DEVELOPMENT OF A FRAMEWORK MATURITY MODEL FOR THE CONTINUED QUALITY IMPROVEMENT OF A LOCALLY CUSTOMISED CLINICAL INFORMATION SYSTEM USED IN CRITICAL CARE MEDICINE

Frank Kirrane[1], Anne Mulvey[2]
[1]*Department of Medical Physics and Bioengineering, Galway University Hospitals, Newcastle Road, Galway, Ireland*
[2]*Department of Critical Care, Galway University Hospitals, Newcastle Road, Galway, Ireland*

Michael Campion
J. E. Cairnes School of Business & Economics, College of Business, Public Policy and Law
National University of Ireland, Galway, Ireland

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS

Keywords: Clinical Information System, Maturity model, Continuous Quality Improvement, Critical care, IT success.

Abstract: This study examines the development of a maturity model (MM) to help determine and monitor perceived improvement areas that would support the ongoing development of a locally customised hospital critical care Clinical Information System (CIS). The model arose from qualitative data collected from a critical care service in a large teaching hospital. The method involved a first principles examination of the priorities of a critical care service through a textual analysis of the documents considered by the hospital to underpin the strategic, professional and operational priorities of the service. These priorities form the dimensions of a MM, where a series of interviews with staff examine how the CIS can facilitate improvement along each dimension. The MM developed consists of seven dimensions, each illustrated along a percentage scale of increasing sophistication. This model is piloted in the critical care department which has been using a CIS for over four years. Results show that the method proposed is suitable for the development of a CIS MM. The results of the pilot study highlight different individual perceptions on the current level of CIS maturity. The MM is also demonstrated as a tool to assess current performance, and guide ongoing CIS customisation effort.

1 INTRODUCTION

The Galway University Hospital (GUH) is a university teaching hospital 545-bed capacity and tertiary referral centre for the western seaboard of Ireland.

A core component of any acute hospital, and wider health system, is the critical care service. At GUH, the critical care service is divided into an 18 bed ICU (Intensive care unit), where the highest level of care is given to the sickest patients, and a 16 bed HDU (High Dependency Units), where an intermediate level of care is provided for those who are not well enough to go back to general wards.

The critical care service at GUH is a tertiary referral centre for the west of Ireland. In 2008 there were over 1300 admissions to the service.

There are approximately 200 practitioners working in, or who provide clinical support to the critical care units. There are at least 40 on duty at any one time. These practitioners include consultant intensivists/anaesthetists, consultant surgeons, specialist medical and surgical registrars, clinical nurse managers and specialists, critical care staff nurses, clinical pharmacists, dieticians, physiotherapists, occupational therapists, microbiologists, and range of referring medical teams, along with technical and scientific support staff.

Kirrane F., Mulvey A. and Campion M..
DEVELOPMENT OF A FRAMEWORK MATURITY MODEL FOR THE CONTINUED QUALITY IMPROVEMENT OF A LOCALLY CUSTOMISED CLINICAL INFORMATION SYSTEM USED IN CRITICAL CARE MEDICINE.
DOI: 10.5220/0003163902860294
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2011), pages 286-294
ISBN: 978-989-8425-34-8
Copyright © 2011 SCITEPRESS (Science and Technology Publications, Lda.)

During the stay of a critically ill patient in a critical care area, approximately 1500-2000 data items (medical notes, physiological signals, parameters, test results, medical orders) are documented and derived daily. Effective patient care may be limited by the difficulty in managing this large amount of data and contributes to an increased risk to the patient. Improving the workflow and presentation of information can lead to improvements in outcome in critical care areas (Breslow and Stone, 2005; Scales, 2004).

The traditional paper based critical care medical record, recognised as the most complex and expansive in acute care, is no longer sustainable as an adequate means to manage information (Frassica, 2004).

Information Technology, such as Clinical Information Systems (CIS) solutions exist so as to offer greater potential to enhance the quality and safety of patient care, and increase provider effectiveness. A critical care CIS was first defined by Morris (1998) as a means to integrate clinical information at the point-of-care. A CIS allows the capture of the entire patient generated clinical and physiological data, and presents it in a form that makes it available as useful information. The real power of the CIS, which facilitates real patient benefits, is that it can become a clinical decision support tool that supports evidence based practice (Bates and Gawande, 2003; Crane and Raymond, 2003).

Galway University Hospital (GUH) undertook the procurement and implementation of a Clinical Information System (CIS) for these reasons. The Critical Care service at GUH is at the forefront of medical technology, and implemented a CIS to 18 bed critical care complex March 2005. The CIS was expanded by an additional 20 beds of the new Cardiothoracic surgery service in September 2007.

The CIS purchased by GUH is a commercially available system, known as *Metavision MVICU*™ (iMDSoft; Needham; Massachusetts; USA), and has been customised to suit the needs of the hospital over the past five years

2 BACKGROUND

System designs have become more sophisticated, such that they allow flexibility within a design framework, that provide for safe localisation and customisation by the clinical end user.

At GUH a group of critical care practitioners and support staff find time during part of normal clinical duties to be part of the 'CIS team' responsible for system customisation and user training

The process of CIS customization is brought about by continuous quality improvement initiatives that are driven by the 'evidence based medicine' philosophy of care. High performing critical care departments are constantly improving and refining procedures, technology, policies, and so on. It is this drive to keep abreast of the latest technological and practice developments that fuels the need for continuous improvement of the CIS platform.

The CIS has a dual role; to facilitate the change process through design of the CIS application workflow; and to assess performance through measurement and audit of key indices (Higgins, 2007).

Orlikowski (2000) notes that "this process of "change" never stops; even when implementation is 'formally' finished, users will still shape and craft the information system to fit their particular requirements or interests". This provides for the notion that implementation of a CIS solution is not a one time event for the project team and end-users; the project essentially does not end. The post-implementation phase becomes one of continuous development and improvement. It may even be necessary to distinguish successful 'installation' (a one time event), from successful 'implementation' (a more longitudinal perspective)

Berg writes that CIS implementation is best considered a process of 'mutual transformation', where the organisation and the technology transform each other during the implementation process. What determines successful implementation is "decided on the work floor, by middle management, by top managers-and it is the outcome of these interactions that settles on the systems fate" (2001 p.144)

Atkinson and Peel provide the useful metaphor that the CIS and the wider socio-technical organisation must "grow together in stages towards a vision created and shared by all" (1998, p.285)

Much of the CIS evaluation literature limits data collection up to the months following implementation (Byrd et al., 2006), and after this point assumes the CIS remains 'a success'. Van der Meijden, in his review of the DeLone and McLean (1992) model of success applications to Health Information Technology success, notes that evaluation of such systems should start before the development and should have "no fixed end point" (2003). He notes that "formative evaluation" – aimed at improving information systems during

development or implementation- were difficult to locate in a review of the literature.

This adds to this research that successful installations can essentially become *unsuccessful* systems in the absence of a continuous evaluation, improvement and feedback mechanisms (van der Meijden et al., 2003).

This is essentially the 'gap in the literature' that this research attempts to address. For an institution that has successfully installed CIS technology into routine clinical use, there is scant advice in the literature on 'how' the hospital should organise itself to maintain the momentum required to continually 'grow' and improve the CIS in the years post implementation.

This research attempts to provide a roadmap for ongoing success. Thomas and Fernandez (2008) make a pertinent point; "having a well defined perception of what has to be achieved to attain success may indeed contribute to achieving the evasive target of project success"

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS

3 RESEARCH OBJECTIVES

The day to day role of the CIS team is to continually develop and improve CIS functionality. This is achieved through a suite of tools; along with specialist training members of the team receive from the CIS manufacturer. Team members received change requests via a number of routes. The typical routes of change requests are:

- Scheduled quality improvement initiatives from individual staff members.
- Ad-hoc daily interaction between CIS users (clinical staff) and the CIS Team members.
- New features released from the CIS manufacturer.
- Data quality and clinical audit work.
- Hospital management requests for service activity data.

In the four years since the first phase of installation, it has become clear to the CIS team, that in order to continually improve the CIS towards optimisation of potential benefits, it requires a shift in emphasis from the ad-hoc to a more strategic approach to how the CIS team and critical care unit are "organised" for continued success. This is particularly the case because, as a member of the CIS team put it, "we have picked all the low hanging fruit".

Another important issue that is increasingly relevant is that the resources, principally personnel expertise and time, employed for CIS customisation projects are becoming more constrained in the tightening healthcare fiscal environment. It has become increasingly important to the critical care service to demonstrate efficient use of its resources and to strategically leverage those areas of CIS potential to greatest patient and business benefits.

This research seeks to address these issues by; (a) providing a framework that provides a basis for a more strategic, targeted approached to CIS development, and (b) pilot the model that will provide a means guide resources to both improving and disseminating the actual and potential value of the CIS to critical care delivery.

The primary Research Question that this work seeks to address is:

"How may a 'maturity model' be developed, for the continued quality improvement of a locally customised critical care Clinical Information System?"

4 LITERATURE REVIEW

The wider business and organisational development literature may provide advice on the socio-technical factors that underpin efforts to drive continued success in high performing, high technology environments such as the use of CIS technology in critical care medicine.

Business process management (BPM) is a systematic approach to improving an organization's business processes. It is considered a "holistic management" approach that promotes business effectiveness and efficiency while striving for innovation, flexibility, and integration with technology. BPM attempts to improve processes continuously. It is often described as a "process optimization process" (Andersen, 2007)

At the core of BPM is the concept of process maturity. The term "maturity" is defined by Fraser et al. (2002) by its literal meaning; "ripeness". It conveys a notion of development or progression from some initial state to a more advanced state.

First published in 1989 by Watts Humphrey, and later by the software Engineering Institute at Carnegie Mellon, the Capability Maturity Model (CMM) – later superseded by CMM integrated - has become an established model in the field of IS development. The CMM provides software organisations with guidance in the form of a framework on how to gain control of their processes (developing and maintaining software). It can help improve the maturity of these processes. The CMM

model comprises five levels; each defined as an evolutionary plateau of process improvement and includes a checklist to evolve on to the next level (van de Wetering and Batenburg, 2009).

A maturity level is a way to characterise the dimensions that describe the process, system or organisation, by assigning a level of performance with regard to the activities contained within each dimension. These levels range from the ad-hoc, or depend on the initiative of an individual so that the outcome is less likely to be repeatable, or as the level increases, to one where the activities are performed systematically, and are well defined and managed (Farrukh et al., 2003b)

Fraser, Moultrie et al (2002) make the point that in practice, maturity models are used as part of an improvement process, and not primarily as absolute measures of success or performance. Its principle function is to identify gaps which can be targeted in subsequent improvement actions, along a pre-defined scale.

In particular, maturity models can be used for three purposes including:

- as *a descriptive* tool enabling an 'as-is' assessment of strengths and weaknesses;
- as a *prescriptive* tool enabling the development of roadmap for improvement; and
- as a *comparative* tool enabling benchmarking framework to assess against industry standards and other organisations.

More recently, maturity models (also termed 'maturity frameworks' by some authors) have been used in the healthcare IS research. Van de Wetering and Batenburg (2009) provide a maturity model for the technological sophistication of Picture Archiving and Communication Systems (PACS) in hospitals.

The focus of the van de Wetering and Batenburg (2009) work is to examine a staged approached to the technical and technological dimensions of a PACS system, and places less emphasis on the cultural, socio-political and organisational aspects of such implementations.

On the other hand, Elwyn, Rhydderch et al. (2004) focus predominantly on the organisational development aspects of health care provision. In this research, the authors describe the development of a 'Maturity Matrix' for assessing the organisational development in primary medical care group of practices. The assessment tool takes the traditional framework maturity model format.

The dimensions in this study include key process areas (KPA) that consider how the GP practice network organises itself with regard to; clinical records, audit of clinical performance, access to clinical information, use of guidelines, prescribing monitoring, practice communication and collaboration, patient-clinician interaction, and patient feedback systems. (Elwyn et al., 2004)

Common threads from both the PACS (van de Wetering and Batenburg, 2009) and the General Practice (Elwyn et al., 2004) maturity models, that are of particular relevance to healthcare are that; (a) the process of developing the model is itself a useful tool for fostering effective intra-professional collaboration, (b) the model provides a useful self assessment or benchmarking tool for an

"as-is" assessment of performance, (c) it provided a forum to develop ex-ante perspective or vision of the more mature, and sophisticated "to-be" state, (d) it facilitates a "bottom up" approach to quality improvement, (e) aligns the strategic and tactical priorities of the organisation and (f) the group assessment process encourages the concept of "double loop learning", where "the organisation 'learns how to learn' so that the concepts of change management are second nature" (Elwyn et al., 2004).

5 METHODOLOGY

Due to the exploratory nature of this research, a qualitative orientation that addresses the research questions is most relevant.

The research philosophy taken in this study is empirical in nature. The research design may be described as a cross-sectional case study. The sampling technique is defined as "purposeful sampling", which is the dominant strategy in the qualitative research literature. A grounded theory approach guides the data analysis (Strauss and Corbin, 1998).

The study participants chosen for this research were taken from a team previously assembled by the hospital to implement and manage ongoing CIS quality improvement and use development work. The group was a multidisciplinary team consisting of consultant anaesthetists (n=3), clinical pharmacist (n=1), clinical nurse managers (n=3), and hospital management (n=1).

The data collection was performed in three phases, as illustrated graphically in figure 1.

The first phase was a Qualitative Content Analysis (QCA) of three texts to determine the themes or categories that describe the dimensions of the critical care service. QCA is a specialised form of qualitative research, which is an extensively

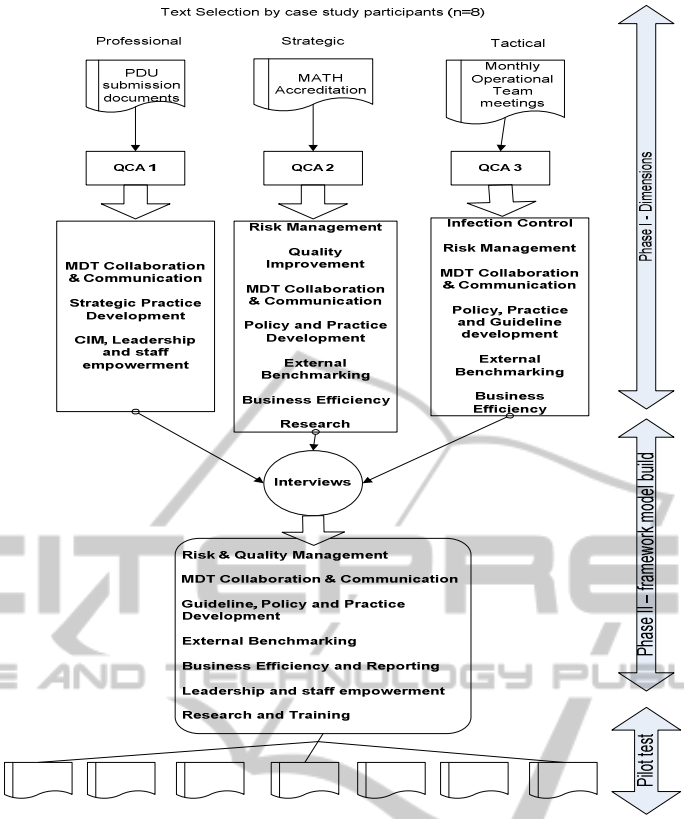

Figure 1: QCA findings for each document, and final dimensions. The top part, Phase I, illustrates the outcome of the QCA on each text . Also shown is Phase II, the circular interview process used to build the model detail; and Phase III, pilot testing among the eight participants in the case study.

Table 1: Maturity Framework dimensions, along with description, developed in this case study.

Dimension	Description
Risk and Quality Management	How the CIS facilitates efforts to reduce risk to patient, staff and organisation., along with how the CIS contributes to increasing quality of care and service delivery
Multi-Disciplinary Team (MDT) Collaboration and Communication	How the CIS can facilitate and foster good inter profession communication and collaboration
Guideline, Policy and Practice Development	How the CIS contributes to good compliance with implementation of unit guidelines, best practices and policies
External Benchmarking	How the CIS generates good quality data that allows the service performance to be benchmarked against national and international best practice indicators
Business Efficiency and Reporting	How the CIS facilitates efficient work practices, and monitors efficiency
Leadership and staff Empowerment	How the CIS helps staff feel empowered in their professional duties, with good quality information and control over CIS functionality and the direction system changes and use takes.
Research and Training	How the CIS contributes, or initiates, medical, nursing and allied health research

employed analytical tool for the systematic analysis of documents (Krippendorff, 1980).

The texts chosen for examination were originally prepared by the critical care team leaders and staff, as part of normal service delivery. These texts were chosen by the study participants as being representative of the Strategic (Hospital National Accreditation report), Professional (Critical Care Practice development accreditation submission), and Operational (meeting minutes from previous year of monthly critical care management team meetings)

The second phase was a series of semi-structured interviews with the eight participants, based on the results of phase I. The objective was to give the

Maturity / Dimension	Level 1 5% 25%	Level 2 50%	Level 3 75%	Level 4 100%
MDT Collaboration and Communication	Paper notes continue to be used by critical care providers. Individual paper notes, and workarounds evident-mismatch of doc. Media formats Isolated professions notes evident Little evidence of collaborative links or ongoing communications with external CIS users	Significant proportion of providers use CIS for documentation, mix of paper and CIS still evident Ad hoc approach to coding of disease and treatments. CIS used as an auditable communication tool of hospital and critical care safety and risk notices Coding difficult to use and search Some evidence of collaborative efforts to infuse coding with documentation process Ad hoc or opportunity link with external CIS users and organisations Good collaboration between different care units in place	Majority of professions access CIS for daily documentation. CIS documentation easily accessible and presented to all users Some disease and treatment coding models used. HIPE coding used for a majority of patients. Existence of in roads to integrated coding – pet projects Some evidence of collaborative problem solving of CIS issues with external users. Comparative exercise in place Some evidence of joint CIS customisation and use efforts presentations at conferences. Management collaborate on CIS related efforts that are strategically important	All anaesthesia, referring, nursing, ICD, ICNARC and SAPII are integrated to CIS. Referring teams have a customised views and input particular to their needs Close links with "sister" units for co-development of CQI initiatives with CIS. CIS team active members of Informatics organisations. Coding used is an integral part of the documentation Doctors not physically in unit have remote access to CIS during telephone consultation with nurse at bed.

Figure 2: Maturity model for the "MDT Collaboration and Communication" dimension developed by the study participants (n=8) in this case study.

participants an opportunity to validate the results of QCA, to provide depth, to enrich, and to add vitality to these dimensions. Through the course of these interviews the detail of the maturity model developed

The third and final phase was a pilot of the final version of the maturity model, where each participant was asked to provide any comments, and score the CIS project along each dimension from each individual perspective.

6 RESULTS

The QCA of the three texts, that in this case study provide an accepted proxy for the strategic, operational, and the professional aspects of critical

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS

care delivery provided seven dimensions, or key practice activities, to which the CIS should positively contribute to continuous improvement.

These are shown in Table 1.

Each dimension is described by the four columns of the traditional maturity matrix. Each column, or level of maturity, was further divided into cells of detailed statements that articulated a level of sophistication of CIS use or functionality that were accepted as consistent for each maturity level.

An example of the maturity model developed for the "MDT Collaboration and Communication" dimension is shown in Figure 2. The framework maturity models for all seven dimensions described in Table 1 were completed in this fashion.

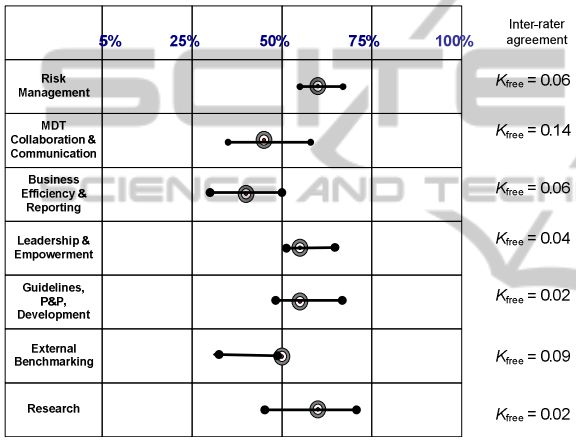

Figure 3: Graphical representation of the scores retuned from raters used in this pilot study (n=8). The target symbol represents the median score (50th percentile) for each dimension, bounded by the 25th and 75th percentile (solid line). The multi-rater free marginal Kappa, K_{free} (Randolph, J. J. (2008), used as a measure of inter-rate agreement, is shown for each dimension.

The final maturity model was piloted individually with the eight study participants. Each was requested to review each dimension, and score their perception of where the CIS maturity currently lay along a scale from 0% to 100% in increments of 5%. The scale was divided equally to illustrate four levels, level 1 ('ad hoc') through to level 4 ('optimised'). All statements that describe a lower level must first be satisfied before moving up to the start of the next higher level.

Figure 3 presents the results of the pilot phase in this case study in a "dash-board" type format.

7 DISCUSSION

The dashboard style presentation of the maturity model points to key messages about how the study participants believe the CIS contributes to critical care service delivery.

Taking a simple visual interpretation of the dashboard, the current state of CIS "maturity" at GUH is approximately half-way on a journey towards the ideal optimised (level 4) state. This indicates that this group believe there remains scope for continued improvement or maturity for all dimensions.

When considering individual dimensions, it seems clear that after five years of CIS use, moving up the maturity levels is difficult. For example, how the CIS contributes to "external efficiency and reporting", lags behind how this group perceives the CIS facilitates improvements in "risk and quality management".

The broad spread of results within each dimension, seen in the results of this pilot study point to interesting issues. By performing a free-marginal multi-rater Kappa, K_{free} (Randolph, 2005), it may be shown that, in this pilot study, different perspectives exist, even when the members of the group work cohesively on CIS development. A K_{free} greater that 0.7 indicates adequate agreement. The differences between individuals have a bearing on the direction improvement initiatives the CIS will take. Uncovering, and understanding the reasons for difference of opinion are an important step first in any improvement initiative.

Another possible explanation for spread of scoring (or divergence of opinion) may be because individuals have different understanding of what the dimensions mean, or more particularly, what role the individual believes CIS technology could have on each in any improvement initiative.

'Maturity' implies that the "process is well understood, supported by documentation and training, is consistently applied through improvement projects and is continually being monitored and improved by its users" (Fraser et al., 2002). Difference of opinion, say between different leaders, is an issue that warrants attention in any improvement initiative, so that the basis for action is strategically sound, and understood by all.

Hammer and Champy (1993), in the context of Business Process Re-engineering, make the point that a consensus based understanding within the organisation of the current state is the critical first step in an improvement initiative. This would be especially the case in complex organisational

structures in critical care. A model that highlights differences between individuals, or between professions, has proved useful in this pilot study.

It could also be argued that the spread of maturity framework scores across all dimensions in this pilot test, point to a model that lacks discriminatory power. This is an issue that has also been considered in the wider maturity model literature. For example, lack of discrimination has been blamed for lack of bottom line results in industrial new product development processes (Kahn et al., 2006).

These authors suggest that this is principally because such frameworks can be too subjective, and lack concrete measures indicators of success (Kahn et al., 2006). Efforts to quantify the proposed framework will facilitate the measurement effort and may offer more concrete results.

One way to achieve this would be to construct the detail of statement or criteria in each column, or dimension, as a series of Guttman scales, also known as cumulative scaling, where greater levels of achievement were dependent on the attainment of previous steps (Elwyn et al., 2004, Trochim, 2000). By this method is possible to provide a more objective means of level and sub-level selection.

The literature shows that for correctly configured maturity frameworks, moving up the maturity levels is difficult (Kahn et al., 2006). In the case of a critical care CIS, improvement and change initiatives are more than just customisation programming and testing work, but a complex mix of socio-political and socio-technical factors that mediate both the prospect of success, and pace of progress. The practice of critical care medicine in an acute hospital is recognised in the literature as one of the more complex environments in which to effect change and improvement (Callen, 2008).

8 CONCLUSIONS

The motivation for this research is to address a gap in the health information technology literature by evaluating the usefulness of a maturity model to guide the ongoing improvement of a locally customised critical care Clinical Information System.

The method by which this CIS maturity model has been developed provides for a path that is grounded in the tactical, strategic and professional requirements of the critical care service, in which it operates. These paths focus on seven general themes, or dimensions, that would be the focus for CIS facilitated continuous quality improvement.

The portrayal of CIS customisation and improvement initiatives from a multidimensional construct is important because it guides the course of action the critical care unit can take to improve the sophistication of its CIS customisation, as part of the overall continuous quality improvement efforts. This research provides a methodology that has been pilot tested for such a construct.

A limitation of this methodology employed in this case study is that the findings extracted, the dimensions chosen along with the details of each model, are based on the subjective opinions of a relatively small group of professionals from one institution, using the CIS of one manufacturer. Further work envisaged moving from the pilot phase to larger participant group.

One of the practical benefits of the maturity mode presented in this paper is that, in the six months since it was developed, it has been used to shape and prioritise customisation effort. For example, the perceived low score awarded for "Business efficiency and reporting" dimension has steered efforts to using the CIS database to monitor patient throughput and resource utilisation issues more closely, and to report these key performance indicators on monthly basis to hospital management.

Similarly, with regard to the "MDT Collaboration & Communication" dimension, the authors are involved in research to examine how the CIS can be further improved to foster and detect better interdisciplinary communication between its different user types

Leveraging the potential of the CIS is not a one time event that is focussed on installation, but a continuous and dynamic process of improvement. This research provides a mechanism that culminates with a maturity model which guides this unit to continually customise and improve both the functions of the CIS, and its use, along a pre-defined strategically driven path. The pilot phase of this research demonstrates that the model does point to those areas that should be the focus for improvement.

REFERENCES

Andersen, B. 2007. *Business process improvement toolbox,* Milwaukee, American Society for Quality.

Atkinson , C. J. and Peel, V. J. 1998 Transforming a hospital through growing, not building, and electronic patient record system, Meth Inform Med, 37:285-93

Bates, D. W. & Gawande, A. A. 2003. Improving safety with information technology. *N Engl J Med,* 384, 8.

Berg, M. 2001. Implementing information systems in health care organizations: myths and challenges, *International Journal of Medical Informatics 64,143–156*

Breslow, M. J. & Stone, D. J. 2005. Technology strategies to improve icu practice. *Perioperative Medicine and Pain,* 24, 11.

Byrd, T. A., Thrasher, E. H., Lang, T. & Davidson, N. W. 2006. A process-oriented perspective of is success: Examining the impact of is on operational cost. *Omega,* 34, 13.

Callen, J. L. 2008. Organisational culture: Putting the horse before the cart. *Hospital Information Technology Europe.* London: Campden Publishing.

Crane, R. M. & Raymond, B. 2003. Fulfilling the potential of clinical information systems. *The Permanente Journal,* 7.

Delone, W. & Mclean, E. R. 1992. Information system success: The quest for the dependent variable. *Information Systems Research,* 3, 35.

Delone, W. & Mclean, E. R. 2003. The delone and mclean model of information systems success: A ten year update. *Journal of Management Information Systems,* 19, 22.

Elwyn, G., Rhydderch, M., Edwards, A., Hutchings, H., Marshall, M., Myres, P. & Grol, R. 2004. Assessing organisational development in primary medical care using a group based assessment: The maturity matrix. *Quality and Safety in Health Care,* 13, 8.

Farrukh, C., Fraser, P. & Gregory, M. 2003b. Development of a structured approach to assessing practice in product development collaborations." *Proc. Instn. of Mech. Engrs. in J. Engineering Manufacturer* 217, 14.

Fraser, P., Moultrie, J. & Gregory, M. 2002. The use of maturity models/grids as a tool in assessing product development capability. *Engineering Management Conference.* IEEE International.

Frassica, J. J. 2004. Cis: Where are we going and what should we demand from industry. *Journal of Critical Care,* 19, 226.

Hammer, M. & Champy.J. 1993. *Reengineering the corporation: A manifesto for business revolution,* London, Harper Collins.

Higgins, T. L. 2007. Quantifying risk and benchmarking performance in the adult intensive care unit. *J Intensive Care Med,* 22, 141-156.

Kahn, K. B., Barczak, G. & Moss, R. 2006. Establishing anpd best ptactices framework. *Journal of Product Innovation Management* 23, 11.

Krippendorff, K. 1980. *Content analysis: An introduction to its methodology,* Newburk Park, Sage Publications, Inc.

Morris, J. E. 1998. How can clinical information systems benefit the audit of critical care. *Int. J. of Intensive Care*.

Orlikowski, W. J. 2000. Using technology and constituting structures: A practice lens for studying technology and organisations. *Organizational Science,* 11, 24.

Randolph, J. J. 2005. Free-marginal multirater kappa. *In Proceedings of the Joensuu University Learning and Instruction Symposium 2005*, Joensuu, Finland

Randolph, J. J. 2008. *Online Kappa Calculator.* Available: http://justus.randolph.name/kappa [Accessed October 2010]

Scales, J. 2004. Medical technology in the intensive care unit. *Current Opinion in Critical Care,* 10, 7.

Strauss, A. & Corbin, J. 1998. *The basics of qualitative research: Techniques and procedures for developing grounded theory,* Beverly Hills, CA, Sage Publications, Inc.

Thomas, G. & Fernandez, W. 2008. Success in it projects: A matter of definition. *International Journal of Project Management,* 26, 10.

Trochim, W. 2000. *The research methods knowledge base,* Cincinnati,OH, Atomic Dog Publishing.

Van der Meijden, M. J., Tange, H. J., Troost, J. & Hasman, A. 2003. Determinants of success of inpatient clinical information systems: A literature review. *Journal of the Medical Informatics Association,* 64, 8.

Van De Wetering, R. & Batenburg, R. 2009. A pacs maturity model: A systematic meta-analytical review of maturation and evolvability of pacs in the hospital enterprise. *International Journal of Medical Informatics,* 78, 14.