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Systems Engineering and Quality Engineering: a Systematic Mapping Study

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ABSTRACT

Background: The need to adopt a systemic approach to achieve business excellence has made the practice at Systems Engineering (SE) and Systems Thinking more widely applied. **Objective:** The purpose of this paper is to describe and analyze the academic efforts on integration between Quality Engineering and Systems Engineering, exploring the current state of the art, the configuration of the discussion about the theme and opportunities for research. **Results:** Using a qualitative approach, based on a systematic literature review in the period 2000-2013 and 30 articles were analyzed with applications ranging from health quality systems to thinking systems approach in quality tools, such as quality function deployment (QFD). **Conclusion:** During the review it was observed that the authors widen the discussion about the contribution of SE and systems thinking on the quality improvement of different issues.

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INTRODUCTION

Quality Engineering is an increasingly field of knowledge for the organisational successes. Despite some decades ago people did not give much importance to some topics like quality of products, process and services, now there are several discussions about that. Over the years, the concept of quality provides the approach to ensure the sustainable development of the most types of organisations. Many researchers too, have taken quality methodologies as an important enabler for achieving business excellence.

The necessity of understanding the whole process brought the development of a method that relates various components of the same system. The systems thinking appear as a new concept structure, contrary to traditional thinking that has a focus on analysis of parts, the systems thinking seeks to obtain the synthesis system based on the interaction between the parts that compose it (ACKOFF, 1981). A systemic way of thinking means that answers to some questions come from the analysis of the interdependence of various factors.

Many systems approach use the Systems Engineering (SE) methodology. Magerholm *et al.* (2009) proposed a six step method developed using the principles of SE: (1) Identify needs; (2) Define requirements; (3) Specify performances; (4) Analyse and optimize; (5) Design, solve and improve; (6) Verify, test and report. Organisations are increasingly faced with issues as product quality, sustainability and social responsibility, enhancing the systems complexity. SE and systems thinking support to orientate a new approach allowing better conditions able to cope with this new scenario.

In Magerholm *et al.* (2009) the SE methodology was applied to enhance the understanding of interactions between the subsystems of a fish food production system. Fet *et al.* (2013) suggested SE methods to environmental analyses in the ship design and compared with many tools for environmental assessment and management.

According to INCOSE (2014), SE is an approach that merges interdisciplinary concepts and defines needs, controlling if the functionality is in accordance with the required. Also pay attention to the whole situation of the project using schedules, deadlines, costs, installations, the manufacture, and so on. It is the interdisciplinary view of SE that makes it relevant to many topics of the body of knowledge of Quality Engineering to increase a firm´s commitment to quality.

This interest, to integrate two extensively used concepts to improve business performance is motivating some authors to apply elements of SE in

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quality management initiatives. So, the main objective of this study is to describe and analyze the academic efforts to integrate these two fields of knowledge: Quality Engineering and Systems Engineering, exploring the current state of the art and the configuration of the discussion about the theme.

Research Description:

In order to identify the academic efforts to integrate "Quality Engineering" and "Systems Engineering" we reviewed the publications in the most important journals between 2000 and 2013, available the full text in Capes Periodic virtual database that is one of the largest virtual libraries in the word (CAPES, 2014).

This study has a qualitative nature, based on a literature review and was conducted through a process that is composed by four steps: (1) first selection of the articles; (2) analyze each article to select it based on the content; (3) identify the variables considered in the various articles; and (4) compare the articles' reviews looking for gaps and opportunities.

The selection of the articles was based on at least one of these criteria: (1) Part of the list that was generated looking for articles with Systems Engineering and Quality in the subject; (2) Part of the list that was generated looking for articles with Systems Thinking and Quality on the subject.

In the first search, 56 results were found in several important databases as Scopus and Web of Science and the second search result in 20 articles resulting in a total of 77 papers. The authors reviewed the abstract of the articles and selected those considered appropriated based on the content and our final sample consisted of 30 articles. Only papers published in journals were considered, so that other works, annotations, for instance, were discarded. Another factor that contributed to the reduction of the number of articles it was that some papers are contained in different databases, generating repeatable results.

The following section is going to describe the reviews of each of the 30 articles found and in chronological order. This is done to try to discover the variables of interest for each of the time periods.

Articles Reviews:

Peppen and Ploeg (2000) introduced a quality management system created to evaluate the quality of a master's degree in the SE field deployed in Delft University of Technology in 1992, the system was named Intraview and it was created to satisfy the needs of course administration.

Jabemkar (2000) suggested a systems perspective related to operations, quality and maintenance management, therefore was used a study case methodology in two companies in where was applied two strategies: Total Productive Maintenance (TPM) and Total Quality Management (TQM). According to Jabemkar (2000), the systems thinking perspective, the creation process and implantation of TPM and TQM were represented by loop diagrams containing concepts and process used in interdependent dynamic systems that could be applied as an example for any dynamic system specific in an organization.

Waks and Frank (2000) recommended Systems Thinking and TQM for the curriculum of communications systems engineers to gain a better understanding as to the impact of their specific design on the whole system.

Hassan (2001) pointed out key differences and similarities between TQM and SE. They introduced the basic concepts of SE and featured TQM as a conceptual, opened, dynamic and continuous system.

Ferner and Vetter (2002) discussed a SE framework to develop an architectural model for better understanding how to define quality of network and pointed out the importance to exist an inter-layer communication. Several benefits of application of SE are illustrated that improve the communication between the end user, which is the real customer, and the underlying network systems.

Conti (2006) introduced a new and complete paradigm to quality engineering, merging concepts from the field with systems thinking, presenting focus on social-cultural features. Likewise, Conti (2006) claimed that the objective of companies is to ensure the quality of services and products, so the organisations must be aware of its values because the final quality will be measured through them. On this account, it is proposed a scheme for the value generation with systems thinking characteristics.

Kopach-Konrad *et al*. (2007) analysed a health care delivery system and stated that the fundamental concepts and tools of SE could be applied to deal with the complexity of health system, pointing to the importance to bring people with SE skills to improve health care delivery. According to Kopach-Konrad *et al*. (2007), there are a six fundamental step of SE, which would mean, identifying the system of interest, selecting applicable measures, choosing the appropriate modelling tool, studying model properties and behaviour under a multiplicity of scenarios, and making design and operational decisions for implementation.

Sitnikova *et al*. (2007) investigated the linkages between the level of process maturity in large software and SE organisations and project outcomes. The results indicated that process capability improvement can positively influence the organisational development leading to enhanced complexity system and found that the most acceptable challenge faced by those organisations was the ability to manage skill gaps in the area of advanced project management, SE, and process improvement.

Cavana *et al*. (2007) presented a framework for considering retention and recruitment issues based on

systems thinking process and the qualitative system dynamics models, which showed several steps to address an improvement in the retention of apprentices related to: recruiting, addressing apprentice needs and pay progression model.

Caldwell (2008) proposed the research human factors and the aid of SE tools to study the health quality performance of a hospital. It was noticed that people involved did not have a systemic view of the organisation andit was applied an engineering model of information systems that indicated the inputs and outputs to make easier the understanding and bringing improvements in the health service quality.

Varkey *et al*. (2008) indicated the importance of SE concepts towards health care quality challenges. The work explored the collaboration between engineers and physician educators as a potential source of quality improvement knowledge and skills.

Feather *et al*. (2008) stated a quantitative risk assessment model to generate quality requirements based in making decisions in early project phases.

Utne (2009) claimed that quality function deployment (QFD) could lead to hand sustainability issues in the fisheries and be positively associated with SE as a tool for converting stakeholder needs in systems requirements.

Swensen *et al*. (2009) emphasized the need for transformative vectors to develop high-reliability health system, which are culture, infrastructure, engineering and execution. The aforementioned study highlighted the positive effects of applying a systematic and a disciplined way in the form of response to the quality chasm in a health system.

Sawyer and Maiden (2009) explained how to use some methods and tools for developing service-centric systems in requirements processes.

Yuniarto and Osada (2009) suggested a framework for quality improvements in maintenance system based on the integration between the six sigma and the system dynamics which is proposed to deliver a maintenance strategy with merged characteristics of the quality system and the systems thinking.

Hershey and Silio (2011) discussed a SE approach to provide a structure for monitoring and analysis in high-speed enterprise communications systems on ensuring a better quality service for the end-user.

Blackburn *et al*. (2011) proposed the theory of inventive problem solving (TRIZ) as a SE approach to eliminate pharmaceutical production system contradictions through which improve the quality performance.

MacKinnon (2011) discussed the application of systems thinking to promote the quality improvement in school education stated in capacities in children's learning.

Mehrjerdi (2011) discussed the application of quality function deployment -QFD as a tool to bring profit for business decision and point out systems thinking perspective designing loops to propose models for demonstrating the different role of QFD in an organisation.

Kheradia (2011) suggested the application of systems thinking, lean management, value methodology and six-sigma through to create a model analysis called TALEVAS, where the principles and concepts of those elements are the baseline requirements to think beyond quality improvement strategies. TALEVAS model identified four key performance drivers that maximize the efficiency and effective in system performance: communication, investigative correction, innovation and synchronization (KHERADIA, 2011).

Lagrosen and Lagrosen (2012) presented a model for depicting an organisation's work-related health status from the systems thinking perspective and highlighted the relationship between quality management and employee health. They adopted six health-promoting quality management dimensions, such as: empathy, presence and communication, integrity, continuity, development, influence and being informed.

Swensen *et al*. (2012) described a value creation system in health care services. They demonstrated improvement on the care of patient and increasing productivity, which are consequences of higher quality because there is a whole view of a value creation related with a core usual SE tools and methodologies.

Shin-Ping Tu *et al*. (2012) analysed the application of SE approaches to deliver health care systems with efficiently performing results. They concluded that is necessary resources to pay for the application of the systems-engineering techniques, which is more available in hospitals and large health care systems. Several benefits of application of value-stream mapping, as systems-engineering methodologies, were illustrated according to Shin-Ping Tu *et al*. (2012) to collect data about the processes throughout the health system that help to identify appropriate value-adding operations.

Cristian and Green (2012), in a study of causes for a patient injury, observed the contribution of systems thinking to promote a whole view of the health system that that led to the patient injury and not just seeing the immediate causes. They pointed out some strategies to improve patient safety through systems thinking, such as: (1) Promote an environment for learning organisation; (2) Constantly evaluate current systems; (3) Develop a culture that patient safety is a fundamental value for the organization; and so on.

Maull *et al*. (2012) explored the contribution of the customers to meeting their requirements for quality and value by taking a systems thinking lens of service supply chains and discussed this conceptualization considering boundaries, hierarchies and mechanisms of control.

Tropello *et al*. (2013) pointed out key principles of SE methodologies and how these principles facilitate to achieve the goal of improving the quality of care and minimizing patient injuries, highlighting a few examples of the application of SE methodologies to a health care system.

Bolboli and Reiche (2013) proposed an approach to business excellence based on systems thinking principles that consider the process of designing and implementing sustainable business excellence such as stakeholder orientation and value generation, which intends to fill the gap between theory and practice of systems thinking in quality management.

Ringrose (2013) discussed principles and practices of the leading excellence frameworks that are practiced in several countries and some of them apply systems thinking principles such as, alignment that is understand the organisation is a system of interrelated and interconnected subsystems.

Gerst (2013) illustrated the application of the command and control thinking in health service system and pointed out this as a cause of the failure to effectively manage it. After a complete analysis, it is highlighted the contribution of a dynamic view of the organisation focusing on the value stream and on the systems thinking to promote a significance change in the health care system.

Discussion and Conclusion:

During the review it was observed that the authors widen the discussion about education, health care, software development, business excellence, supply chain, maintenance with systems thinking and SE. This could serve as the basis to understand the contribution of SE and systems thinking on the quality improvement of different issues.

Based on the SE approaches, it is possible the development of a framework to transform the health care system which depends on the dynamic view of the organisation that is essential to integrate all different perspectives and promote the quality of patient care.

We found an important relationship between the works of Jabemkar (2000), Hassan (2001), Conti (2006), Kheradia (2012), Bolboli and Reiche (2013) and Ringrose (2013), owing to the similarities between the variables investigated. They both seem to want to stress the contribution of systems thinking in the context of the development of a business excellence model based on quality improvement.

In reviewing this body of publications, further research needs to recognize the contribution of systems thinking and SE to the field of quality engineering. Our recommendation for future research includes using more case studies to understand the constraints of applying SE and how to integrate SE in the whole organization satisfying the stakeholders' needs.

Thus, our review suggests that the debate about systems thinking and SE could be improved if we considered the integration of several fields of knowledge of industrial engineering, such as supply chain, product development, and so on.

REFERENCES

Ackoff, R.L., 1981. Creating the corporate future: plan or be planned. John Wiley & Sons, Nova York.

Asche, S.E., D.H. Klevan, L.I. Solberg, 2007. Crossing the quality chasm for diabetes care: The power of one physician, his team, and systems thinking. JABFM, 20(3): 299-306.

Barros, V.F.D.A. and J.E.D. Menezes, 2010. Estudos de Confiabilidade na Modelagem de Sistemas. Cadernos de Educação, Tecnologia e Sociedade, 1(1): 86-103.

Blackburn, T.D., T.A. Mazzuchi and S. Sarkani, 2011. Overcoming inherent limits to pharmaceutical manufacturing quality performance with QbD (quality by design). J Pharm Innov., 6: 69-76.

Bolboli, S.A. and M. Reiche, 2013. A model for sustainable business excellence: implementation and the roadmap. The TQM Journal, 25(4): 331-346.

Caldwell, B.S., 2008. Tools for developing a quality management program: Human factors and systems engineering tools. International Journal of Radiation Oncology Biology Physics, 71(1): 191-194.

Cristian, A. and J. Green, 2012. Patient safety and quality improvement in rehabilitation medicine. Phys Med Rehabil Clin N Am., 23: 221-230.

Clayton Ferner, C. and R. Vetter, 2002. An integrated framework for implementing quality of network concepts. Journal of network and systems management, 10(4), December.

Conti, T., 2006. Quality thinking and systems thinking. The TQM Magazine, 18(3): 297-308.

Feather, M.S., S.L. Cornford, K.A. Hicks, J.D. Kiper and T. Menzies, 2008. A broad, quantitative model for making early requirements decisions. I E E E Software, March/April.

Fet, A.M., D. Margrethe Aspen and H. Ellingsen, 2013. Systems engineering as a holistic approach to life cycle designs. Ocean Engineering, 62: 1-9.

Gerst, R.M., 2013. Deming's systems thinking and quality of healthcare services: a case study. Leadership in Health Services, 26(3): 204-219.

Hassan, M., 2001. TQM as a system for quality management. Systems Engineering, 4(4): 262-271.

Hershey, P. and C.B. Silio, Jr., 2011. Systems engineering approach for high speed enterprise systems. IEEE A&E Systems Magazine, September.

Jambekar, A.B., 2000. A systems thinking perspective of maintenance, operations, and process quality. Journal of Quality in Maintenance Engineering, 6(2): 123-132.

Juran, J.M., 1992. A qualidade desde o projeto: novos passos para o planejamento da qualidade em produtos e services. Thomson, São Paulo.

Lagrosen, Y. and S. Lagrosen, 2012. Organisational learning for school quality and health. International Journal of Educational Management, 26(7): 664-677.

Kheradia, A., 2011. TALEVAS model: an integrated quality methodology. The TQM Journal, 23(4): 403-422.

Kopach-Konrad, R., M. Lawley, M. Criswell, I. Hasan, S. Chakraborty, J. Pekny and B.N. Doebbeling, 2007. Applying systems engineering principles in improving health care delivery. J Gen Intern Med., 22(3): 431-7.

MacKinnon, N., 2011. The urgent need for new approaches in school evaluation to enable Scotland's curriculum for excellence. Educ Asse Eval Acc., 2: 89-106.

Magerholm Fet, A., E.M. Schau and C. Haskins, 2010. A framework for environmental analyses of fish food production systems based on systems engineering principles. Systems Engineering, 13(2): 109-118.

Maull, R., J. Geraldi and R. Johnston, 2012. Service supply chains: a customer perspective. Journal of Supply Chain Management, 48(4), October.

Mehrjerdi, Y.Z., 2010. Quality function deployment and its extensions. International Journal of Quality & Reliability Management, 27(6): 616-640.

Mehrjerdi, Y.Z., 2011. Quality function deployment and its profitability engagement: a systems thinking perspective. International Journal of Quality & Reliability Management, 28(9): 910-928.

Peppen, A.V. and M.R. Ploeg, 2000. Practicing what we teach: quality management of systems-engineering education. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 30(2): 189-196.

Ringrose, D., 2013. Development of an organizational excellence framework. The TQM Journal, 25(4): 441-452.

Sawyer, P. and N. Maiden, 2009. How to use web services in your requirements process. I E E E So f t wa r e, January/February.

Shin-Ping Tu, S. Feng, R. Storch, M. Yip, H. Sohng, Mingang Fu and A. Chun, 2012. Applying systems engineering to implement an evidence-based intervention at a community health center. Journal of Health Care for the Poor and Underserved, 23(4): 1399-1409.

Sitnikova, E., T. Kroeger and S. Cook, 2007. Software and systems engineering process capability in the South Australian defence industry. Innovations Syst Softw Eng., 3: 129-139.

Swensen, S.J., J.A. Dilling, D.S. Milliner, R.S. Zimmerman, W.J. Maples, M.E. Lindsay and G.B. Bartley, 2009. Quality: The Mayo clinic approach. American Journal of Medical Quality, 24(5).

Swensen, S.J., J.A. Dilling, M. Harper and J.H. Noseworthy, 2012. The Mayo clinic value creation. American Journal of Medical Quality, 27(1): 58-65.

Tropello, S.P., A.D. Ravitz, M. Romig, P.J. Pronovost and A. Sapirstein, 2013. Enhancing the quality of care in the intensive care unit: a systems engineering approach. Crit. Care Clin., 29: 113-124.

Utne, I.B., 2009. Improving the environmental performance of the fishing fleet by use of Quality Function Deployment (QFD). Journal of Cleaner Production, 17: 724-731.

Varkey, P., S.P. Karlapudi, K.E. Bennet, 2008. Teaching quality improvement: a collaboration project between medicine and engineering. American Journal of Medical Quality, 23(4).

Waks, S. and M. Frank, 2000. Engineering curriculum versus industry needs—a case study. IEEE Transactions on education, 43(3).

Yuniarto, H.A. and H. Osada, 2009. Developing a Novel Framework for Quality System and Systems Thinking to Integrate: A Paradigm Shift in Maintenance, 1: 1-3.