HIGHER CAPABILITY MATURITY DYNAMICS OF UK CONSTRUCTION ORGANISATIONS

K. Keraminiyage[1], D. Amaratunga[1], R.Haigh[1]
[1]Research Institute for the Built and Human Environment,
The University of Salford, UK
Email: K.P.Keraminiyage@Salford.ac.uk

ABSTRACT: This paper attempts to identify the dynamics of the CMM (Capability Maturity Model) higher capability maturity level characteristics within the UK construction context from a theoretical perspective. Firstly, this paper follows a literature survey and a synthesis to identify the nature of CMM higher capability maturity level dynamics and its specific attachments to the software industry. Based on this synthesis, this paper presents a model to mimic the likely higher capability maturity dynamics of the UK construction industry.

Keywords: Construction Process Improvement, Software CMM, SPICE, Higher Capability Maturity Level KPAs.

1. BACKGROUND

Unpredictability and the under achievements of the UK construction industry have been a strong concern within various studies and institutional reports (Koskela et al, 2003, Santos and Powell, 2001; Egan, 1998; Love and Li, 1998; Latham, 1994). Fragmentation and confrontational relationships have been identified as the main causes of this unacceptable level of performance of the UK construction industry (Love and Li, 1998; Egan, 1998; Latham, 1994). Further, the traditional functional view of construction projects could be highlighted as the main reason for the fragmentation and confrontational relationships identified within the UK construction industry (Fairclough, 2002; Holt et al, 2000).

In the light of the above argument, it is suggested that the UK construction industry should focus on its processes, in order to overcome its performance related problems. The importance of this focus shift has been stressed specifically within the Egan's report. Egan (1998) has highlighted the importance of taking process improvement initiatives within the UK construction industry as a measure to overcome its problems. At the same time, the importance of learning lessons from other industries has also been stressed within the same report. However, the expected synergic advantage of learning process improvement lessons from other industries to construction has raised some concerns of the researchers. It has often been argued that even though the performance improvements have been achieved through process improvement initiatives within the manufacturing and services sectors, the direct applicability of this strategy within construction has to be given careful thoughts (see: Santos and Powell, 2001; Love and Li, 1998; Egan, 1998). It has further been argued that the principles of process improvement of the industries such as manufacturing and services are not readily applicable within the construction context, due to the "unique" nature of the construction product. Further, the complex supply chain arrangements and project based product delivery systems have also been identified as inhibits for process improvement initiatives.

On the other hand, some researchers have argued against the above view by raising concerns about the fundamental assumption of process improvement being successful only within the services and manufacturing disciplines where same process is repeated for mass production activities. Being a project based industry the software industry provides examples in favour of this argument through the success stories of its highly successful process improvement initiatives (Sarshar, at el, 2000a). On the other hand the concepts such as lean construction place the construction within the manufacturing framework suggesting similarities between the manufacturing and construction. These arguments suggest that the process improvement initiatives within construction cannot be treated as impossible. However, as Lilrank (1995), the practices of one industry cannot be used directly within another industry rather the practices will have to be recreated within the second environment after considering its own characteristics and existing practices. Accordingly, the process improvement in construction is not a simple repetition of what is being done within other industries; rather the construction should have its own process improvement methodology.

2. CONSTRUCTION PROCESS IMPROVEMENT INITIATIVES

Until recently, the construction industry has had few recognised methodologies or frameworks on which to base a process improvement initiative (Sarshar et al 2000a). This is particularly apparent when considering the availability of such frameworks or methodologies to look at the organisational maturity and capability aspects. Unlike in a linear production situation, the project based nature of construction demands complex relationships between various parties. These complexities are influential factors when determining the organisational capabilities which are visible in varying degrees. Moreover, this hinders the capabilities of organisations to assess their standards and prioritise their process improvements appropriately. Further, absence of clear guidance at the macro level, hinders the repeatability and benchmarking capabilities of individual performance improvements (if any) at industry level (Sarshar et al 2000a). Thus it is important to establish a structured, common approach to construction process assessment and improvement based on the current capabilities of the organisation.

Lessons from the software industry

As a process improvement initiative the Software Capability Maturity Model (CMM) has demonstrated its success within the software industry. CMM was developed for the US department of Defence (DoD) who is a major software purchaser (Sarshar et al 1998). The use of CMM includes the evaluation of software manufacturing organisations prior to award them contracts. CMM is based on a five levelled structure. Within this, organisations are ranged from level 1 to level 5 based on their maturity. Within this framework, a maturity level has been defined as “a well defined evolutionary plateau towards achieving mature processes. Each maturity level provides a layer in the foundation for continuous process improvement” (Paulk et al 1993). Level 1 organisations are the least matured organisations where as level 5 organisations are the most matured organisations. In order to achieve a specified maturity level, organisations must satisfy all the “key processes” defined within the immediate below maturity level. The organisations are tested against “key enablers” to determine weather they have satisfied each key process within a maturity level. Through this framework, organisations are guided to adopt stepwise process improvements and ensure that the organisation in question is ready for the next level of process improvement. This, intern initialise a process improvement culture within the organisation and guides the procedures and the people towards improvements, using the available and potential tools.

The SPICE model

Sarshar et al (1998) have attempted to apply the principles of the software CMM model within the construction industry. This attempt was named as the Structured Process Improvement in Construction Enterprises (SPICE). The similarities between a software development projects and construction projects have laid the foundation for the SPICE to consider CMM as its base. Adopting the five level architecture of the CMM, the SPICE framework has also organised the process improvements of a construction organisation into five evolutionary steps. Each step is known as a maturity level. Within this paper maturity levels up to the third maturity level are identified as lower maturity level and 4th and 5th maturity levels are considered as higher maturity levels.

Each maturity level has several "Key Process Areas". In order to achieve a level of maturity, the organisation should successfully perform all key processes related to that maturity level. This ability of performing key processes of that particular organisation is evaluated against five key process enablers. Those are,

- Commitment
- Ability
- Evaluation
- Verification
- Activities

It is also said within the SPICE framework that one organisation cannot skip maturity levels while progressing. As an example, to achieve third level maturity, organisations have to go through the second maturity level and cannot advance directly from first maturity level to third maturity level.

The SPICE Level 1 organisations have been identified as organisations which use ad-hoc processes during their day to day activities. And generally these organisations are surviving or performing due to the ability of some individual characters within the organisation.

Within the SPICE framework the level 2 has been identified as planned and tracked. At this level there is a degree of project predictability. A level 2 organisation has established policies and procedures for managing the major project-based processes (Sarshar et al, 2000b). SPICE Level 3 is identified as "Well Defined". Within this level practices are well defined and institutionalised. Knowledge capturing and sharing mechanisms are established within these organisations to institutionalise the good practices and processes. After this institutionalisation, a high level of predictability can be expected towards future projects of an organisation.

The current SPICE model does concentrate on higher capability maturity levels of construction process improvements. As the Sarshar et al (2000b) have explicitly mentioned, so far the SPICE research has had little focus on level 4 and 5 issues. While lower maturity levels of CMM establish the required capability and the background of the organisation, the higher maturity levels are responsible for dramatic and sustainable process improvements. Within the SPICE, the dynamics of higher maturity levels were not explored thoroughly, leaving its full potential unexplored. This part of this paper is attempted to address this research gap from a comparative basis. The CMM level 4 and level 5 Key Process Areas will be analysed thoroughly, comparing the distinctive characteristics of both the software and construction industries. Furthermore, this analysis will be extended to discuss the applicability of these CMM higher maturity level dynamics within the construction environment.

3. LEVEL 4 CHARACTERISTICS OF CMM

CMM level 4 is classified as the “The Managed Level”. Many characteristics of levels 4 and 5 are based on the concept of statistical process control (Paulk et al, 1993). From a project management and organisational perspective, the focus of level 4 is on establishing quantitative process management processes, while from engineering processes perspective, it is on establishing Software Quality Management processes (Paulk et al, 1995; Paulk et al, 1993).

There are two Key Process Areas (KPAs) at CMM level 4, which are based on above mentioned focuses. One has to do with process quality, that is, process performance (Quantitative Process Management – QPM) and the other, Software Quality Management, with product quality (Dymond, 1995).

Quantitative Process Management (QPM)

The purpose of QPM is to control the process performance of the software project quantitatively. Software process performance represents the actual results achieved from following a software process (Paulk et al, 1995). QPM involves establishing goals for the performance of project’s defined software process, taking and analysing measurement of the process performance and making adjustments to maintain process performance within acceptable limits (Paulk et al, 1995).

Once the process performance is within the acceptable limits, the settings are established as a baseline and used to control process performance quantitatively. Further, within this KPA, special causes of variations in process performance will be identified and removed (Dymond, 1995). Collection of process performance data across all the projects of the organisation will be used to characterise the process capability of the organisation’s standard software process. This process capability data in turn will be used by the software projects to establish and revise their process performance goals (Paulk et al, 1995).

Software Quality Management (SQM)

The second KPA of the CMM level 4 is SQM. The purpose of SQM is to develop a quantitative understanding of the quality of the project’s software products and achieve specific quality goals (Paulk et al, 1995). This KPA involves defining quality goals for software products, establishing plans to achieve these goals, monitoring and adjusting the software plans and products to satisfy the needs and desires of the affected stakeholders.

The determination of quality goals is based on the plan developed for the project software quality. This plan takes its quality requirement input from customers, organisational and project quality plans and organisational capabilities. The quality requirements become numeric quality goals when data values describing those quality features are produced from the measurement plan (Dymond, 1995). After establishing the quantitative quality goals, the actual quality is measured against the goal at the start of each life cycle stage and corrective measures will be taken as and when necessary.

4. 4^{TH} LEVEL DYNAMICS WITHIN CONSTRUCTION

Within the construction context, the principles of the above KPAs can be interpreted from a different view point. Taking QPM into consideration as a KPA in within the construction context, it is important to establish the definition of "construction process performance" in relation to the "software process performance". Since "performance" is a relative measure, firstly it is important to establish an objective basis within which the "construction process performance" can be defined. Since the major objectives of a construction project are based on the time, cost and quality aspects, scaling it down to the process level, the objectives of a construction process can also be identified within a time, cost and quality framework. In effect this means that the performance of the construction processes can be measured monitored in terms of time, cost and quality. The major emphasis is on the ability to take quantitative measurements of these parameters to establish "goals" for the processes based on which the performance of the processes can be evaluated for improvements. However, it is not the intention of this study to investigate and propose suitable methodologies for measuring and monitoring the performance of the processes in place, rather it is intended to identify whether the organisation;

- has the commitment to quantitatively measure the performance of processes as described above
- has the ability to perform quantitative measurements of its processes
- have activities in place to perform the quantitative measurements
- evaluate the activities in place to measure the performance of processes (internal evaluation)
- verifies the activities to measure the performance of the processes are in compliance with standard practices (external verification).

The above five items are the key process enablers against which each of the KPAs has to be tested.

When mapping the "Software Quality Management" KPA to construction, the main emphasis has to be given to the quality of the final product. This effectively reflects on the performance of the "core processes" or "technical level processes" as well as other related parameters such as programmer's skill within the software industry and workmanship and material quality within the construction industry. While the software industry uses quantitative measures such as number of bugs per thousand lines of code to quantify the quality of its final product, construction industry practices various material testing techniques and industry standards for material quality determination to ensure the quality of its final product. Due to the reason that the software quality does not heavily depend upon external factors such as material quality or the soil bearing pressure, it is sensible to assume a strong relationship between the software quality and the software processes in place. This is further justifiable since the measures such as number of bugs for thousand lines of code have a higher chance to get a high figure if the programmers work under stress within ad-hoc fire fighting situations in contrast to the existence of a working environment where proper processes in place to ensure minimal stress to the programmer.

Within this context, construction has a strong requirement to monitor the quality of its final products as it will be determined by a combination of various factors. These factors include quality of workmanship, construction processes in place, external factors such as ground and weather conditions, supply chain arrangements, etc. In order to enable continuous improvements within an organisation, it is important to monitor the impact of these parameters to the quality of the final product. This establishes justification for the need a different KPA within construction to quantitatively monitor and manage the quality of the construction product. Further, it is required to emphasis here that it is not the intention of this study to identify "how" the quality of the construction product is measured within construction organisations, but to identify the level of the construction quality measurement within the five key process enablers described above.

After establishing the "Quantitative Control", the next aspect of the organisation is to move towards an "Optimisation" where the monitored processes are continuously improved. This is the main objective of the CMM level 5.

5. CMM LEVEL 5 CHARACTERISTICS

CMM level 5 is classified as "Optimising". The focus of this level is on the continuous process improvement. The software process is changed to improve quality, and the zone of quality control moves to establish a new baseline for performance with reduced chronic waste (Paulk et al, 1993). Lessons learnt during these improvements will be applied in future projects. At this point, common causes of variations are addressed which in tern will result in reduced chronic waste and new baselines for improved performances. This feedback loop completes the cycle of continuous process improvement. CMM Level 5 consists of three KPAs which lead the organisation towards the ultimate goal of continuous process improvement. Those KPAs are;

- Defect Prevention
- Technology Change Management
- Process Change Management

a) Defect Prevention

Even though the defect prevention (DP) is identified as a KPA within the level 5, it doesn't prevent organisations at lower levels from practicing DP. But DP is one of the key considerations of a level 5 organisation (Dymond, 1995). The purpose of the DP is to identify the common causes of defects and prevent them from recurring (Paulk et al, 1995). DP involves analysing defects that were encountered in the past and taking preventive actions to systematically eliminate those from the future projects.

b) Technology Change Management (TCM)

The second KPA of the CMM level 5 is the technology management. The purpose of TCM is to identify new technologies (i.e. tools, methods and processes) and transition them to organisation in an orderly manner (Paulk et al, 1995). It involves identifying, selecting and evaluating new technologies and incorporating effective technologies into the organisation. The objective is to improve software quality, increase productivity and decrease the cycle time for product development.

c) Process change management (PCM)

PCM KPA is aiming to continuously improve the software processes used in the organisation with the intention of improving software quality, increasing 1 and decreasing the cycle time for product development (Paulk et al 1995). It involves defining process improvement goals and systematically identifying, evaluating and implementing improvements to the organisation's standard software process and project's defined software process on a continuous basis. These improvements are piloted before integrating to the normal software practice. Once the improvements are approved for normal practice, the organisation's standard software process and project's defined software process are revised as appropriate.

6. 5TH LEVEL DYNAMICS WITHIN CONSTRUCTION

When viewing the above KPAs from the construction perspective, it is important to take the construction specific characteristics into consideration. The place of Defect Prevention KPA in software CMM is justifiable as a 5th level capability maturity level dynamic as lesser number of defects (bugs) found in a software product directly contribute to the software quality positively, as this is the major measurement of software quality. Further the quantitative measurement and control of the software quality has considered as a key process area within the 4th maturity level enabling the organisation to concentrate on preventing measures once the organisation reaches the 5th maturity level.

In contrast, the construction "defects" does not covers the full aspects of construction product quality as explained under the 4th maturity level dynamics. Rather "defects" in construction projects are treated separately and treated under the arrangements such as "defect liability period" and "maintenance period". However, if a construction organisation to practice defect prevention measures at the 5th maturity level, it has to establish quantitative defect measurements and control preferably within the 4th maturity level. This initiates the necessity to consider the establishment of a new KPA within the 4th maturity level, "quantitative defect control". Once this is established, the defect prevention measures can be considered as an explicit KPA within the 5th maturity level.

While technology change management has considered as a key process area within the 5th maturity level of the software CMM, construction industry may not be able to limit this within these boundaries. Technology Change in software is relatively straight forward due to the fact that software uses relatively less number of different technologies within different sections of the product. As an example, in software a technology change would mean migrating from one programming language to another. In this case the change effect is organisation wide. But the construction utilises different technologies within different sections of the product. As an example, a new technological innovation in fabrication of steel structures might influence the processes involve for the erecting of the steel structure but might not have significant effects on processes to erect other elements like services or finishes. And due to these diversifications it is difficult to adopt an organisation wide technology change management as a single key process area within the 5th level of the construction capability maturity. This in effect suggests that operational level technologies within construction have to evolve with the processes in concern. An institutionalising effort may not be practical for these core technologies within a construction process improvement initiative. On the other hand, supportive technologies to these core technologies can have an organisational wide improvement strategy. Information Technology can be considered as an example, where it provides a technological infrastructure to all the core technologies to initiate their own innovations. Based on the improvement requirements of these technological processes and the capabilities of the IT, different elements of the construction product can initiate continuous improvement of its own underlying technologies. However, the level of use of IT as a supportive (enabling) technology within the construction process is also depend upon the maturity

level of the organisation in question. Due to these reasons it is impractical for a construction organisation to consider Technology Change Management as a single KPA within the 5th Capability Maturity Level as seen in the software CMM. However, this research further queries how the IT usage within construction organisations can mature with the maturity of its capabilities. The objective of this query is to establish a process-IT co maturation model to be used by the construction organisations.
The final KPA considered within the software CMM is the process change management, which is the core to achieve continuous process improvements. The principle of this KPA is generic and the same principles can be used within the construction industry. Since the 4th level capabilities ensure the availability of the quantitative data within the organisation to reflect the opportunities for improvement, this KPA can be used to establish new stretch goals for the processes in place which can stimulate innovative processes. Thus this can be used as the starting point for the "revolutionary process improvements" within the organisation with out straining the organisational resources.

7. CONCLUSION

By considering the similarities between the two industries, some construction process improvement initiatives have adopted the principles of software industry's Capability Maturity Model. However to date, the higher maturity level characteristics of the software CMM has not been analysed thoroughly to evaluate its applicability within the UK construction environment. Thus, this paper looked analysed these characteristics within the comparative setting between the software industry characteristics and the construction industry characteristics to build a initial model how the CMM higher capability maturity level characteristics fit within a construction environment.
After considering the CMM model, software industry practices and construction practices, three KPAs can be identified within construction which has to be tested against the five key enablers described above as 4th capability maturity level dynamics. Those are;

- Quantitative Process Management in Construction
- Construction Product Quality Management
- Quantitative Defect Management in Construction

Within the 5th capability maturity level two KPAs have been identified as applicable within construction. Those are;

- Construction Defect Prevention
- Construction Process Change Management

However, the Technology Change Management KPA identified within the software CMM level 5 has its limitations if to be implemented within the construction due to the diversification of technologies used within a construction project. However, it is intended within this research to investigate the role of IT as a supporting (enabling) technology to be used within the construction industry.

8. WAY FORWARD

As this is a part of an ongoing PhD, it is intended to validate this initial understanding about the higher capability maturity dynamics through a case study approach. Further, this model is intended to go through several refinement cycles to ensure that it captures the actual industry characteristics and requirements. Moreover, special emphasis will be given within this research to understand the role of the information technology within this process to achieve higher capability maturity dynamics within the UK construction organisations.

9. REFERENCE

Dymond, M. (1995) *A Guide to the CMM: Understanding the Capability Maturity Model for Software*. Maryland: Process Inc US.

Egan, J. (1998) *Rethinking Construction,* Department of Environment. Transport and the Regions

Fairclough, J. (2002) Re thinking construction innovation and research: A review of

Hammer, M. and Champy, J. (1993) *Re-engineering the Corporation: a Manifesto for Business Revolution*. London: Brealey Publishing.

Hammer, M. (1990) *Reengineering Work: Don't Automate, Obliterate*. Harvard Business Review, July/August, pp. 104-12.

Harrington, H. (1991) Improving Business Processes. *TQM Magazine*, February, pp. 39-44.

Healy, M. and Perry, C. (2000) Validity and Reliability of Qualitative Research Within the Realism Paradigm. *Qualitative Research Journal*: *An International Journal*, 3(3), pp. 118-126.

Holt, D. Love, D. and Nesan, F. (2000) Employee Empowerment in Construction: An Implementation Model for Process Improvement. *Team performance Management: An International Journal, 6* (3/4), pp. 47-51.

Humphrey, W. and Sweet, W. (1987) *A Method for Assessing the Software Engineering Capability of Contractors*. Pittsburgh: Software Engineering Institute.

Humphrey, W. (1989) *Managing the Software Process*. New York: Addison-Weslley publishing company Inc.

Jha, S. and Noori, H. Michela, J. (1996) The dynamics of continuous improvement, *International Journal of Quality Science*, 1(1), pp. 19-47.

Juran, J. (1991) Strategies for World-Class Quality. *Quality Progress*, March, pp. 81-5.

Kagioglou, M. Aouad, G. Cooper, R. and Hinks, J. (1999a) The Process Protocol: Process and IT modelling for the UK Construction Industry. IN: Amor R. (ed.) Product and Process Modelling in the Building Industry ,*Proceedings of ECPPM'98, Building Research Establishment,* Watford, 19-21 Oct., Clowes Group, Beccles, Suffolk, UK, pp. 267-276.

Kagioglou, M. Cooper, R. and Aouad, G. (1999b) Re-Engineering the UK Construction Industry: The process protocol. IN: *The Proceedings of Conference on Construction Process Re-engineering*, University of South Wales, Sydney, Australia, pp. 317–327.

Kagioglou, M. Cooper, R. Aouad, G. Hinks, J. Sexton, M. and Sheath, D. (1998) *Generic Design and Construction Process Protocol: final report*, The University of Salford.

Koskela, L. Ballard, G. and Howell, G. (2003*) Achieving Change in Construction. Virginia:* International Group of Lean Construction.

Latham, M. (1994), *Constructing the Team*, HMSO.

Lillrank, P. (1995), The Transfer of Management Innovations from Japan. *Organisation Studies,* 16(6), pp. 971-89.

Love, D. and Li, H. (1998) From BPR to CPR – Conceptualising Re-Engineering in Construction. *Business Process Management Journal*, 4(4), pp. 291-305.
Love, D. Li, I. Irani, Z. and Li, H. (2000) Total Quality Management and the Learning Organisation: A Dialogue for Change in Construction. *Construction Management and Economics,* 18, pp. 321-331.
Love, P. and Gunasekaran, A. (1997) Concurrent Engineering in the Construction Industry. *Concurrent Engineering: Research and Applications*. 5(2), pp.155-162.
Lowe, D. & Cox G. (1996) Implementing the Capability Maturity Model for Software Development. *Hewlett Packard Journal*.
Mills, M. and Huberman, A. (1994) *Qualitative Data Analysis: An Expanded Source Book.* CA: Thousand oaks.
Morton, M. (1991) *The Corporation in the 1990's: Information Technology and Organisational Transformation*. Oxford: Oxford University Press.
O'Conner, T. and Yang, L.(2004) Project Performance versus Use of Technologies at Project and Phase Levels. *Journal of Construction Engineering and Management,* 130(3), pp. 322-329.
Oakland, S. (1993) *Total Quality Management.* 2nd Ed. Oxford: Butterworth-Heinemann.
Paulk, C. Weber, C. Garcia, S. Chrissis, B. and Bush, M. (1993) *Key Practices of the Capability Maturity Model*. Pittsburgh: Software Engineering Institute.
Paulk, C. Weber, C. Garcia, S. Chrissis, B. and Bush, M. (1994*) The Capability Maturity Model for Software*. Pittsburgh: Software Engineering Institute.
Paulk, C. Weber, C. Garcia, S. Chrissis, B. and Bush, M. (1995) *The Capability Maturity Model: Guidelines for Improving the Software Process*. Pittsburgh: Addision-Wesley.
Pheng, L. and Ke-Wei, P. (1996), A Framework for Implementing TQM in Construction. *The TQM Magazine*,8(5), pp. 39-46.
Raynus, J. (1999) *Software Process Improvement with CMM. Norwood:* Artech House Inc.
Samuelsson, P. (2003) Improvement Processes in Construction Companies IN: Atkin, B. Borgbrant, J. and Josephson, P. (eds.) *Construction Process Improvement,* Oxford: Blackwell Science ltd, pp. 225-238.
Santos, A. and Powell, J. (2001) Assessing the Level of Teamwork in Brazilian and English Construction Sites. *Leadership and Organization Development Journal*, 22(4), pp. 166-174.
Santos, A. Formoso, C. and Tookey, E. (2002) Expanding the Meaning of Standardisation within Construction Processes. *The TQM Magazine*, 14(1), pp. 25-33.
Santos, A. Powell, J. and Formoso, C. (2000) Setting Stretch Targets for Driving Continuous Improvement in Construction: Analysis of Brazilian and UK practices. *Work Study, 49*(2), pp.50-58.
Sarshar, M. Finnemore, M. and Haigh, R (2000b*) Introduction to SPICE*. Construct I.T., University of Salford.
Sarshar, M. Haigh, R. Finnemore, M. Aouad, G. Barrett, P. Baldry, D. and Sexton, M. (2000a) SPICE: A Business Process Diagnostics Tool for Construction Projects. *Engineering Construction & Architectural Management*, 7(3), pp. 241-250.

Sarshar, M. Hutchinson, A. Aouad, G. Barrett, P. Minnikin, J. and Shelley, C. (1998) Standardised Process Improvement for Construction Enterprises (SPICE). IN: *Proceedings of 2nd European Conference on Product and Process Modelling*, Watford.

Talwar, R. (1993) Business Re-Engineering – A Strategy-Driven Approach. Long Range Planning, 26(6), pp. 22-40.

Tanswell, A. (1993) Business Restructuring: The Key to Radical Change. *Professional Engineering,* 6(1), January, pp. 24-5.

Tinnila, M. (1995), Strategic Perspective to Business Process Redesign. *Management Decision,* 33(3), pp. 25-34.

Yin, R. K (2003), *Case Study Research: Design and Methods*. 3rd ed. London: Sage publications.