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ACHIEVING HIGHER CAPABILITY MATURITY IN CONSTRUCTION PROCESS IMPROVEMENT

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Abstract: Process improvement has been identified as one of the potential mechanisms to achieve the desired performance improvements within the UK construction industry. In addition, it has further been recognised the importance of learning construction process improvement lessons from other industry examples. Software industry has exemplified a successful implementation of a process improvement strategy, based on the Capability Maturity Model (CMM) which evaluate the capabilities and maturities of organisations in concern to establish the next level of process improvements needed. This model consists of five maturity levels where level 1 being the least matured and level 5 being the most matured. After considering the close similarities between the software industry and the construction industry, the principles of software CMM were attempted to be applied within the construction industry, under the research project "Structured Process Improvement in Construction Enterprises (SPICE)". Within this research the Key Process Areas (KPAs) of level 1, 2 and 3 of software CMM were evaluated and customised to the UK construction industry, after taking its unique characteristics into consideration. This leaves the software CMM level 4 and 5 KPAs unevaluated and un-customised, leaving the maximum potential of SPICE un-revealed. This paper aims at addressing this gap by reviewing the literature on construction process improvement and the software CMM to evaluate the applicability of software CMM higher capability maturity level KPAs within the UK construction context.

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

1. BACKGROUND

It is generally admitted that there is a need for performance improvements within the UK construction industry as it is unpredictable and under-achieving (Koskela et al, 2003, Santos and Powell, 2001; Egan, 1998; Love and Li, 1998; Latham, 1994). Further studies about this need revealed that the fragmentation and confrontational relationships are the major inhibits for performance improvement initiatives (Love and Li, 1998; Egan, 1998; Latham, 1994). Fragmentation and confrontational relationships are sharpened due to the traditional functional view of construction projects, where the tasks are assigned to individuals based on their functions with minimum attention given to the integration issues (Fairclough, 2002; Holt et al, 2000).

Having identified this nature, Egan (1998) highlighted that "focusing on the customer" and "integrating the process and the team around the product" as two of the key drivers to achieve the desired change within the UK construction industry. This emphasises the need within the UK construction industry of deviating from its functionally oriented project structures towards a customer focused, process oriented project delivery mechanisms. It appears that the above recommendations from Egan are based on the view that the process improvement is the way forward to improve the performance of the UK construction industry (Sarshar et al, 2000a).

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 is debated (see: Santos and Powell, 2001; Love and Li, 1998; Egan, 1998). It is argued that the principles of process improvement of the industries like manufacturing and services are not readily applicable within the construction context, due to the "unique" nature of the product. Further, the complex supply chain arrangements and project based product delivery systems have also been identified as inhibits for process improvement initiatives. Contrary to this view, Egan (1998) argues that the construction is a set of repetitive processes when viewing from the organisational point of view. He further emphasises that the project based nature should not be a barrier for process improvement initiatives within the construction industry. Reinforcing this argument, despite its project based nature, the software industry exemplifies the successful implementations of process improvements (see: Sarshar et al, 2000a). This suggests that there are similarities between the construction industry and other industries which have success stories in process improvement where the construction industry can learn lessons from.

However, the above argument does not suggest that the innovations and improvement initiatives within other industries can readily be applicable within a construction environment. As Lillrank (1995) have pointed out, the core idea of an innovation in one industry should be abstracted and then recreated in a form, which it fits in local conditions. The problem then becomes how to recreate process improvement initiatives and innovations of other industries within the UK construction environment.

2. CONSTRUCTION PROCESS IMPROVEMENT STRATEGIES: CURRENT RESEARCH STATUS

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 within construction process improvement initiatives. Unlike in a linier 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. One such approach which was a success within the software industry is "The Software Capability Maturity Model (CMM)". The Software Capability Maturity Model 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, s 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. Through this framework, organisations are guided to adopt stepwise process improvements. This framework ensures 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.

Sarshar et al (1998) have attempted to apply the principles of this model within the construction industry. The next section provides a background description about this research project and its current status.

3. THE SPICE MODEL

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. The five maturity levels of SPICE can be illustrated as follows.

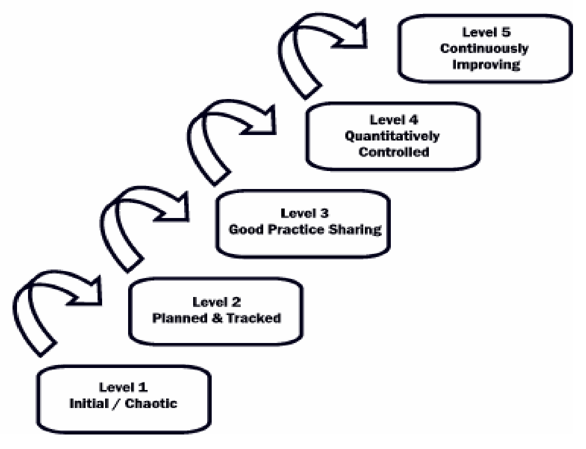

Figure 1 – SPICE maturity levels (source: Sarshar et al, 1998)

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. In addition to the SPICE framework, the SPICE project has produced a mechanism of testing the position of an organisation within the SPICE framework. The mechanism is basically a questionnaire and a series of interviews, through which an organisation can evaluate their position against requirements of key processes and key process enablers within a given maturity level.
The initial SPICE project was aiming at improving processes at individual construction projects. In addition, it concentrated on the development of level 2 characteristics and key processes. 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. And generally these organisations are trying to survive today, rather than planning for the future.

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).

After publishing the first iteration in 2000, due to the increased interest of industrialists, the second phase of SPICE was commissioned in 2002 focusing on process improvement across the construction organisation. During this phase the third level parameters and key processes were evaluated. 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.

Up to date research status of the SPICE project shows clear gaps in identification of the characteristics of higher maturity levels. As the Sarshar et al (2000b) have explicitly mentioned, so far the SPICE research has had little focus on level 4 and 5 issues. Since level 4 and 5 of the CMM are specifically aiming at continuous process improvements, the exploration of the dynamics of these levels is essential within the construction context, to achieve the desired performance improvements.

4. HIGHER CAPABILITY MATURITY LEVEL DYNAMICS

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 the paper investigates this gap from a comparative basis. The CMM level 4 and 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 4th maturity level dynamics within the construction environment. In addition, the 5th maturity level dynamics will also be evaluated briefly visualising its potential applicability within construction.

4.1 Level 4 Characteristics of CMM

CMM level 4 is classified as the "The Managed Level". The most significant quality improvements begin at this level (Humphrey, 1989). The characteristics of this level (and level 5) are relatively an unknown within the software industry as there are too few examples of software organisations to draw general conclusions about the characteristics (Paulk et al, 1993; Dymond, 1995). As and example, as of March 1999, of the 807 organizations active in the SEI's assessment database, only 35 were at levels 4 and 5 (Paulk, 1999). However, the characteristics of these levels have been defined by the analogy of other industries and the few examples in the software industry. 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).

The KPAs of the level 4 are probably the most misunderstood requirements in the entire CMM structure, because the directions about how to move from Level 3 to Level 4 are very fuzzy (Raynus, 1999). There are two 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.

4.2 Applicability of CMM 4th level KPAs 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. Within the UK construction context, it is visible that some of these practices are in place within some construction organisations. Often these practices are embedded within work studies or performed as a part of initiatives such as Key Performance Indicators (KPI). Even though these initiatives may have had some impact upon the performance improvement of the organisation, it is questionable whether these statistics are used for its maximum potential. Without a optimisation plan these statistics may just lead the organisation towards a sub-optimisation. 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.

4.3 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 (DP)
- Technology Change Management (TCM)

- Process Change Management (PCM)

The purpose of the DP is to identify the common causes of defects and prevent them from recurring (Paulk et al, 1995), while 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. PCM is aiming at continuously improving the software processes used in the organisation with the intention of improving software quality (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.

4.4 Applicability of CMM 5th level KPAs 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 triggers a necessity to revisit the 4th maturity level dynamics with the flexibility of modifications. The same applies when considering the Technology Change Management. 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. 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.

5. 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 analysed these characteristics within the comparative setting between the software industry characteristics and the construction industry characteristics to build a initial model on how the CMM higher capability maturity level characteristics fit within a construction environment.

6. 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. This paper presents a partially the initial understanding of how the construction higher capability maturity dynamics can be. Further, this initial understanding is intended to go through several refinement cycles to ensure that it captures the actual industry characteristics and requirements. It is an objective of this PhD research to build a comprehensive framework ultimately, to guide construction organisations on the steps of achieving higher capability maturity levels as a mean of improving the organisational processes continuously. On the other hand, this research further looks at the role of the information technology as an enabler to achieve higher capability maturity dynamics within the UK construction organisations. It is therefore intended to build a process – IT co-maturation model to guide construction organisations to use information technology strategically for their process improvement initiatives.

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