A systems approach to customizing lean six sigma implementations

Richard Orme (ormera@aston.ac.uk)
Aston University

Ben Clegg
Aston University

Chris Rees
SigmaPro

Mike Titchen
SigmaPro

Abstract
Contemporary research questions the universal applicability of a commoditized lean six sigma approach to organizational improvement. This paper empirically investigates how organizations customize lean six sigma programmes; presenting new quantitative and qualitative systemic models describing organizational processes and dynamic behavior in terms of improvement program maturity and cost of quality.

Keywords: lean, six sigma, lean six sigma

Background to lean and six sigma
Lean and six sigma have gained mainstream popularity in organizations wishing to improve organizational performance. Lean is based on the Toyota Production System which aims to improve the efficiency of organizational processes through the continual reduction of *muda (waste), muri (unreasonable work)* and *mura (unevenness)*. Six sigma was initially developed by Motorola to improve the effectiveness of its manufacturing processes through the application of statistical analysis to reduce process variation. Since their inception each technique has been applied to manufacturing and service organizations however the success of such programmes has varied considerably resulting in criticisms and perceived weaknesses of both techniques. As a result the combination of lean and six sigma approaches, known as lean six sigma, has gained popularity in practice as an attempt to fuse the two techniques, which may realize the benefits of both while mitigating their perceived weaknesses (Clegg et al. 2010). However despite practical successes and similarities between the aims, tools and methodology of each technique, the guiding philosophy and overall approach differ making it unclear how they should be

combined in practice (Bjurstrom 2012). Although there are numerous practitioner guides existing models have unclear theoretical underpinning, weak rationale for the choice of techniques (Pepper and Spedding 2010) and provide no method by which implementation can be monitored, understood and optimized (Brady and Allen 2006). Further contemporary research contends that it is not possible to simply implement a commoditized improvement approach uniformly in different organizational settings, consequently it is necessary "to attune quality practices to contextual requirements" through the synergistic integration of 'hard' (technical) and 'soft' (philosophical and cultural) elements (Wu et al. 2011) to produce outcomes for the organization as a whole (Clegg et al. 2010; Pepper and Spedding 2010). Thus to be successful improvement programmes require the development of technical competence and the adoption of a value system (Ohno, 1988, Liker, 2004, Wu et al. 2011) that must practically combine the numerous inter-related elements in a holistic, systemic and systematic manner (Naslund 2008, Checkland 2006) that is appropriate to the organizational context. However such an approach is inherently difficult to cognitively process, the field of systems thinking was specifically developed to understand and find solutions to such complex problems. The authors contend that the use of a systems thinking approach will result in a scalable and adaptable lean six sigma which will add to knowledge of Lean Six Sigma implementation and aid practitioners in designing Lean Six Sigma programmes to 'fit' their organizational context, aid decision making and help maximize overall impact.

Definitions of lean, six sigma and lean six sigma

Lean thinking

Lean thinking has its origins in the Toyota Production System and scientific management (see Shah and Ward 2007 for a timeline). It was popularised through management guides and has since been applied in manufacturing and service contexts to improve efficiency through the steady identification and reduction of *muda*, *muri* and *mura*, Muda is waste (non-value add activities) and uses specific solution tools such as value stream mapping and 5 S; Muri is unreasonable work imposed on the workers by the management such as carrying heavy objects; Mura is unevenness which involves the smoothing of production flow using production levelling pull production. However despite the popularity of lean it is often applied on the basis of 'principles' rather than a clearly defined model (Alfieri et al. 2012) consequently it is difficult to understand exactly how a lean system 'should' function (Bjorstrom 2012). The concept of lean has been broadly defined as a "holistic system for the elimination of waste" containing elements of quality control, quality assurance and respect for human factors (Ohno 1988). and an integrated system of 'long term philosophy', 'process management', people and partner development' and 'continuous improvement and learning' (Liker 2004). While the academic literature tends to consider lean from one of two perspectives; the practical focus on application of tools and techniques and the philosophical mind-set governing how a business regards itself and its processes, successful lean initiatives must use a process of organizational management and change that becomes part of organizational culture (Liker 2004). Thus lean initiatives must combine both philosophical and practical perspectives synergistically as part of any management system (Shah and Ward 2007). Such an 'holistic' approach is inherently cerebrally challenging, as it must integrate numerous social and technical elements, which requires a 'system of systems' approach to understand the inter-connected nature of different related inter-dependent systems (Alfieri et al. 2012)

Six sigma

Six Sigma was developed at Motorola in 1987 as a means of reducing variation in its production processes and subsequently adopted by Allied Signal and General Electric to improve financial performance rather than quality. Proponents of Six Sigma considered it to be an improvement on earlier approaches, particularly Lean, because of its clear and refined deployment method.

Similarly to the lean concept there is no one singular definition of six sigma (Aboelmaged 2010). Six sigma can generally be described as a continuous and breakthrough improvement programme that increases efficiency and effectiveness through variation reduction. The technique uses a structured deployment method that includes specific roles, including Champions, Master Black Belts, Black Belts, Green Belts and Yellow Belts; specific structured improvement methods such as DMAIC and DMADV; and utilizes statistical tools and techniques in a scientific approach (Chakrabarty and Tan 2007). Expected project outcomes are clearly defined by the 'voice of the customer' and the utilization of measurable, quantifiable metrics including sigma scores, cost of poor quality and return on investment. Although general definitions have been developed the academic literature focuses on the elements of the six sigma phenomenon rather than how they fit into the enterprise management system (Zu et al. 2008, Schroder et al. 2008). Thus despite its clear deployment approach it remains unclear how six sigma should be applied in specific organizational contexts. Thus there is a clear need for research into how six sigma is used in practice as part of an overall business strategy incorporating lean six sigma.

Conceptual models of lean and six sigma

Lean and six sigma approaches are complementary under a quality management philosophy (Clegg et al. 2010) and a systems approach is capable of embedding philosophical and cultural aspects of lean with the rigorous scientific approach of six sigma through a unified hard / soft systems philosophy (Pepper and Spedding 2010). In particular, best practices for management leadership and people management must be combined with core technical practices for process management in order to achieve organizational performance (Anand 2006). While practitioner guides prescribe brief implementation models they do not describe how they should be adapted to particular organizational contexts. Similarly academic models provide overviews of key elements of lean six sigma implementation and critical success factors (Aboelmaged 2010) but they do not outline the organizational processes involved or how they are interrelated in an overall business approach to improvement. In an attempt to generate a guide to developing a systemic and systematic conceptual model Pepper and Spedding (2010) suggest that lean and six sigma should be combined through the integrated management of quality, a scientific approach and an 'all-one-team' approach "which optimises systems as a whole and focuses on the right strategies in the correct places". They conclude that any such model should be: strategic and process focused; balanced between the two philosophies to harness the recognised advantages of both; balanced between complexity and sustainability; and structured around the type of problem experienced.

Key factors for lean six sigma theoretical model development

The literature provides a range of factors that are considered important for successful lean and six sigma deployment these are summarised in Table 1.

Table 1, The factors affecting organizational improvement program maturity.

Factor	Reference
Support, involvement and commitment from management	Aboelmaged 2010
Communication of organizational values, attitudes and ethics	Liker 2004
Translation of organizational strategy into operational business plans	Liker 2004
Development of departmental and individual goals and their deployment	Liker 2004
Performance measurement of the improvement program.	Bititci et al. 2006
Alignment of projects with organizational strategy	Aboelmaged 2010
Appropriate choice of tools and techniques	Shah & Ward 2007
Knowledge capture and communication	Anand et al. 2010
Implementation and maintenance of change	Naslund 2008
Process control and standardization	Liker 2004
Selection, development and involvement of employees	Liker 2004
Supply chain development	Shah & Ward 2007
Holistic perspective	Shah & Ward 2007

Cost of quality (COQ)

The overall objective of lean and six sigma is not only to achieve higher quality, that is important to the customer, but also to achieve this at the lowest possible cost. The COQ approach provides a guide to the most appropriate attribution of improvement spending by defining the value of improvement effort, identifying the relatively strong and weak areas of the program and identifying the relative importance of quality problems; not simply in terms of defect rates but for the organization as a whole (Setijono and Dahlgaard 2008). Thus COQ may address the shortcomings of current lean six sigma models by providing a logical, theoretically sound, basis for choosing between techniques and monitoring, understanding and optimizing lean six sigma implementation (Pepper and Spedding 2010, Brady and Allen 2006).

The Prevention-Appraisal-Failure COQ model is commonly used in the literature and British Standard BS 6143 is the most common approach implemented by organizations (Schiffauerova and Thompson 2006) and hence is utilized in this paper. In the context of BS 6143: prevention costs are those incurred through any action that is taken to investigate, prevent or reduce the risk of non-conformity or defect and appraisal costs are those incurred in the initial ascertainment of the conformance of the product or service to the quality requirements. Failure costs are those arising within the organization due to non-conformity or defect either before, an internal failure, or after, an external failure, delivery to the customer. Thus COQ data, in combination with investment criteria such as cost reduction, improving customer service or obtaining market share, can be used to assess desirability of investment through the cost / benefit relationship between investment and potential return. In general as an organization progresses from a very low to a very high level of effectiveness, total COQ, appraisal and internal failure cost will initially increase before declining, prevention cost gradually increases and external failure cost gradually decreases. Increases in appraisal cost correspond with reductions in external failure costs and increased prevention cost corresponds with reduced internal and external failure costs (Sower et al. 2007). Logically increased prevention cost, such as improved design and activities such as error-proofing will result in reduced appraisal.

Methodology

Initial systemic models were developed from the extant literature and tested in action research case studies. The paper employs a novel systems methodology that combines elements of Process-Oriented Holonic modelling (PrOH) (Clegg, 2007), and System Dynamics (SD) in a combined soft / hard approach. Subsequently empirical data has been collected from 10 case studies. Each case study has a set of quantitative and qualitative data on which the hard / soft models are based. Each model is used to describe the process and support improvement changes (as per Mingers, 2003). Specifically the models reveal ‘change program maturity’ and the relationship to the ‘Cost of Quality’ (based on British Standard BS6143).

This paper presents a strategic level PrOH model developed from the extant literature and subsequently discusses the application of the techniques to the project selection process in one of these cases – Company X – an outsourced operations management company, and how the cost of quality relates to customization of the process. Other on-going research includes 9 other companies based case studies in manufacturing and service environments varying in size from small and medium sized to multinationals. These are found are in the logistics, internet, construction, facilities management, aerospace and printing sectors. In subsequent cross-case analysis the authors will develop a scalable and adaptable LSS deployment framework

The PrOH model, figure 1, presented describes the primary processes, agents, artefacts, critical success factors and decisions which the literature suggests are necessary for a lean six sigma programme. However to increase the understanding of how organizational processes can be customized (for a particular process) a PrOH and a system dynamics model are presented based on the same data source relating to project selection in the case study. By combining the two techniques the models presented and the assumptions used can be discussed, questioned and augmented on the basis of organizational context.

Theoretical lean six sigma model

The PrOH model, figure 1, presented describes the primary processes, agents, artefacts, critical success factors and decisions which the literature suggests are necessary for a lean six sigma programme. The core process, highlighted by the bold arrows in figure 1 and represented in the first line of Table 2, can be read as *Stock market performance may motivate shareholders to attend the annual general meeting which is acted on by the executive board who co-ordinate the organizational system to benefit the customer who receives improved product service utility.* Similarly the Executive Board would subsequently carry out planning activities represented by the process *Executive Board develop strategic objectives which directs departmental process owners who negotiate and deploy departmental goals which guides supervisory management*, represented in the second line of table 1. In the same way the ‘do’, ‘check’ and ‘act parts of the Plan-Do-Check-Act cycle are represented in third, fourth and fifth lines of table 2.

Table 2. PrOH logic table for figure 1. Executive co-ordinate the organizational system.

Previous key human resource	Input	Key human resource	Performs an activity	Output	Next key human resource
(Stock market performance may motivate) Shareholders to attend	AGM	(acted on by) Executive Board	(co-ordinate) the organizational system	Org. system	(to benefit the) customer (who receive improved product service utility)
Executive Board (develop)	Strategic objectives	(directs) Dept Process Owner	Negotiate and deploy Dept Goals	Dept. Goals	(guides) Supervisory Management
Departmental Process Owner (negotiate and deploy)	Dept. Goals	(guides) Supervisory Management	Manage day-to-day processes	Day-to-day processes	(performed and adhered to by) Non-Managerial Staff
Supervisory Management (manage)	Day-to-day processes	(performed and adhered to by) Non-Managerial Staff	Collect and monitor Operational Process Performance	Operational Process Performance	(used by) Departmental Process Owner
Lean six sigma project selection team (develop)	Project portfolio	(managed and performed by) Project Teams	Perform Lean six sigma projects	Lean Six Sigma projects	(reviewed, communicated and maintained by) Departmental Process Owners

Project selection in the case study organization

For the purpose of discussing the customization of the lean six sigma program in the case study organization the project selection process will be consider, in particular the factors effecting the choices made to improve, increase the maturity of, the project selection process. The PrOH model, figure 2, represents a simplified model of the original process.

PrOH model of the project selection process

The case study organization utilize a similar process to that described in the theoretical model, figure 1, (*Executive develop strategic objectives which inform the lean six sigma project selection team who develop a project portfolio managed and performed by project teams*). In the case of the enriched model for the case study project selection process the core process reads, '*Head office and customer requirements guide the executive who develop strategic objectives which guide the lean six sigma project selection team who develop a project portfolio which is allocated to project teams who manage the project phase.'* The process that was considered to be in need of improvement involved the manual process interventions (based on a kaizen approach) that were part of day-to-day operations. This process can be read as *'operators insure the success of day-to-day operations (including the use of manual process interventions (kaizen) to meet the requirements of the service level agreement) which is monitored by the control room staff who report process performance which informs and used by the* *lean six sigma project selection team.* Importantly only the service level agreement is monitored by the control room staff not the effect of the manual process interventions.

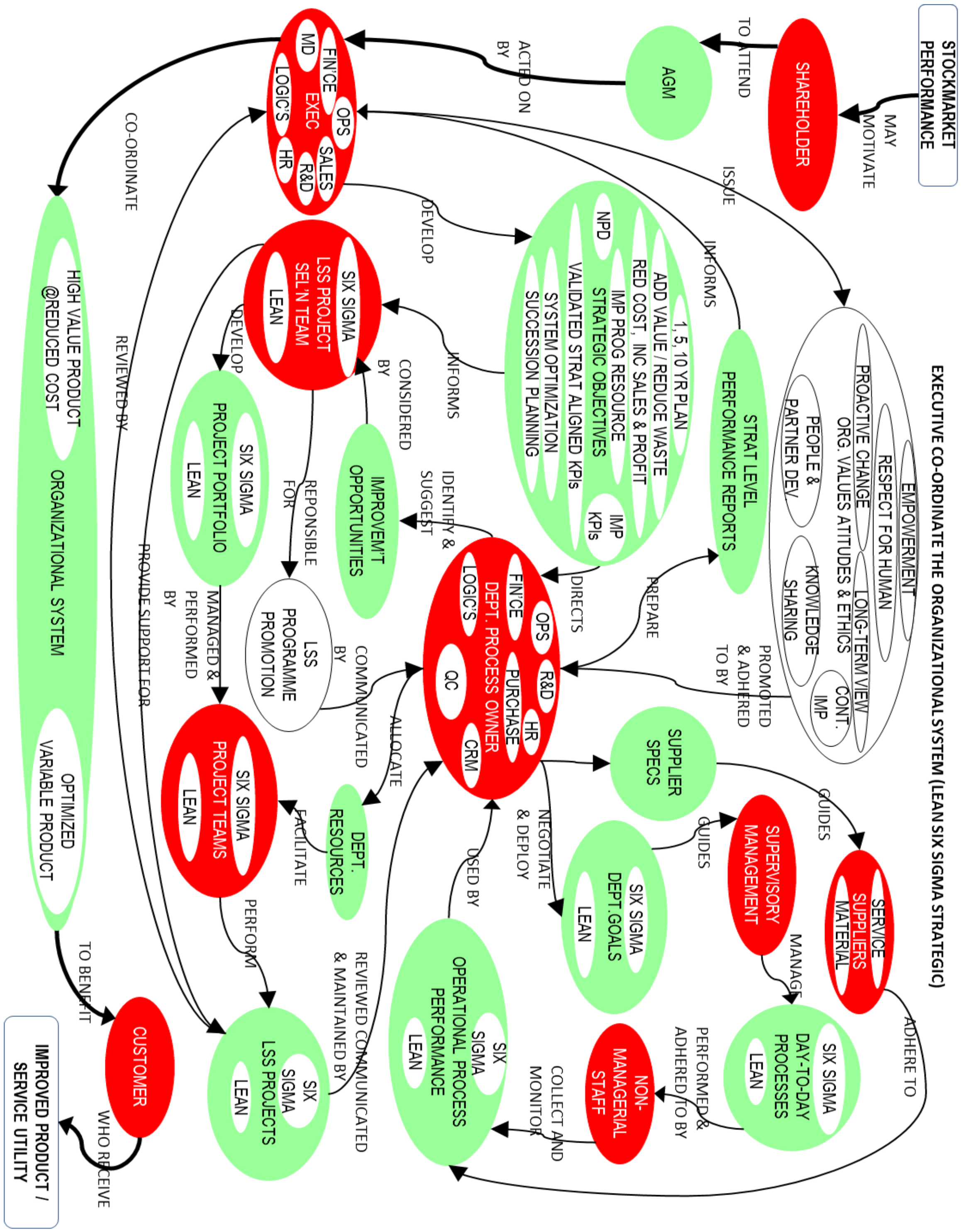

Figure 1. Executive co-ordinate the organizational system.

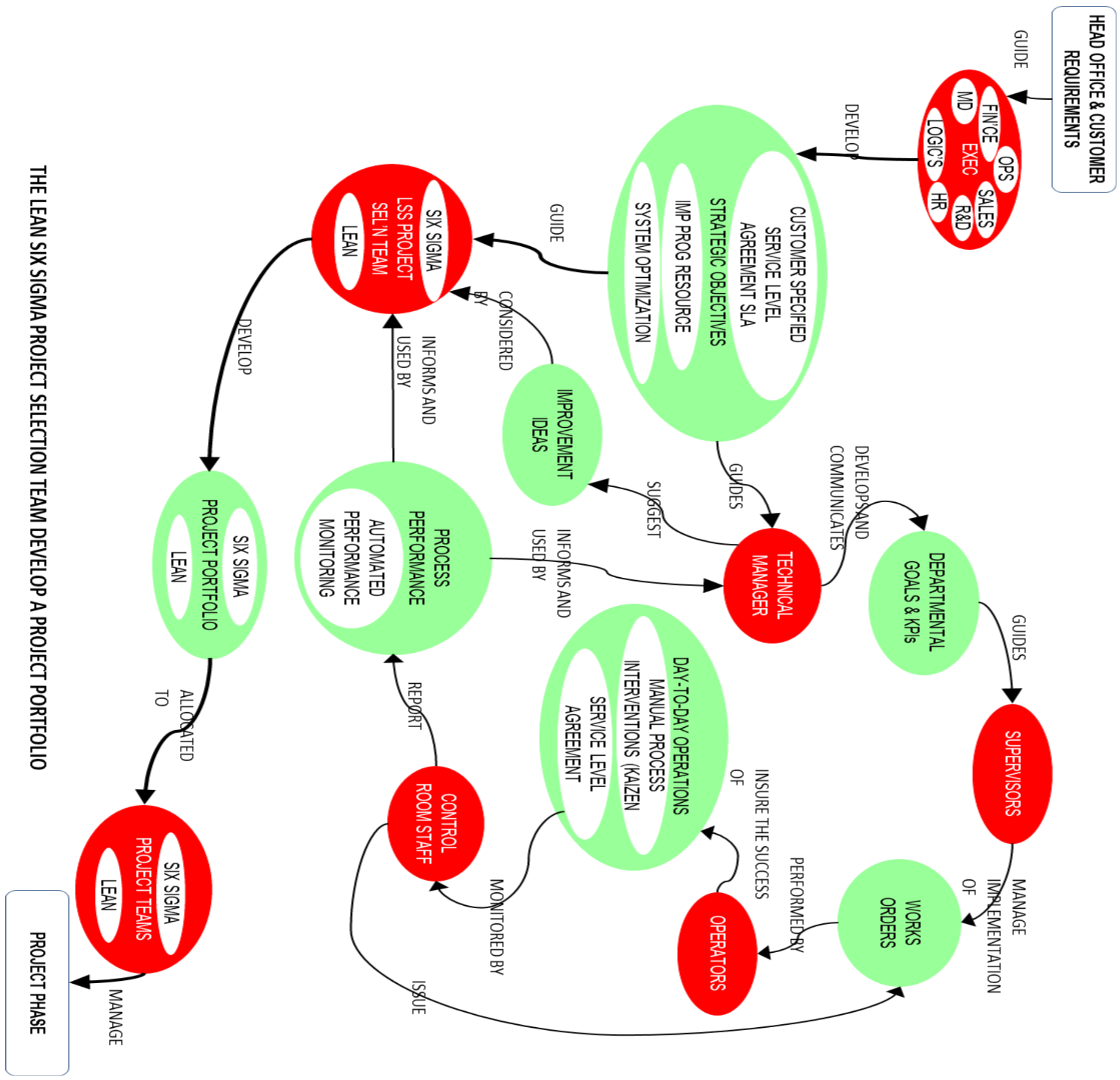

Figure 2. The lean six sigma project selection team develops a project portfolio

System dynamics model of case study project selection process

The same information can be used to develop a system dynamics model of the project selection process. In figure 3, the presence of strategic customer goals and organizational financial goals will increase the ability to set departmental goals and KPIs and increase in the ability to manage day-to-day operations. This will result in an increase in the ability to measure process performance because the day-to-day operations are managed to a consistent set of measureable goals. The increased ability to measure process performance will subsequently increase the ability to produce a project portfolio because the performance shortfall against requirements will be known. Similarly the ability to generate improvement ideas will be increased by strategic customer and organizational financial goals. The level of ability to produce a project portfolio will increase the prevention cost which if it is to be beneficial should result in an associated reduction in the internal failure cost. As can be seen in figure 2 operators carry out manual interventions to resolve on-line problems however these are not monitor, consequently manual interventions have a negative effect on the ability to measure process performance by 'covering up' failures creating a higher observed performance and increases internal failure costs (rectifying failures). However it has a positive effect in the elimination of external failure as defined by the strategic customer goals. Similarly the current level of 'ability to measure process performance' is sufficient to prevent external failures. The prevention, appraisal, internal and external failure cost all contribute to the cost of quality the knowledge of which is positively correlated to the ability to produce a project portfolio. In the case in question it is most financially beneficial to reduce the internal failure cost however this requires a balance between the level of manual intervention, the ability to measure process performance and the ability to produce a project portfolio (based on a six sigma approach).

The model can be used to assess the best way to manage these three aspects in order to reduce the internal failure cost; for example it would not be beneficial to simply remove all manual intervention (thereby maximizing the ability to measure process performance) because of the associated increase in external failure cost which would outweigh any saving in internal failure cost. Alternatively it may be possible to introduce a measure of the effect of manual intervention on process performance and consequently increase the ability to measure process performance. The approach chosen in the case study (on the basis of lowest risk) was to introduce a measurement system to record information regarding manual interventions. This had the advantage of increasing the ability to measure process performance and therefore understand the causes of manual interventions from a statistical six sigma approach resulting in an increased ability to produce a project portfolio that will provide a greater reduction in internal failure costs and the need for manual interventions. Thus there was a shift in focus toward the use of a six sigma approach.

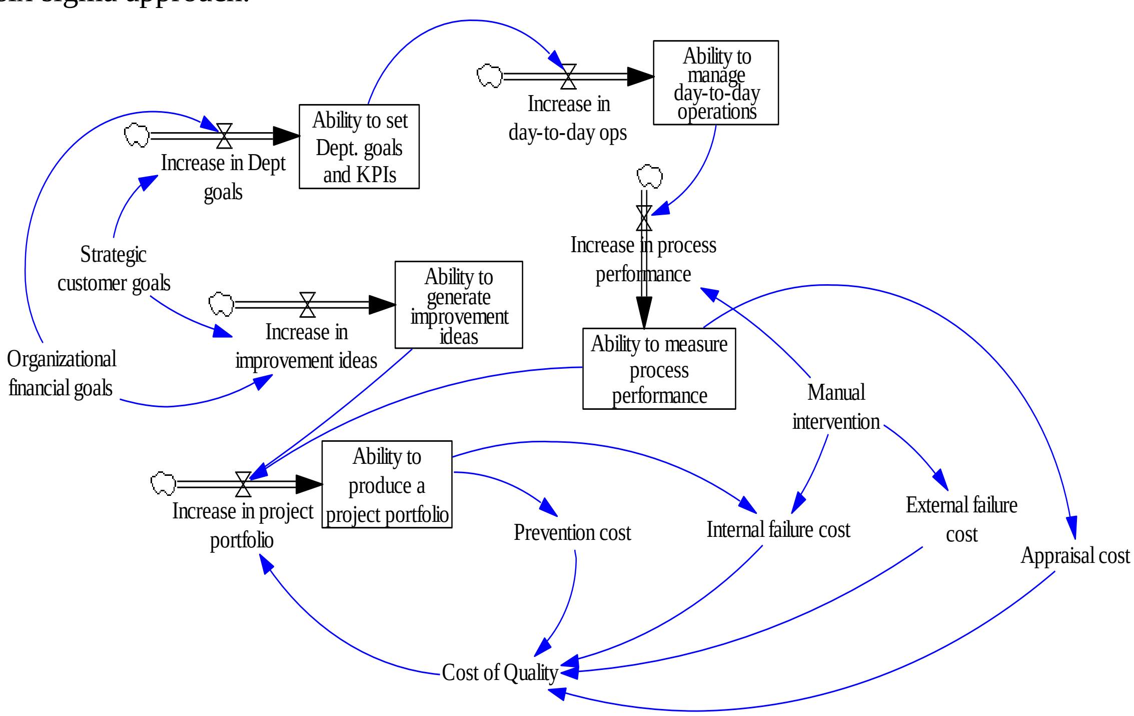

Figure 3. System dynamics model for the development of the project portfolio

References

Aboelmaged, M. G. 2010. Six Sigma quality: a structured review and implications for future research. *International Journal of Quality & Reliability Management.* **27**(3):268-317.

Alfieri, A., M. Cantamessa, and F. Montagna. 2012. The SoS approach for lean manufacturing systems. *International Journal of Technology Management*. **57**(1/2/3):149-165.

Anand, N. 2006, "Meta-analysis of the relationship between quality management practices and firm performance – implications for quality management theory development", *Journal of Operations Management*, **24**(6): 948-975.

Anand, G., P. T. Ward, and M. V. Tatikonda. 2010. Role of explicit and tacit knowledge in Six Sigma projects: An empirical examination of differential project success. *Journal of Operations Management.* **28**(4):303-315.

Bititci, U.S., K. Mendibil, S. Nudurupati, P. Garengo, and T. Turner. 2006. Dynamics of performance measurement and organisational culture. *International Journal of Operations & Production Management.* **26**(12):1325-1350.

Bjurstrom E. 2012. Minding the contexts of mindfulness in quality management, *International Journal of Quality & Reliability Management* **29** (6): 699-713

Brady. J. E., and T.T. Allen. 2006. Six Sigma Literature: A Review and Agenda for Future Research. *Quality and Reliability Engineering International*. **22**(3):335-367.

Chakrabarty, A. and Tan, K.C. 2007. The current state of six sigma application in services, *Managing Service Quality* **17** (2): 194 - 208

Checkland, P. and Poulter, J. 2006. *Learning for action: a short definitive account of soft systems methodology and its use for practitioners, teachers and students*. John Wiley & Sons. Chichester.

Clegg, B.T. 2007. Building a Holarchy Using Business Process-oriented Holonic PrOH Modeling. *IEEE Transactions on Systems, Man and Cybernetics-Part A: Systems and Humans.* **37** (1): 23-40.

Clegg, B., C. Rees, and M.Titchen. 2010. A study into the effectiveness of quality management training: A focus on tools and critical success factors. *The TQM Journal.* **22**(2):188-208.

Liker, J. K. 2004. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. 1st Ed. McGraw-Hill. London.

Mingers, J. 2003. A classification of the philosophical assumptions of management science methods. *Journal of the Operational Research Society.* **54**: 559-570.

Naslund. N. 2008. Lean, Six Sigma and Lean Sigma: Fads or real process improvement methods? *Business Process management Journal.* **14**(3): 269-287.

Ohno, T. 1988, *Toyota Production System: Beyond Large-scale Production,* Productivity Press, Cambridge, MA.

Pepper, M. P. J., and T. A. Spedding. 2010. The evolution of Lean Six Sigma. *International Journal of Quality & Reliability Management.* **27**(2):138-155.

Schiffauerova, A., and V. Thompson. 2006. A review of research on the costs of quality models and best practices. *International Journal of Quality & Reliability Management.* **23**(6):647-669

Schroder, R.D., K. Linderman, C. Liedtke, and A. S. Choo. 2008. Six Sigma: Definition and underlying theory. *Journal of Operations Management*. **26**(4):536-554.

Setijono, D., and J. J. Dahlgaard. 2008. The value of quality improvements. *International Journal of Quality & Reliability Management*. **25**(3):292-312

Shah, R., and P. T. Ward. 2007. Defining and developing measures of lean production. *Journal of Operations Management*. **25**(4):785-805.

Sower, V. E., R. Quarles, and E. Broussard. 2007. Cost of quality usage and its relationship to quality system maturity. *International Journal of Quality and Reliability Management*. **24**(2):121-140.

Wu, S. J. Zhang, D. and Schroeder, R.G., 2011, Customization of quality practices: the impact of quality culture. *International Journal of Quality and Reliability Management*. **28**(3):263-279

Zu, X. Fredendall, L.D. and Douglas, T.J. 2008. The evolving theory of quality management: The role of Six Sigma. *Journal of Operations Management.* **26** (5): 630-650.