# An empirical study into the limitations and emerging trends of Six Sigma in manufacturing and service organisations

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## Abstract

**Purpose:** The purpose of this paper is to carry out an empirical study of the limitations and emerging trends of Six Sigma in manufacturing and service companies.

**Methodology:** The authors developed an online survey instrument based on the existing literature addressing the current limitations and emerging trends of Six Sigma in manufacturing and service companies. In this study, 75 Six Sigma Master Black Belts, 39 Black Belts and 12 Green Belts from large manufacturing and service companies participated; each of whom is familiar with the Six Sigma topics.

**Findings:** This study reports the top five limitations and emerging trends of Six Sigma from the viewpoints of subject matter experts from large manufacturing and service companies from over 20 countries. The main finding is that the top four limitations were identical for both manufacturing and service companies. These limitations include: *the integration of Six Sigma with Big Data, the use of Six Sigma in Small Medium and Micro enterprises, an over emphasis of Six Sigma on variability reduction and the poor implementation of Six Sigma and its resultant negative impact on employee satisfaction.*

**Practical Implications:** In order to sustain Six Sigma initiatives in organisations, the authors argue that the limitations and emerging trends of this powerful business strategy should be understood and appropriate remedial strategies developed to address said limitations.

**Originality of Value:** To the best of our knowledge, this is the first empirical study to examine the limitations and emerging trends of Six Sigma in both manufacturing and service organisations. Moreover, the findings of the study can be very beneficial to many organisations.



**Keywords:** Six Sigma, Limitations, Empirical Study, Emerging Trends

## 1. Introduction

Since its origins in the mid-1980s, the Six Sigma business strategy for business process improvement has become widely adopted by a number of manufacturing and service organisations internationally. A number of high profile companies such as Allied Signal (also known as HoneyWell), General Electric, Caterpillar, Cummins, ABB, Johnson and Johnson, American Express, and Bank of America helped to popularise and legitimise this problem solving methodology, resulting in millions of dollars of bottom line savings (Swink and Jacobs, 2012; Antony 2017).

Organisations have adopted Six Sigma as a powerful problem solving methodology led by process improvement specialists such as Black Belts (BBs) or Green Belts (GBs). The focus of the Six Sigma approach is to reduce defects in those critical processes that result in unacceptable quality in the eyes of customers. Six Sigma principles can be used to; improve the process average and design, create robust products, services and processes, and reduce excessive variation in the process (Shah et al., 2008). Schroeder et al. (2008, p. 540) defined Six Sigma as "*an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives*". This definition of Six Sigma contains both the "what" and "how" of the theory, thereby making it one of the most comprehensive definitions of Six Sigma to date.

Research has indicated that there is a paucity of papers which elucidate the limitations of Six Sigma (Antony, 2004a; Mitra, 2004; Goodman and Theuerkauf, 2005; Bisgaard and De Mast, 2006; Angel and Pritchard, 2008; Chakravorty, 2009a, 2010). The purpose of this study therefore is to systematically review literature in order to identify the limitations and emerging trends of Six Sigma followed by evaluating the findings through an online survey protocol targeting process improvement experts such as Six Sigma Master Black Belts (MBBs), Black Belts (BBs) and Green Belts (GBs) in both manufacturing and service organisations. The limitations of Six Sigma should be understood by both practitioners and leading academics alike so that such limitations can be addressed and organisations can develop strategies to minimise their impact. Moreover, the emerging trends of Six Sigma provide the necessary platform for both industrial and academic fraternities for further growth of this powerful methodology in problem solving scenarios.

## 2. Literature Review: Limitations, Trends, and Gaps in Six Sigma Research

A systematic literature review of the key limitations of Six Sigma in addition to emerging trends and research gaps identified 15 limitations/research gaps/emerging (Sony et al., 2018). In authors' view, this is possibly the most comprehensive study carried out explicitly covering the major limitations, research gaps and the emerging trends of Six Sigma. Moreover, the article was based on a thorough review of existing literature looking into the limitations, critique and cons of Six Sigma.

### *2.1 Limitations of Six Sigma*

The first limitation of Six Sigma is viewed as a gap in the sense that it addresses the reasons for Six Sigma failures in many organisations today. For instance, Glasgow et al. (2010) and Albliwi et al. (2014) report that over 60% of Six Sigma initiatives failed to deliver the desired results. Many companies who had implemented Six Sigma enjoyed its benefits in the first 2 to 3 years but then failed to demonstrate a lasting impact over time. This implies that the initial enthusiasm and momentum diminished after a certain period of time into the journey; with many organisations quickly falling back into the old habits of executing things at their workplace (Chakravorty, 2005).

Several studies show that around 60% of all corporate Six Sigma initiatives fail (Angel and Pritchard, 2008; Chakravorty, 2009a, 2009b, 2010). Due to these failures, more corporations across multiple industry sectors are pulling back on their Six Sigma initiatives due to cost ranging from several thousands to millions of dollars. It is essential to understand the reasons for Six Sigma initiative failures and to further understand at what level (i.e. individual, team, project, organisational, etc.) such failures occur (Angel and Pritchard, 2008; Chakravorty, 2009b). Once the reasons for failures are understood, frameworks for mitigating future failures can be developed.

The second limitation is associated with the high costs of implementation at the early stages of Six Sigma adoption (Berg, 2006). Due to the substantial start-up costs associated with Six Sigma initiatives, organisations (both small and large) can be reluctant to adopt this business improvement strategy (Fursule et al., 2012; Vendrame Takao et al., 2017; Homrossukon and Anurathapunt, 2011).

The third limitation is that Six Sigma may have a negative impact on customer satisfaction if not implemented properly (Hindo, 2007a; Hindo and Grow, 2007; Angel and Pritchard, 2008). Two major global US corporations (3M and Home Depot) abandoned their Six Sigma programme due to a negative impact on customer satisfaction (Hindo, 2007a; Hindo and Grow, 2007; Chakravorty, 2009a). It was also interesting to note that a number of studies in the literature suggest that the proper implementation of Six Sigma initiatives promotes customer satisfaction and innovation (Fortenot et al., 1994; Behara et al., 1995; Montgomery, 2008; Antony et al., 2016; He et al., 2017).

The fourth limitation concerns the negative impact on employee satisfaction of poor Six Sigma implementation. For example, a study carried out by Alexander (2001) has shown that differing levels of Six Sigma implementation may result in differing levels of job satisfaction amongst employees. Moreover, another study from Schön et al. (2010) suggests that the poor implementation of Six Sigma has a negative impact on employee morale and engagement.

The fifth limitation of Six Sigma is that the structured and disciplined nature of this problem solving approach can stifle employee creativity and innovation (Hindo, 2007a; Hindo and Grow, 2007). Six Sigma's sequence of steps and rigorous, analytical method can lead people towards rigidity (Hindo, 2007b; Angel and Pritchard, 2008). There are two schools of thought concerning this limitation; one claiming that Six Sigma stifles employee's innovation skills (Hindo, 2007a; Hindo and Grow, 2007; Angel and Pritchard, 2008) and the other claiming that Six Sigma fosters innovation ((Montgomery, 2008; Hoerl and Gardner, 2010).

The sixth limitation of Six Sigma relates to the ratio between the effort and cost of Six Sigma implementation and the accruing benefits (Foster Jr, 2007). A number of practitioners and researchers argue that the effort required to implement Six Sigma is comparatively higher compared to the benefits accruing from complex projects which consume resources and time (Foster Jr, 2007; Gupta, 2008; Chakravorty, 2009a). At the same time, a number of studies report successful Six Sigma implementation has resulted in significant financial savings (Kwak and Anbari, 2006; Asefeso, 2014; Pyzdek and Keller, 2014). A number of large corporations have reported financial savings and other non-financial benefits were generated from Six Sigma programmes. However, very few Small and Medium sized Enterprises (SMEs) have reported the ratio of investment to benefits from their Six Sigma initiatives.

This suggests empirical studies are needed to understand the relationship between Six Sigma investment by corporations and the benefits (hard and soft savings) accrued over time.

The seventh limitation surrounds a stringent and fundamental assumption such as a 1.5 σ shift in the process mean for any long-term variability study in business processes. According to Ramberg (2000), the above assumption is groundless and makes little sense from a practical perspective. If the Six Sigma process mean was centred on the target value with no σ shift, then the process would have produced defects at a rate of two parts per billion (Antony, 2004a; Shahabuddin, 2008). When the process mean shifts by 1.5 σ, the defect rate will increase from 2 parts per billion to 3.4 ppm defects per million opportunities (Raval and Muralidharan, 2016). A number of researchers argue that this assumption cannot hold true for non-manufacturing processes including; billing, recruitment, admissions process, customer complaints handing process, surgical processes in hospitals etc. (Antony, 2006; Natarajan and Morse, 2009; Muralidharan, 2015a).

The eighth limitation is centred on the over importance Six Sigma places on variance reduction in processes. Whilst Six Sigma is a powerful methodology for understanding and reducing process variation, it is important to look at the trade-off between the degree of variability reduction and the potential accruing benefits (Pande et al., 2000; Natarajan and Morse, 2009). Many companies have built entire cultures upon this foundational concept (Ranjan Senapati, 2004), yet variation reduction is only one aspect of organisational inefficiency to be considered, and should not always be the only focus.

The ninth limitation is a question of originality: what is new in Six Sigma? A number of practitioners clearly spelled out the critical and fundamental differences between many quality improvement initiatives of the past including Total Quality Management and Lean (Snee 2004; 2010; Antony, 2009; Pyzdek, 2014). For instance, Snee (2004) provides a detailed commentary on the critical differences between Six Sigma and TQM. Firstly, Six Sigma places an unprecedented emphasis on the financial savings to be generated and the typical commitment of senior executives in organisations. Secondly, there is a clear and specific infrastructure required for the successful deployment of Six Sigma including; champions, Master Black Belts, Black Belts, Green Belts and Yellow Belts. Finally, the focus of Six Sigma is not just on the use of tools but on the integration of such tools in each phase of the problem solving methodology.

The tenth limitation of Six Sigma is a criticism concerning the non-standardisation of the curriculum. The problems associated with curriculum non-standardization and the delivery of training have been emphasised in the work of Lauraeni and Antony (2011). Many training providers regularly use off-the-shelf manufacturing training material for service and other non-manufacturing sectors. Additionally, very little attention is paid to customising Six Sigma curriculum for Small and Medium sized Enterprises (SMEs) as well as public sector organisations such as Healthcare, Police Services, Higher Education, Fire and Ambulance Services, Criminal Justice, etc. A non-standardised education system facilitates the development of a variety of learning patterns and behaviours, which may be detrimental not only to the successful implementation of Six Sigma but also to its further growth.

*2.2 Emerging trends and gaps in Six Sigma research*

An emerging trend associated with Six Sigma is its integration with Big Data (Antony et al., 2017). This study highlights that a limited number of studies explore the relationship between Six Sigma and Big Data directly, through either theoretical or empirical research. Stojanovic et al. (2016, p. 1647) propose "a novel approach for data-driven Quality Management in industry processes that enables a multidimensional analysis of the anomalies that can appear and their real-time detection in the running system". In another study they emphasise the use of Big Data for identifying real-time defects and their root causes in processes (Stojanovic et al., 2015).

The second emerging trend and gap in Six Sigma research is the integration of Six Sigma with Environmental Management Systems (EMS). The integration of Six Sigma and EMS strategies based on a systems approach can provide financial, environmental, social benefits and present a promising opportunity for sustainable improvement. For example, research carried out by Calia et al. (2009), which analysed a company's pollution prevention program from 1995 to 2007, found a 62% improvement in performance of the Pollution Prevention program as a result of implementing Six Sigma. Moreover, the authors argue that this integrated approach could provide numerous benefits such as cost reduction, decreased consumption of raw materials, decreased amount of waste water, longer resource life through reduced usage, reduced emissions, reduced energy consumption, and improved employee health and safety due to less exposure to harmful chemicals.

The third trend of Six Sigma concerns the challenge of integrating Six Sigma and Industry 4.0 (Basios and Loucopoulos, 2017). Industry 4.0 is a concept better known as the "Smart Factory". It refers to an omnipotent cyber system, integrating different socio-techno-economic functions to allow fully automated production integrate with the internet of things (IOT). In an Industry 4.0 factory, machines are connected as a collaborative community to collect, exchange and analyse data systematically (Rüttimann and Stöckli, 2016). A recent study has claimed that Lean Six Sigma integration with Industry 4.0 has the potential to make a highly optimized ideal process flow which is defect free and 'boasts' minimum wastage (Jayaram, 2016). In another relevant study within the context of health services, Six Sigma integration with Industry 4.0 resulted in improved quality of care for patients as well as reduced operational costs (Arcidiacono and Pieroni, 2018).

The fourth emerging trend of Six Sigma is its suitability in the context of Small and Medium Sized Enterprises (SMEs) particularly small and even micro enterprises with less than 10 employees (Deshmukh and Chavan, 2012). One of the biggest challenges in the context of SMEs remains the availability of talented staff in executing projects together with a consideration of budget and time constraints in such environments. There are a number of research gaps identified in the existing literature on Six Sigma's applicability in SMEs including: How many Green Belts and Yellow Belts are required for the successful deployment of LSS in an SME environment? What is the scope of Six Sigma projects in an SME environment? and What is the nature of Six Sigma curriculum most suited to SMEs? (Alexander et al., 2018).

The fifth emerging trend of Six Sigma is its applicability in public sector organisations. Whilst articles have been published on Lean and its applications in various public sector contexts such as healthcare and education, the impact of Six Sigma on local councils, higher education, emergency services, municipalities etc. should be further researched for its long-term suitability (Antony et al., 2016; Antony et al., 2017).

## 3. Research Methodology

The main objective of this study is to critically evaluate the limitations and emerging themes or research gaps of Six Sigma from leading practitioners such as Master Black Belts, Black

Belts and Green Belts in a number of manufacturing and service companies. The motivation for the investigation of this research stems from a number of discussions and workshops conducted by one of the authors. It was found that although a number of limitations of Six Sigma were addressed by a few authors ((Antony (2004a); Mitra (2004) and Montgomery (2008)), there was no research conducted to empirically test these limitations in the eyes of practitioners and leading consultants working in industry. Moreover, the same principle can be applied to the emerging trends as well. Our purpose is to capture the views of Six Sigma professionals in industry for validating the limitations associated with applications of Six Sigma as well understanding some of the emerging trends or themes on the topic for further research. The above has led us to arrive at the following research questions:

*a) What are the top five limitations/emerging trends/research gaps of Six Sigma from the viewpoint of Six Sigma experts such as Master Black Belts, Black Belts and Green Belts in both manufacturing and service companies?*

*b) Is there a difference in the perceptions of limitations/emerging trends/research gaps of Six Sigma between Six Sigma experts from manufacturing and service companies?*

*c) Is there a difference in the perception of limitations/emerging trends/research gaps of Six Sigma between European and North American manufacturing and service companies?*

In order to address the above research questions, the authors utilised an online survey for data collection targeted at large manufacturing and service companies. Each question in the survey protocol was framed based on the previous systematic literature review developed and published by the authors (Sony et al., 2018). The survey protocol consists of ten limitations and five emerging trends of Six Sigma. This has formed the foundation of the survey questionnaire in our study. The survey questions can be seen in Appendix A. For this study, online survey method is the best data collection strategy as it enables us to gather a larger amount of data and information from target respondents within a short period of time. The online survey protocol was piloted with five academics who have extensively published peer reviewed articles as well as five Six Sigma practitioners such as MBBs and BBs who have pursued a number of process improvement projects in their respective businesses (Boynton,and Greenhalgh 2004). A pilot study is one of the important stages in a research project and is conducted to identify potential problem areas and deficiencies in the research

instruments and protocol prior to implementation during the full study. Moreover, one may pursue a pilot study i) to determine the feasibility of the study protocol; ii) to test the survey instrument validity and finally iii) to check that the results data is meaningful and useful to participants and wider audience (Teijlingen et al., 2001). The purpose of piloting the survey questionnaire was to ensure that the contents were valid and the questions aligned with the research questions set by the researchers (Couper and Miller, 2008).

Comments and feedback from the above five practitioners were further examined and some modifications were made especially with respect to flow and readability of questions in the survey instrument. Majority of the feedback from the pilot survey were quite positive and confirmed that the questionnaire was suitable for distribution. The online survey comprised two parts; general participant information and the fifteen limitations and emerging trends identified from the literature. Each participant was asked to rate the limitation / research gap/emerging trend using a scale of 1 to 7 (1= strongly disagree and 7 = strongly agree). These scales provide adequate levels of discrimination among the choices given to target respondents.

The revised online survey link was sent out to 500 subject matter experts who are working in their respective organisations as MBBs, BBs or GBs. The researchers used three criteria in the selection of such subject matter experts*; i) all respondents should have a minimum of five years' experience in their role as a process improvement specialist, ii) all respondents should have carried out a minimum of two process improvement projects and iii) have been involved in at least 3 process improvement projects as a team member.* Setting such criteria will enable the researchers to glean a high calibre of experience from the survey participants who are responsible for the execution of process improvement related projects in their respective organisations.

A total of 126 responses were collated over a 12 week period yielding a response rate of 25.2%. The participants were contacted via Linkedin by the first author through his network of contacts with Six Sigma and Lean Six Sigma professionals. 150 participants have agreed to participate in the online survey. However only 126 have completed the survey instrument in the end and these responses were further used for analysis. Easterby-Smith et al.(2012) argue that a 20% survey response rate is widely considered to be sufficient, while the literature on Lean and Six Sigma suggests that a 10% response rate is acceptable (Shah et al.

2008)(Collis and Hussey, 2013). In our study, we had a response rate of over 20% which was quite satisfactory from a statistical analysis point of view.

Table 1 and Figure 1 respectively show the distribution of the characteristics and countries of the respondents. It is interesting to observe that almost 60% (75) of survey respondents were Six Sigma MBBs, followed by 31% (39) Six Sigma BBs and 9% (12) Six Sigma GBs.

**Table 1**: Distribution of expertise in Six Sigma

| | | Which of the following sector you work for? | | |
|---|---|---|---|---|
| | | Manufacturing | Service | Total |
| **Six Sigma Belt** | Black Belt(BB) | 20 | 19 | 39 |
| | Green Belt (GB) | 6 | 6 | 12 |
| | Master Black Belt (MBB) | 35 | 40 | 75 |
| Total | | 61 | 65 | 126 |

Figure 1 shows that more than 40% of survey participants are from the UK and USA, followed by India, Italy and Brazil.

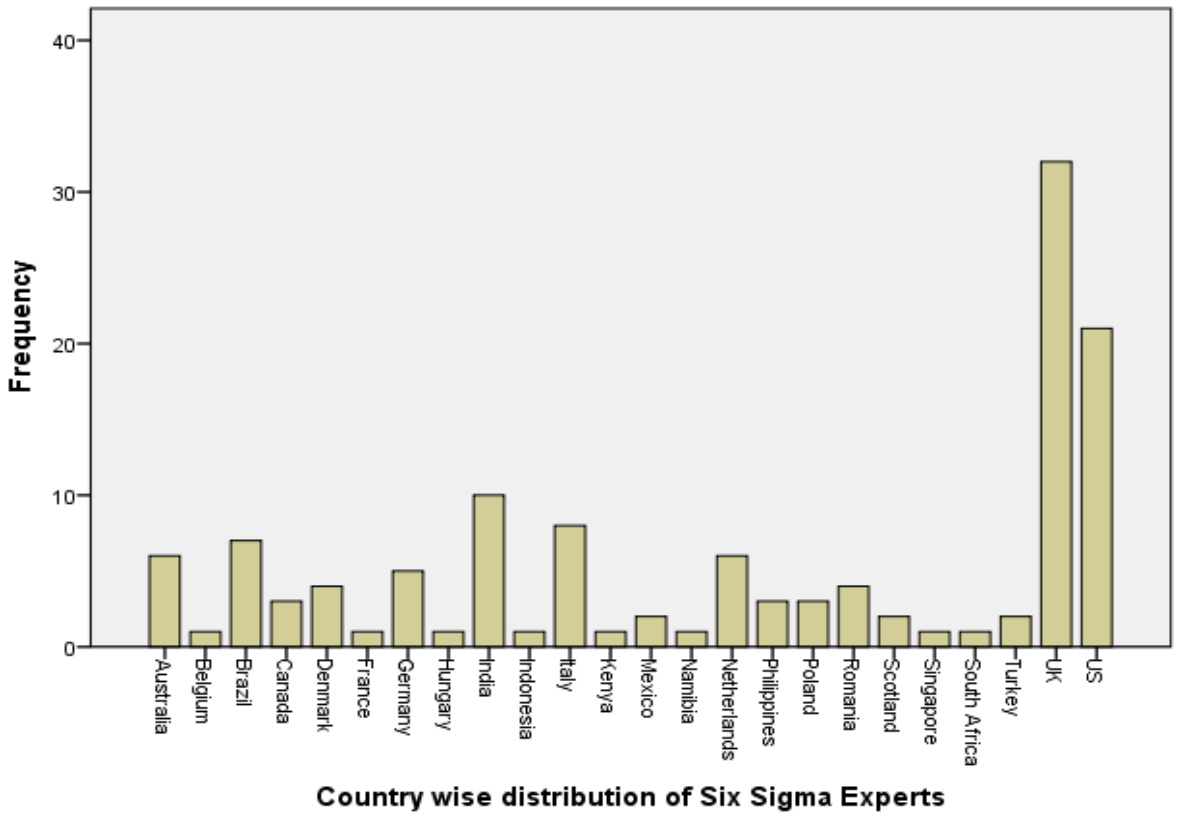


**Figure 1**: Country distribution of survey participants

Figures 2 and 3 illustrate the distribution of participants in the service and manufacturing sectors. In the service sector, most of the respondents were from consulting and financial services. In the manufacturing sector, the majority of respondents come from the Mining, Automotive, Heavy electricals, Petroleum and Chemicals industries.

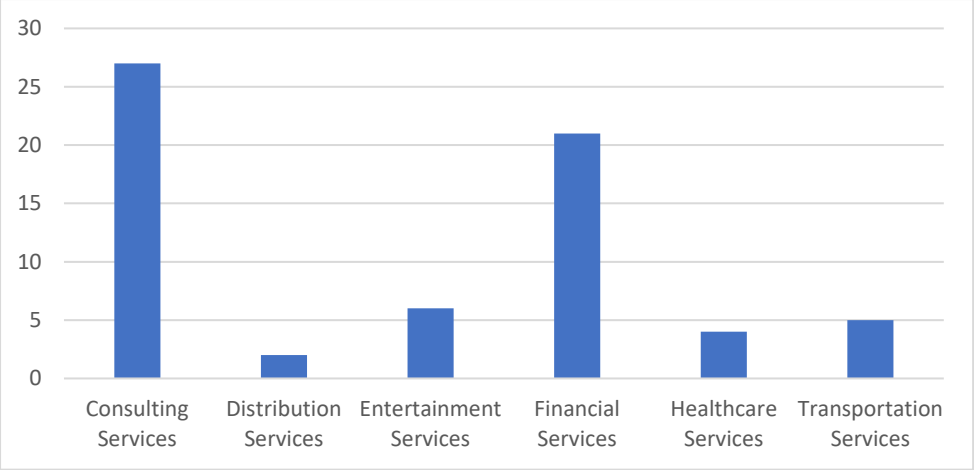


**Figure 2**: Service sector

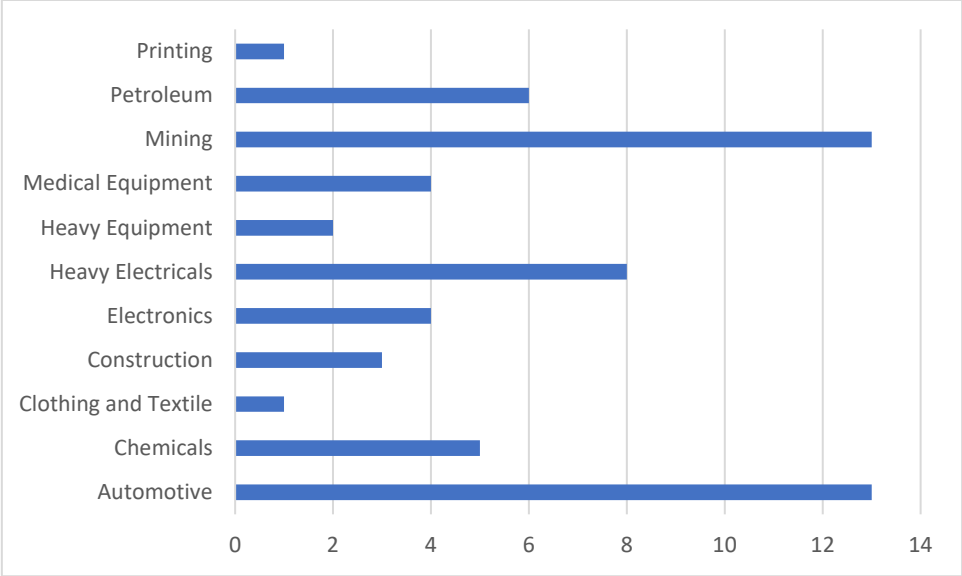


**Figure 3**: Manufacturing sector

## 4. Results

The top six limitations and emerging trends/research gaps of Six Sigma in Manufacturing and Service companies are show in Tables 2 and 3 respectively. It was very interesting to observe that there was very little critical differences in the top six limitations and emerging trends/research gaps between the manufacturing and service clusters. However it was quite surprising to realise that the non-standardisation of Six Sigma curriculum for training has not appeared in the top six limitations for the participants. Moreover, high start-up costs associated with the implementation of Six Sigma did not appear to be a limitation although

this was considered to be one of the most important limitations according to many practitioners in the past (Snee, 2010; Pande et al., 2000; Pyzdek and Keller; 2014).

**Table 2:** Top six limitations/emerging trends/research gaps of Six Sigma from experts in the manufacturing sector

| | N | Sum | Mean |
|---|---|---|---|
| *Integration of Six Sigma with Big Data can bring superior results to many organizations in the future* | 61 | 378 | 6.20 |
| *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises* | 61 | 374 | 6.13 |
| *Over emphasis on Variance reduction* | 61 | 362 | 5.93 |
| *Poor implementation of Six Sigma can have a negative impact on employee satisfaction.* | 61 | 355 | 5.82 |
| *Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics* | 61 | 346 | 5.67 |
| *Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies* | 61 | 341 | 5.59 |
| Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction | 61 | 329 | 5.39 |
| The initial cost of implementing Six Sigma in an organization is very high | 61 | 273 | 4.48 |
| The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high | 61 | 263 | 4.31 |
| The technical limitations of Six Sigma like 1.5σ shift needs to be addressed in layman terms and should not be over emphasised | 61 | 254 | 4.16 |
| Non-Standardization of training Curriculum for various Six Sigma Belts | 60 | 242 | 4.03 |
| Six Sigma is TQM on steroids | 61 | 182 | 2.98 |
| Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation | 61 | 175 | 2.87 |
| The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts | 61 | 107 | 1.75 |
| Six Sigma and its applicability for public sector organizations | 61 | 104 | 1.70 |

**Table 3:** Top six limitations/emerging trends/research gaps of Six Sigma from experts in the service sector

| | N | Sum | Mean |
|---|---|---|---|
| *Integration of Six Sigma with Big Data can bring superior results to many organizations in the future* | 65 | 405 | 6.23 |
| *Over emphasis of Variance reduction* | 65 | 398 | 6.12 |
| *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly* | 65 | 398 | 6.12 |
| *Poor implementation of Six Sigma can have a negative impact on employee satisfaction.* | 65 | 374 | 5.75 |
| *Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies* | 65 | 345 | 5.31 |
| *Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction* | 65 | 327 | 5.03 |
| Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics | 65 | 321 | 4.94 |
| Non-Standardization of Curriculum | 65 | 316 | 4.86 |
| The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high | 65 | 299 | 4.60 |
| The initial cost of implementing Six Sigma in an organization is very high | 65 | 270 | 4.15 |
| The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instill confidence in Organizations to implement Six Sigma | 65 | 255 | 3.92 |
| Six Sigma is TQM on steroids | 65 | 230 | 3.54 |
| Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation | 65 | 169 | 2.60 |
| The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts | 65 | 158 | 2.43 |
| Six Sigma is not suitable for public sector organizations | 65 | 97 | 1.49 |

In order to understand whether or not there are any perceived differences in the mean scores on limitations/emerging trends between the two sector means (i.e. manufacturing vs service) a two sample Mann-Whitney U test was performed (Navarro, 2014). The Mann-Whitney U

test is the most appropriate test as the two samples are independent and categorical. The observations are independent in the sense that the participants in each sample group are different (Montgomery et al. 2011). The summary of key findings from both clusters (i.e. experts from manufacturing and service companies) is provided in Table 4.

**Table 4:** Summary of key findings from both clusters (experts from large manufacturing companies and service companies)

| Limitations/Emerging Trends/Research Gaps | Mean Scores of Experts from Services | Mean scores of Experts from Manufacturing | Mann-Whitney U test (Asymp. Sig.) |
|---|---|---|---|
| The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high | 4.60 | 4.31 | 0.381 |
| The initial cost of implementing Six Sigma in an organization is very high | 4.15 | 4.48 | 0.257 |
| Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction | 5.03 | 5.39 | 0.337 |
| Poor implementation of Six Sigma can have a negative impact on employee satisfaction. | 5.75 | 5.82 | 0.894 |
| Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation | 2.60 | 2.87 | 0.634 |
| The benefits due to Six Sigma implementation for companies are minimal with respect to the effort required | 2.43 | 1.75 | **0.001*** ** |
| The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six Sigma | 3.92 | 4.16 | 0.480 |
| Variance reduction should not be the only goal of Six Sigma implementation | 6.12 | 5.93 | 0.828 |
| Six Sigma is TQM on steroids | 3.54 | 2.98 | 0.082 |
| Non-Standardization of Six Sigma Curriculum | 4.86 | 4.03 | **0.002*** ** |
| Integration of Six Sigma with Big Data can bring superior results to many organizations in the future | 6.23 | 6.2 | 0.841 |
| Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies | 5.31 | 5.59 | 0.190 |
| Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics | 4.94 | 5.67 | **0.001*** ** |
| Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly | 6.12 | 6.13 | 0.651 |
| Six Sigma is not suitable for public sector organizations | 1.49 | 1.7 | 0.606 |

Note: *** 1% significant level

Table 4 shows that there were significant differences in the means for three key findings at 1% significance level. These are:

i) **The benefits due to Six Sigma implementation are minimal compared to the effort required**. Although there are differences between manufacturing and services clusters, experts from both clusters ranked this low on the Likert scale of 1 to 7. Manufacturing participant experts scored this item lower than their service counterparts; a finding which was not at all surprising to the researchers, as it implies a maturity of Six Sigma integration in manufacturing companies compared to service companies.

ii) **The non-standardisation of Six Sigma curriculum** has been an issue for both manufacturing and service companies. Different companies set different training and certification standards manifesting as an inconsistent issue across companies and countries. Although this problem has been addressed partially through the development of ISO 18404:2015 which defines the competencies for the attainment of specific levels of competency with regards to Six Sigma, Lean, and Lean & Six Sigma. However, it is still not yet accepted at a global level.

iii) **The integration of Six Sigma with Industry 4.0**. While there is currently a paucity of research on this topic, the authors firmly believe that this will be one of the topics which will be given serious attention for creating and sustaining competitive advantage across many organisations irrespective of their size and nature.

The next phase of the analysis was to understand whether or not there was any perceived differences in the limitations/emerging trends between the European and North American manufacturing companies and also by European and North American service companies. The authors have not included other continents as our response rate was too low (i.e. Asia, Australia, Africa and South America).

Table 5 presents the mean scores of each limitation/emerging trend for manufacturing organisations for the European and North American continents. It was interesting to note that there was no significant difference in the mean scores of each item in Table 5 except for one item; Six Sigma may stifle employee creativity and innovation. The mean score for this item was comparatively lower in Europe compared to North America. This may be due to the maturity of the use of Six Sigma in many North American manufacturing companies compared to their European counterparts. The three areas where the mean scores ranked the highest were:

1) **Six Sigma implementation in Small and Medium Sized Manufacturing Enterprises**. The authors do not find this result at all surprising especially given that this has been one of the 'hot topics' for many researchers and practitioners around the world (Alexander et al., 2019). More empirical studies should be conducted to critically evaluate the most appropriate curriculum for Small and Medium Sized Enterprises (SMEs). Moreover, there is an immense need for the development of a customised Belt System to fulfil SMEs particular needs.
2) **The integration of Six Sigma with Big Data**. Although a number of studies concern this topic, more empirical studies are needed in order to better understand how these two methodologies can be integrated in the most efficient and effective manner.
3) **Poor implementation of Six Sigma and its impact on employee satisfaction**. It is important to note that this is one of the limitations of Six Sigma. Six Sigma demands the selection of the most talented people for training and execution of projects (Snee and Hoerl, 2018). More empirical studies in different cultural contexts should be pursued to understand the interrelationship between poor implementation and employee disengagement and dissatisfaction.

It was also found that two items have mean scores less than 2.0 in both continents. The first item concerned the ratio of benefits from Six Sigma against the effort required by organisations. This result clearly implies that Six Sigma delivers tangible and measurable financial benefits to organisation's bottom-line according to MBB/BB participants. The second item worth highlighting is the fact that participants agreed with the view that Six Sigma is applicable to Public Sector organisations. This is an area which deserves greater attention for research in the forthcoming years.

**Table 5 :** Summary of key findings from America and Europe (respondents from manufacturing companies)

| Limitations | Mean Scores North America (n=14) | Mean Scores Europe (n=37) | Mann-Whitney U test Asymp Sig |
|---|---|---|---|
| The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high | 3.64 | 4.16 | 0.249 |
| The initial cost of implementing Six Sigma in an organization is very high | 4.57 | 4.08 | 0.44 |
| Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction | 5.79 | 5.16 | 0.414 |
| Poor implementation of Six Sigma can have a negative impact on employee satisfaction. | 6.07 | 5.97 | 0.48 |
| Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation | 4.21 | 2.3 | **0.002*** ** |
| The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts | 1.79 | 1.62 | 0.418 |
| The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six Sigma | 4.07 | 4.08 | 0.847 |
| Variance reduction should not be the only goal of Six Sigma implementation | 5.86 | 5.92 | 0.835 |
| Six Sigma is TQM on steroids | 3.07 | 2.62 | 0.356 |
| Non-Standardization of Curriculum | 3.71 | 3.95 | 0.593 |
| Integration of Six Sigma with Big Data can bring superior results to many organizations in the future | 6.14 | 6.16 | 0.502 |
| Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies | 5.36 | 5.49 | 0.768 |
| Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics | 5.21 | 5.76 | 0.112 |
| Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly | 6.29 | 6 | 0.363 |
| Six Sigma is not suitable for public sector organizations | 1.5 | 1.54 | 0.597 |

Note: *** significant at both 5% and 1% significant levels

Table 6 presents the mean scores of each limitation/emerging trend for service organisations for European and North American continents. The table shows that there was a significant difference in the mean scores for two items. The first item was the non-standardisation of the curriculum. This has been reported widely as one of the major limitations of Six Sigma (Laureani and Antony 2011, Albliwi et al., 2014). Although this is quite common across many organisations, the authors felt that this is more common across many service and public sector organisations compared to manufacturing counter parts. This is due to the fact that

manufacturing companies have a higher maturity with the use of Six Sigma compared to service and public sector organisations. The second item highlights the integration of Six Sigma with Industry 4.0 as an emerging trend. Industry 4.0 has been around for more than a decade and it is not at all surprising to see that there is a clear gap for this item between the two continents. The mean score of this item for North America was comparatively higher than for Europe. This may be due to the fact that Six Sigma may be more mature in many North American service organisations than their European counterparts. We would expect this gap to be much narrower over time especially when many European organisations begin to integrate Lean with Industry 4.0 as well as Lean Six Sigma with Industry 4.0. The importance of the integration of Big Data with Six Sigma and the growing significance of Six Sigma in SMEs was very evident from the table. It was interesting to observe that participants in the service sector had a similar view to their manufacturing counterparts that Six Sigma has a role to play for the public sector organisations. It is evident from recent publications that many leading research scholars have been active in Six Sigma and Lean Six Sigma research in the public sector domain (Rodgers et al, 2018; Rodgers et al.; 2019; Antony et al., 2017;Cudney et al., 2018; Antony et al., 2019).

**Table 6 :** Summary of key findings from North America and Europe (respondents from service companies)

| Limitations | Mean Scores North America (n=19) | Mean Scores Europe (n=31) | Asymp Sig |
|---|---|---|---|
| The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high | 4.79 | 4.39 | 0.515 |
| The initial cost of implementing Six Sigma in an organization is very high | 4.05 | 3.9 | 0.714 |
| Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction | 5.21 | 5.13 | 0.884 |
| Poor implementation of Six Sigma can have a negative impact on employee satisfaction. | 6 | 5.81 | 0.303 |
| Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation | 2.37 | 2.74 | 0.329 |
| The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts | 2.84 | 2.19 | 0.502 |
| The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six | 3.84 | 3.9 | 0.984 |

| | | | |
|---|---|---|---|
| Sigma | | | |
| Variance reduction should not be the only goal of Six Sigma implementation | 5.89 | 6.29 | 0.825 |
| Six Sigma is TQM on steroids | 3.53 | 3.42 | 0.725 |
| Non-Standardization of Curriculum | 5.42 | 4.45 | **0.016**** |
| Integration of Six Sigma with Big Data can bring superior results to many organizations in the future | 6.32 | 6.1 | 0.282 |
| Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies | 5.21 | 5.13 | 0.992 |
| Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics | 5.37 | 4.48 | **0.016**** |
| Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly | 6.47 | 6.23 | 0.195 |
| Six Sigma is not suitable for public sector organizations | 1.32 | 1.65 | 0.188 |

Note: ** significant at 5% significant level

## 5. Discussion, Limitation & Implications

Our findings suggest that the top three limitations/emerging trends/research gaps of Six Sigma in both manufacturing and service organisations according to leading practitioners such as Six Sigma Master Black Belts, Black Belts and Green Belts are:

- Integration of Six Sigma with Big Data: Big Data is referred to as the large data sets that are often challenging to examine and investigate due to their complexity and variability (La Valle et al., 2011). The Big Data Analytics (BDA) can help the firms to unveil the hidden patterns, market trends, customer preferences, unknown causality and correlations between the different parameters. BDA and data mining aim to get deep insights into processes and act as a supplement to Six Sigma. The future research should focus on the development of a practical framework to integrate the best attributes of Six Sigma as a problem solving methodology together with the characteristics of Big Data methodology as a vehicle for making better fact-based decisions. Gupta, Modgil and Gunasekaran (2019) argued that the complementary relationship of Big data and Lean Six Sigma can support and enhance the performance of a firm in the dynamic environment. Moreover, they explicitly stated that the continuing research interest and application of Big Data Analytics (BDA) in Lean Six Sigma (LSS) in the view of storing, mining, integrating, interpreting and modelling the big data can lead to practical solutions to today's business problems.

Antony et al (2018) emphasised the importance of integrating Lean Six Sigma with Big Data and highlighted this as one of the emerging trends of Lean Six Sigma (Antony, Snee and Hoerl, 2017). Six Sigma being a data-driven approach to process improvement; Snee (2010) supported the view that the success of measurement phase of Six Sigma problem solving methodology depends heavily on the availability of data over various operations, time periods, operators etc. and Big Data can play an immense role to bridge this gap.

- Six Sigma in Small and Medium Sized Enterprises (SMEs): Although there are a number of papers published on this topic, there remain a number of research gaps which are not yet addressed and deserve further attention from leading academics and industry practitioners. For instance, questions such as What is the best infrastructure for the successful deployment of Six Sigma in SMEs? What is the scope of Six Sigma projects and What are the savings to be generated from the execution of Six Sigma projects in SMEs? remain unanswered. Additionally, the attributes and traits of Six Sigma experts operating in an SME environment should not necessarily be the same as those in larger organisations such as GE, Motorola, Bank of America, Caterpillar. More empirical studies are necessary to address the above points raised by the authors.
- Over emphasis of variance reduction: Although the primary objective of Six Sigma methodology is to reduce process variation and consequentially reduce defects/errors, it is quite important to understand the trade-off between the degree of variability required and the benefits to be gained from such exercises in real life scenarios. In certain cases, process adjustments may be more relevant than variation reduction where an understanding of factors influencing the process mean may be more beneficial than trying to bring the process mean to the target.

Some studies have found that Six Sigma can be influenced by national culture (Schön et al., 2010). Pisani et al. (2009) suggested that applying Six Sigma in other national cultures may find discrepancies between their cultural values and behaviours. The authors proposed a conceptual model utilising Hofstede's cultural dimensions (Hofstede and Bond, 1984) to examine the potential national cultural impact at each stage of the Six Sigma process. Cronemyr, Eriksson and Jakolini (2014) provided a good commentary on the implications of implementing and applying Six Sigma in countries with different national cultures. The

authors in this study argued that taking different aspects of national cultures into account when implementing Six Sigma within a global organisation will enhance understanding, cooperation and performance of the organisation. In another study, Qamar et al. (2013) suggested that implementing Six Sigma in other countries with different cultures, norms and behaviours may have different adjustment problems, as the required culture, values and behaviours for Six Sigma do not match with the local cultures of countries.

The rapid growth of Six Sigma in US corporations compared to those in Europe is due to a better cultural fit, whereby US corporations are typically decentralised and formal (Crom, 2000; Klefsjö et al., 2008). In Europe, many firms continue to go through the Lean transformation journey and only a handful number of larger organisations have embraced Six Sigma or Lean Six Sigma as their core business process improvement strategy in order to create and sustain a competitive advantage. In our study, one of the noticeable differences in manufacturing companies was the link of Six Sigma and creativity/innovation. The results of our study indicated that the mean score of Six Sigma may stifle employee creativity / innovation is significantly lower in European companies compared to North America. The two possible factors which influence the outcomes for this item were culture and maturity in the use of Six Sigma between the two continents. A number of studies have shown that more than 70% of business transformation efforts through Lean or Six Sigma fail in organisations (McLean et al., 2017; Bhasin, 2012; Pedersen and Huniche; 2011) and that a number of factors are attributed to such failures. For more information, readers are advised to refer to the above stated references as this aspect is beyond the scope of this research.

The findings from this study include a number of practical /managerial implications. Firstly, an understanding of the major limitations / emerging trends/ research gaps of one of the most powerful business process improvement methodologies creates a foundation for both industrial experts and leading academic scholars. An understanding of the major limitations / emerging trends/ research gaps can form the basis upon which to discuss and develop combined academic and industry strategies to address and overcome such limitations and research gaps and leverage emerging trends. For instance, Six Sigma is not commonly used in SMEs due to various misconceptions around the topic including a lack of understanding and awareness of the benefits of Six Sigma in an SME context. The use of Six Sigma in a Public Sector context is worth exploring further in the forthcoming years as the findings from this study clearly indicate that Six Sigma has a critical role to play in this sector according to a majority of the expert respondents. However senior managers in many public sector

organisations have a general lack of awareness concerning the benefits of Six Sigma and also when and where this methodology could be utilised in their processes. Ongoing debate concerning the topic of Six Sigma and Process/Product Innovation deserves more empirical research and preferably longitudinal studies to understand whether they complement each other or compete with each other. Findings from this study also suggest that manufacturing and service experts are of the view that Six Sigma does not stifle employee innovation. However, there was a significant difference in the mean scores associated with this limitation between the manufacturing and service organisations perhaps due to the difference in the maturity of Six Sigma deployment between these two clusters.

As with any research, this study has some limitations. Firstly, the sample size of the survey was not very high for making statistically valid conclusions from the data. One of the major challenges in the study was in obtaining reliable responses from experts within the duration of the project. Moreover, very few responses emanated from Asia, Africa, Australia and South American continents. The researchers also recognise that it would be extremely beneficial to understand the limitations and emerging trends and research gaps between the matured continents which have been utilising Six Sigma for three decades compared to those who are less mature in the deployment of Six Sigma. Moreover, the authors could not pursue any analysis to understand if the limitations vary between larger and smaller organisations.

## 6.0 Conclusion & Directions for further research

Although Six Sigma has been around for over 30 years, only a few papers have addressed the limitations and the emerging trends / research gaps associated with this powerful business process improvement methodology. The authors argue that this is the first empirical study to address the identification of the limitations and the fundamental research gaps of Six Sigma for its further growth and sustainability in organisations. The top three limitations and research gaps identified from this global study were:

- *integration of Six Sigma with Big Data;*
- *use of Six Sigma in Small Medium and Micro enterprises; and*
- *overemphasis of Six Sigma on variability reduction*

It was interesting to observe some perceived differences in the mean scores between the manufacturing and service organisations on three items:

- *the benefits due to Six Sigma implementation for companies are minimal with respect to the efforts;*
- *integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics; and*
- *non-standardization of Six Sigma curriculum*

There were also significant differences in the mean scores for a number of limitations/emerging trends between the North American and European continents. For instance, the mean score for the integration of Six Sigma with Industry 4.0 in North American manufacturing companies was relatively larger than its European counterpart. This could be due to the fact that the degree of maturity of Six Sigma in American manufacturing companies is higher than many of their European counterparts. Perhaps the nature of the maturity of companies could have been taken into account in order to understand if this factor impacts on the mean scores between the above two clusters. The authors intend to include a number of SMEs in the next study in order to conduct a comparative study on the limitations between large and SMEs (manufacturing). Finally, the authors plan to include service and public sector organisations in future research, which will enable the authors to critically evaluate the limitations and emerging trends of Six Sigma across various sectors. However, the authors recognise that the data collection from public sector organisations can be very challenging, as many of them are still pursuing their Lean journeys with few integrating Lean with Six Sigma.

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## Appendix A

### A Survey to critically evaluate the limitations and emerging trendsof Six Sigma

We are conducting a research on the key limitations of Six Sigma. Our thorough integrative literature review has transpired 15 themes on the limitations and emerging of Six Sigma. We will be delighted to have your personal views as a subject matter expert on both limitations and emerging trends. In Part A, please rank the limitations and emerging trends of Six Sigma on a Likert scale of 1 to 7 (1= strongly disagree and 7= strongly agree). Your valuable inputs will help us to address some of the limitations and emerging trends of Six Sigma further and pursue research projects to address these limitations in the forthcoming years. Once again thank you for all the efforts.

1. Name (optional)
2. Sex :
3. Six Sigma Belt:
4. Organization & Department (Optional if you prefer anonymity):
5. How many Six Sigma projects have you been involved with in the organization?:
6. Which of the following sector you work for? (Please tick)
   - Manufacturing
   - Service
   - Public Sector
   - Voluntary Sector
   - None of the above
7. How many employees are working in the company where you have been involved in Six Sigma initiative? (Please tick)
   - Less than 50
   - 50 - 250
   - 250-1000
   - More than 1000
8. The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high (Please tick)
   - Strongly Disagree
   - Disagree
   - Slightly Disagree
   - Neutral
   - Slightly Agree
   - Agree
   - Strongly Agree
9. The initial cost of implementing Six Sigma in an organization is very high (Please tick)
   - Strongly Disagree
   - Disagree
   - Slightly Disagree
   - Neutral
   - Slightly Agree
   - Agree
   - Strongly Agree
10. Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction(Please tick)

Strongly Disagree
Disagree
Slightly Disagree
Neutral
Slightly Agree
Agree
Strongly Agree

11. Poor implementation of Six Sigma can have a negative impact on employee satisfaction. (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
12. Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
13. The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
14. The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six Sigma (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
15. Variance reduction should not be the only goal of Six Sigma implementation (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
16. Six Sigma is TQM on steroids (Please tick)
    Strongly Disagree
    Disagree

Slightly Disagree
Neutral
Slightly Agree
Agree
Strongly Agree

17. Non-Standardization of Curriculum (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
18. Integration of Six Sigma with Big Data can bring superior results to many organizations in the future (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
19. Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
20. Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree
21. Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree
    Neutral
    Slightly Agree
    Agree
    Strongly Agree

22. Six Sigma is not suitable for public sector organizations (Please tick)
    Strongly Disagree
    Disagree
    Slightly Disagree

Neutral
Slightly Agree
Agree
Strongly Agree