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Quality Management in the 21st Century Enterprises

Quality Management in the 21st Century Enterprises: Research pathway towards Industry 4.0

Professor Angappa Gunasekaran (*Managing Editor*)
School of Business and Public Administration
California State University Bakersfield
9001 Stockdale Highway
Bakersfield, CA 93311-1022
USA

Tel: +1 (661) 654-2184
Email: agunasekaran@csub.edu

Professor Nachiappan Subramanian
School of Business Management and Economics
University of Sussex
Jubilee Building 303, Falmer
Brighton BN1 9SL
UNITED KINGDOM

Tel: +44 1273872982
Email: N.Subramanian@sussex.ac.uk

Professor Eric Ngai
Department of Management and Marketing
The Hong Kong Polytechnic University
Hong Kong
CHINA

Tel: +852 2766 7296
Email: mawtngai@polyu.edu.hk

Abstract

Quality management is an evergreen research theme in the contemporary world. Given the dominance of technological and turbulent environment with unprecedented customer expectations, the aim of this special issue to explore the developments in quality management in the era of Industry 4.0. In particular, our focus is to unravel the advancements in quality and their implications in terms of economics, decision models, business models, human and technological perspectives. This call for papers for the special issue of IJPE ended up in attracting ten high quality studies covering the above perspectives. In addition, the special issue recommends potential unattended future research pathways such as importance of human issues in quality

management as per industry revolution and the alignment between technological revolution over time and involvement of human aspects in quality management.

Keywords: Quality management; industry 4.0; technology; quality culture; behavioural aspects

1. Introduction

Although quality management became popular in the 80's and 90's, 21st century enterprises in the era of Industry 4.0 are still struggling with the concept. Recent product recalls by General Motors and Toyota are notable examples of serious quality management issues that have led to substantial profit losses because of the increase in the costs of poor quality. Service enterprises have multiple quality challenges in offering affordable care and innovation through service design and delivery processes. These perennial quality challenges raise the questions of where we are in the quality journey and how far traditional quality management practices and methods have absorbed changes in product development stages, cycle time compression, and employee effort to match demand and customer expectations in the era of Industry 4.0.

A recent study (Srinivasan and Kurey, 2014) confirms that an excellent quality environment can be created through a true culture where every employee should have a passion to imbue rather than simply follow mundane rule-based techniques, such as quality control tools or imitation of best procedures and practices. Creating passion through leadership emphasis, message credibility, peer involvement, employee ownership, and autonomy may substantially reduce the cost of poor quality and the total cost of quality initiatives (Srinivasan and Kurey, 2014). The cost of poor quality is estimated to range from 5% to 30% of gross sales for manufacturing and service companies (Metricstream report, 2014). The good news is that companies with a highly developed culture of quality spend on average \$350 million less than companies with poorly developed quality cultures (Srinivasan and Kurey, 2014).

Clearly, due focus is essential in capturing the human aspects of quality dimensions in meeting customer expectations, peer-driven target setting, grass roots autonomy, employee empowerment, good credibility, and accountability in addition to rule-based techniques in the economic performance of Industry 4.0. The purpose of this issue is to unpack the challenges in blending the soft aspects (human aspects) of quality and the evolutionary strategies, tactics and methods to create quality culture. The target is to identify the soft and hard control limits of quality to deal with problems, such as

inflexibility, high levels of customization, lengthy supply chains, and monitoring of suppliers. The focus is on exploring innovative business applications of quality. Economics, business, and decision-making play an important role rather than statistical quality control techniques.

The call for papers has attracted forty-eight high quality papers and the total number of submissions is one among the highest numbers for a special issue that we have handled so far as the guest editors till now. Out of forty-eight papers, ten papers have been accepted after several rounds of rigorous reviews. Almost 120 reviewers have been engaged to review the papers that were screened by the handling IJPE editor and the assigned guest editor. All the ten papers are of highly quality and cover different facets of call for topics listed. Our sincere appreciation goes to the reviewers who served as a quality developer and travelled along with the authors to bring out the meaningful contributions from their studies. In addition, we are so thankful to the IJPE area editors for their suggestions and guidance in developing this special issue in particular our sincere appreciation goes to Professors Peter Kelle and Bart McCarthy who were instrumental in bringing out this special issue proposal.

We are confident that this special issue will serve as a forum for the exchange of new research results in quality management, while focusing on creating the right climate, cultures, and strategies for quality improvement in the era of Industry 4.0. Certainly this special issue shares different perspectives on how to build a novel quality culture that pays due attention to strategies, tactics and methods or techniques that include, human dimensions to improve firm's economic performance.

We aim to explore a few potential research topics on quality management in the era of Industry 4.0 as given below:

- Economic aspects in quality in the era of Industry 4.0
 - The basic role that quality plays in the economic performance of companies
 - New performance measures and metrics for peer-driven target settings and customer expectations
 - Sophistication in quality standards, practices and methods to gain sustainable competitive advantage

- Decision models in quality in the era of Industry 4.0
 - Decision models related to contemporary quality management
 - Costs of poor quality decision models with customer expectations and credibility
- Business models in quality in the era of Industry 4.0
 - Contemporary lean techniques and economical influences in manufacturing and services
 - Outsourcing/offshoring quality challenges in logistics and supply chain operations in the era of Industry 4.0
 - Continuous improvement strategies and models that results in minimal viable change and pivoting
 - Emerging philosophies and business tactics that looks beyond total quality management and six sigma
 - Role of product innovation, design (R&D) and gross root autonomy in quality management
- Human aspects in quality in the era of Industry 4.o
 - Capturing message credibility and supplier involvement aspects in qualify function deployment
 - Leadership emphasis and process flexibility in achieving economical sustainability
 - Business models and tactics for peer involvement of employees within enterprises
 - Business models that studies quality management influence in a multi-cultural environment
- Technological aspects in quality in the era of Industry 4.0
 - Role of technology, automation and IT/IS in quality management and its relationship with employee empowerment

2. Summary of studies in the special issue

We categorised the final accepted papers as per the above classification, interestingly we did not find any study that addresses the role of technology and its impact on quality management in the era of Industry 4.0. Most of the studies are within business models in quality in the era of Industry 4.0. Overall papers accepted for this special issue included innovative developments, interesting concepts, and research opportunities in quality management in the era of Industry 4.0. In terms of methodologies, the paper included empirical studies that extended from mathematical models to simulation, and conceptual models with suitable case studies or large-scale survey.

2.1 Economic aspects in quality in the era of Industry 4.0

One study discussed the development of economic framework to reduce food loss and cost. The study justified the usage of new integrated procedure and purpose, specifically it focuses on the role of quality in the economic performance of the company.

Xiao et al. developed an economical framework to reduce product deterioration and sampling cost through a joint process product monitoring procedure. The two step joint monitoring procedure combines product and process information to achieve the required quality control. The authors explained the monitoring process variables and product quality to develop an economic model for the two step joint monitoring procedure. Later, the authors compared the joint monitoring procedure with product and process control charts. Interestingly the authors state the scenarios when to use the proposed two step joint monitoring procedure.

2.2 Decision models in quality in the era of Industry 4.0

Three studies out of ten accepted in the special issue developed decision models to deal with quality issues ranging from trade-offs in number of inspections, risk prioritization in a quality procedure and performance measurement of service outsourcing. The first study's focus is on a two different versions of inventory policies in terms of trade-off in carrying out inspection policies, the second study prioritizes risk in a real time handling of failure mode effect analysis (FMEA) and the third study proposed a hybrid network data envelopment analysis model to measure the performance of service outsourcing.

Tai et al. studied inventory control for perishable items including mixed sales items with different inventory policies. The study evaluated the role of inspection policies at different point of time and the trade-Off between one inspection per cycle and effective continuous inspection throughout the cycle. In addition, authors considered the maximum lifetime of each product by modelling it as a random component. The authors considered quantity and time based replenishment policies with different versions such as no inspection, one inspection and continuous inspection. The findings states that one inspection at fixed point of time guarantees both improvement in quality and reduction of inspection costs.

Liu et al. proposed an integrated risk prioritization approach including interval-valued intuitionistic fuzzy sets (IVIFSs) and the multi-attributive border approximation area comparison (MABAC) method to improve the conventional Failure Mode Effect Analysis performance. The authors attempted to address the conventional challenges in using FMEA in terms of quantifying assessment using a crisp or exact risk numbers between 1 to 1000 that are multi-dimensional in nature. The proposed model comprises of three stages including failure mode evaluation, risk factor weighting and failure mode ranking. In particular, the author demonstrated the validated of the approach using radiotherapy department within healthcare as an example.

Pournader et al. proposed a hybrid network data envelopment analysis (nDEA) model to assess the outsourcer's processes in a supply chain that comprises of several internal and external entities. In particular, the study investigates comparative quality assessment in outsourcing service activities based on organisational performance and contributes to performance measurement of outsourcing in service supply chains. The banking supply chain is used to illustrate the application of the proposed hybrid approach involving subdivisions as internal entities and collaboration of investment bank with commercial bank as an external entity. The study suggest the possibility of having positive or negative impact on bank's efficiency when outsourcing certain activities with external entities.

2.3 Business models in quality in the era of Industry 4.0

Almost fifty percent of studies accepted in this special issue discussed one way or other the business model perspectives. A few key issues discussed in the studies are determining innovation pathway, aligning quality management in small and medium enterprises as per agile external environment, development of service system quality

model, integration of quality within firm and supply chain and understanding the relationship between supply chain quality integration and quality related performance.

Subramanian et al. studied the complexity involved in quality innovation process in coordinating the internal and external resources to achieve the innovations. In particular, the authors analysed two innovation pathways such as “out-in referred as identification of quality innovative suppliers” and “in-out referred as quality knowledge transfer ability ” that could benefit both buyers and supplier in the new product development process. The authors used dyadic data to find the common and contrasting factors in the innovation process. The study identified supplier’s innovation ability and passion as the common factor for new product development irrespective of innovation pathways. In addition, cooperative attitude and cost reduction ability of suppliers are the differentiating factors among the two innovation pathways.

McAdam et al. explored the contingency theory perspective in quality management. In particular, the study focuses on alignment of quality management of small and medium enterprises (SME) in agile environment. The research questions addressed by this study stretches from macro to micro level, including understanding the relationship and level of alignment between the contingency variables and the development and implementation of quality management practices in service based SMEs. In addition, the study develops propositions by investigating the relationship between alignments of quality management practices for each of the contingency variable. The study developed a conceptual framework to illustrate the contribution of contingency theory investigated. The study mapped contingency variables of strategy, culture, life-cycle and customer focus with micro processes such as legitimising, critical debate, experimentation, development and redundancy with respect to market relevance and current & projected market knowledge.

Akter et al. advances theory and practice in service systems quality research by developing a services quality model using service dominant logic and sociomaterialism. The model identifies three dimensions and nine sub-dimensions of a service quality with a focus on individual, organisation and social outcomes using Bangladesh’s transformative mhealth service system as a context. Three major dimensions of service system quality includes systems quality, interaction quality and information quality. In addition, sub dimensions for system quality are system reliability, system efficiency, system flexibility and system privacy. Similarly, sub

dimensions of interaction quality are responsiveness, assurance and empathy. The final major dimension information quality consists of two sub dimensions such as utilitarian and hedonic. The study states the mediating effect of service system satisfaction and service system value between service system quality and the outcome such as quality of life and continuance intentions.

Zhang et al. investigated the effect of mass customisation and product modularity on supply chain quality integration and competitive performance. In particular, the study is interested to understand the quality of integration within firm, suppliers and customers. Specifically, the study contributes to operations management including mass customisation, product modularity, and supply chain quality management literature. Typically the study from the evidence of global high performance manufacturers concluded the role quality of internal integration have direct and indirect influence on competitive performance and with the suppliers and customers. Especially this study could be useful to deal with the closed loop supply chain with product recalls and to extend in the context of process and product modularisation in the future.

Huo et al. studied the relationship between supply chain quality integration and quality related performance. In particular, using resource-based view as a theoretical lens and contingency theory approach the authors identified different supply chain quality integration patterns such as high uniform, low uniform, medium customer forward, medium customer backward and medium supplier backward patterns. In addition, the authors investigated how different patterns influence product quality related performance, supplier quality integration improvement and customer quality integration improvement performance.

2.4 Human aspects in quality in the era of Industry 4.0

Interestingly, one out of ten studies accepted in this special issue dealt with the human issue such as individual's readiness to change to successfully implement total quality management program.

Haffar et al. gathered the empirical evidence that studies the influence of individual readiness to change (IRFC) on effective total quality management (TQM) programme implementation. The study found out two significant supportive dimensions such as personal benefits and change self-efficacy of the team for successful TQM implementation. In addition, employee affective commitment to change positively mediates the relationship between IRFC and TQM implementation. The authors made

advancements in quality management literature by studying the readiness of individual's or employees' acceptance towards change in successful implementation of quality management programme especially to the social cognitive theory. The study depicts the importance of micro level process at Individual level that leads to successful TQM implementation.

Overall, we did not find any study on technological aspects and its relationship with quality management in the era of Industry 4.0. This symptom raises a debate about academic thinking on futuristic technologies that unveils the future road map to investigate the potential quality challenges in implementing emerging technologies such as the Internet of Things, Blockchain, big data, business analytics, smart supply chain and interaction of human with cyber physical systems.

3.0 Potential research pathway

Initial thought of our special issue call was to attract substantial amount of studies addressing development of quality culture including human involvement aspects in quality over time from 1980 until now. In terms of 21st century enterprises or in the era of Industry 4.0 our aim to find the critical quality issues and is there any alignment between the two. Typically quality issues gathered prominence in the era of industry 3.0 that is evolution of Internet and use of automation technologies in manufacturing. However, until now the research on involvement of human in quality challenges is not progressing as per the pace of technology development. A potential research gap exist that needs to be addressed in the near future. Interestingly in academic research, we did not find the match between involvement of human aspects in quality over time and the technology revolution aspects in quality over time as shown in figure 1.

Figure 1 maps the human involvement in quality and technology revolution in quality over time and classifies the mapping as micro and macro. Deeper engagement in terms of individual involvement and newer technology is referred as micro level engagement. For example, micro level engagements are referred as the involvement of human to deal with radical issues such as security, risks, compliance management, alignment of quality management systems of new technologies such as Blockchain, the Internet of Things, Big data, smart supply chain and cyber physical systems. Similarly, macro level engagement is more about continuous improvement issues addressed by both human aspect and technology revolution.

Human aspects in quality over time	High	Micro human and macro technology and	Micro level engagement
	Low	Macro level engagement	Macro technology and micro human involvement
		Low	High
Technology revolution aspects in quality over time			

Figure 1: Alignment between human aspects and technology revolution in quality management.

3.1 Macro level engagement

This section classifies some of the topics listed in the call for papers as shown below

- The economic aspects includes the basic role that quality plays in the economic performance of companies.
- Decision models aspects includes the costs of poor quality decision models with customer expectations and credibility.
- Business models aspects the continuous improvement strategies and models that result in minimal viable change and pivoting.

This special issue finds still there is a potential topic to study in the context of decision models that captures the costs of poor quality decision models with customer expectations and credibility. However, a few papers covered the other two topics.

3.2 Micro human macro technology

Potential topics from the call for this special issue is classified as per figure 1 is given below.

- Human aspects includes i) leadership emphasis and process flexibility in achieving economical sustainability and ii) business model and tactics for peer involvement of employees within enterprises and capturing message. credibility and supplier involvement aspects in qualify function deployment
- Decision model aspects include decision models related to contemporary quality management.
- Business model aspects include: i) contemporary lean techniques and economical influences in manufacturing and services and ii) emerging philosophies and business tactics that look beyond total quality management and six sigma.

Interestingly within micro human and macro technology classification category, the special issue call did not find any study related to business model and tactics for peer involvement of employees within enterprises and capturing messages. Similarly, there is a paucity of studies in developing decision models to contemporary quality management. On the other hand, it is hard to find developments in contemporary lean techniques and human based tools and techniques beyond total quality management and six sigma.

3.3 Macro technology micro human

In this section, we classify the special issue call for topics as per figure 1, which includes two major categories such as economic aspects and business model aspects.

- Economic aspects include: i) new performance measures and metrics for peer-driven target settings and customer expectations and ii) sophistication in quality standards, practices and methods to gain sustainable competitive advantage.
- Business model aspects include: i) outsourcing/offshoring quality challenges in logistics and supply chain operations in the era of Industry 4.0 and ii) role of product innovation, design (R&D) and gross root autonomy in quality management.

We find that technology revolution is not exactly reflected in the academic studies corresponding to quality management. In particular as per economic aspects in quality management, we did not see new performance metrics for peer-target setting and customer expectations and sophistication in quality standards and methods to gain sustainable competitive advantage. In terms of business model, our special issues have a couple of studies in outsourcing quality challenges and product innovation, but it does not cover industry 4.0 and gross root autonomy.

3.4 Micro level engagement

This category is considered as the top most level that includes individual level commitment for both technology revolution and human involvement in addressing quality challenges. Under this category, we had one topic that is

- Technological aspect: Role of technology, automation and IT/IS in quality management and its relationship with employee empowerment

4.0 Future research questions

Typically, the special issue uncovers many unanswered research pathways as per the four classification described in the previous section:

1. What changes need to be done in quality management to commit micro level human involvement with respect to emerging new technologies such as Blockchain, The Internet of Things, Big data, Business analytics, cyber physical systems and smart supply chains?
2. What are the new quality related performance measures and metrics for the futuristic supply chains?
3. Development of sophisticated methods to capture new emerging quality challenges such in terms of quality risk, security, trust and compliance
4. How to deal with service outsourcing in the era of Industry 4.0?
5. How to encourage radical quality innovation by including gross root autonomy in quality management?
6. Development of contemporary lean management and techniques as per the present industrial revolution.
7. What would be the emerging philosophy other than six sigma and total quality management?
8. How to create leadership emphasis and process agility to achieve economic sustainability in the era of Industry 4.0?
9. How to engage employees to meet quality standards in the era of Industry 4.0?
10. How to make quality trade-offs with the support of sophisticated methods in the futuristic supply chains?
11. How to scale the cost of poor quality decision models with customer expectations and credibility to suit the futuristic supply chains?

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