

# A CRITICAL LOOK AT INTEGRATING PEOPLE, PROCESS AND INFORMATION SYSTEMS WITHIN THE CONSTRUCTION SECTOR

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## ABSTRACT

The problems that the construction industry faces are widely discussed over the years. The pressure is increasing on the industry to deliver projects with minimal buffers of time, space and resources; and with minimal negative impact on the surrounding environment. The industry has been slow to respond to these challenges and continues to be criticised for that reason. There have been a number of attempts to address these challenges within the research community with varying degrees of success. However majority of these projects tend to address specific areas within the construction process rather than looking at the process as a whole. Lean principles help address the inherent wastes lying within the construction process, however there is no evidence of widespread implementation of such principles. People, process and Technology are three important aspects from Lean perspective. However in construction, technology is mostly being applied to peripheral processes resulting in less than satisfactory outcomes. There is a need address the construction process as a whole with a view to integrate various areas and aspects involved. The goal of this paper is to provide a new conceptualization for doing this with a specific focus on application of ICT within construction.

Based on a literature review, prior arguments and propositions for a holistic view are reviewed. Based on them, outline of a tentative new framework for integrating processes, people and information systems is presented.

## KEY WORDS

construction process integration, ICT in construction, construction efficiency

## INTRODUCTION

Over the years the construction sector has been criticised for having wasteful processes, unsafe working practices and less than satisfactory environmental awareness (Latham

1994; Egan, 1998). Also, compared to other industrial sectors such as manufacturing and automotive, construction processes are less standardised, less automated and exploit less technological innovation. There is a need to redesign the

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construction process, to put the construction user in focus and deliver an efficient, safe, sustainable and integrated industry sector.

A significant number of past and current research and development initiatives have identified that the construction industry must embrace innovative and efficient ways of working in order to remain competitive and to grow sustainably. In order to achieve this, the core organisational pillars<sup>1</sup> of construction industry must be strengthened; People, Process and Information

However the past R&D initiatives have not taken a holistic view of the construction process, and hence met with only partial success. This paper aims to highlight the problems currently associated with the construction industry with a specific focus on ICT initiatives, the shortcomings of the existing R&D activities, and proposes an integrated view of construction process, where people, process and information systems support each other.

The structure of the paper is as follows: First the research problem is discussed highlighting the problems associated with each of the problem areas. The next chapter provides a literature review on the subject. Next a way forward is presented followed by concluding remarks.

## RESEARCH PROBLEM

As discussed above, often three core elements that support any business are identified as; people, process and information systems, which need to be

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<sup>1</sup> This division of three aspects (people, process and ICT) is proposed as given, however from theoretical perspective it is open for discussion.

addressed/improved simultaneously to increase efficiency. However the problem is that these are seldom addressed in an integrated fashion, where it is essential to understand that these three factors are very closely interrelated. Any attempt to improve/address one aspect while ignoring other may not bring desired benefits, or indeed may actually negatively impact the business activity in question.

## RECENT TRENDS IN ICT, PEOPLE AND PROCESSES:

**ICT:** A significant research and development effort has been put into improving the efficiency of the construction sector over the years. Following the developments within the ICT sector it has remained a major research topic within construction. Due to the wide scope and relatively “clean slate” construction offered, it has encouraged researchers and practitioners to experiment with available technologies for possible efficiency gains, resulting in a large scale implementation of ICT solutions across the industry, some well planned and rest otherwise. Initial implementation of ICT systems within construction industry involved standalone systems such as CAD, Estimating and Tendering, Scheduling (Bar Charts), Accounting and Payroll, etc. General productivity software such as word processing and spreadsheet were also widely used. In recent years, applications such as Enterprise Resource Planning (ERP), collaboration tools such as Intranet and Extranet, 3D modelling and BIM tools have found increased use within construction industry. The growing trend of ICT implementation within construction is reflected in various

surveys carried out around the world (Howard et al. 1998; Rivard 2000; Arif and Karam, 2001; Samuelson, 2002; Ingrige and Aouad, 2001; Issa et al., 2003; Tas and Irlayici, 2007). However, recent literature and research has shown that the industry has not yet been able to gain the desired benefits from ICT projects due to varying factors (Pena-Mora et al. 1999; Tatari et al. 2007; Stewart and Mohammed, 2003; Marosszeky et al. 2000; Nitithamyong and Skibniewski 2003, Pensuapap and Walker, 2005). It emerges from discussion that unplanned and ill managed ICT systems and badly managed processes are actually disempowering construction workers rather than improving the ways of working as it should do.

Frustrations related to Information Systems implementations are not limited to the construction industry alone. Legris et al. (2002) has reported that only 26% of all MIS projects are completed on time and within budget, with all requirements fulfilled.

**People:** Construction industry in the UK relies heavily on subcontracted work. Most of the large construction companies today do not employ workers directly but only project manage the work using subcontracted labour. This has made construction a

heavily fragmented industry sector where organizational capabilities vary greatly. The problems rising due to conflict of interest between project management and subcontractors have been discussed by Bertelsen and Sacks (2007). The industry also suffers from lack of trust between various stakeholders interacting during a construction project, where disputes and litigation are commonplace. Such a hostile environment does not lend itself to innovation and efficient ways of working.

The problem of construction supply chain has been discussed before (Vrijhoef and Koskela, 2002), where poor communication, articulation and activation of commitments are attributing factors. Language/action paradigm (Winograd and Flores, 1986) highlights that at the core of communication process, there is a performance of linguistic acts which brings forth different kinds of commitments. Vrijhoef, et al (2003) has discussed that language/action perspective provides a plausible explanation for many root causes of construction supply chain problems. Although still in infancy in construction, an initial review of related tools and methods provides an optimistic view on practical usability of this approach in construction.

Table 4 - A typology of organisations

|                         |      | Type of formalisation |             |
|-------------------------|------|-----------------------|-------------|
|                         |      | Enabling              | Coercive    |
| Degree of formalisation | Low  | Organic               | Autocratic  |
|                         | High | Enabling Bureaucracy  | Mechanistic |

In the context of organisational efficiency, people are the most important aspect as they are the core driving force behind the process and technology. Adler and Borys (1996) have discussed different types of organisations and how they affect employees (table 1). Here it is interesting to note that along with the degree of formalisation, the type of formalisation is also very important. The conventional view that any bureaucracy is restrictive to employees is challenged. Organisations with high degree, but enabling type of formalisation can operate with enabling bureaucracy, which may provide the needed guidance and clarified responsibilities; easing role stress and make employees feel more effective.

Also, the role of technology whether enabling or restrictive is also important from people perspective. A poorly implemented information system may result in disempowered people rather than empowering them to higher efficiency. Morgan and Liker (2006) have discussed that technology should enhance people, not replace them.

**Processes:** Along with innovation in ICT, process improvement and reengineering are also popular research and development activities within construction. Similar to ICT, construction has been relatively slow to take process initiatives in consideration compared to other industry sectors such as manufacturing and automotive. Also, the lean

manufacturing (Womack, 1993) techniques developed by Toyota has also transformed how companies look at their production system. The lean approach provides a new way of looking at wastes lying within any production system and how to reduce/eliminate it to improve efficiency. However, construction industry has been unable to systematically assess processes, prioritise improvements or direct resources appropriately (Sarshar et al. 1999). Also, in spite of initial work done in Lean Construction, there is no widespread diffusion of such practices in the construction industry. Fragmented nature of supply chain, one of a kind projects, temporal nature of construction activities are some excuses used by the industry not to implement process improvement/management initiatives.

Construction projects are a dynamic working environment where variability is inherent within the process. A thorough study of construction process can enable measurement and quantification of variability and level of performance (Picard, 2002). In order to improve the construction process, it is essential to understand it first and provide effective ways of measurement. According to the TFV theory (Koskela, 2000), construction can be viewed from three different angles; Transformation (T), Flow (F) and Value (V). The following table (Table 2) shows influence of the TFV perspective on People, Process and ICT in construction.

**Table 2 - Matrix showing TFV perspective on People, Process and ICT in construction**

|   | <b>Process</b>  | <b>People</b>  | <b>ICT</b>   |
|---|---|--|--|
| T | Task based approach, leading to fragmented processes                      | Vertical or "silo" type organisation separated by functional departments | Leads to the view that ICT on its own brings benefits. Islands of information with virtually no or very little integration                           |
| F | Emphasis on waste reduction, time compression, flexibility, transparency, | Horizontal or team based organisation.                                   | ICT increases transparency but adds to variability. ERP type approach to integration, leaving the core construction processes relatively "untouched" |
| V | In addition to F processes focus on value                                 | Same as T, but organisations have direct focus on customers              | Focus on requirements capture software, supporting information flow through the project.   |

**PRIOR VIEWS ON HOW TO INTEGRATE PEOPLE, PROCESS AND INFORMATION SYSTEMS**

**IT as a source of benefit**

The earlier view taken was a very simple one, that simply implementing ICT solutions will bring significant improvements on its own. No significance was given to integration of people and process issues, resulting in less than satisfactory outcomes. Limitations of this approach were soon realised and efforts were put into integrating process issues along with ICT implementation. Business process reengineering/redesign (BPR) initiatives advocate the importance of integration process with information systems. However, BPR became more of a buzzword and focus shifted to reorganising the workforce and processes rather than integrating information systems with people and processes. Socio-technical approaches have tried to address the challenge of integrating people issues with information systems. However, this approach lacks the much needed focus on process. It can be concluded that prior views on integrating the three core elements of business have been of

limited effectiveness as they have only partially addressed the problem.

Koskela and Kazi (2003) have discussed the effectiveness of ICT within the construction sector. They have reported that although ICT has improved productivity on a general level as far as individual tasks are concerned, productivity of the industry on the whole has not benefited. Specifically the site and project management activities have not been addressed properly by the ICT implementations. A number of studies in impacts of ICT in construction are cited where the findings have indicated that even if high levels of benefit from ICT systems are found in design and administration type of work, site management and other construction related activities have remained virtually unaffected. And in certain cases of subcontractors and clients, the impact has indeed been negative. An even more worrying trend is reported which states that increased spend in IT has resulted in decreased productivity and safety standards.

The authors have argued that the view taken by construction industry

regarding ICT benefit is a very simple one that implementation of ICT systems brings benefits, where a simple formula of more ICT investment = more benefits has been applied. The same organisations which critically evaluate even the smallest of investment through rigorous ROI calculations, are not thinking twice on spending enormous amount of money behind ICT implementation. Also, most ICT implementation projects are led by technical experts rather than business experts, who fail to appreciate the intricacies of construction process and actual business needs as a result.

**IT and processes**

At the core of construction there are physical processes which are supported by information flows among others. ICT projects aim to improve these supporting information flows and hope that this will improve the whole process. However, if the actual production process is as chaotic as construction the implementation of ICT will not bring desired results, if not make it even worse.

This view is supported by a recent survey carried out by McKinsey and London School of Economics (2004) where productivity trends of around 100 companies across France, Germany, UK and the United States were surveyed in a period from 1994-2002. The survey shows that investing solely in ICT offerings has a very little impact on company's performance unless accompanied by operational change; and that regardless of the company's size, location, sector or past performance, better management practices improve organisational productivity. This is reflected in the results where lean manufacturing and better people management practices such as performance management and talent management coupled with ICT implementation brings 20% productivity increase, whereas isolated implementation of ICT brings only 2% productivity increase and management practices result in 8% increase. The survey rated the companies from 0-5 in how they utilised the three important tools, the following figure shows the results from the survey.

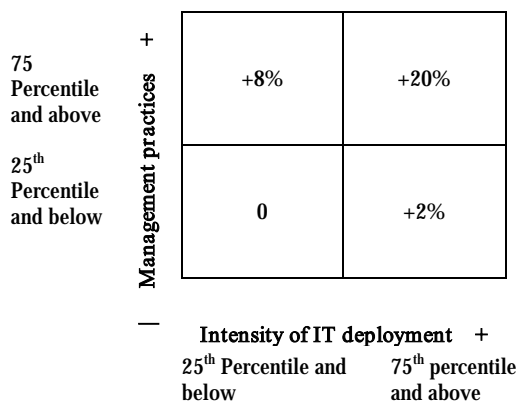


Figure 1 - % increase in total factor productivity (London School of Economics & McKinsey)

### The problem of IT integration

Researchers have also widely discussed the problem of disparate systems within the construction firms which results in islands of information (Bowden et al. 2006). Various departments across the construction team use their own software system which results in duplication of efforts and less efficient processes. This coupled with fragmented nature of construction supply chain adds to the problem of information integration across the industry (Alshawi and Ingrige, 2003).

The earlier consensus amongst researchers has been that implementing enterprise resource planning (ERP) systems results in a well integrated system which will reduce duplication of work and increase efficiency in general. However, in a study carried out by Tatari et al (2007) in the current state of construction enterprise information systems (CEIS), findings which are contrary to this belief are

reported. The survey has shown that only 16% of participants were satisfied with their current level of integration from their CEIS implementation. Table 3 shows the levels of functional integration found in the survey carried out by the authors.

It can be seen that most construction companies don't realise full integration from their system implementations with only 1.3 % claiming full integration across the whole supply chain and only 12.7 claiming full integration internally. Also very important to note is the fact that out of 101 firms studied, only 4% had actually implemented project management modules, hence leaving out the actual core production processes unchanged. This reinforces the view that majority of ICT solutions within construction industry are applied to the peripheral processes, neglecting improvement of the core production processes.

Table 3 - Level of functional integration within the construction industry (Tatari et al, 2007)

| Level of integration   | Percent |
|--|---------|
| Full integration with other parties (all functions and many different entities are integrated with seamless real-time integration) | 1.3     |
| Full integration (all functions integrated with seamless real-time integration)  | 12.7    |
| Partial seamless integration (several functions integrated with seamless real-time integration)                                    | 32.9    |
| Partial relayed integration (several functions computerized and consolidated in certain periods (e.g. daily, weekly and monthly))  | 32.9    |
| No integration (several standalone computer applications with no integration)  | 17.7    |
| No informational system (manual business processes and operation)  | 2.5     |
| Total  | 100     |

Rettig (2007) has pointed out that even if businesses aim to radically transform their processes through their high investment ERP implementation projects to achieve significant efficiency gain, very few actually go on to realise these benefits. In reality the companies who start with a vision

of integrated system where all elements of business processes are streamlined, end up with a patchwork of systems where a large number of software programmes are installed over the years. As a consequence, companies end up spending enormous amounts of money behind their IT investment which in fact take them

towards rigidity rather than innovative, efficient and responsive business processes. In a study carried out at MIT (Ross, et.al, 2006) where 400 companies were studied, it was reported that IT departments are seen as cost sinks and liabilities rather than centre for innovation.

It can be concluded from the above discussion that organisations have yet to realise the full potential from their ICT initiatives. Also, from construction perspective ICT is not yet addressing the core production processes, and full integration between systems is not yet present. The initial view of - more ICT spending brings more benefit has been challenged, and research now shows that ICT implementations must take into account people and process issues and undergo equal amount of scrutiny as other investment opportunities.

#### **ORGANISATIONAL EFFICIENCY AND ICT**

Flexibility is a key to responsive business, and organisational efficiency. In order to remain competitive, businesses must be able to respond to challenges faced by the changes in the surrounding world; these could be: changes in legislation, changing market conditions, availability of resources, changes in environment, etc. Hence business agility is vital to the survival for today's organisation. By building large and complex information systems, organisations are not able to remain flexible. Even a small change in the process, causes days if not months to implement as changes in the information systems are highly complex and expensive. Some of the most common mistakes made by organisations when selecting/implementing ICT are (Basu and Jarnagin, 2008):

**FAILURE TO REALISE TRUE POTENTIAL OF ICT:** Many companies fail to realise the true potential of ICT and merely use ICT as a tool to automate business functions or processes, or to expedite communication. However, issues such as business process transformation and maximising people's true potential are seldom addressed.

**RACE FOR THE LATEST AND GREATEST:** The current view of ICT (more ICT investment = more benefits) motivates organisations to implement the latest and "best" available technological solutions available. This is done regardless of whether there is actually a business need, adding to cost overheads rather than profit.

**GAP BETWEEN ICT AND BUSINESS PERSONNEL:** There is a clear difference in the thinking of ICT professionals and business managers. Due to differences in mind-set and language between management staff and IT staff, social influences, flaws in IT governance, and the difficulty of managing rapidly changing technology the gap has widened rather than decreased. This is also proven in a survey carried out by Shpilberg et al. (2007), in which 452 companies were studied with a view to identify relationship and trends between effectiveness of IT projects and alignment of IT and business goals. Only 7% of companies reported IT enabled growth, when a majority 74% were within "maintenance zone" equating to less aligned and less effective IT systems.

#### **THE WAY FORWARD**

Liker (2004) has pointed out that Toyota has remained flexible compared to competitors by selecting only those ICT opportunities which are needed and which can actually



reinforce the business processes, and also by making sure by testing that these are appropriate “fit” to the organisational infrastructure (people, process and other ICT). Shelbourn et al. (2007) has discussed that to leverage maximum potential from ICT projects there must be harmonisation of these three key strategies. In a survey carried out by the authors on the importance of 3 key strategies for effective collaboration, respondents attributed 40% importance to people, 34% to business processes and 26% to

technology (figure 2). The findings clearly reinforce the view presented by Wilkinson (2005), that any technology implementation in construction industry should be split; 40% people, 40% process and 20% technology.

This research has discussed a very current topic within the industry and identified the complementary nature of people, process and information systems. However, more work is needed to explore the area further and to identify solutions that can help industry improve.

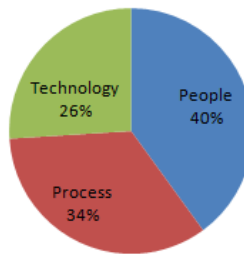


Figure 2 - Importance of three key strategies in collaboration projects (Shelbourn, et al. (2007))

Figure 3 shows the underlying concept behind the proposed framework where people, process and information systems support each other. In Figure 4 an outline of the proposed framework is presented. Here the initiatives which provide the underlying platform for

people, process and technology integration are proposed. It should be noted that this is only a broad outline and details are expected to emerge once further research is carried out in the proposed area. A brief introduction to the framework is given below:

Table 4 - Description of emergent topics within the proposed framework

| Domain  | Illustrative examples of emergent topics        | Characteristics of emergent topics   |
|---------|---|--|
| People  | Language Action Theory/Promise based management | Aims to resolve the communication problem existing within construction   |
|         | Agile project management                        | Transfers the flexible and iterative approach of project management to construction industry                               |
| Process | Last planner system                             | Addresses the core construction process based on the lean construction project delivery process                            |
|         | TFV theory                                      | Improves the understanding of construction process based on an integrated definition of TFV                                |
| ICT     | BIM/4D modelling                                | Enhances value generation of the construction process by improving requirements management, transparency and communication |
|         | Service Oriented Architecture (SOA)             | Provides an interface between business processes and IT infrastructure allowing flexibility and scalability                |
|         | Web 2.0 technologies                            | Upcoming internet applications offering improved information management and communication having synergy with SOA.         |

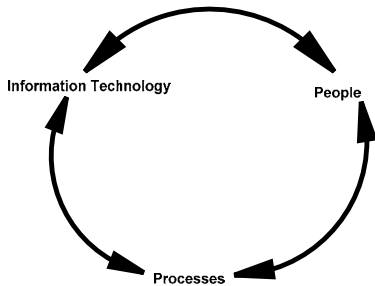


Figure 3 – Proposed Framework

Khanzode, et al. (2006) has discussed the application of Virtual Design Lifecycle (VDC) to lean project delivery process (LPDS), providing a good example of correct use of technology to reinforce the core construction process. The concept of VDC (Fischer and Kunz, 2004) uses multidisciplinary performance models of design-construction projects including the product (i.e., facilities), organization of the design-construction-operation team, and work processes, to support design and construction processes. Another good

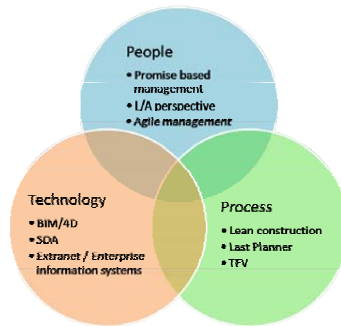


Figure 4 – Emergent topics

example is provided by Alshawi (2007), where the potential of ICT to improve business performance in architecture, construction and engineering organisations is discussed, suggesting the move away from technology thinking to IT-enabled business thinking has been proposed.

**CONCLUSION**

The construction industry has realised the importance of improving its performance following criticism. This paper has shown that the industry is investing a significant amount of

resources in ICT in an effort to respond to the criticism; however it has yet to see the true benefit of this investment. In order to improve the performance of the construction industry, it is important to address the core aspects

of the construction process rather than addressing the peripheral aspects of the process. A simple framework is proposed which looks at integrating three core organisational areas; people, process and information systems.

#### REFERENCES:

- Adler, P., and Borys, B. (1996). Two types of bureaucracy: enabling and coercive. *Administrative science quarterly*, 41, pp 91-89
- Alshawi, M., and Ingrige B. (2003). Web enabled project management: an engaging paradigm in construction. *Automation in Construction*. 12 no 4, pp 349-364
- Alshawi, M. (2007). *Re-thinking IT in Construction and Engineering: Organisational Readiness*. Taylor & Francis.
- Arif, A. and Karam, A. (2001). Architectural Practices and Their Use of IT in the Western Cape Province, South Africa, *ITcon Vol. 6*, pg. 17-34, <http://www.itcon.org/2001/2>
- Basu, A. and Jarnagin, C. (2008). How to tap IT's hidden potential. *Business Insight – MIT Sloan Management Review*.
- Bertelsen, S., and Sacks, R. (2007). 'Towards a new Understanding of the Construction Industry and the Nature of its Production.' *Proceedings of the 15th Conference of the International Group for Lean Construction*, C. Pasquire and P. Tzortzopoulos (Eds.), Michigan State University, East Lansing, Michigan, pp. 46-56
- Dawood, N., Akinsola, A. and Hobbs, B. (2002). Development of automated communication of systems for managing site information using internet technology. *Automation in construction*, 11, pp 557-72
- Dorgan, S.J. and Dowdy, J.J. (2004). When IT lifts productivity. *Research in brief. McKinsey Quarterly*. Nov, pp 9-11.
- Egan Sir J (1998). *Rethinking construction*. Rethinking construction: report of the construction task force on the scope for improving the quality and efficiency of UK construction. London: Department of the Environment, Transport and the Regions.
- Fischer, M., and Kunz, J. The role of information technology in construction. *CIFE technical report # 156* (2004).
- Howard, R., Kiviniemi, A. and Samuelson, O. (1998) *Surveys of IT in the Construction Industry and Experience of the IT Barometer in Scandinavia*, *ITcon Vol. 3*, pg. 47-59, <http://www.itcon.org/1998/4>
- Ingrige, B. and Aouad, G. (2001) *Awareness and usage of information standards in the UK construction industry: A survey by the SIENE network*. *Proceedings CIB W78-17*, South Africa.
- Issa, R. R. A., Flood, I. and Caglasin, G. (2003) *A survey of e-business implementation in the US construction industry*, *ITcon Vol. 8*, pg. 15-28, <http://www.itcon.org/2003/2>
- Khanzode, A., Fischer, M., Reed, D. and Ballard, G. (2004). *A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process*. *CIFE Technical Report #093*. Stanford University.
- Koskela, L. (1995), *On foundations of construction process modelling*. *CIB Workshop on Computers and Information in Construction*. Stanford University, Stanford, USA, August 1995. (*CIB Proceedings, Publication 180*). CIB; Stanford University, pp. 503 – 514

- Koskela, L. (1999), *Management of Production in Construction: Theoretical View*, Proceedings of the 7th Annual Conference of the International Group for Lean Construction
- Koskela, L. (2000), *An Exploration Towards a Production Theory and its Application to Construction*, PhD Dissertation, VTT Building Technology, Espoo, Finland. 296 p., VTT Publications: 408, ISBN 951-38-5565-1; 951-38-5566-X
- Koskela, L., and Kazi, A.S. (2003). *Information Technology in Construction: How to realise the benefits? – Socio technical and human cognition elements of information systems*. Clarke, S., Coakes, E., Huner, M. G. and Wenn, A. (eds.) Information Science Publishing, pp 60-75
- Latham Sir M, (1994) *Constructing the team*. Final report of the government/industry review of procurement and contractual arrangements in the UK construction industry, HMSO, London.
- Legris, P., Ingham, J., Collette, P. (2003). *Why do people use information technology? A critical review of technology acceptance model*. *Information & Management* 40, 191-204.
- Liker, J.K. (2004), *The Toyota Way*, McGraw Hill, London.
- Marosszekey, M., Sauer, C., Johnson, K., Karim, K. and Yetton, P. (2000). *Information technology in the building and construction industry: the Australian experience*. In: Q.P. Li, D. Shen and P.E.D. Scott, Editors, *Implementing IT to Gain a Competitive Advantage in the 21st Century*, Hong Kong Polytechnic Univ. Press, Hong Kong, pp. 183–196
- Morgan, M.J., and Liker, J. K., (2006) *The Toyota Product Development System; Integrating people, process, and technology*. Productivity Press, New York.
- Nitithamyong, P. and Skibniewski, M. (2003). *Critical Success/Failure Factors in Implementation of Web-Based Construction Project Management Systems*. Proceedings of the Construction Research Congress – Winds of Change: Integration and Innovation in Construction, Honolulu, Hawaii, Molenaar K. R. and P. S. Chinowsky, American Society of Civil Engineers.
- Peansupap, V. and Walker, D. H. T (2005). *Factors enabling information and communication technology diffusion and actual implementation in construction organisations*. *ITcon* Vol. 10, pg. 193-218, <http://www.itcon.org/2005/14>
- Pena-Mora, F., S. Vadhavkar, E. Perkins, T. Weber (1999). *Information technology planning framework for large-scale projects*, *Journal of Computing in Civil Engineering* (ASCE), 226-237
- Pietroforte, R. (1997). *Communication and governance in the building process*. *Construction Management and Economics*, 15, pp 71–82
- Rettig, C. (2007). *The Trouble with Enterprise Software*. *MIT Sloan Management Review*. 49 no 1, pp 21-27
- Rivard, H. (2000) *A Survey on the Impact of Information Technology in the Canadian Architecture, Engineering and Construction Industry*, *ITcon* Vol. 5, pg. 37-56, <http://www.itcon.org/2000/3>
- Ross, J.W., Weill, P., and Robertson, D.C., (2006) *Enterprise Architecture as Strategy: Creating a Foundation for Business Execution* (Boston: Harvard Business School Press, 2006)
- Samuelson, O. (2002) *IT-Barometer 2000 - The Use of IT in the Nordic Construction Industry*, *ITcon* Vol. 7, pg. 1-26, <http://www.itcon.org/2002/1>
- Sarshar, M., Haigh, R., Finnemore, M., Aouad, G., Barrett, P. (1999), *Standardised process improvement for construction enterprises (SPICE): research methodology and*

- approach, *Challenge of Change: Building and Construction in the New Millennium*, Salford,
- Shelbourn, M., Bouchlaghem, M., Anumba, C., Carrillo, P. (2007). Planning and implementation of effective collaboration in construction projects. 7(2007) no 4, pp 357-377
- Shpilberg, D., Berez, S., Puryear, R. and Shah, S. (2007). Avoiding the alignment trap in Information Technology. MIT Sloan Management Review. 49 (2007) no 1, pp 51-58
- Stewart, R.A. and Mohammed, S. (2003). Evaluating the value IT adds to the process of project information mgmt in construction. *Automation in Construction* 12 (2003) 407– 417
- Tas, E. and Irlayici, F. P. (2007) A survey of the use of IT in building product information acquisition in Turkey, *ITcon* Vol. 12, pg. 323-335, <http://www.itcon.org/2007/22>
- Tatari, O., Castro-Lacouture, D. and Skibniewski, M. J. (2007). Current state of construction enterprise information systems: survey research. *Construction Innovation*, 7 (2007) 310-319
- Vrijhoef, R., and Koskela, L. (2000) “The four roles of supply chain management in construction.” *European Journal of Purchasing and Supply Mgmt*, 3-4 (6), 169-178
- Vrijhoef, R., Koskela, L., and Howell, G. (2003), Understanding construction supply chains: An alternative interpretation. *Proceedings 11<sup>th</sup> Lean Annual Lean Construction Conference (IGLC-11)*, 22-24 July 2003, Blacksburg.
- Wilkinson, P. (2005), *Construction Collaboration Technologies*, Spon Press, London
- Winograd, T., and Flores, F. (1986) *Understanding Computers and Cognition: A New Foundation for Design*. Ablex, Norwood. 207 p.

