A SYNCHRONISED PROCESS/IT MODEL TO SUPPORT THE CO-MATURATION OF PROCESSES AND IT IN THE CONSTRUCTION SECTOR.

Ghassan Aouad, Rachel Cooper, Mike Kagioglou, John Hinks, Martin Sexton.

Time Research Institute
University of Salford
Salford M7 9NU
UK
e-mail g.aouad@surveying.salford.ac.uk

ABSTRACT

In recent years many efforts had taken place in the construction sector in order to develop process and IT maps. However, the subject of co-maturation between IT and the process has not been given enough attention. This has often resulted in the development of impractical solutions because of an apparent lack of balance between the IT and process capabilities. For instance, some organisations in the construction sector have adopted the rapid prototyping concept which is widely used within the manufacturing sector without even investing in 3D modelling and VR technologies which are the most appropriate for this task. Paradoxically, some organisations have invested in these technologies, but rapid prototyping is non existent. This paper addresses the issue of co-maturation between the process and IT in order to establish a balanced profile. The work is based on the CMM (Capability Maturity Model) model which was developed by the Software Engineering Institute at Carnegie Mellon University for the purpose of developing software for the US government, particularly to be used by the Department of Defence. The CMM is a five-level model which include ad-hoc, repeatable, defined, managed and optimised stages. The model is designed so that capabilities at lower stages provide progressively stronger foundations for higher stages, reducing the change management risks. Each development stage - or "maturity level" distinguishes an organisation's process or IT capability.

This paper builds on the work achieved within the generic design and construction process protocol (GDCPP) which is being undertaken at the University of Salford. The main contribution of this paper is a conceptual model of co-maturation between IT and process. A synchronised IT/process model will be presented and discussed. This model is being developed through knowledge obtained form the industrial collaborators of the GDCPP project and data collected from ten large contracting companies in the UK dealing with Design and Build projects.

Keywords: Process, IT, Maturity, Map, Capability Maturity Model, Process Protocol

INTRODUCTION

The Capability Maturity Model (CMM) was developed by the Software Engineering Institute at Carnegie Mellon University in order to manage the development of software for the US government, particularly that which was to be used by the Department of Defence (Paulk (1993), Humphrey (1987, 1991), and Johnson & Brodman (1997)). This paper considers its application in terms of an analogy to software production capability maturity within the context of IT and process co-maturation. The CMM model is also currently being used at the

Construction Informatics Digital Library http://itc.scix.net/
paper w78-1998-9.content

University of Sussex in developing benchmarks for process positions across various industries (Groak 1997). The research has also revealed that the CMM model has been used by Karandikar et al (1992) in order to assess the process and technology readiness of companies for implementing concurrent
engineering.

The CMM is a five-level model (see Figure 1) which includes: ad-hoc, repeatable, defined, managed and optimised stages. The model is designed so that capabilities at lower stages (ad-hoc) provide progressively stronger foundations for higher stages (optimised), reducing the change management risks. Each development stage - or "maturity level" distinguishes an organisation's process capability. The ad hoc capability level is recognisable by inconsistency in Process operations, and generally ill-defined protocols for the operation or use of process support tools (including IT) (Karandikar et al (1992)). At level 2 of the CMM model (Repeatable), a process must rely on consistent project management approach and repeatable practices. At level 3 (defined), standards should be used in order to consistently develop quality information systems. Level 4 (managed) of the CMM model demands quantitative controls and metrics for software development project performance. Finally, at CMM Level 5 (Optimizing), a framework for continuous software process improvement needs to be devised and adopted. The key process areas for Levels 2 and 3 have been the most completely defined. Since few organisations have been assessed to be at Levels 4 or 5 (Humphrey 1991, Kitson 1992), less is known about the characteristics of such organisations within the software engineering context. The problem is compounded in construction as these organisations are striving to develop measures within the first three levels of CMM. It also compounds the problem with the construction industry search for a changed industry (at a level of maturity which is currently undefinable) rather than a changing industry. This paper adopts the Capability Maturity Model (CMM) in order to describe the co-maturation of the process of design and construction and the IT that could be used to support such a process. The IT use is addressed as a process and its maturity is evaluated.

Figure 1 shows the various stages of the CMM model together with the positioning of various processes of a construction project and the IT that supports them. A stage called "emerging" has been added to the CMM model. In the figure shown below, feasibility and facilities management are positioned at the ad-hoc stage whereas construction is positioned at the defined stage. This positioning is based on data collected from ten large contracting companies in the UK dealing with Design and Build projects and from knowledge extracted from the industial collaborators of the GDCPP project. It is clearly shown in Figure 1 that construction is the most matured process in construction and has been positioned at the "defined" stage as this process is relatively consistent and a set of procedures within most construction organisations are followed to a large extent. In terms of maturity, design as a process is more matured than feasibility and facilities management, but less matured than construction. In terms of technology maturity, it is widely recognised in the construction sector that applications such as project planning, accounting, CAD and cost control are more matured than those of VR, 3D and knowledge-based. The maturity interface between process and technology is the main theme of this paper and will be covered in detail.

As mentioned previously, the CMM approach was adopted for developing scenarios for process and technology maturation. This helps in developing a methodology for the gradual synchronised progression of process and technology within the construction sector. This paper argues that too much is expected too soon in the construction sector. It also proposes the maturation model approach in order to ensure that the industry is capable in undertaking the

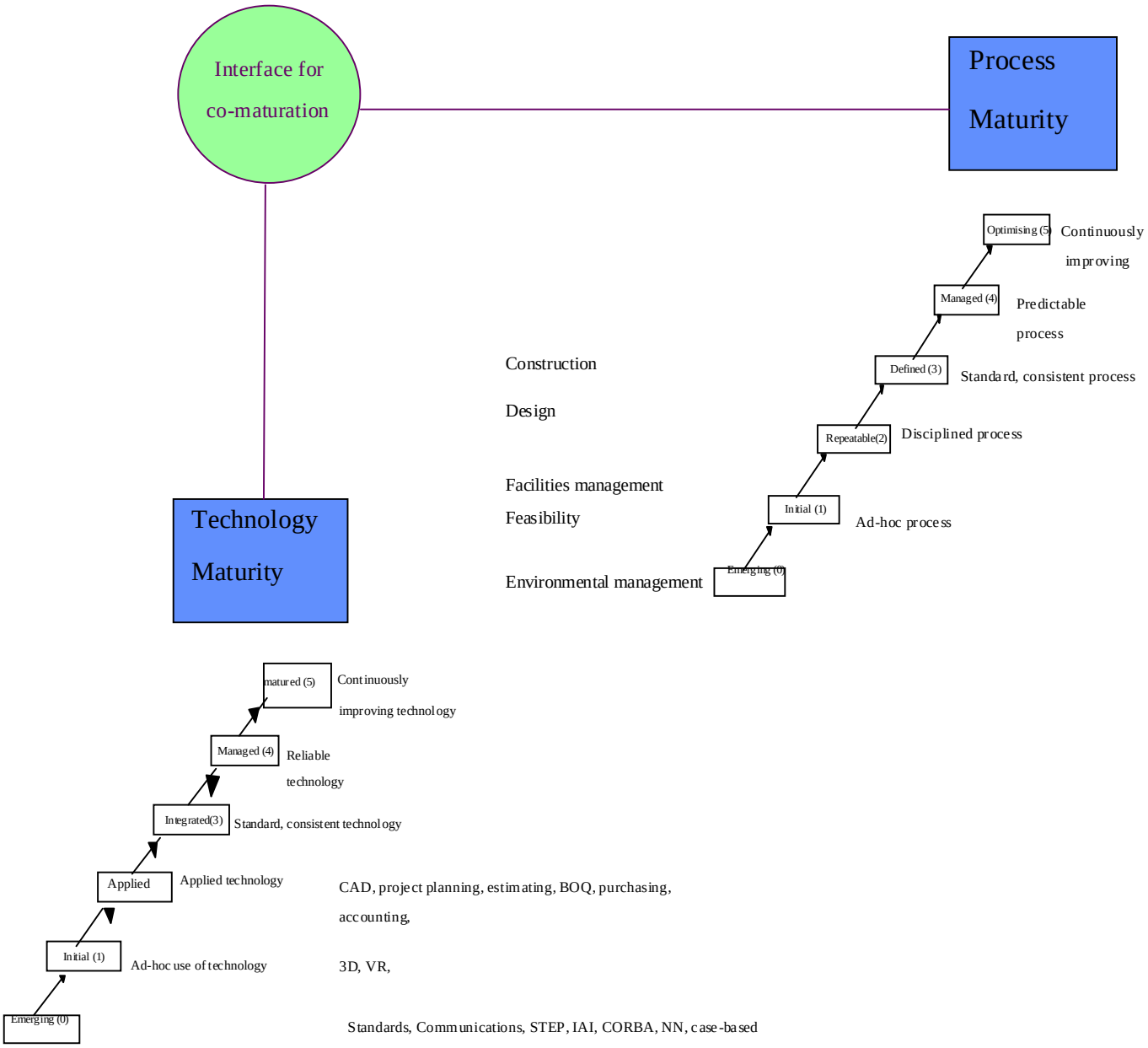


Figure 1 The CMM model and positioning of IT and processes.

necessary steps in the right direction through a sustainable continuous improvement and a gradual change to its current practices. Sustainable continuous improvement must be a feature of all the co-operating organisations in the design and construction process if the virtual companies which operate on particular projects are able to continuously improve their operating maturity - a necessity for whole industry evolution to be realised. Research being undertaken at the University of Salford has managed to develop both IT and process maps for the construction sector based on experiences learnt from the manufacturing industry (Kagioglou et al 1998). These IT and process maps will be put under scrutiny in order to assess whether it is feasible for these to be developed and adopted by the industry. In order to facilitate this task, this paper attempts to show the inter-link between the process and technology. The major aim of this paper is to define a potential synchronisation of *IT and process,* which can firstly help locate individual organisations and the entire construction

industry within this complex environment and to describe the scope for strategically planning individual organisation and whole-industry evolution in *IT and process* capability.

IT AND PROCESS CAPABILITY MATURATION

Conventionally, IT and process capability maturation is interpreted as relating to information technology in the context of how IT can catalyse and/or support change. The argument put forward in this paper is that not only does IT catalyse process change (and it can also stagnate it), but construction IT is also catalysed (or stagnated) by process change. Synchronicity between the process and the tools of the process (of which IT is one) results in process and construction IT maturation (Hinks et al 1997)

This co-maturation is what takes the industry forward, initially at the level of the individual organisation, and gradually through the consistent spread of process practices and applications of construction IT at the level of the whole industry.

For a long time, efforts have been put into upgrading the available information technology (in software and hardware terms), in its specialisation or customisation for use in the industry, and the way in which construction operations are managed using IT. In broad terms IT & process based developments have been sporadic, and current research requirements identified by the industry lead bodies includes identifying the focal needs and priorities of construction IT in relation to the process of construction (Aouad et al 1997). Some work has been done to date on how information technology is or can be used to support the construction process, less still has been conducted on the issue of how construction IT and process interrelate.

Figures 2 and 3 show respectively process and IT maps developed to support an improved design and construction process as part of an IMI funded project at the University of Salford. These maps have been used to position IT in relation to the design and construction process. A conceptual maturation model based on both IT and process maps is developed to show the current positioning of these two aspects.

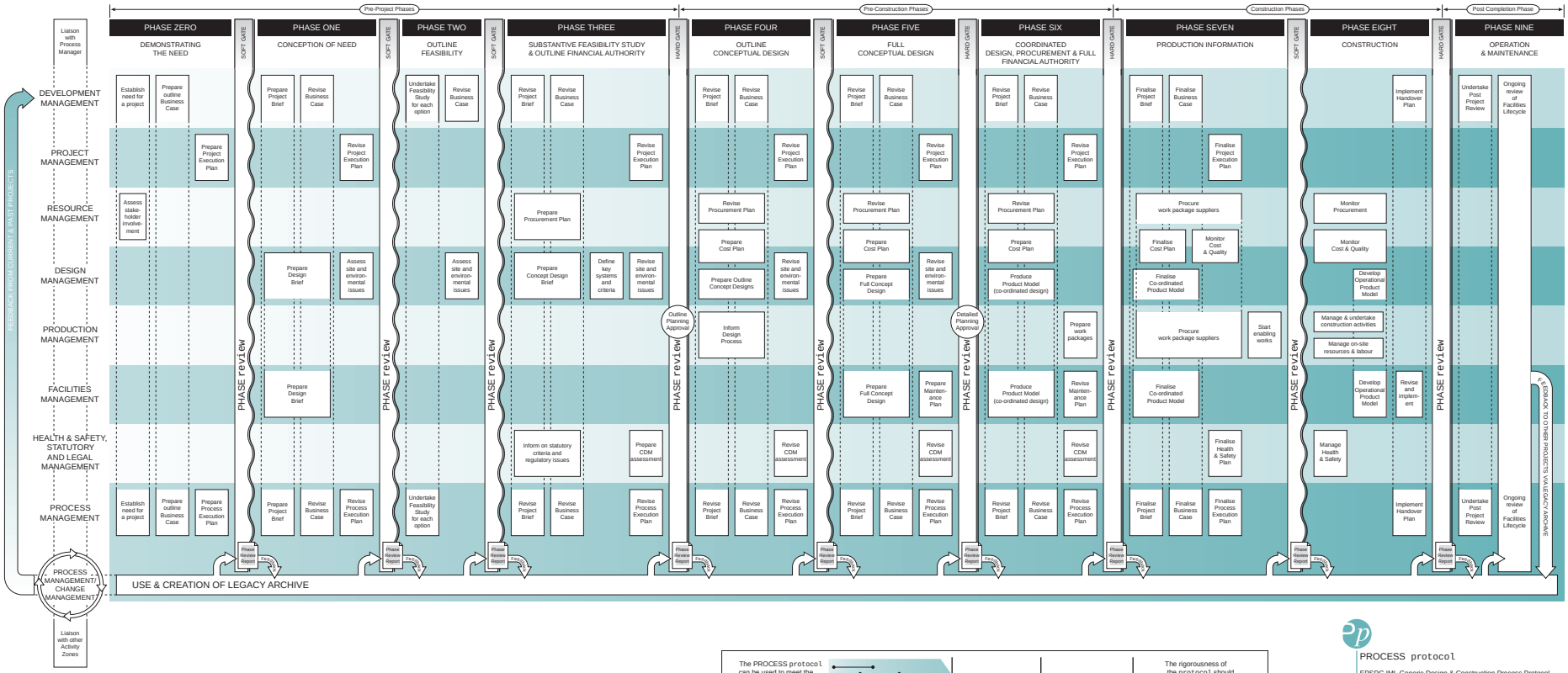
The process map has been used to identify the various phases of a construction project namely: pre-project, pre-construction, construction and post-construction. In addition sub-processes performed within these phases are identified and analysed in terms of process maturity. On the other hand the IT map has helped in identifying technologies which can support the process. These technologies have been classified under six main headings (Aouad et al 1997) which are as follows:

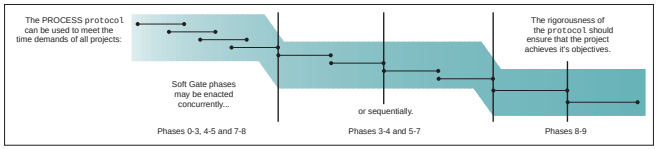
- Simulation (e.g. what if, project simulation, economic appraisal)
- Integration (e.g. integrated databases)
- Communication (e.g. EDI, Internet)
- Intelligence (e.g. artificial intelligence, KBS, neural networks, case-based reasoning)
- Visualisation(e.g. VR, 3D)
- IT support (e.g. CAD, project planning, cost control)

These technologies and their corresponding elements have been used to develop the synchronised process/IT models shown in Figures 4 and 5.

PROCESS protocol

DRAFT B : 27 August 1997





PROCESS protocol

EPSRC IMI Generic Design & Construction Process Protocol

University of Salford
Alfred McAlpine Construction
Engineering Technology
BAA plc
B.T.
EDM Architects
Waterman Partnership
Boulton & Paul Ltd.

Figure 2 The GDCPP process map

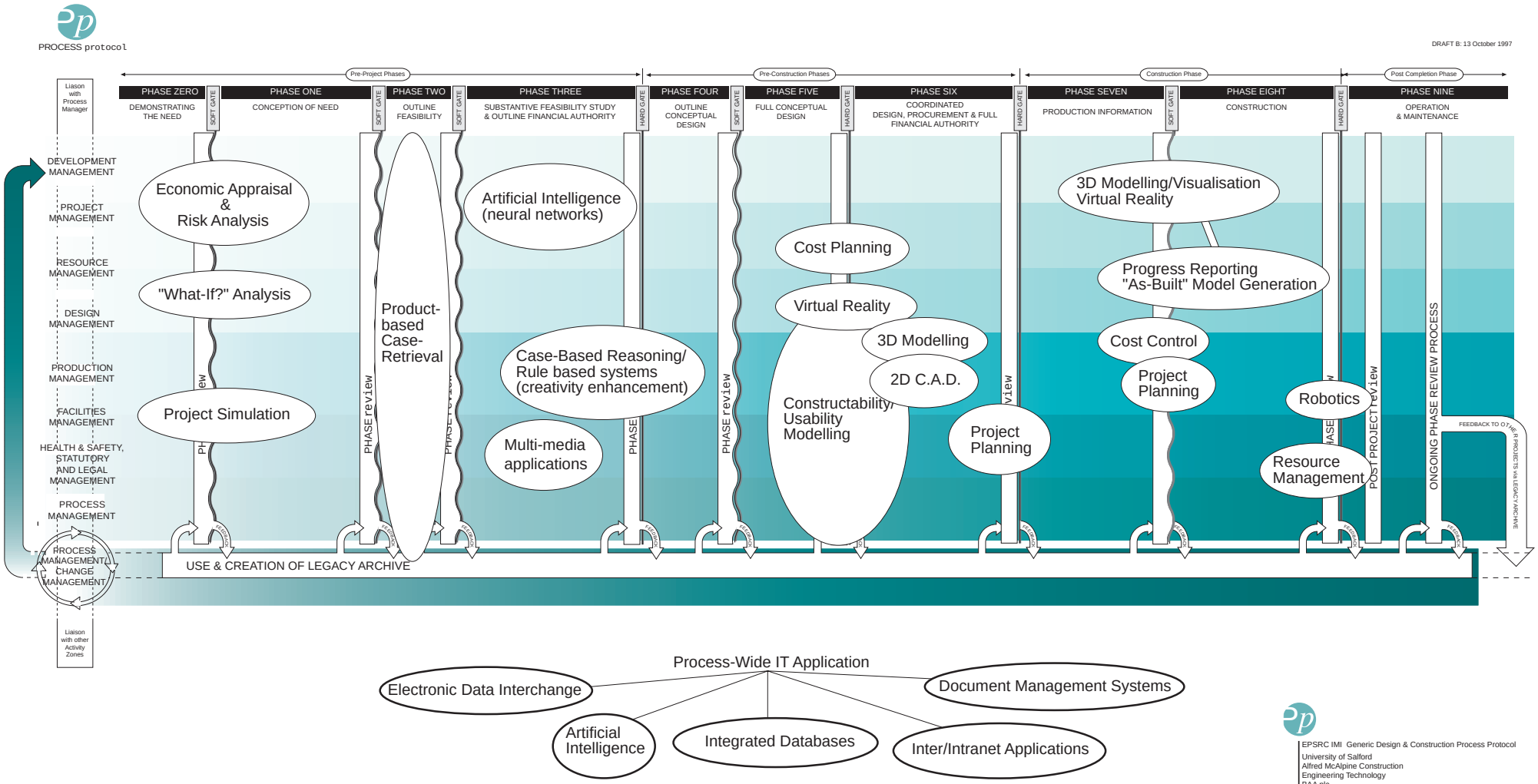


Figure 3 The GDCPP IT map

As mentioned earlier, this paper uses the developed maps to identify some processes and information technologies that can be analysed in terms of maturity. A full description of these two maps can be found in Cooper et al (1998), Kagioglou et al(1998) and Aouad et al (1998). The diagram shown below (idea adopted from karandikar et al 1992, for a different scenario) shows the process and IT maturation based on the CMM framework. It is clearly shown on the diagram that there is an apparent lack of balance in terms of process and IT maturation. It is evident that some corrective measures are required in order to establish a balanced IT and process at any level. Maturation occurring at higher levels is, however, more beneficial.

In construction and unlike manufacturing, it is not very well understood what needs to be done at the pre-project phase. This is why the maturity level is shown to be at the ad-hoc stage. The same could be applied to the post-construction stage. However, the maturity of these phases could be improved dramatically through the introduction of process thinking and new procurement systems such as partnering and Private Finance Initiative in the UK. With regards to technology, IT support applications such as accounting, CAD and project planning have been placed at the defined stage whereas technologies such as communications and integration have been placed at the ad-hoc stage. However, it is also true to say that recent developments within standards (particularly work being done within the IAI) will help such technologies to improve their maturities in a short time scale.

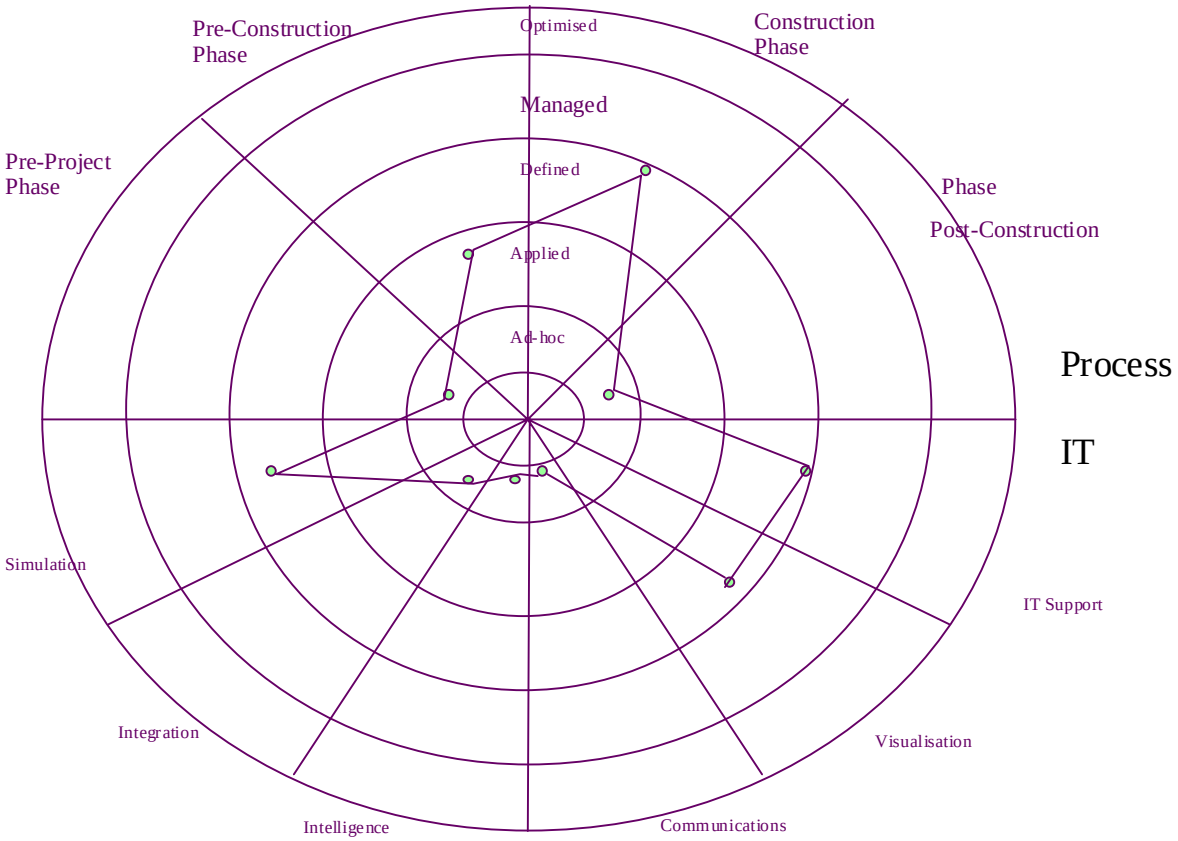


Figure 4 A high level synchronised process/IT model

The problems associated with IT are related to its uptake which has been apparently relatively uncoordinated and its strategic application appears to have been determined by the availability of it rather than its suitability. Evidence exists of unsuitability of IT systems causing dysfunctionality in the process infrastructures which they are expected to support. It is evident that the uptake of IT systems by the industry systems has been broadly technology led, with the industry using basic communication tools in a widespread (but not comprehensive) manner, and that the application of particular industry specific tools is more localised, probably because of communication problems.

In part this is due to a lack of understanding of the way in which organisations and their operational and managerial processes operate, compounded by the lack of appreciation of how information technology supports them; at a more sophisticated level of analysis, the organisational capability and maturity of a company (or industry) is related to a number of issues including the role of process management and information systems in their maturation.

Figure 5 shows a detailed model of process and specific IT maturities based on its current use by the industry within a project context. The model shows similar patterns in terms of un-balanced maturity which will result in communication problems. It is surely desirable to have a balanced profile of maturity even if it occurs at the ad-hoc level. The model is based on expressed views about the maturity of processes and technologies. The information about maturity was elicited from the industrial collaborators of the GDCPP project through a series of workshops. However, an industry-wide study would help in establishing a more accurate picture on the current level of processes and IT within the construction sector.

An emerging process or technology will go through the process of refinement/ improvement in order to reach level 5 (optimised). A process can mature to a certain level when the corresponding technology is within the boundaries of that level. For instance, a rapid prototyping process can only co-exist with the enabling technologies such as VR, 3D modelling, etc.

Creating an appropriate interface between construction IT and Process is a matter of designing the IT introduction and application to suit the existing process capability - which in turn requires a realistic perception of the relevant process capability maturity. In a multi-disciplinary organisation, the disparity in localised professional capability maturity makes this a difficult and sensitive issue in the strategic management of change. Construction IT evolution has generally followed a steeper gradient of maturation than process (if measured against a notional time line). This has frequently translated into an IT-Process capability maturity gap, behind which lies localised (micro) and whole industry (macro) variations in IT/ Process capability maturity.

The conceptual interface model between IT and process once developed can be used as maturity IT/process health check audit which can help construction organisations in defining their strategies in the next decade. This will contribute to the study conducted by the Construct IT centre of excellence on IT health check for construction organisations and add a new dimension which might help organisations to uptake and adopt this IT health check approach (Shafagi and Betts, 1997).

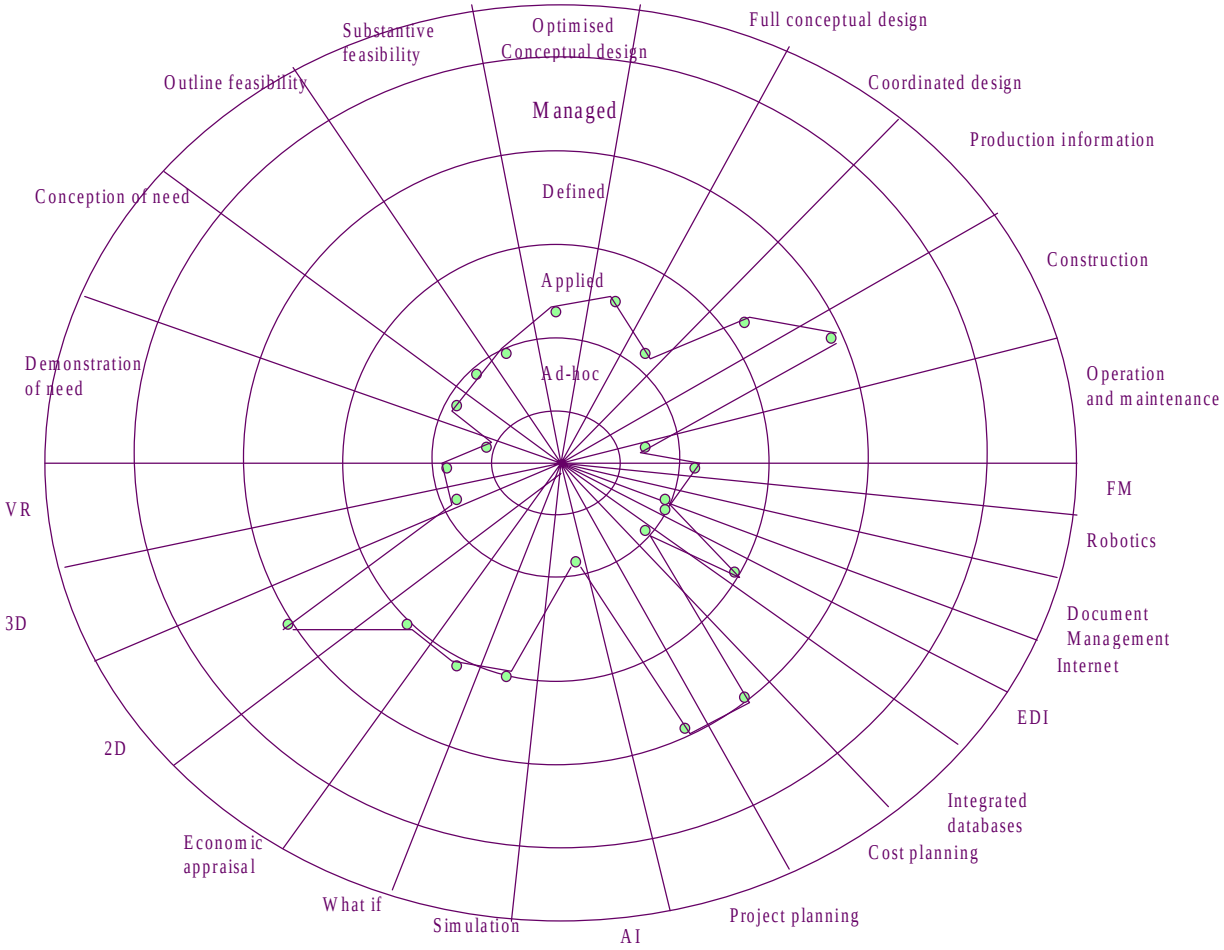


Figure 5 A detailed synchronised process/IT model

CONCLUSIONS

This paper presented initial views on how process and IT can be inter-related in a maturity model. The work is still in its infancy. This paper presented a framework for maturity in order to bring discussions for this important subject. The model can be used aa a positioning map by organisations in order to identify areas within the process and IT that need particular attention. To make the work presented in this paper generic, it is essential to have a set of guidelines for process and IT maturity in construction. Also, it is necessary to use large sample of projects and organisations in order to provide the statistical validity required for this type of work.

This paper outlines a conceptual model for co-maturation between IT and process maturity at the project level. This phenomenon can be applied to the strategic planning of maturation at the level of the organisation in connection with the adoption and integration of IT within the existing processes and as facilitator for new developments in process practice. With a collective vision of process practice for the whole industry the local improvements in process may synergise to produce the phase change required and expected by the industry as a whole.

An improved relationship within the industry and between the industry and its clientele requires a change in process and contractual arrangements. All need to be changed in synchronicity if there is to be a significant change in culture necessary to sustain new industry attitude. The process itself is reliant upon information technology - largely a lack of information technology and lack of application currently. What is clear is that information technology or process change cannot solve the industry problems alone, but may do in concert. This paper is about how the phenomenon of concerted change, or synchronicity between two of those key facets may operate - information technology and process maturation. Other elements of a systemic synchronicity such as relationships within the industry and between the industry and its clientele and the inter-related issue of process are also important, and will be discussed in more detail in other papers.

REFERENCES

Aouad.G, Hinks.J, Cooper.R, Sheath.D, Kagioglou.M & Sexton, M, 1998, An IT map for a generic design and construction process protocol. Accepted by the International Journal of Construction Procurement.

Aouad, G, Alshawi, M and Bee, S,1997, Priority topics for construction IT research.; *The International Journal of Construction IT*, Winter 1997.

Cooper, R, Kagioglou, M, Aouad, G, Hinks, J, Sexton.M, Sheath, D, 1998 .Development of a Generic Design and Construction Process. Accepted by the PDT conference. BRE, 1998.

Groak, S 1997. Research at Ove Arup, Seminar materials, Ove-arup, London, March.

Hinks. J, Aouad. G, Cooper. R, Sheath. D, Kagioglou. Sexton, 1997. M. IT and The Design and Construction Process: A Conceptual Model of Co-Maturation. The international journal of construction IT, July 1997.

Humphrey, W.S, 1987, Characterizing the Software Process: A Maturity Framework, Software Engineering Institute, CMU/SEI-87-TR-11, ADA182895, June 1987.

Humphrey, W., Kitson, D.H, and Gale, J,, 1991, A Comparison of U.S. and Japanese Software Process Maturity, Proceedings of the 13th International Conference on Software Engineering, Austin, TX, 13-17 May 1991, pp. 38-49.

Johnson.D.L & Brodman.J.G. 1997 Tailoring the CMM for small businesses, small organisations, and small projects. Software process newletter, IEE computer society, no 8, winter 1997.

Kagioglou, M., Cooper, R, Aouad, G J. Hinks.J, Sexton.M, Sheath, D, 1998, Cross-Industry Learning: The development of a Generic Design and Construction Process Based on Stage/Gate New Product Development Processes Found in the Manufacturing Industry . Accepted by the Engineering Design Conference, Brunel Univerisity, June 1998

Karandikar, H.M., Wood, R.T., and Byrd, J. Jr., 1992 Process and Technology Readiness Assessment for Implementing Concurrent Engineering CERC Technical Report Series

Technical Memorandum 92 004, Concurrent Engineering Research Center, West Virginia University.

Kitson, D.H, Masters, S, 1992, An Analysis of SEI Software Process Assessment Results: 1987-1991, Software Engineering Institute, CMU/SEI-92-TR-24, July 1992.

Latham M, 1994, Constructing the team, H.M.S.O.

Paulk, M. et. al., 1993 “Capability Maturity Model for Software”, Version 1.1, Tech Report. CMU/SEI-93-TR-24, Carnegie Mellon University, Pittsburgh, 1993.

Shafagi, M and Betts, M 1997, A health check of the strategic exploitation of IT., Construct IT centre of excellence, University of Salford.

Sheath.D, Hinks. J, Aouad.G, Cooper.R, Kagioglou.M & Sexton.M, 1998. The process protocol: re-engineering the design and construction process, Internal paper, University of Salford.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the following industrialists involved in this project:

- Alfred McAlpine (Special Projects) Ltd.
- BAA plc
- Engineering Technology
- BT
- Waterman Partnership
- EDM Architects
- Boulton & Paul Ltd.

This research is funded by the EPSRC through the Innovative Manufacturing Initiative