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CONSTRUCTION INFORMATICS IN TURKEY: STRATEGIC ROLE OF ICT AND FUTURE RESEARCH DIRECTIONS

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SUMMARY: *Construction Informatics deals with subjects ranging from strategic management of ICTs to interoperability and information integration in the construction industry. Studies on defining research directions for Construction Informatics have a history over 20 years. The recent studies in the area highlight the priority themes for Construction Informatics research as interoperability, collaboration support, intelligent sites and knowledge sharing. In parallel, today it is widely accepted in the Architecture/Engineering/Construction (AEC) industry that ICT is becoming a strategic asset for any organisation to deliver business improvement and achieve sustainable competitive advantage. However, traditionally the AEC industry has approached investing in ICT with a lack of strategic focus and low level of priority to the business. This paper presents a recent study from Turkey that is focused on two themes. The first theme investigates the strategic role of ICT implementations from an industrial perspective, and explores if organisations within the AEC industry view ICT as a strategic resource for their business practice. The second theme investigates the 'perspective of academia' in terms of future research directions of Construction Informatics. The results of the industrial study indicates that ICT is seen as a value-adding resource, but a shift towards the recognition of the importance of ICT in terms of value adding in winning work and achieving strategic competitive advantage is observed. On the other hand, ICT Training is found to be the theme of highest priority from the academia point of view.*

KEYWORDS: *ICT, Strategic, Vision, Roadmap, Turkish*

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1. INTRODUCTION

The AEC industry has been using information and communication technologies (ICTs) for more than 40 years, to facilitate its processes and transform the industry. Research on the use of ICT in the AEC industry has created an interdisciplinary scientific area known as Construction Informatics. Construction Informatics deals with a diverse range of subjects ranging from integration to interoperability, and from knowledge mining to strategic management. As outlined in Isikdag (2006), Construction Informatics research emerged from two fields. The first one was related to the use of computers for creating drawings, making structural analysis, and carrying out time and cost calculations. The second one was concerned with the use of computers to classify, store and manage the construction information. The research in the first field enabled the development of software applications that support various different tasks/processes in the construction lifecycle. Research in the second field enabled the development of information classification and Building Information Modelling standards. During the mid 1990s, a new research field of Construction Informatics was emerged. This new field focused on the strategic management of ICT within the enterprises in construction industry. Currently, integration, interoperability, process facilitation and innovation, along with strategic management of ICTs can be considered as the key research areas of Construction Informatics.

In parallel with the developments in academia and the software industry, organisations in the AEC industry have adopted new (information) technologies in support of their businesses and the implementation of ICT is now becoming strategically important. Currently in most industrially developed countries (such as UK), organisations believe the need for implementing and using new technologies for gaining competitive advantage but are reluctant to invest in these technologies. The financial return appears to form the basis for IT investment related decisions. The investments are driven by 'value' but inhibited by the state of readiness of organisations (Alshawi *et al.*, 2008). Similar to the current view in U.K., the results of previous research on measuring the ICT use and trends in Turkey (Sarshar and Isikdag, 2004) suggested that the Turkish AEC industry has been facing difficulties related to inefficient communication and loss of information due to fragmentation in the industry. Although ICT was viewed as a strategic resource (to overcome these difficulties) by senior industry figures in Turkey at that time, there was no evidence demonstrating, either the industry is investing on ICTs with a strategic (and value-driven) focus or decisions for implementing information systems have been taken from a strategic perspective.

The research presented in this paper aimed to identify i) the perception of the Turkish AEC industry on the strategic role of ICT and ii) research directions for the future of Construction Informatics in Turkey. The research was focused on exploring the strategic role of ICTs and research directions for Construction Informatics specifically in Turkey and, based on its (Turkish) focus, results of the study can be regarded as an original contribution to the Construction Informatics literature. The research methodology is summarised in the following section.

2. METHODOLOGY IN BRIEF

The study began with a comprehensive literature review by focusing on the role, usage and benefits of ICT in the AEC industry along with investigating the factors influencing investments on ICTs. The following phase of the review was on the vision studies and roadmaps for Construction Informatics.

In the next stage, in order to determine the industrial state of the art in terms of the strategic role of ICTs, semi-structured interviews were conducted with contractors and consultants in Turkey, in light of a questionnaire. During the interview process, a range of areas such as the role of ICT strategy in the organisation, the reasoning behind investments on ICT, and barriers to successful implementation of ICT for the organisations were investigated.

In the final stage of the research, two academic workshops were organised (in 2007 and 2008) in order to determine research directions (i.e. the priority themes for the future) of Construction Informatics in Turkey. In the first meeting of the series, following the presentation of the industrial state of the art (on the strategic role of ICTs) to academia, the research directions were determined by academia. The findings are depicted in the form of a thematic map showing research directions of Construction Informatics. In the following meeting (which was held a year later), the identified priority topics were refined and validated through discussions, leading to a new (revised) version of the thematic map being defined.

Following the background section, the paper in the first stage presents the findings of the interviews on the strategic role of ICTs) and later presents the (developed) thematic map and elaborates on the research areas that are presented within this map.

3. BACKGROUND

3.1 Exploring the Role of ICT within the AEC Industry

The research started with a literature review on the role, usage and benefits of ICT within the construction industry, which mainly focuses on the use of ICT within the construction enterprises. Numerous studies that explored and evaluated the role of ICT within the construction enterprises, and factors affecting investments on ICT were identified as a result of this literature review. A selection from the recent studies in the field in last five years is presented below:

- Love *et al.* (2004) presented findings of a questionnaire survey related with IT investments of SMEs in the Australian construction industry. Three findings of the study were; (i) the different organization types significantly differ in the amount they invest in IT but this is not influenced by organisation size, (ii) strategic benefit varies with different organization types and (iii) the way in which employees adapt to change as a result of IT implementation differs with organisation size. Based on the above mentioned findings, Love *et al.* (2005) proposed a pragmatic ex-ante IT evaluation framework which can be used by construction organizations to ameliorate their investment decision-making process.
- Tse and Choy (2005) investigated the differences in the use of IT by conducting an in-depth interview with three major quantity surveying organisations in Hong Kong. The authors found that the full potential of IT to improve organizations' efficiency, effectiveness and flexibility has seldom been reached and then they apprised that a sector to enter the IT era must employ the right sort of technology by a sufficiently large number of the supply chain and stakeholders.
- Hua (2005) explained an IT Barometer survey conducted in Singapore. In the study, the author compared the results with previous IT Barometer studies on Nordic Countries. Hua (2007) later conducted an industry-wide survey by adopting the IT Barometer questionnaire and applying stratified sampling to Singapore's AEC SMEs. The study compared the characteristics of ICT usage by the AEC companies and examined the alignment of business and ICT strategies of the AEC companies.
- Other recent studies include El-Ghandour and Al-Hussein (2004) who presented a holistic view of ICT applications in the AEC industry during the years 1992 and 2002, Rivard *et al.* (2004) who presented case studies on the usage of IT in Canadian construction industry, Oladapo (2007) who investigated the level of use ICT usage and the factors impacting the level in the Nigerian Construction Industry, Scheer *et al.* (2007) who sought the application experiences of IT in AEC industry in Brazil, and El-Mashaleh (2007) who carried out a modified version of IT Barometer survey in Jordan's AEC industry.

A comprehensive review of the recent studies can be found in Isikdag *et al.* (2008).

3.2 Vision and Roadmaps for Construction Informatics

The vision and roadmaps of construction informatics are generally developed in light of inputs from both industry and academia. In fact, the thematic map (on the priority topics for Construction Informatics in Turkey) presented in this paper is developed only with input from academia (in light of the industrial state of the art and works presented in this section).

The vision and roadmapping efforts for Construction Informatics have an history of more than 20 years. In the mid 1990s, Aouad *et al.* (1996) presented priority topics for Construction Information Technology, which can be regarded as one of the early works in the area. In fact, everybody was aware that it would not be easy and that it would take decades when Hannus (1998) indicated the need for bridging the gaps between the Islands of Automation in the construction industry (Fig. 1).

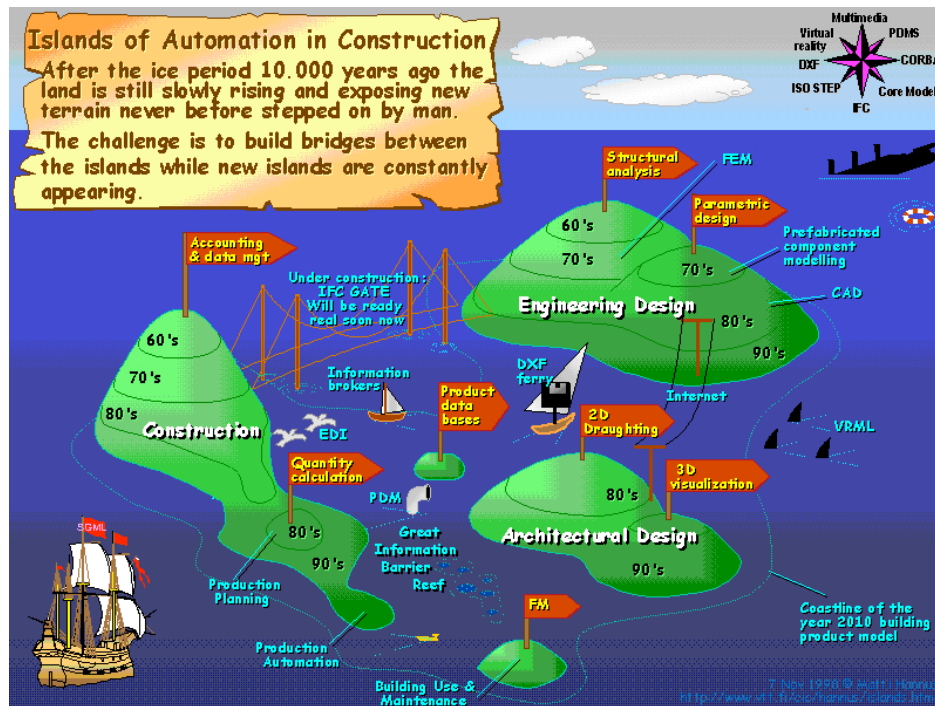


FIG .1 Islands of Automation in Construction (Hannus, 1998)

In 1999, 'Berkeley-Stanford CE-M Workshop: Defining a Research Agenda for AEC Process/Product Development in 2000 and Beyond' was held in Stanford University, with an aim of defining a research agenda for the future of computer integrated construction and 70 papers were presented in the workshop (Sarshar and Isikdag, 2004). Based on the papers presented, the trends for the use of IT appeared as:

- *ICT as the enabler of integration* - through the use of 3D Modelling and Visualisation, Virtual Reality Applications, Object Oriented Project Models, Four Dimensional CAD, Data Exchange Standards, Simulation of Construction Processes and Software Integration.
- *ICT as the enabler of Collaboration and Knowledge Management* - through the establishment and use of Knowledge Discovery in Databases, Knowledge Management Systems, Knowledge Warehouses, Enterprise Planning and Management Systems, Decision Support Systems, Virtual Engineering Teams, Groupware Applications, Object Oriented CAD.
- *ICT as the enabler of Procurement and Site Management* - through the use of, Digital Catalogues, GIS Applications and Mobile Computing.

The vision formulated by Construct IT for Business in the UK was inspired from the findings of the Berkeley-Stanford CE-M Workshop, and have taken these findings one step further when examining how construction projects and their processes will be supported by IT in next 5-10 years (Sarshar *et al.*, 2000). The UK vision was formed following academic and industrial expert workshops and was formulated in the form of seven major themes:

- Model driven as opposed to document driven information management on projects.
- Life cycle thinking and seamless transition of information and processes between life cycle phases.
- Use of past project knowledge in new developments.
- Dramatic changes in procurement philosophies as a result of the internet.
- Improved communications at all life cycle phases, through visualisation.
- Increased opportunities for simulation and what-if analysis.
- Increased capabilities for change management and process improvement.

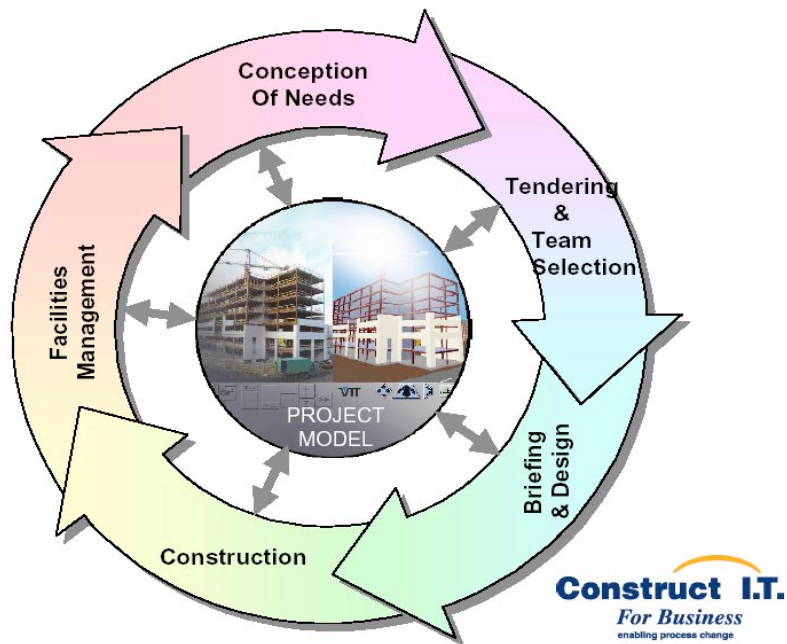


FIG 2: The Project Model and Project Life Cycle Phases (Sarshar et al., 2000)

Based on these major themes and in order to reflect the impact of the themes in a project life cycle, a scenario was developed during this effort. As seen in Fig. 2, the phases of the project lifecycle that are considered in the scenario development process were: conception of needs, tendering and team selection, briefing and design, construction, and facilities management. These phases were then arranged around ‘model driven systems’ concept, where each phase can build on the knowledge from the previous phase, adding value by increasing the level of project information detail.

A similar effort, the European Union research project European Large Scale Engineering Wide Integration Support Effort (ELSEWISE) resulted in a roadmap (Fig. 3) which illustrates possible steps towards exploitation of information and communication technologies in large scale engineering industry (Hassan and McCaffer, 2002).

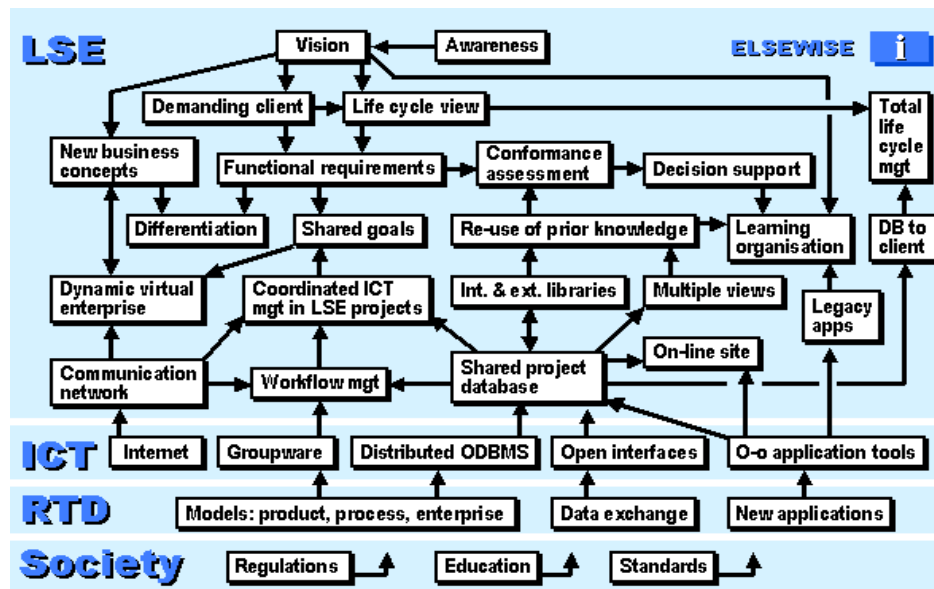


FIG 3: ELSEWISE Strategy Roadmap (ELSEWISE Workpackage 4 Report, 1998)

The objective of the EU research project ROADCON (Strategic Roadmap towards Knowledge-driven Sustainable Construction), was to develop a vision of ICT support in the construction sector and form a strategy for future research and development towards this vision. The strategic research and development roadmap

produced as a result of this project was focused on new and emerging ICTs. The roadmap also indicated opportunities to the industry to take up existing technologies. The future trends on ICT, determined as a result of the ROADCON project, is illustrated in Fig. 4.

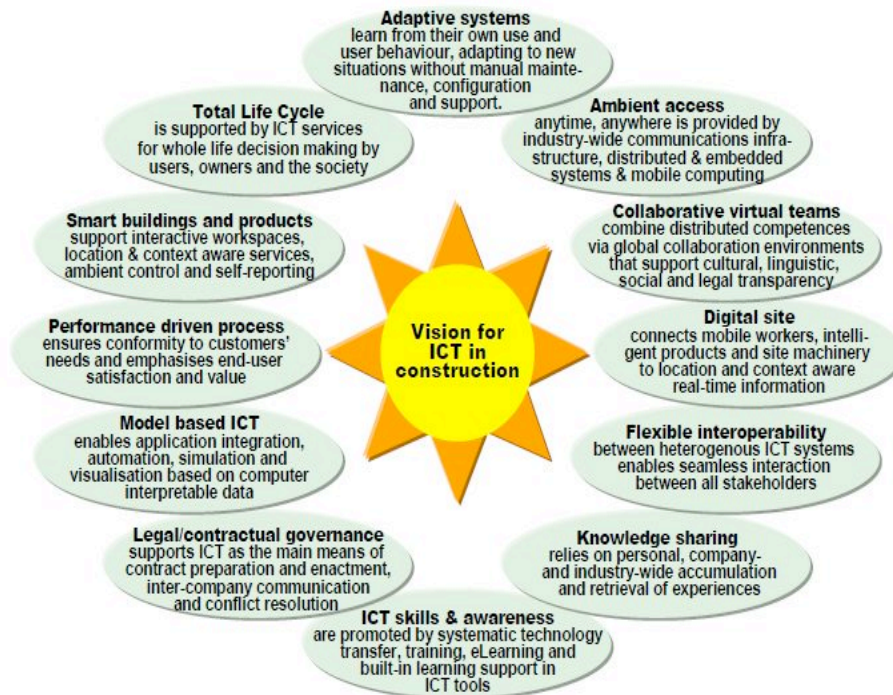


FIG 4. Vision for ICT in Construction (ROADCON, 2003)

Construction 2020 was an Australian initiative carried out by the Cooperative Research Centre for Construction Innovation, to investigate the future research directions for the AEC industry and explore the barriers to achieving them. In the study, the qualitative responses from the questionnaires and workshops were analysed with the help of text analysis software and grouped based on similarities. The responses reflected the major concerns of the industry and the expected improved future environment in which its stakeholders would like to work. Based on the industrial responses, nine key visions for the future emerged. Vision 5 was on ICT for construction, and it was suggesting the development of a seamless web of communication that is available to all participants in the development, construction and operational cycle of the project/organisation. This would allow management information to be readily available to all relevant personnel, to monitor performance and to speed up decision making using shared data models. The vision required industry to endorse standard approaches to interoperability, to seek generic approaches to process and to engage in continuous education for all personnel (Hampson and Brandon, 2004).

The most recent research effort in the field is the Strat-CON project. The project was launched in May 2006 to September 2007. The participants worked in unison with members of Focus Area 7 (FA7) on Processes and ICT of the European Construction Technology Platform (ECTP) with the aim of developing strategic roadmaps and implementation actions for ICT in AEC industry (Strat-CON Final Report, 2007). The project made use of four thematic areas identified by FA7 of the ECTP when developing its roadmap(s). The areas that were focused on are:

- 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.

Each of these four thematic areas was then broken down into two themes (research priorities) and main business drivers and key research topics are identified for each of these themes (Table 1). The project later presented roadmaps for each of these eight themes.

TABLE 1: Research Priorities for Construction Informatics and Main Business Drivers

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

4. STRATEGIC ROLE OF ICT IN THE INDUSTRY

Following the literature review on both the role of ICT within the AEC industry and visions and roadmaps for Construction Informatics, a series of semi structured interviews were carried out with 21 major contractor and consulting organisations in the Turkish AEC Industry to determine the industrial state of the art in ICT implementation from a strategic perspective along with the strategic role of ICT within the organisations in the industry.

The interviews were conducted in light of a questionnaire consisting of 19 questions. The first group of questions investigated the role of ICT strategy in the organisation, while the next set explored the reasons behind ICT investments, and further questions focused on the facilitating factors for successful ICT implementation and barriers to successful implementation ICT within the organisations.

The semi-structured interviews were conducted mostly with ICT managers of each organisation. The interviews started with an informal introduction to the context of the research which lasted around 20 minutes. The interviewees were later interviewed based on the questionnaire by two interviewers. The interview results were cross-checked by the interviewers at the end of the interview. The overall interview process took between 1 and 1.5 hours per organisation. The list of interviewees is given at Appendix 1. The details on the survey questions and responses (of the interviewees) can be found in Isikdag *et al.* (2008). The following presents an analysis on the findings of the survey in order to portray an industrial state of the art in ICT implementation from the strategic perspective and the strategic role of ICT within the organisations in the industry.

The results of the first set of questions demonstrated that ICT is seen as a value adding resource as a part of an overall business strategy, for gaining competitive advantage and for winning work. For example, around 1/3 of the organisations viewed ICT as a critical resource for their competitive strategy and similarly 38% mentioned that ICT strategy is a critical element of their overall business strategy. 40% viewed ICT as non-critical in winning work.

These results suggest that ICT is not seen as a strategic resource, however it should be noted that the strategic role of ICT is not totally underestimated among the organisations (as 1/3 identified ICT as a strategic resource). The role of ICT in winning work was not found to be critical. This was due to the bidding criteria in the country which is not requesting a well established organisational ICT infrastructure as one of the main requirements.

Most of the organisations that participated in the interviews mentioned that they do not have a properly documented ICT strategy, while the organisations that have a documented ICT strategy developed this in the requirement for standardisation reasons (i.e. ISO 9001).

The survey results indicated that the organisational culture in terms of ICT has not reached a level of maturity where ICT activities are planned and managed with a properly documented strategy. The majority of the organisations have chosen to follow technological developments/advancements in order to make decisions for further investments on ICT. This approach can be seen as a technology-oriented/driven approach for forming a strategy. However, the organisations were not aware of/concerned with the bigger (industry) picture while formulating their strategy, as most of them are not driven by their competitors' actions and investments.

The survey results highlighted that business needs/objectives play a key role in forming ICT strategies. In addition, the organisations also follow an approach towards implementing the latest technologies possible to accomplish their business objectives.

The majority of the organisations invest in ICT either to reduce costs or add value to the current form of processes, i.e. ICT investments are not made for strategic reasons (gaining competitive advantage) but are made for supporting the processes. As previously explained, the findings indicated that the organisations do not fully underestimate the strategic role of ICT, but this has not been reflected in their investments. The findings of the interviews showed that 55% of the organisations do not calculate ROI for ICT expenditures, which is another indicator that ICT investments are not perceived as -investments of a critical importance- in terms of the business. The majority of the organisations (90%) outsource IS development, but 55% also carry out in-house development to mainly align information systems into their business needs. The organisational view in regard to the issue is towards developing and implementing systems on an 'as-needed' basis.

While half of the organisations have never considered investing in ICT related R&D, the findings of the survey indicate the willingness of 61% of organisations to participate in such activities.

In parallel with the results of a previous survey (Sarshar and Isikdag, 2004), training on ICT appeared as an important aspect of the overall organisational strategy. The reasoning behind ICT training was various but the main focus was towards facilitating business processes through the better use of technology.

Most of the organisations have an ICT department. However, the ICT departments are mostly composed of support staff rather than of staff responsible for strategic development and systems implementation. In contrast to the willingness of middle level management to join R&D projects, this result indicates that the senior management still views ICT as a supporting resource/utility.

The greatest barriers related to successfully implementing and managing ICT were identified as, inefficient use of software, ill-defined processes and infrastructure related problems. On the other hand, the importance given to ICT training, re-design of current processes and support from software vendors appeared as the most critical factors for successfully implementing ICT (Isikdag *et al.*, 2008). The interviewees thought that ICT training acts as a road from failure to success.

In response to final question, the majority of interviewees mentioned that the role of ICT as 'supportive' in different phases of the construction lifecycle; this indicates that (similar to the role of ICT from an organisational point of view) ICT is also not perceived as a strategic resource (by the majority of respondents) from the construction lifecycle management perspective.

5. FUTURE RESEARCH DIRECTIONS

5.1 Methodology

The efforts towards developing an academic perspective on the future of Construction Informatics in Turkey has initiated with a series of academic and industrial meetings between 2002 and 2006. These meetings played a role in explaining various dimensions of Construction Informatics to both industry and academia. Following these meetings the first workshop for establishing an agenda on Construction Informatics was organised in January 2007 as a part of a nation-wide academic IT conference (Akademik Bilisim).

In this first workshop 8 papers were presented by participants from 4 universities and 26 participants joined the workshop. The findings of authors' research on the strategic role of ICT (demonstrating industrial state of the art) were amongst the papers presented in the workshop. After the presentation of results of the research on evaluating the strategic role of ICT in Turkey (along with other papers), a brainstorming session were initiated with presentation of recent vision and roadmaps of Construction Informatics (such as the visions of Construct IT for Business UK, ELSEWISE and ROADCON).

Following this, the participants were asked to identify the priority themes of Construction Informatics for Turkey. The session was facilitated by the use of brain-mapping tools. As a result of this session, five priority themes were established for Construction Informatics. These themes were later organised in the form of a Thematic Map. The priority themes identified in the first version of the Thematic Map were as follows:

- Information Management and Integration
 - (Sub-theme) Information Classification
 - (Sub-theme) Software and Information Integration
 - (Sub-theme) Interoperability/Shared Models/Building Information Modeling
- ICT Training
- Strategic Management of ICTs
- Process Reengineering
- Technologies Supporting Site and Building Automation

In February 2008, the second academic workshop was organised for refining the agenda on Construction Informatics and updating the first version of the Construction Informatics Thematic Map, which demonstrates the research priorities in the field. In the second workshop 12 papers were presented by participants from 7 universities, and 35 participants joined this workshop. Similar to the first workshop, a brainstorming session was initiated after the presentation session. The brainstorming session this time started with presentations explaining Strat-CON roadmap (the most recent research project on ICT roadmapping which was not explored in the first workshop), and BuildingSmart concepts (which is becoming a research priority globally). After the presentations, the brainstorming session was carried out in order to refine the first version of the Thematic Map and as a result, a second version of the Thematic Map was developed.

The themes that remained the same in both versions were grouped together in the second version of the Thematic Map, and are referred to as the 'Core Cloud' of the map. The Core Cloud of the map covers the following themes.

- ICT Training
- Strategic Management of ICTs
- Technologies Supporting Site and Building Automation
- Process Reengineering

The theme 'Information Management and Integration' identified in the first version of the thematic map were covering three sub-themes as:

- Information Description and Classification
- Information and Software Integration
- Interoperability/Shared Models/Building Information Modeling

This theme has evolved into two separate themes in the second workshop as the participants mentioned that the concepts of Interoperability, Shared (Product) Models and Building Information Modeling need to be separated from the issues related to Information and Software Integration.

The global BuildingSmart vision encourages the use of BIMs for enabling data level interoperability. The use of BIMs forms the first pillar of the vision. The Information Description and Classification standards (such as International Framework for Dictionaries) are starting to appear as one of the three pillars of the BuildingSmart vision. The other pillar is Information Delivery Manual/Model View Definition (ERABUILD BIM Final Report, 2008). The interpretation of BuildingSmart vision in Turkey is not extensive as the global vision, and

BuildingSmart vision is generally interpreted as the use of shared BIMs for facilitating tasks throughout the building lifecycle, and Building Information Modeling is interpreted as the process of information management based on BIMs.

On the other hand, issues related to Information and Software (Systems) Integration has gained more enterprise focus, thus these research themes are grouped under Enterprise Integration. As a result, in the second version of the map the two new themes emerged as:

- Building Smart
- Enterprise Integration.

The second version of the thematic map is presented in Fig.5. Two themes that emerged as a result of the second workshop (as a result of expanding a theme in the first version of the map) will be referred to as the ‘Recent Themes’ in the paper.

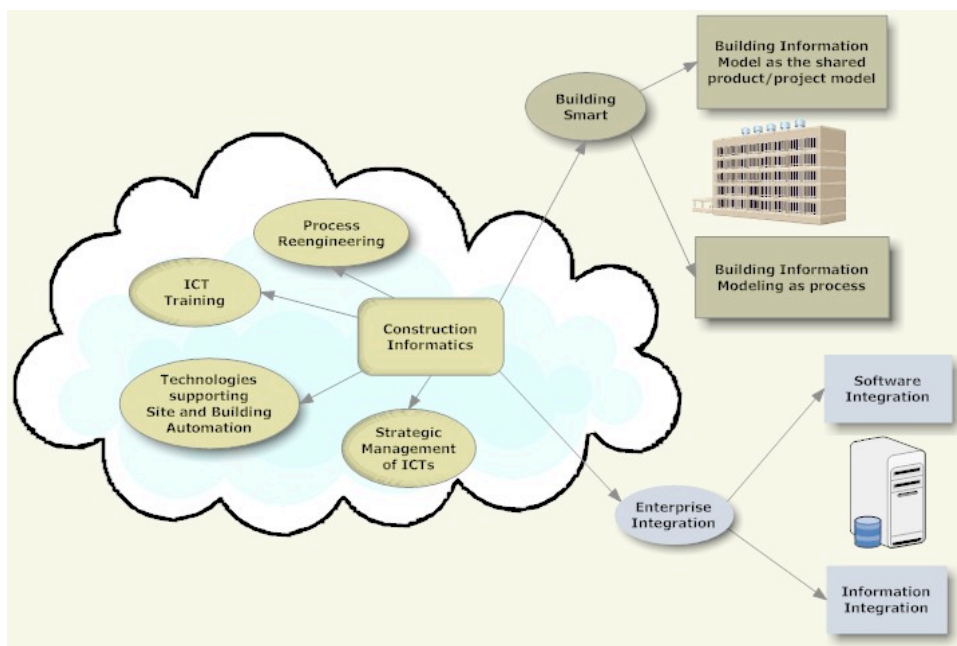


FIG 5: Construction Informatics Thematic Map

The following sections will explain each theme in the map in detail. In the first stage the themes that form the ‘Core Cloud’ will be elaborated, while the ‘Recent Themes’, i.e. the emerging priority themes for Construction Informatics in Turkey will be elaborated on later.

5.2 The ‘Core Cloud’

As explained in the previous section, the ‘Core Cloud’ covers the themes that remained unchanged between both versions of the maps, i.e. ICT Training, Strategic Management of ICTs, Technologies Supporting Site and Building Automation and Process Reengineering. The following explains these themes (of the ‘Core Cloud’) in detail.

Theme 1: ICT Training

In the beginning of the brainstorming session, the academics (taking the industrial barriers indicated in the first stage of the study such as ‘inefficient use of software’ into account) reached a consensus on the need for training activities in order to increase the ICT awareness and facilitate efficient use of software applications within the industry. The participants of the workshop believe that in the first stage, training activities need to focus on structural analysis applications. This need appeared in parallel with the importance given to building up earthquake-resistant structures in Turkey. The public opinion in Turkey highlights that errors related to structural analysis of the buildings can be one of the reasons behind structures collapsing or becoming unusable following earthquakes. The participants indicated that these errors can either be caused, by misuse of structural analysis applications, or from the inconsistencies within these applications. Thus, the participants indicated that ICT

training should cover both the application developers and end-users, and needs to be provided in parallel with training on the theoretical aspects of structural engineering. In the second stage, the field to be focused on was determined as increasing ICT awareness to facilitate electronic exchange of documents between designers and engineers. In the last five years the AEC industry in Turkey has become keen on exchanging documents electronically during the design stage. However, this can not be fully achieved (mainly within SMEs) due to the lack of ICT skilled personnel in the AEC community. Thus, the second focus area (within this theme) was determined as -training focused on increasing the ICT skills of employees working in SMEs-. The third area of focus was determined as training on visualisation applications, as visualisation now plays an important role in facilitating collaboration during the construction stage and in marketing process. The fourth area to be focused on appeared as 4D/5D simulations. Although there is a demand for 4D simulations in the industry, the lack of skills in this area is evident. Other areas of training to be focused on were identified as ERP systems, applications supporting collaboration (such as groupware applications) and GIS.

Theme 2: Strategic Management of ICTs

The second theme to be focused on appeared as the management of ICT at the strategic level. As mentioned in the previous section (on the strategic role of ICT), industrial practice still currently views the role of ICT as value-adding. The results of the industrial survey pointed out a shift towards the recognition of the strategic importance of ICT, but the investments are still towards facilitating process improvement. The paradigm shift from 'value added practice' to 'strategic thinking' is still yet to be achieved. Based on the industrial findings, academia suggested that in order to enable this paradigm shift, senior management needs to explore and be informed about the strategic role of ICT. This vision can be supported by, informing senior level management on tools and techniques for strategic management of ICT (such as Porter's 5 Force Analysis, Nolan Stages of Growth Model, Value Chain Analysis) and encouraging them to take IT self assessment exercises and participate in benchmarking activities. The participants from the academia also indicated that the industry might benefit from the establishment of a non-profit organisation for achieving this paradigm-shift.

Theme 3: Technologies supporting Site and Building Automation

The technologies that facilitate automation in, construction sites and buildings are becoming more widely used every day. The participants from academia indicated that research should focus on enhancing (and supporting) the use of these technologies in the construction industry. The primary technology to be focused on is determined as Radio-frequency identification (RFID) sensors, which will allow the tracking of building components and vehicles in the construction site, while the use of RFID tags in the building components can also aid in the Facilities Management tasks. The second technology to be focused on was mentioned as Global Positioning System (GPS) tools and applications, as it will help in surveying activities and tracking of vehicles and workers within the construction site. Mobile computing was also identified as one of the core technological advancements that will facilitate the automation of tasks in the construction site. Other technologies to be focused on were identified as photogrammetric technologies (i.e. 3D scanning and model reconstruction), construction site surveillance technologies (such as webcams, video streaming) and technologies that facilitate automation in buildings (i.e. intelligent building technologies).

Theme 4: Process Reengineering

The industry viewed 'ill-defined processes' as a barrier to successful ICT implementation. Taking this industrial view into consideration academia denoted that the redesign of the variety of processes within the construction lifecycle (in light of the new technological developments) will enable better communication, collaboration and cooperation between the stakeholders of the process. Academia believes that process reengineering will lead to efficiency in, the management of key resources (including time and cost), knowledge management and improve teamwork, and thus will facilitate various tasks from conception to demolition/recycling stage of the construction lifecycle. As the use of shared information resources and integrated product models is becoming essential and more prevalent, the reengineering of construction processes to align with the new way of working is becoming inevitable. Documentation of current processes and identification of the (process) changes to be made will be a good starting point for adapting to the new ways of working in the emerging era of Building Information Modelling and Integrated Project Delivery. The redesign/reengineering of current processes will avoid the inefficient use of ICT in the industry, and will reveal the functionalities of ICT which are currently underestimated in Turkey.

5.3 Recent Themes

The Recent Themes is determined mainly by the input from academia. The first theme of the 'Recent Themes' group, 'Building Smart' covers a large spectrum of issues (to be focused on) such as, i) enabling interoperability

between software applications, ii) the interpretation of Building Information Modelling as a process (that is facilitating the shared use of (intelligent) digital building models), iii) encouraging the use of Building Information Models (BIMs), iv) exploring the barriers to adapting and using BIMs in construction processes, and v) investigating the consequences of using BIMs in real-life projects. The second theme 'Enterprise Integration' focuses on issues related to enabling information integration, service oriented architectures, building up a successful enterprise architecture within a organisation, enabling efficient use and implementation of ERP systems and integration of ERP systems with other applications. The following two sections present these two themes that emerge in the second (revised) version of the Thematic Map (and their focus areas) in detail.

Theme 5: Building Smart

In recent years, Building Information Modelling has become an active research area in order to tackle the problems related to information management and interoperability. The main aim of BIMs (as models) and Building Information Modeling (as a collaboratively managed design/build process) is enabling information management and data level interoperability (between various different applications used in the industry) throughout the lifecycle of a building.

BIMs of today have emerged as a result of an evolution from de-facto drawing exchange formats such as DXF through semantic AEC information models (which in the main are based on STEP technologies). Today, an implementation of the BIM paradigm is achieved by using IFC models, i.e. several CAD and structural analysis applications are capable of importing and exporting their internal models as IFCs, and some applications are also capable of acquiring information from an IFC model through the use of a shared resource, such as a shared file or a model server database. Building Information Modelling is applied in many different areas, ranging from 4 to N dimensional analysis/simulation applications to code compliance checking.

The participants of the second workshop agreed that Construction Informatics research in Turkey needs to focus on, facilitating the implementation of BIMs in real life cases, the use of shared product databases, the use of shared product models supporting time/resource management, and encouraging the use of BIMs together with online collaborative environments. The participants from academia mentioned that the developments towards transition to CAD based working practices to Building Information Modeling should be gradual; otherwise failure will be inevitable as result of resistance to change in working practices. The transition from working practices that support CAD to the practices that support BIM have been identified as a long term objective. In the beginning (of the nation/industry wide implementation efforts) a number of case studies need to be carried out to demonstrate the value that can be gained by the use of shared project information. The academics suggest that a case supporting the use of a shared database (of CAD files) between various project participants will be a good starting point. In the second stage, studies on 'the shared use of information sources related to time/cost management' can be supported. Following this, the use of BIMs in small scale projects should be encouraged. As this transition requires the redesign of processes, the research on this theme needs to be supported by the research on Process Reengineering (Theme 4), as the process and product models can be thought as two pillars of Building Information Modeling.

Theme 6: Enterprise Integration

Enterprise integration can be achieved at the data and information levels by integrating the information resources of the enterprise and the application and service levels by integrating the application components (or information systems) used within the organisation. As explained in Acikalin *et al.* (2008) and Bernstein and Haas (2008), various methods exist to enable integration at both levels. Methods for integrating information resources include physical file exchange, transfer of information from a physical file to a database and vice versa, the transfer of information between databases (i.e. data replication), sharing of data in a central or a federated (virtual) database, and data transformation between files, databases, from file to the database and vice versa (with the help of schema mapping and schema matching). In addition, the use of search engines and knowledge warehousing techniques also facilitates this type of integration. Methods for integrating the application components (or systems) include the use of distributed objects, messaging and web services. Enterprise Service Bus is a popular architectural style that is focused on establishing this type of integration through interactions based on web services.

Although various methods exist for integrating enterprise wide information and systems components, building up a successful Enterprise Architecture requires more than 'just' integration. The architectural frameworks such as The Open Group Architecture Framework (The Open Group, 2007) and Zachman Framework (Zachman, 1987) provide the insight into design and implementation of enterprise wide information system architectures.

The participants from academia mentioned that Construction Informatics research needs to be focused on enabling information and systems integration at the enterprise level. The efforts towards enabling information integration needs to look at facilitating the integration of different information resources used by different software applications. Enabling information integration within construction enterprises is a tricky task due to the diversity in types of information resources to be integrated. A good starting point towards enabling this might be selecting application couples such as ERP/Project Management, CRM/Groupware, Design/Analysis and working on the integration of the information sources of these couples. These efforts can make use of schema standards if they are developed for that integration domain (i.e. Industry Foundation Classes -IFC- can be used in facilitating information integration in a Design/Analysis application couple). Research towards enabling the integration of remote applications or systems also needs to be carried out in parallel with research on information integration. Although the main research interest of the academic community in Turkey is towards enabling information integration, the participants indicated that the issues such as integration of applications via web services, and the concept of using applications as services also needs to be a focus for research. Enabling enterprise architecture is not identified as the topic of high priority by academia although the advancements in information integration and application/service level integration will bring out implementing (these integrations within) an enterprise architecture context as an inevitable requirement.

6. DISCUSSION OF RESULTS

In Turkey, the findings of the industrial analysis (on the strategic role of ICT) pointed out the shift towards the recognition of the importance of ICT in terms of value adding in achieving strategic competitive advantage, as opposed to simply supporting and facilitating business processes. In fact, the development of a well formulated and documented ICT strategy is not common practice. These findings indicate that the industry has not reached a level of maturity in terms of recognizing ICT as a strategic resource towards achieving sustainable competitive advantage.

The ICT strategy in the organisations is driven by business needs focused on technological advancements/developments, while investments of competitors are of no concern, i.e. pointing towards an internally focused nature to investment. The organisations invest in ICT to reduce cost or add value to current processes. The focus on investments is not correlated with gaining competitive advantage. The level of R&D related to ICTs is currently very low. Interestingly, there is significant interest in possibly becoming involved in ICT in construction related research in the future.

In terms of the successful implementation and management of ICT, the main barriers identified were predominantly technological and process related rather than associated with strategy. In terms of the critical success factors, these were very much aligned with the barriers, in that continuous training policy, learning from previous implementation efforts, and the re-design-engineering of currently ill-defined processes were identified. Finally, overall ICT is having a supporting role throughout the lifecycle of a facility/project, however, ICT is perceived vital particularly during the design phases along with the management of time/cost and the supply chain.

Academia is keen on initiating research related Construction Informatics in Turkey. Six priority themes for Construction Informatics were identified as a result of two academic workshops in 2007/2008. The theme of highest priority appeared as ICT training, while five other themes can be regarded with equal priority. The identified themes were:

- ICT Training
- Strategic Management of ICTs
- Technologies supporting Site and Building Automation
- Process Reengineering
- Building Smart
- Enterprise Integration

In parallel with the industrial view, the results of the academic workshops also mentioned a strong need for ICT training. There are few examples of training courses in Turkey, but academia believes that the number of these courses should be increased. The participants of the academic workshops mentioned that such courses also need

to cover theoretical aspects of computing science, architectural design and structural analysis along with practical aspects of software-in-use.

ICT is still perceived as the ‘value adding resource’ by the industry. As the strategic management of ICT can be facilitated by decisions of senior level management, academia believes that research in this theme needs to focus on studies that will increase the awareness on the importance of ICT in the strategic level (i.e. in order to gain competitive advantage). The participants from industry indicated that benchmarking is not a regular activity in Turkey (which might be caused by not having well established institutionalisation and adhocracy in the construction enterprises). In response, the academia suggests that benchmarking and case studies on ICT best practice need to be encouraged.

Academia mentioned that research on site and building automation technologies should concentrate on site automation technologies in the first stage, as research on building automation technologies usually follow the industry demand (i.e. formed by ‘industry-pull’). According to the academics, the field of positioning, tracking and navigation technologies (RFID, GPS) provides a range of research opportunities, and results of the research in the area will enable the industry to work in ‘intelligent construction sites’. The use of geospatial explorers (i.e. Google Earth) will become more prevalent in the future and the use of these tools with tracking and navigation technologies will facilitate various tasks in the construction process.

Although process redesign was mentioned as a priority theme, it can also be regarded as the ‘inevitable need’ for the future. Thus, the process redesign within organisations will eventually be established either as a result of ‘technology push’ (i.e. to implement a new integrated information system) or as a result of a ‘competitive requirement’ (i.e. in order not to lose competitive advantage through ‘inefficient’ processes). Thus, academia recommends that research in the area needs to focus on process change and to prepare organisations (‘ready’) prior to their investments in ICT. This state of readiness (organisational e-Readiness) will help them to deliver strategic value and achieve sustainable absorption from their ICT investments.

The use of shared product models, interoperability of software and Building Information Modeling (as a process of managing all design/construction activities by making use of shared digital models) is gaining global popularity in removing the barriers to communication and collaboration. Academia forecasts that the Turkish industry will be influenced by this global trend and therefore research should focus on Building Information Modeling.

The participants of the academic workshops raised that the industry in Turkey is facing problems due to the lack of integration of information systems at the enterprise level. Academia believes research in the field needs to focus on information integration in the first stage, but service oriented approaches to integration also need to be taken into account.

Table 2 provides a comparison of the themes identified in the Strat-CON project and the priority themes for Turkey. Although it is not possible to exactly establish a 1 to 1 match between the themes (and the subjects they cover), the table is provided for positioning the situation in Turkey in relation to the EU research picture.

TABLE 2: Strat-CON Themes vs. Priority Themes for Turkey

<i>Strat-CON Themes</i>	<i>Priority Themes for Turkey</i>
Value-driven business processes	Process Reengineering
Industrialised production	Technologies supporting Site and Building Automation
Digital models	Building Smart
Intelligent Constructions	Technologies supporting Site and Building Automation
Interoperability	Building Smart
Collaboration support	N/A
Knowledge sharing	(through) Enterprise Integration
ICT enabled business models	Strategic Management of ICTs
N/A	ICT Training

7. CONCLUSION

The industrial state of the art (on the strategic role of ICT) indicated that although there is recognition in the importance of ICT in attaining competitive advantage, the focus of investments in ICT is very much towards business process improvement rather than achieving strategic competitive advantage. In parallel to this, the development of a documented ICT strategy is not a common. This poses further research into exploring this gap between the 'strategic thinking' and the actual 'process-focused practice'.

ICT strategy is driven by business demand and ICT-related R&D is currently not perceived an important strategic activity and therefore receives very little attention and investment. In fact, the industry figures indicated that there is intention of initiating ICT related research in the future.

The barriers to successful implementation and management of ICT were identified as technological and process related, and industry believes that these barriers can only be overcome by training on new technologies and improvement of processes. Finally, the ICTs found to be a supportive process of the building lifecycle management by the industry.

The need for ICT training for AEC industry professionals is found as a very evident one, as this need is both expressed by industry and academia. There is a strong need for academia to take action in the field and develop short training courses and provide training and education for higher level academic degrees (i.e. at the level of MSc and PhD). The paradigm shift towards understanding the 'strategic value' of ICT or its value in providing 'sustainable competitive advantage' can only be achieved by support from academia. Academia recommends focusing on studies that will increase the awareness on the use of ICT as a strategic resource. Another research focus of academia is towards developing technologies for enabling 'intelligent construction sites', while research on sensor and positioning technologies is highly encouraged. Research on process re-engineering and re-design is indicated as a need both by industry and academia. Research in Turkey needs to focus on encouraging the use of shared Building Information Models in real-life projects, but the academia suggests that the steps in this direction need to be taken carefully to prevent 'stories of failure', e.g. the transition from CAD based practice to model driven project management should be gradual. Finally, enterprise level (systems and information) integration is indicated as an area where Construction Informatics research needs to be focused.

The industrial barriers preventing the efficient use of ICTs and the generation of organisational value are well recognised by academia when determining the priority themes for Construction Informatics research. For example, the theme 'ICT training' was determined as a priority theme as the result of the industrial views. Similarly, the academia indicated the need for strategic thinking in management of ICTs, based on the current industrial state of the art (focused on process improvement rather than strategic thinking). The industrial state of the art indicated that a major barrier is caused by ill-defined processes. Based on this identification, academia indicated that added value will be created by process reengineering and redesign. On the other hand, three other priority themes, 'Building Smart', 'Enterprise Integration' and 'Technologies supporting Site and Building Automation' were only brought forward by the academia. The academia appears to be mainly influenced from the global research trends and directions in bringing forward these priority themes.

The realisation of research in parallel with these six areas of priority will help the Turkish AEC Industry to explore the strategic value of ICTs, exchange information in a more effective manner (through standardisation and interoperability of systems), make use of shared project information through all phases of the construction lifecycle (by the use of Building Information Models and integrated project databases), benefit from professionals with high ICT skills, manage constructions sites more efficiently (through better automation), and gain competitive advantage through the use of ICTs in well-defined processes.

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9. APPENDIX-1: LIST OF INTERVIEWEES

Organisation	Contact Person	Position
Guris Insaat	Handan YUCEL	IT Manager
KC Group Yapı	Bedir AKSAN	IT Manager
Tepe Insaat	Ferhat BOLUKBAS	IT Manager
Nurol Holding	Emine ONGUN	IT Manager
Metis Insaat	Secimer TEZ	MIS Manager
MNG Holding	Murat KASABOGLU	IT Manager
Akfen Holding	Sinan OZKAN	IT Manager
Mesa Mesken Sanayi	Semra CANKIRILI	IT Manager
Gama Holding	Mehmet BESEN	IT Manager
Akturk Yapi Endustrisi	Timucin DIKMEN	IT Supervisor
Koray Yapi Endustrisi	Dr. Vehbi TOSUN	IT Manager
Tekfen Insaat	Cem AKTAS	IT Manager
Eston Yapi	Kutay SEYYALIOGLU	Planning Engineer
Sinpas Yapi Endustrisi	Taner AKKAS	ERP Specialist
Alarko Taahhut Grubu	Osman ISHAKOGLU	Planning Manager
STFA Insaat Grubu	Ali AVCAR	System Administrator
Soyak Holding	Murat TANATAR	IT Coordinator
Yuksel Proje	Sükrü BAYKAN	IT Manager
Limak Holding	Ersun GULBAS	IT Manager
Dolsar Muhendislik	Ali Onur KUYUCAK	Head of IT Division
Borova Yapi Endustrisi	Murat YAMAN	IT Manager