information, at the right time, in the right format, and from the right sources (both internal to an organisation and external). This encompasses also the achievement of tools / services and environment allowing sharing previous experiences, best practice and knowledge within and, increasingly, between organisations. The ultimate objective is access to and sharing of semantic information resources, with:</p> <ul style="list-style-type: none"> <li>• Knowledge embedded in management systems, products, services, software, digital models and catalogues;</li> <li>• Automatic indexing of both textual and non textual content (e.g. multimedia resources, like photos or video);</li> <li>• Search engine able to take into account the implicit knowledge / implicit environment of the users to enrich his search and gave him only the most relevant information according to his profile.</li> </ul>
ICT-enabled business models	<p>The vision of ICT-enabled business models in the Construction industry is that innovative companies will offer new knowledge based products and services in the construction sector based on: branding, business networking, ICT, innovation, knowledge, specialisation, system &amp; service integration etc.</p>

For each of the roadmaps and in connection with the visions proposed above, some futuristic business-oriented scenarii have been developed. We hereunder only introduced to two of them as examples, but invite the reader to refer to (Hannus et al, 2007).

### 3.1 Intelligent constructions business scenarios: Ambient assisted living for the elderly

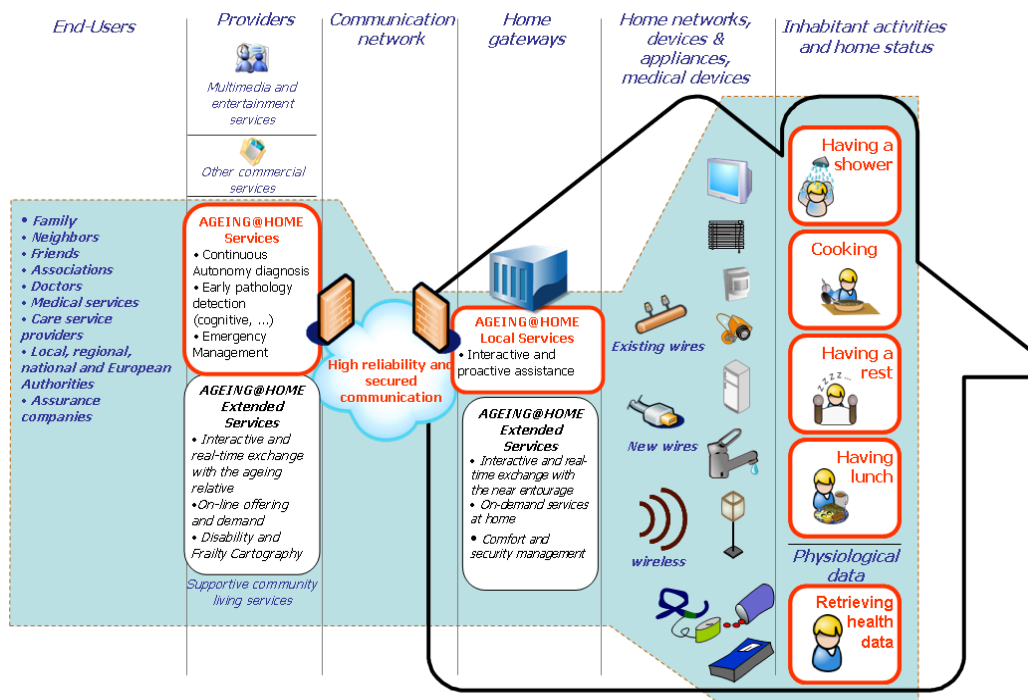
This scenario springs from a societal objective to assist elderly people to remain in their familiar home surroundings, prolonging independent living and postponing their need to move into institutional care. Age is beginning to affect wider society in very challenging ways. According to the UN report 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”. It is likely that never again will societies be shaped demographically as in the past with more young than old. In 2002, the number of persons aged 60 years or older in the world was estimated by UN to be 629 million. That number is projected to **triple** to 2000 million by 2050, when the population of older persons will be larger than that of children (0-14 years) for the first time in human history.

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



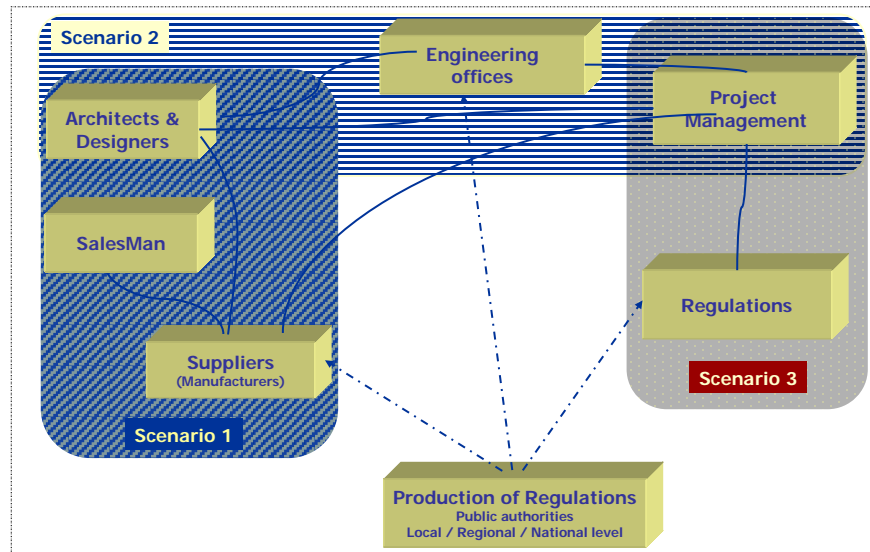
### 3.2 Knowledge sharing business scenario: the added value of semantic bridges among dedicated/specific construction processes/scenarios

Let's start the development of such a scenario by a typical example: an individual faces a problem (e.g. leakage through the roof of a concrete basement due to excessive rainfall). His/her KM environment should be able to search across multiple data repositories, mine the relevant information (e.g. from potential similar problems or occurrences) and return the potential solution(s) and relevant contact people. At the same time, it should have the capability through a combination of ontologies (or a meta-ontology) to exploit relevant content for identification through the semantic web and retrieval of the same into end-user applications using intelligent knowledge agents. The retrieved content may come from a different domain (e.g. aerospace) and relate to a different problem whose solution may yet be relevant and adaptable to the problem in context. Generalising such a scenario, a “meta” scenario is depicted in the figure below, especially based on a key issue in the Construction sector which is about access to regulations information. It is indeed a concatenation of three major scenarios described below.

- The *first scenario* is basically focused on the exchange of design-related information. It is an extension of CAD drawing exchange (that primarily focuses on exchange of geometry) into semantic representation of construction objects and relationships.



- The *second scenario* is focused on e-procurement of construction products. It shows the use of intelligent electronic catalogues to support both design and sales process. In the first case the designer wants to try different



products in his/her project. In the second case, the salesman uses the catalogue to show different alternatives to his clients. The catalogues are compliant to a given standard (e.g. XML, RDF, OWL) and a given software tool is used to support all interactions. Tools that can be considered here are the following: catalogue server and taxonomy server. The former helps publishing the respective catalogues of product (standard-compliant); the latter supports the specification of the products and helps treating the queries properly.

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

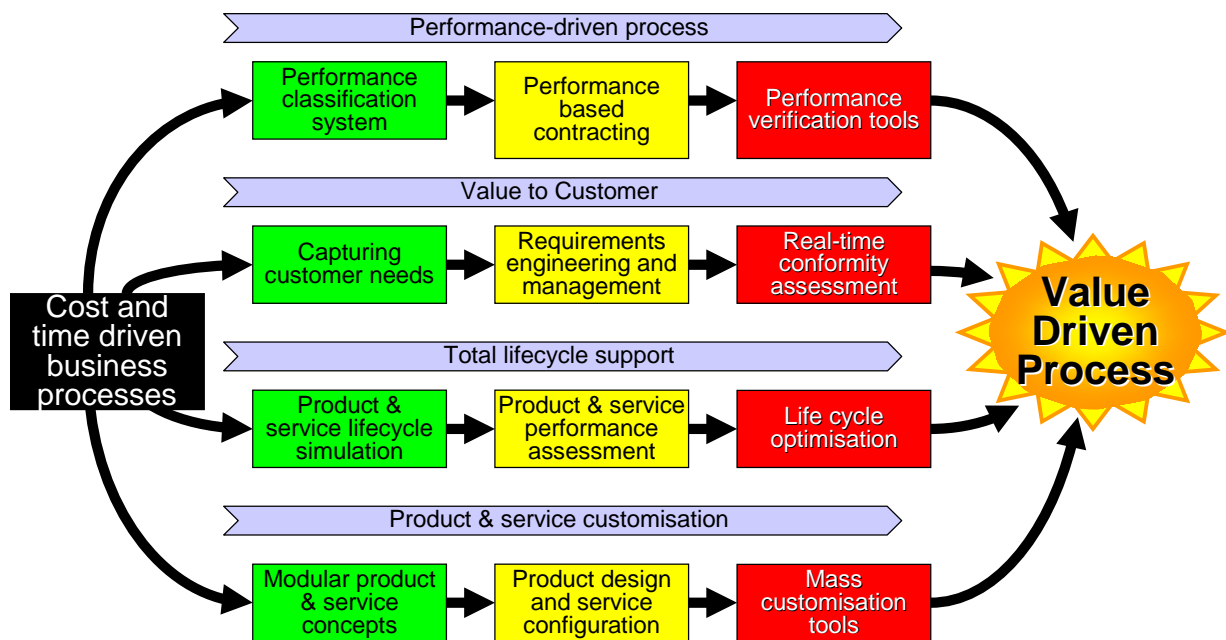
It is worth noticing that these scenarios could be developed both in an intra or inter organisation level. The development of a semantic framework able to establish gateways/equivalence among the different semantic resources manipulated in these sub scenarios will be an important step toward the achievement of a Construction Semantic Space.

#### **4. FORESEEN INDUSTRIAL IMPACT FROM Strat-CON ROADMAPS**

The Strat-CON project developed eight complementary roadmaps towards realizing the vision of ICT in the construction sector. Though a detailed presentation of all eight is out of the scope of this paper, the roadmap on value-driven business processes (Figure 4) is shown as an example of how the roadmaps look like followed by short briefs on the foreseen industrial impacts of each of the eight roadmaps.

##### *Value-driven business processes*

This will lead to rationalization of construction processes, with off-site assembly of large, fully-fitted components and mechanization of site activities aided by new automation and guidance technologies which have the potential to open construction to a wider range of potential workers. Buildings, infrastructures and urban achievements resulting from the re-engineered processes will integrate all new constraints, including a rational use of energy, minimising risks, trouble and discomfort for the individual users, and minimising pollution and risks of any kinds for all users in general and the society.



**Figure 4 : Roadmap for Value-driven Processes**

#### *Industrialised production*

The solutions shall radically improve safety at working place and offer attractive knowledge intensive employment opportunities and shall also address retrofitting. Construction sites will be safer, better organised (and therefore less expensive) and optimising refurbishment, while at the same answering to a strong societal demand of minimising discomfort of people living around, or being customers of the building or infrastructure.

#### *Digital models*

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

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

#### *Intelligent constructions*

These solutions shall increase comfort, security and safety at working and living place and reduce energy consumption, and needs for travelling and transports. They will support the elderly and disabled through real-time monitoring and remote control of living environments.

#### *Interoperability*

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

### *Collaboration support*

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

### *Knowledge sharing*

Intra- and Inter-company Knowledge Management that will:

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

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

### *ICT enabled business models*

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

- Logistics services focused on creating new operating models in the network level.
- Structured recording of experience and knowledge in order to improve information management, workflow management, interface management and document management.
- Risk management system including diagnostic and decision support tools that enable the identification, analysis, tracking, mitigation, and communication of risks in software-intensive programs.

## **5. BICT: AN EVALUATION OF ICT POTENTIAL FOR CONSTRUCTION IMPROVEMENT AND INDUSTRIALISATION**

### *5.1 Aims of the BICT project*

This section presents some ideas for future joint action of academia and industry in order to promote the development of the construction industry through advanced use of ICT. The ideas are based on the results of the investigations done in the joint Swedish-French BICT project. BICT stands for "Evaluation of benefits of ICT for the industrialization of project and product processes in the construction industry" (Molnar et al 2007, Robertson et al 2007). A more advanced use of ICT is fundamental to a further industrialization of the construction industry. The objective of BICT is to establish a mutual understanding between construction industry and R&D actors of the needs and possibilities of ICT. The research was carried out through steps including workshops with construction industry representatives and researchers, a case study of a representative Swedish multi-storey house-building project, a survey with active developers dealing with R&D in the field of ICT and statistical analyses of market data. The project also includes a study of State-of-the-Art ICT for immediate, short and medium term uptake in areas considered of greatest importance for industrialization of the processes.

### *5.2 BICT results*

Based on the case study of the house-building project, specific ICT-related development areas were identified as being potentially beneficial for improved productivity and quality within

multi-storey house-building and further analysed in the survey and workshops. Computer aided design, interoperability, virtual reality, cooperation and ICT-policies, the product definition process, use of systems products, quantity take-off and reuse of experience are identified as development areas where ICT can play an important role to improve productivity and quality. Highest potential to achieve improvement by immediate uptake is attributed by the survey persons to computer aided design, interoperability and reuse of experience. A time span of 2 - 5 years is needed to obtain benefits by more efficient cooperation and ICT-policies and rational quantity take-off.

Typically, in a Swedish multi-storey house-building project, relations between most of the projects participants are ad-hoc. ICT-use is regulated by the architect's CAD manual regarding layer structures, routines for information exchange during design, use of project network, hardware, software and filing. 2D CAD is the predominant design tool. ICT is widely used for administrative purposes, especially by the large contractors. Typically, more than 20 different software applications are used by the participants. Information transfer between participants in and between different stages of the project is often carried out manually, which requires creation of redundant information with a high risk of mistakes.

### 5.3 Recommendations for joint R&D and industry action regarding processes and ICT

Only through dealing with problems relevant to practice, can research and industry cooperate. In order to arrive at a common understanding between academia and industry of necessary and relevant action, joint studies of practical information management in building projects are needed. Since the beginning of the 1950's and the development of the SfB-system there has been an established and well founded information systematic for the Swedish building process (BSAB 96). This has served drawing based information management well, but needs extensions to cover an object oriented information management throughout the complete design, production and facilities management sequence of construction processes. The reasons for this will be demonstrated in a few examples below.

A series of new initiatives towards increasing industrialisation have been taken in Sweden to render the processes more effective and raise the quality of its results. Two main tracks, with several intermediate practical applications, are followed. One is an industrialisation through continuous development of existing processes and products, stressing new forms of cooperation, e.g. partnering and integration of supply chains, as well as an increased use of industrially produced systems and components. Another concerns industrial production, especially for house-building, modelled on production methods from the manufacturing industry, with the enterprise as process owner in complete control of product development, production and on site assembly.

These two directions give different prerequisites for implementing ICT. Companies that have engaged in industrial production of dwellings can use experiences from the manufacturing industry in their choice of ICT. Typical for these are that the products down to smallest detail are managed in proprietary ICT-systems. This enables efficient integration of product information management systems, manufacturing management systems, and enterprise resource management systems. Such integration put severe requirements on information systematics, e.g. classification, and exchange formats, but can be resolved within the company and its suppliers, more or less in accordance with established sector standards.

Continuous development of existing processes through increasing use of strategic partnering and utilization of systems products promote the use of advanced ICT-applications. This requires sector wide achievements in standardisation and information systematics. A typical problem in today's information management is the frequent manual input of data in different applications, due to lack of standardisation of exchange formats and information. But

increased interoperability which is a prerequisite to concurrent engineering and CSCW, computer supported collaborative work, will only be achieved when object oriented applications are developed on the basis of carefully analysed processes. These may not mean a principle difference to today's tasks and responsibilities in established information management routines. However, ICT-based information management must be based on explicit semantic definitions for different project stages and needs. Here, joint studies by academia and industry that could clarify the information needs and establish a foundation for software development are missing. As an example, the requirements that quantity and cost calculations put on the content of object oriented information is discussed below

The building project starts out by brief development, using basic 3D applications for sketches and early idea development. Quantity take-off and cost calculations are based on building types, areas and volumes in relation to known reference projects. A first step in establishing a BIM, building information model, is to attach this information to a construction entity object with attributes like classification, geometry and other overall properties.

In the building proposal stage several designers cooperate on a main proposal starting from the brief stage 3D geometry model. The main proposal presents a detailed organisation of the building's spaces based on the requirements of a user. The project database, the BIM, may hold defined space objects with attributes like classification, surface materials, equipment, required ventilation and sound reduction etc. A cost calculation can now be made in greater detail, but mainly based on reference project data.

During the systems design stage, a more thorough study of the building's technical systems is made. This enables definition of functionally determined building objects, e.g. external wall, internal wall, roof, load bearing structure, ventilation system, electrical system, etc., with specification of geometrical and other properties, e.g. sound reduction, heat capacity, thermal insulation, elasticity, or colour. Based on building objects defined in the systems level, it is possible to make calculations of cost, energy consumption, ventilation needs, load-bearing capacity, etc.

During detailed design the technical solutions and constituent resource parts are determined. Not until this stage is it possible to define detailed functional objects, e.g. classified according to the Swedish BSAB building as elements. Only rather far into the design process is it possible to define detailed functional objects related to technical solutions. With this as a starting point, it is possible to determine resources like construction products, machinery, and man hours which are necessary to make a more detailed cost calculation for the project as a whole. These prices are based on actual sales prices and contractor's experiences.

Many of today's 2D design applications allow a separation of information into layers according to the structure of the building classification systems. Sector agreements concerning their use in specifications, contracts and orders are the basis for the subdivision. The problem that object-oriented information management faces is the lack of corresponding standards for information objects at earlier stages. Only through agreements on the sector level, is it possible on a larger scale to introduce object-oriented information management supporting a further industrialisation of the building processes. It is an urgent task for academia and industry to jointly carry out necessary process and product studies in order to define the required objects and develop the needed standards. The work in the BICT project has pointed at these problems, but has not aimed at proposing solutions. However, it seems obvious that further efforts to develop ICT to support industrialisation of the construction processes must focus on development of international standards for information management and building information objects appropriate to the requirements in different stages of building design, production and facilities management.

## **6. CONCLUSION**

This paper has introduced to future tangible R&D to be developed in the field of Construction ICT, as well as to evaluation efforts to better identify (and therefore further convince about) the tremendous potential benefits of ICT for the future improvement of the Construction sector. Especially, preliminary scenarios has been identified within the Strat-CON project: developing these scenarios while generalising the BICT approach seems to be key so as to ensure that, in the future, companies (including small and medium-sized enterprises) from the building and civil engineering sectors achieve maximum business benefits from the adoption of ICT solutions in the knowledge economy. BICT represents a shift of focus in construction ICT from technology to process, contributing to the overall picture as a necessary step to take in order to support a future industrialisation of the sector using advanced ICT.

As builders and building owners increasingly demand smarter ways to design, build, document and deliver their building projects, modelling as a large (should it be in terms of technical modelling like IFC and their BIM generalisation, knowledge modelling through taxonomies and ontologies, and organisational modelling ) seems to be the cornerstone to cross the bridge from pioneering technology to mainstream adoption. From an “impact” point of view, ICT is expected to enable enhanced automation, integration and communication in the Construction value chain, better contribute to support the needs of the construction industry through customer-driven design, manufacturing and build, and finally increase the impact of construction on sustainability, economical growth, employment, and quality of life.

In its analyses, the BICT project points at two distinguishable but also overlapping development tracks, including several intermediate practical applications. One is an industrialisation through continuous development of existing processes and products, stressing new forms of cooperation, e.g. partnering and integration of supply chains, as well as an increased use of industrially produced systems and components. Another concerns industrial production, especially for house-building, modelled on production methods from the manufacturing industry, with the enterprise as process owner in complete control of product development, production and on site assembly. Future development must take these different processes and their specific needs into account.

By themselves, projects like Strat-CON and BICT are not a end: their purpose is to initiate discussion and thinking, and generate views and ideas on the major issues and achievements within the Construction industry that need to be addressed through a pan-European comprehensive approach. Even more importantly, the outcomes of the two projects should lead to detail actions items and implementation plan to start exploiting the opportunities and meet the promises laid out by Information technologies in the Construction sector.

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