Engineering communication - current view on past and future

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ABSTRACT: Since the end of the 1990s the problem of engineering communication, collaboration and collaborative working environments has been addressed by a number of national and European projects. All projects have some common denominators with the vision of developing the infrastructure that would change the way professionals work being the most obvious one. This is especially true for dynamic and mobile environments such as AEC industry, where time constraints often play important role and present the difference between success and failure. In the following years the construction industry will have to deal with the changes that newly developed IT Ecosystems are bringing and to cope with the shift from self-integrating technology and software investments based on ownership to those based on subscription (that is assembled, managed and maintained by the outside provider). The authors claim that newly emerged trend known as Enterprise 2.0 could offer solution to ever-present problems of AEC industry.

1 INTRODUCTION

Arguably the products of the AEC domains are unique, while the processes in which they are built are always dispersed amongst different companies, dealing with separate portions of projects. These processes were (and in some way still are) heavily fragmented, although they all contribute to the same goal – the final product. With the development of information and communication technologies, the majority of tasks (for example bridging the gap between collaborators, processes and applications) can successfully be handed over to the Web, its technologies and applications. Furthermore, the Internet proved its significant role in the expansion of the working range of construction companies and in the appearance of virtual organizations. This was possible due to the web-based solutions, which gave different clients the opportunity to cooperate despite the distance, saving them time and money and opening them the door to the remote markets.

One of a kind product or service delivery (typical for the AEC industry) is strongly influenced by the one-time collaboration of different organizations that have to consolidate and synergize their dispersed competencies in order to deliver a desired product or service. This naturally has an implication not only in the way information is exchanged and shared, but the way in which secure, quick to set-up, transparent and non-intrusive (to the normal ways of work of an individual/organization) ICT is used for this purpose. This has been a central research theme in various research projects in last decade.

In the beginning of this paper the role of I(C)T in AEC is depicted, historic development described and communication challenges of AEC outlined. In addition, common strategic points of key projects addressing the problem of engineering collaboration since the mid 1990s will be presented. Following this, common requirements for successful collaboration in the AEC will be outlined and key requirements compared against new trend in business that emerged just recently.

2 I(C)T AND AEC

Information technology can be defined as a technology that is used to handle data, information and knowledge. It should not necessarily be linked to computers because telephone, copying machine and technical drawing can also be characterized as information technology (Turk 2001). Nevertheless, in most cases the term ICT is tightly connected to the use of computers.

According to Turk (2001), there are 4 main domain specific groups of ICT services and activities that can be noticed on the first sight:

– INFORMATION. The creation, flow and acquisition of relevant information.

– COLLABORATION. Involved working force can communicate through variety of different channels.
– COMMERCE. Branch that deals with the commerce side of the AEC processes.
– WORK. In opposition to the first three activities this is the only core engineering activity. It is done by an engineer or an architect at his desk with the appropriate computer software.

In construction industry, it is not enough to create information, but it is also important to find and retrieve information, as it can save a lot of time and money (Turk 1997). There has been an enormous success of the World Wide Web, and part of its success is also the practicability and flexibility of the Internet in retrieving information.

It was soon realized that that is a very comfortable and useful technology as it makes the flow of information easier, faster, cheaper and even more reliable compared to the traditional methods.

2.1 *Historic development of I(C)T in AEC*

Only a century ago construction process was always controlled by a single master builder with the skill and responsibility to follow and coordinate the project from scratch to the successful finish. In those times, the only communication technology (besides the technical drawing) was speech, and there was almost no collaboration between all-in-one builders. In the following decades, the construction activities became more and more specialized and complicated. Processes had to be distributed to subtasks and dispersed among a number of people. This made the task more difficult and forced the whole construction (and the AEC) domain to open to new technologies, which were emerging at that time. That is why the computer and related technologies were soon discovered and still remain an important part of the AEC procedures.

Turk & Cerovšek (2001) argued that the construction industry embraced computer (and also the I(C)T) technology in three waves:

– At first, computers were used to help engineers in solving larger and larger models, saving them a lot of time and giving them the possibility to reach higher precision and develop more complicated models.
– The next wave came when computers replaced drawing boards.
– The third wave came in the mid 1980s with the introduction of personal computers. From that time on, the computer has become a ubiquitous tool and is used in everyday work, at least for the documentation needs.

The wide public appearance of the Internet is considered as the fourth big wave of the ICT in construction.

Computers have been used in engineering since the 1960s, but the wide expansion had to wait until the 1980s, when personal computers were introduced, and early 1990s, when the first version of global operating system, called World Wide Web (WWW), was formulated (Christiansson et al. 2008).

AEC and specially construction joined the explosion of the WWW and the Internet in the mid 1990s. ICT technologies and the Internet were at first explored in a number of research papers and discussed on conferences and workshops (Turk 2001). In the second half of the 1990s, the Internet was intensively explored as a platform for collaboration in engineering projects in order to enhance and improve both engineering collaboration and communication.

The whole potential of new technology was soon discovered. For few years, only the communication aspect and advantages of the ICT were explored and extensively used among the construction industry, although the potential has been much bigger.

Although the original purpose of the Internet was nothing but presenting information, modern Web applications offer much more (Ziemer 2002). Many applications today are developed exclusively for the Web and use the Internet's infrastructure to deliver their functionality, with all their strengths (and weaknesses).

2.2 *Communication challenges of AEC*

Communication intensity of construction industry has been known for a long time and is (with the advances in the information and communication technologies) becoming even larger. With the adoption of the latest findings in ICT and modernization of business concepts, the way the design and construction of the built environment is being done has dramatically changed (and is still changing). Nevertheless, one of the key challenges of AEC is still to provide an efficient, effective and flexible access to information and to provide all possible channels of communication.

Benefits of the ICT in AEC are similar as within different domains. Among the most noticed is the price of the ICT specific ubiquitous tasks, such as sending e-mails, establishing on-line conferences etc. The price of any of these tasks is almost always the payment for Internet services to the ISP, which is negligible if compared to the price of similar services, provided in a non-ICT fashion. Besides PRICE other benefits are:

– SPEED. For example, sending an e-mail takes a few minutes of ones time and arrives almost instantly to the senders' address, irrespective of the senders' location. On the other hand, sending a letter through the regular post service takes at least one day. In the very remote locations, it can

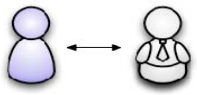
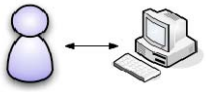
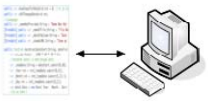
take days or even weeks. The same goes for the other ICT technologies.
- RELIABILITY. Even though the velocity of processes in which the ICT tasks are completed is very high, it is most likely that they will be successfully completed.
- ADAPTATION. ICT related processes can easily be accommodated to the new findings in technology.
- ACCESSIBILITY. Most of the ICT tools can be accessed from any location. The only condition is that the remote location must have a connection to the Internet.

Guevara & Boyer (1981) stated that communication systems are the central nervous systems of construction companies that enable many people to perform many tasks in an integrated and orderly manner.

The present situation in the AEC industry is forcing companies to collaborate on higher levels than they used to in the past. The consequences of capitalistic approach toward small- and mid-sized companies forced them to establish interactions in order to compete with large companies and to be able to master big projects. Responsibility among parties is legally settled.

Most virtual organizations in AEC involve people linked by computer and telecommunications networks such as the Internet or an intranet in order to communicate and collaborate with each other. Virtual organizations also allow companies and involved parties to collaborate over larger distances. For virtual company it is in fact the same if the involved members cooperate over a room, neighborhood, state or continent, because they are all interconnected using only the appropriate ICT tools and related technologies.

Table 1: Types of interaction - who (Turk 1998)

combinations	traditional	with I(C)T
 human : human	speech, telephone, fax machine, mail	e-mail, video conference, IM, blog
 human : program	/	virtual reality, GUI
 human : machine	direct manipulation	manipulation
 program : machine	/	robotics, sensors

The presence and effectiveness of the virtual organization is tightly related to the effectiveness and functions of the ICT tools (communication tools, shared workspaces, etc.) used.

Titus & Bröchner (2005) stated that managing information in AEC besides information processing and enhancing information flow also includes decision making of various actors involved. Therefore three types of interaction between various deciders were identified (Titus & Bröchner 2005):
- Human ↔ System
- Human ↔ Human
- System ↔ Human

Another important aspect of AEC communication is the identification of when the communication really happens (see Table 2).

Table 2: Types of interaction - when (Turk 1998)

	traditional	with I(C)T
just-in-time	book search, telephone call, consultation	database search, web search, e-mail, agents
just-in-case	reading books, conference events, journal subscriptions	subscriptions to specialized content
one-time	television radio	unarchived discussions, channels

Turk (1998) identified similar actors and combinations of interactions between them:
- Human ↔ Human
- Human ↔ (Computer) Program/System
- Human ↔ Machine
- Machine ↔ (Computer) Program/System

Even though types differentiate when comparing traditional methods with information and communication technology supported methods (see Table 1), it is interesting to see that I(C)T is already embedded and taken into consideration when actors and decision makers were identified.

Most of the tools supporting collaboration today enable one-time and just-in-case communication, but lack stronger, systematic and structured support for just-in-time connections. Most of the emerging problems are still solved in traditional ways, usually by phone, in the form of informal communication. Kraut et al. (2002) argue that informal communication is an important mechanism that helps all members of a project to achieve both production and social goals of the team. Informal communication is spontaneous, interactive and rich. That is why it is important to address the challenge of supporting informal communication with the use of I(C)T in order to provide additional channel for successful collaboration among different AEC project partners.

There have been a lot of European projects dealing with platforms for the successful collaboration of such virtual organizations. A number of them (see Figure 2) was started in order to investigate poten-

tials of information and communication technologies (ICT). In 1995, two of the early ICT motivated projects began - Mobile integrated communication in construction (MICC) and Collaborative Virtual Environments (COVEN). While MICC was aiming to introduce the use of on-site mobile communications as a way of improving the global competitiveness of the European construction sector, COVEN's overall objective was to comprehensively explore the issues in the design, implementation and usage of multi-participant shared virtual environments at scientific, methodological and technical levels. Several more projects were launched in the following years (TOCEE, Prodnet II, CONCUR, VIVE, CONNET, PROCURE, etc.), mostly with the intention to investigate and develop various methods and/or systems of information exchange in support of concurrent engineering environments. The explosion began when a large group of projects commenced their work in January 2000 (BIDSAVER, DIVERCITY, e-Colleg, External, GLOBEMEN, ICSS, ISTforCE, OSMOS). From there on number of projects increased rapidly.

According to Guevara & Boyer (1981), AEC enterprises have to (in order to function effectively) introduce communication systems of different types: a) interpersonal, b) interdepartmental, and c) interorganisational. Most of the projects were primarily focused on interdepartmental and interorganisational communication and have not dealt with the interpersonal interaction of the AEC project participants, although the importance of formal and especially informal 1:1 communication and collaboration was emphasized many times.

Another common denomination of all those projects is that they follow the graph of the development of the technological environment (see Figure 1) perfectly, with a small discrepancy in time.

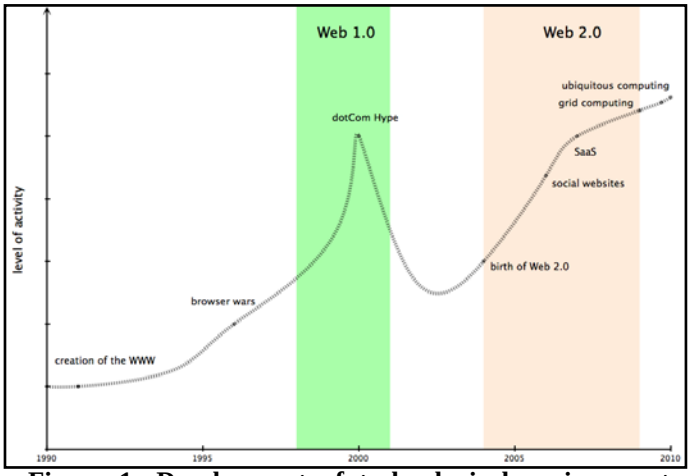


Figure 1: Development of technological environment (EU Commission 2008)

The other similarity includes predefined key user roles relevant to the developed platform and the proposed high-level architecture with the layered bot-

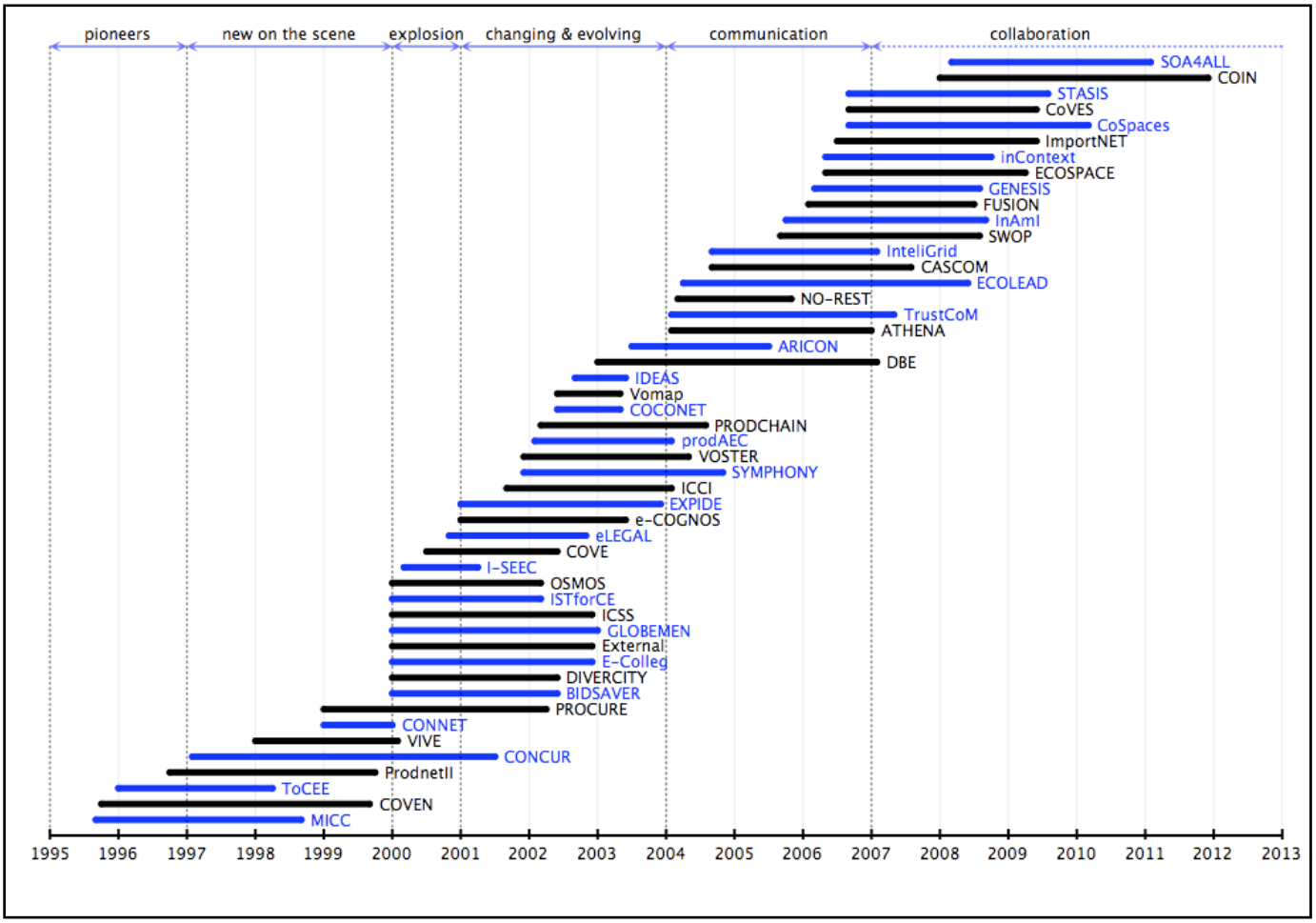


Figure 2: AEC projects timeline

tom-up approach. The problem with these approaches is that in this case every aspect of the enterprise is locked in the technology it uses, even though the employees today are technology aware and no longer satisfied with the predefined set of rules and tools that have to be considered and used. This is especially true for the dynamic and mobile environments such as AEC industry, where time constraints often play important role and present the difference between success and failure.

3 TOWARDS AEC ENTERPRISE 2.0

The fact is that at first the potential of ICT and Web based technology in AEC domain was discovered because of the possibility for a more advanced communication. The current state of the AEC (and probably any other) industry is that there is always a shortage of working personnel, which is distributed over a number of remote locations such as construction sites, offices and workrooms. To be able to have a close connection to all of the involved parties is a valuable privilege and was (before the explosion of the ICT) almost impossible task. That is why the communication part of the Web (and ICT) technology was almost instantly adopted and has been widely used since.

After that there was a gap of few years with no considerable progress in the use of the advanced ICT and Web technologies. The gap was the result of the insufficient Internet infrastructure, which was expensive to use and did not offer satisfactory connection speed to adopt any other advanced technologies. With a revolution of the Internet access and increased number of ISP providers the explosion of appropriate technologies began.

The current economic situation is such that only technology-aware companies can prosper as only they can gain advantage (in a matter of processes and reduced costs). The consequence is that every company is trying to adopt as many new technologies as it can in order to reduce expenses and survive. Advanced ICT communication offers technology aware companies:

- cheap control over different sectors of the company (even over those on remote locations and construction sites),
- the ability to always be up-to-date and have a clear overview on the document progress through Web based shared workspaces,
- to use their applications from any location and for less money,
- to solve problems on-site in the exact time they are made aware of them (with the use of mobile devices),
- to use previously unused computer power and reduce computing time.

In the last years, a phenomenon of Web 2.0 attracted a lot of attention not only on the Internet, but also in business community. It is considered as a next step and a major evolution of the traditional Web from both technological and social perspective. New online applications not only make traditional tasks easier, but they also have the capability of upgrading the experience by using the vast amount of information from the Internet, previous sessions and so called collective intelligence of its users. Some of the industries such as marketing, real estate, medicine, and newspaper have already discovered benefits of the Web 2.0 and social network technologies introduced (more on Web 2.0 and possible benefits of Web 2.0 to construction industry can be found in Klinc et al., 2008).

In contrast to the traditional methods for collaboration in business enterprises, workers in their personal life are used to the tools that are freely available and that provide the desired functionality through the intuitive, self descriptive, user oriented interfaces and that “that just works”. Forrester surveys show that approximately 45% of employees are using instant messaging, app. 16% blogs and RSS, 14% wikis and 13% social networking for business purposes regardless of the effort of their employers to bring those technologies to the workplace (Young 2007). Some projections show that by 2010, end-user preferences will decide as much as half of all software, hardware and services acquisitions made by IT departments (Gartner 2008).

All of that reflects on the expectations of knowledge workers in AEC as well. Stewart (2008) just recently stressed that “the continuous process improvement via the strategic implementation of innovative information and communication technologies is essential for the long-term survival of construction firms”. Despite that observation, common practice in the AEC industry is still the same as it was in the 1990s - the IT department provides a new user all the equipment (laptop computer and/or stationary workstation, mobile phone device) needed when the user joins the company. In addition, all the necessary tools and software programs are also provided, including office program suites, email, access to email, secure access to internal network of some sort, anti-virus and anti-spyware tools etc. The IT department usually maintains all the above-mentioned equipment with the security as a core requirement in mind.

The problem with this is that the IT departments in the AEC related companies cannot cope with the pace of the advancements in the technology and software. Nowadays it is relatively hard to even follow the versions and the updates of the core business applications, not to mention keeping up with the security threats when working over the Internet.

Turk et al. (2003) determined as a result of the ISTforCE project the following properties of a successful collaborative environment:

– Independence,
– Individuality,
– Capability,
– Sustainability,
– Leanness.

The problem is with the core nature of the engineering companies that have always been working on the "inside-out" manner, while the world is more and more "outside-in". Today it is impossible to close the knowledge workers inside the boundaries of their intranets and personal computers because the whole world is connected and they want to be a part of it. That is why IT departments have to change the focus and the scope of their work. Usually they are maintaining and establishing infrastructure from the ground up, taking care of all aspects of the business IT infrastructure. Instead, they will have to become a service taking care of the layer for adaptability of services that originally resides in the computer clouds, established and maintained by others.

While it was not easy to keep with all of the requirements in the solutions that have to be built ground-up, 2.0 technologies are offering some great potentials. Web 2.0 services and solutions are known to be easy to use with the rich user experience being a main driver of success. Usually, they can be seamlessly connected with other related services using widely accepted standard adaptors and APIs with detailed specifications. All services can usually scale rather well and are building added value on semantics gathered from their users. As the Internet based trends are evolving today (see Figure 3), Enterprise 2.0 initiative, building momentum on motivation of the employees itself, could have the answers to most of the above mentioned requirements.

According to Collins (2008) there are six key steps on the road to success when implementing Enterprise 2.0 ideas into an organization:

1 Enterprise 2.0 is not all about tools. It is primarily about people and the way they are working and solving real problems. While the whole cultures are changing, people find a way to function on a completely different level. Brian Tracy, a business guru, said: "People are not the only thing, people are everything."
2 Introducing Enterprise 2.0 into an organization can have a lot of benefits if it is done right. Successful implementations are followed by dramatic shifts in ability to locate expertise and information, collaborate, innovate and introduce leadership and management change.
3 Research on the organization and issues is needed while experimentation is not prohibited. Sometimes it is enough to give a willing group of participants an option and step aside. Encouraging them to try it with their everyday work instead of pure introduction of the tools is a way to a success. If the tools prove to be useful it is advisable to work from there on.
4 It is better to fail than to work on mistakes. When experimenting, there is always some risk present. It is better to stop as soon as it is realized that it is not working.
5 Do your homework. When introducing Enterprise 2.0, it is necessary to look at best practices of similar organizations that have solved similar issues and try to learn from their examples.
6 Focus on success. If there is no improvement or added value for the company reported, there is no need to evangelize Enterprise 2.0 any further.

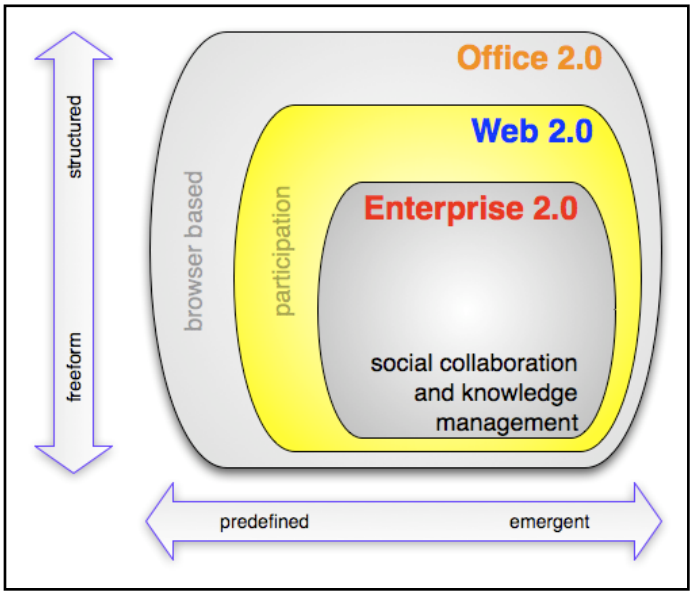


Figure 3: Meet the 2.0s: The major next generation software trends for business and life (Hinchcliffe 2006)

Despite those loose rules the only major rule in Enterprise 2.0 implementation is that there are no rules and no real requirements as the most successful Enterprise 2.0 initiatives evolves organically. If this is compared to the core nature of AEC business where most of the time workers are involved in one-time settings with a goal of delivering one-of-a-kind products it can instantly be noted that it fits perfectly. Another rule that fits perfectly is that flexibility has to be built into the system meaning that the existing controls have to be questioned and changed for greater human performance and better oversight. Instead on technology, Enterprise 2.0 is focused on changing the system and business to optimize the potential of the people. This alone should be enough for AEC industry to look closely at the Enterprise 2.0 and success stories since the current I(C)T collaboration system does not have answers to ever-changing nature of user roles and projects in the built environment.

4 DISCUSSION AND CONCLUSIONS

The whole principle of the web based application for the AEC domain could be characterized as an attempt to ease the collaboration between co-operators and to ease the time consuming and the unchallenging processes, in which a lot of intellectual effort is lost.

The fact is that at first the potential of ICT and Web based technology in AEC domain was discovered because of the possibility for a more advanced communication. The current state of the AEC (and probably any other) industry is that there is always shortage of working personnel, which is distributed over a number of remote locations such as construction sites, offices and workrooms. The possibility of having a close connection to all of the involved parties is a valuable privilege, which was (before the explosion of the ICT) almost impossible to reach. That is why the communication part of the Web (and ICT) technology was almost instantly adopted and has been widely used since.

After that there was a gap of few years with no considerable progress in the use of the advanced ICT and Web technologies. The gap was a result of the insufficient Internet infrastructure, which was expensive to use and did not offer satisfactory connection speed to adopt any other advanced technologies. With the revolution in the Internet access and increased number of ISP providers the explosion of appropriate technologies began.

The presented newly emerging trends (technologies, services, tools, solutions, etc.) are already changing business processes as we know and even though one might think they will not play an important role in the future all the projections show that a lot can be expected from them in the following years. Regarding AEC, the trend is moving to its favor since smaller devices are very suitable for mobile work force and off-site work places, Web based software used as a service can lower license cost, overcome limitations, improve productivity and help in critical situations. What is more, web based software is usually platform (software and hardware) independent and can be used in combination with variety of devices (including desktop machines, laptops, phones, smart phones and other hand-held devices).

The key reasons why AEC industry is not adopting Enterprise 2.0 technologies with a greater pace can be grouped into the following:

- Cultural barriers. Successful implementation is closely connected with the human side of the collaborative working. The use of new tools is heavily impacted by organizational culture, confidence and trust – in other words, by people. Up until now most of the enterprise technology has focused on business processes instead of people, even though the way in which people use Web 2.0 (or social) technologies depends mostly on the culture of the organization.
- Technological and security barriers. Concerns regarding privacy, security and protection are always important in any serious business – AEC is not an exception.
- Awareness and generational differences. The lack of awareness of what tools are available or how to use them.
- There is no one-size-fits-all model. One of the major barriers of effective utilization of Web 2.0 technologies to the working environment is the recognition that there is no model for a successful implementation that would fit to any organizational structure.

It took almost 10 years for people to figure out how to use the Web properly and it will probably take another 10 years before decision makers in the traditional industries will realize how to incorporate lessons from Web 2.0 in their core business processes. Although there are still issues that have to be solved, the end result will have a tremendous effect on how business is done.

While predictions about the future (especially for IT based trends) are always a bit untrustworthy, it is probably safe to announce the expansion of the Web 2.0 related business application market in the near future. At the same time the perception of how things are done in the AEC industry will have to be changed. It is important for the industry to become highly collaborative, much more open, decentralized, on demand, ad hoc, capable of quick adoption, lightweight and customer-oriented while staying cost effective and competitive. Organizations will have to listen to initiatives, novelties and innovations coming from the bottom-up since people are the ones who create the added value.

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