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Review of Risks Associated with Six Sigma Deployment in South Africa: A Laboratory Perspective

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Abstract

The focus of this scoping review paper was to highlight the risks and opportunities associated with the implementation of the Six Sigma methodology (SSM) in the laboratory industry in South Africa (SA), and thereby theoretically establish guidelines for successful implementation. In this review, a total of 43 studies obtained from the two databases, namely Emerald and Google scholar, dated from 2008 to 2021 were used to systematically answer three research questions. The findings showed that organizational leadership commitment or involvement and support is the main key to unlock factors that negatively affect the successful implementation of the SSM.

Keywords

Risk Management, Lean Six Sigma, Laboratory.

1. Introduction

Six Sigma (SS) has been successfully implemented in both small and large organisations in South Africa (SA) for more than 25 years to improve process efficiencies (Bhat et al. 2014). A study by Chan et al. (2012) indicates that successful SS implementation depends on the following factors: management commitment and involvement, cultural change, organizational infrastructure, project management skills, project prioritisation and selection reviews and tracking, understanding of Six Sigma Methodology (SSM), use of appropriate SS tools and techniques, linking SS to business strategy, human resources and suppliers. The successful implementation of SS ensures sustainability, profitability and better competitiveness in many organizations in developed and underdeveloped countries (Nguenang 2010).

Thus predictably, there has been an uptake in the usage of the SS in the laboratories (Deshmukh et al. 2016) in all sectors of industry around the world. Many critical decisions are taken in laboratories based on laboratory results; hence Chan et al. (2012) and Deshmukh et al. (2016) suggested that the adoption of SS is pivotal to ensure the viability of operations by striving for increased reliability and accuracy. Against this backdrop, the primary objective of an analytical laboratory is to provide analytical data about the quality of a process or product or newly developed product. Notably, Deshmukh (2016) argues that there has been a significant increase in the number of testing laboratories in many industrialized nations and consequently increased demand for testing and certification of the diverse products over the few decades. Within this laboratory context, Nguenang (2010) and Deshmukh et al (2016) claim SS adds value by improving efficiency by eliminating errors or process deviations.

Research by Nguenang (2010), suggests that it is possible to identify and examine general risks and opportunities that commonly arise during SS implementation and then apply the principles to a specific industry such as the South African laboratory industry. Thus the findings of this scoping review is believed to have the potential to assist the South African laboratory industry to improve their processes, and thus ultimately improve the level of the South African laboratory competitiveness on a global scale (Nguenang 2010).

1.1 Background to Six Sigma

Six Sigma was initially developed by Bill Smith of Motorola in 1986 and is orientated towards eradicating defects in the manufacturing sector (Deshmukh et al 2016). In contemporary times, SS is regarded as a versatile methodology and is currently applied in different sectors worldwide to improve the quality of the process outputs (Bhat et al. 2014). It has also been referred to as a strategy for continuous improvement which involves using a structured approach philosophy that employs five sequential stages. These stages are Define-Measure-Analyse-Design-Validate (DMADV) for new projects, or the Define-Measure-Analyse-Improve-Control (DMAIC) for existing business processes that need improvement (Sesane 2019). Sesane (2019) adds the DMAIC framework provides a systematic approach to find permanent solutions to well-structured or semi-structured problems. Therefore, the adoption of the DMAIC framework helps the organization in developing its operations to a world-class or operational excellence level (Prashar 2020).

Each phase in the DMAIC improvement cycle employs of a set of tools or techniques used for analysing data (Anthony et al. 2012). Sesane (2019) advances that these tools include both statistical and non-statistical data interpretation tools to make appropriate decisions and draw

adequate conclusions about the performance of a particular process. It is argued that SS is the ideal methodology (Deshmukh et al. 2016) that can be adopted in the laboratory to improve imprecision during the analysis. The methodology helps to improve both accuracy and efficiency in the laboratory. Furthermore, Kalra and Kopargaonker (2016) assert that the application of the SSM is necessary for the laboratory industry to minimize variation and quality control process to improve compliance with the specifications. Moreover, Alcaide-Muvioz and Gutiervez-Guttierred (2017) described SSM as the perfect approach to drive the vision of delivering error-free and timely service in the laboratory.

2. Methodology

Against the backdrop presented above, the research objective, three associated research questions, followed by search strategy, eligibility criteria pertaining to data extraction and analysis will be discussed next.

2.1 Research Objective

To investigate the footprint and impact of the Six Sigma Methodology (SSM) within the laboratory industry in South Africa, including the factors that influence its successful implementation as well as the potential risks and opportunities associated with adopting SSM in this sector.

2.2 Research Questions

The three research questions are:

1. While it is acknowledged that the SSM has been broadly implemented across the different sectors worldwide to improve the excellence of their quality services or products or process, *what is the footprint of the SSM in the South Africa laboratory industry?*
2. *What are the factors that could a positive effect on the successful deployment or implementation of SSM within the South African laboratory industry?*
3. *What are the risks and opportunities of implementing SSM within the laboratory industry in SA?*

The questions of this review paper were constructed to explore the risks and barriers to implementing SSM, opportunities or benefits of successful application of SSM and the footprint of SSM application.

2.3 Research Inclusions and Exclusions

Two databases, namely Google Scholar and Emerald Engineering were used when selecting the peer-reviewed published studies using the advance all content. The selection of the databases was determined the availability of databases to the researcher, who performed this review study in the Faculty of Engineering and the Built Environment at a University of Technology (UoT) in the Western Cape in South Africa. Only four designated engineering databases were available to the researcher via the engineering library at the UoT. These were Emerald Engineering, SpringerLink Engineering Books, De Gruyter eBooks collection and Jove Science Education: Electrical Engineering. Two databases were excluded because they only contained collections of e-books and the other database dedicated to electrical engineering, thus unrelated to the subject of this study. Since only one database remained, it was deemed appropriate to also use an additional scholarly database, which was also freely available to the researcher, to ensure sufficient breadth of this review study. Google Scholar was selected as the additional database.

Both empirical and theoretical peer-reviewed studies dated between 2008 to 2021 were reviewed and the relevant studies (43-studies), were chosen and used during the conduct of this study. Advanced database search was performed on all content using the following search strings: **"***Application of Six Sigma in South African laboratories*", "*Six Sigma and laboratories in South Africa*", "*Challenges of Six Sigma implementation in SA*" and "*Application of Six Sigma in laboratories*".

The research originally only focused on the studies conducted in South Africa however due to insufficient data, Australia, Chile, France, Gujarat, India, Namibia, Portugal, Singapore, UK and USA were included based on the relevance of the studies in providing answers to the research questions, as illustrated in Table 1 below.

The sectors that were selected in this study included the sectors that conducted and published research on Six Sigma namely, manufacturing, services, education and for benchmarking purposes from other sectors such as Laboratory, Medical services from the other countries were also included. The other sectors such as design and others were excluded because they were irrelevant to this research.

A total number of 43 studies were identified as potential literature sources which could provide answers to the research questions of this study. Notably, although this study aims to explore factors that influence SS implementation in SA, the papers that were reviewed during this study were not limited to research only performed in South Africa. The studies that were reviewed to provide answers to the research questions are presented in Table 1 below.

Table 1: Information used to collect data

Publication year	Industry(s)	Country(s)	Research question(s) answered
2008	Manufacturing	SA	Q1 & Q2
2010	Enterprises Service	SA	Q1, Q2 & Q3
2011	Manufacturing	SA	Q2
2012	Mining	SA	Q1 & Q2
2012	Multiple	India	Q1, Q2 & Q3
2012	Services	Australia & Singapore	Q2
2012	Multiple	UK	Q3
2013	Laboratory	UK	Q3
2013	Service	Singapore	Q3
2013	Clinical Laboratory	Gujarat	Q2
2014	Manufacturing	India	Q1 & Q2
2014	Manufacturing	Norway	Q2
2014	Service	Brazil	Q2
2014	Medical Hospital	India	Q3
2014	Manufacturing	India	Q3
2015	Manufacturing	USA	Q3
2016	Service	UK	Q1, Q2 & Q3
2016	Manufacturing	SA	Q2
2017	Manufacturing	Portugal	Q2
2017	Manufacturing	SA	Q2 & Q3
2018	Manufacturing	SA	Q1, Q2 & Q3
2018	multiple	USA	Q2
2018	Medical Laboratory	Namibia	Q2
2019	Manufacturing	SA	Q1 & Q2
2019	Manufacturing	Chile and France	Q2
2020	Manufacturing	India	Q2
2020	Education	SA	Q2
2020	Manufacturing	India	Q2 & Q3

3. Results, Discussion and Interpretation of Findings

3.1 Research question number one: What is the utilization footprint of Six Sigma within the South African laboratory industry (n=8)

A finding of an explorative study performed by Dondofema (2018) indicates that the South African manufacturing industry initiated the utilization of SS aided at improving the competitiveness of its business by benchmarking from the other branches that have successfully implemented SS globally.

According to Nvuenang (2010), there was an expansion in the utilization of SSM in SA in 2010. The author reported on eighteen specific industries in SA that embarked on the journey of adopting SS to improve their processes or services namely, aerospace, consultation, finance, petroleum, automotive, education, food services, utilities, transportation, chemical, electronics government, computer or software, consumer goods, hospitality and telecommunication. The increased application of SSM in SA generates more South African perspectives resulting in the advancement of knowledge in SA. Moreover, knowledge that is shared, triggers the development of strategies on how to overcome bottlenecks to achieve successful deployment of SSM. As the SSM was successfully implemented in most industries in the past decade, such as mining and mineral, food and beverages processing sector as well as within the education sector in SA. Madanhire et al. (2019) deduced that this is also possible in the laboratory industry. Research by indicates that in 2019 the implementation of SSM increased into the chemical industry, ABSA, Transnet, Barloworld, Sasol Mining, Discovery Health, and Indwe Risk Services which resulted in enhanced competitiveness of the organisation worldwide (Kumara and Singa 2014), (Psychogios and Tsironis 2016).

The literature that was reviewed showcased that there has been a slow increase in the implementation footprint of SSM in other industries in SA from 2008 until 2020, as a total of 9 empirical studies were published each year namely, 2008, 2010, 2011, 2012, 2016, 2017, 2018, 2019 and 2020, respectively applicable to this research study. However, the increase in the footprint is excluding the South African laboratory industry, as illustrated in Figure 1 below; which is constructed using the data tabulated in Table 1 above. This implies that there is still much room for the South African laboratory sector to start adopting SSM and continually improve their processes and service competitiveness Research (Naiker 2008) indicates that on a global scale, the uptake of SSM in laboratories has been slow. The successful implementation of the SSM within the laboratory industry can be accomplished by benchmarking from the organizations in other industries that have successfully implemented this methodology in SA (Antony et al. 2012).

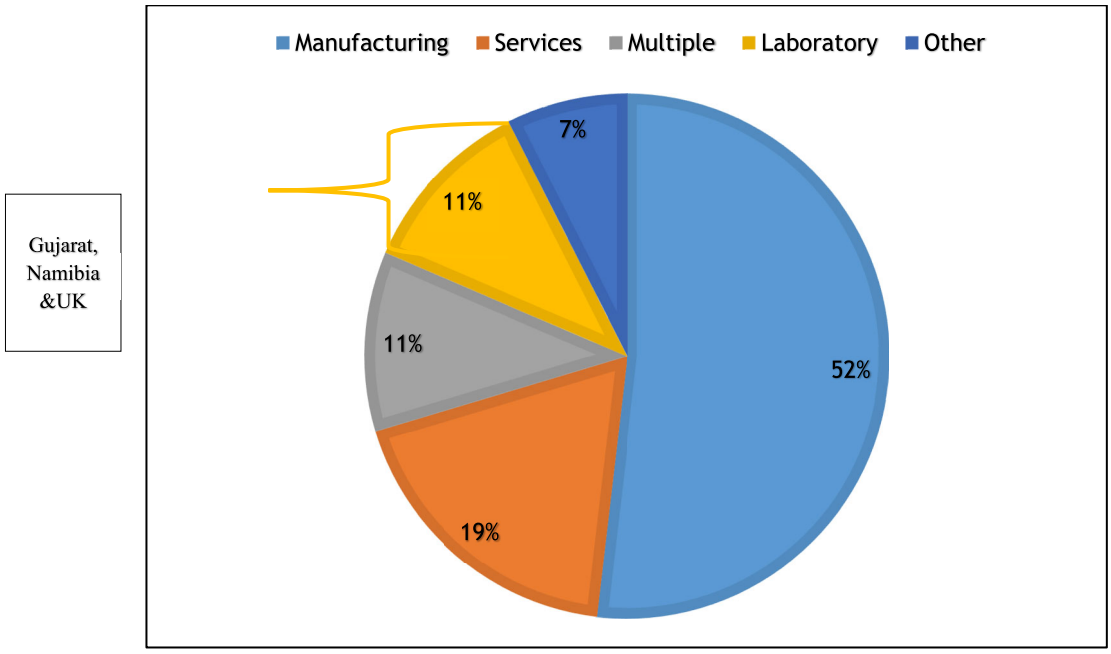

Figure 1: Six Sigma Application in South African Laboratory Industry

3.2 Research question number two: Factors affecting effective implementation of SSM in SA laboratory industry (n = 22)

3.2.1 Leadership or Top management commitment and involvement

The sustainability of SSM implementation in SA is negatively impacted by the lack of resources; such as black belt specialists (skills) to facilitate the effective process of the implementation of SS (Dondofema 2018). Sufficient resources to ensure successful implementation of SSM is assured by the committed and involved leadership/top management to drive/lead the process of the implementation of SSM through the organization (Chan et al 2012), (Nguenang 2010), (Antony et al. 2012), (Chakraborty and Tan 2012), (De Carvalho and Miguel 2014), (Marques and Matthe 2017), (Chakraborty et al. 2018), (Cebekhulu et al. 2017). The support of the top management is essential to plan and provide with all the necessary resources; including support to build the solid foundation of SSM as an organizational culture (Aaboen and Assarlind 2014).

The top management involvement is one of the most important keys for ensuring the successful implementation of SSM (Naiker 2008). By creating awareness among employees through the leadership that is capable of selling and getting the buy-in within the organization and encouraging a learning environment for the employees to thoroughly comprehend the significance of the correct application of SSM (Naiker 2008).

Active and supportive leadership creates a good environment that motivates employees to actively participate in Six Sigma projects (Chakraborty et al. 2018). This results in SSM that is embedded within the organisational culture and instead of being used as a secondary or end support project which will result in strategic failure and financial prejudice (Psychogios and Tsironis 2016). The leadership is actively involved by planning and providing adequate training and therefore educating the employees and developing new skills that are essential for the successful SSM implementation and sustainability, this empirical study was conducted in 72 medical Namibian laboratories (Chakraborty et al. 2018).

3.2.2 Importance of awareness, education and training to ensure successful deployment of Six Sigma Methodology

Provision of education eliminates the misunderstanding and incorrect application of the SSM tools and techniques (Nguenang 2010), (Moonsamy 2011), (Baker and Witt 2018), thus results in successful SS projects and process improvements. This is accomplished through educating, training and guiding employees by creating a common language within the organization to ensure (Kumara and Singa 2014), (Mai 2020). The change in the management is required to facilitate continuous learning with an organization while changing the organizational culture to build sustain foundation (Madanhire et al. 2019). South Africa is still a developing country; thorough education of SS is essential for low employee skills that come from disadvantaged backgrounds that impact negatively on employee`s morale (Mbohwa and Seseni 2016).

Education and training promote more understanding of SSM and training by involving employees in SS projects develop SSM implementation and sustainability skills within the organization (Moonsamy 2011), (Cebekhulu et al. 2017). Educating and training provision aligns SSM with organizational culture and promote effective communication throughout the organization (Prashar 2020). Effective SS leadership and communication, education and training eliminate the lack of organizational culture change and misunderstanding of SSM (Chaudhary et al. 2013).

Six Sigma education, training and skill development are achieved through structured training provided by the SS consultant or master black belt experts to ensure success when implementing the SSM in the organization (Singh et al. 2020). Experience SS consultants will iron out poor buy-in during the introduction that is caused by inexperienced SS couches and thus generates multiple misunderstanding of the SSM principles and ineffective SS results (Mai 2020).

The summary of the findings from the (Nguenang 2010), (Prashar 2020), (Chaudhary et al. 2013), (Bai et al. 2021), (Psychogios and Tsironis 2016), (Antony et al. 2012), (Baker and Witt 2018), (De Carvalho and Miguel 2014), (Marques and Matthe 2017), (Chakraborty et al. 2018), (Cebekhulu et al. 2017), (Aaboen and Assarlind 2014), (Mai 2020), (Mbohwa and Seseni 2016), (Camargo et al. 2019) reviewed studies indicated the factors that affect the effectiveness and sustainability of SS in **Figure 2** below shows that the leadership commitment and support is a vital major factor that could positively or negatively affect the deployment of SSM (Naiker 2008). Partial of unevolved leadership is not involved or committed will result in the unsuccessful implementation of SSM; on contrary, if the opposite is applied, successful implementation of the SSM could be achieved. This factor "leadership commitment and support" is vital because it is also interconnected to all the factors that can have either a positive or negative impact depending on how they are addressed and applied. Therefore, from the reviewed literature in this study, it can be deduced that the Top management factor needs to be addressed properly to ensure the successful implementation of the SSM.

Figure 2. Factors that affect effective implementation of the SSM

3.3 Research question number three: Opportunities and risks of adopting SSM within the SA laboratory industry (n = 13)

3.3.1 Opportunities or benefits of successfully adopting Six Sigma Methodology

Six Sigma methodology helps to improve the correctness of the processes and their productivity within the service industry and manufacturing industry (Antony et al. 2012), (Singh et al. 2020). Successful implementation of SS enhances the performance, improve employee morale, reduces turnaround time and cost, yield to better efficiency and improved customer satisfaction (Psychogios and Tsironis 2016), (Cebekhulu et al. 2017), (Singh et al. 2020).

The SSM can be used to improve processes by removing process errors and reducing or eliminating process variability (Chasseur et al. 2013). Proper SSM execution results in improved operational excellence within organizational processes and consequently improve its competitiveness worldwide (Dondofema 2018), (Psychogios and Tsironis 2016). Six Sigma employs a flexible and systematic methodological approach to improve the quality characteristics of a product using an experimental designs process Bhat et al. (2014).

Notable, the entire world is moving towards the fully automated technology "Industry 4.0"; which helps to unveil the hidden patterns of the market trends, customer preferences, insight of the process which act as a supplementary to SS to create a suitable competitiveness advantage across its competitors globally, reduce excessive variation, create robust products and to improve processes and services (Anthony and Sony 2020).

3.3.2 Risks or barriers that hinders the successful implementation of the Six Sigma Methodology

Cebekhulu et al (2017) assert that lack of leadership involvement is a core risk that diverges into other risks, such as the resistance of the employees and lack of perseverance caused by poor SS leadership This is aligned with the view of Jadhav et al. (2014) who also states that the lack of support from the leadership directly results in financial constraints to implement the SSM fully throughout the organization, due to the lack of finances allocated to initiate and sustain the implementation (Cebekhulu et al. 2017). The allocation of finances includes awareness and training to integrate SS within the organizational culture (Psychogios and Tsironis 2016), moreover, the invisible and weak leadership causes resistance in driving a successful SS culture change within an organization. employee resistance towards the change is due to a lack of conceptual knowledge on the methodology and absence of SS culture (Cebekhulu et al. 2017).

The lack of finances and poor planning can also lead to partial implementation of SSM in the selected areas or departments within an organization; which creates non-uniformity and risks for SS failure; which is caused by other neglected processes (Nguenang 2010). The partial SS application creates other issues besides the non-uniformity, namely inadequate training that causes poor projects improvement parameters, incorrect project scopes and incomplete projects. On the other hand, both Chakraborty and Chuan (2013) and Cada and Johnson (2015) point out that financial constraints will result in not fully trained or experienced consultants in facilitating the SS projects. Therefore, Cada and Johnson (2015) recommend making use of low skilled consultants such as white, yellow or green with a lack of project management skills avoiding the expensive labour of the experts will fail SS implementation.

Importantly, Antony and Laurean (2012) advance that incorrect understanding and utilization of the personnel with SS belts (white, yellow, green, black and master black); where their roles, profile, training and proper application of the tools are not correctly defined, can lead to the failure of SS in organisations. The utilization of low skilled consultant or personnel causes the inability of linking SS to the business strategy, correctly prioritize projects and correctly use tools and techniques within the SS project (Antony et al. 2012).

4. Conclusion

The intention of this scoping review was to explore the feasibility of SS deployment in laboratories in South Africa. The primary finding of this research was that organizational leadership commitment or involvement and support is the main key to unlock factors that negatively affect the successful implementation of the SSM. The studies reviewed indicates that successful implementation of SS enhances the performance, improve employee morale, reduces turnaround time and cost, yield to better efficiency and improved customer satisfaction, however lack of leadership involvement is a core risk that diverges into other risks. Based on this research, we suggest that the successful implementation of the SSM within the laboratory industry can be accomplished by benchmarking from the organizations in other industries that have successfully implemented this methodology in SA. Ultimately the application of SSM in the South African laboratory industry will improve laboratories efficiency and elevates the competitiveness of the South African laboratories on a global scale.

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