Gordon Institute of Business Science
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Integrating process improvement methodologies to increase manufacturing industry success

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

7 November 2018

Abstract

Manufacturing is still an important area of modern civilisation and various companies use improvement methodologies to improve their competitive edge. The purpose of the research was to determine the breakdown of each improvement methodologies used in the manufacturing industry and it set out to determine how to structure a hybrid methodology. It also identified inhibitors that need to be managed to improve improvement methodology implementation. This was then integrated into a hybrid improvement methodology called DaMi-TLS.

This study found that 24% of the manufacturing industry still use Lean manufacturing followed by 17% using Lean Six Sigma. Furthermore 10% still use TQM and 7% use TOC. Although not considered improvement methodologies, 12% of manufacturing industries use Cost saving and 13% of use ISO 9001 as mean means to advance their business.

The main inhibitors to process improvement implementation was found to be Change Management, Time inhibitors and Impression as well as Analysis and Interaction. These inhibitors was built into the framework to improve implementation success.

The DaMi-TLS framework consists of the following steps: Define and Align, Manage inhibitors, Identify bottleneck, Exploit constraint using Lean tools, Exploit constraint using Six Sigma tools, Subordinate to constraint, Elevate constraint.

Keywords: Lean, Six Sigma, TOC, Integration

Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

____________________ . 7 November 2018

Paul Eloff Date

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Chapter 1: Research problem and Purpose

1.1. Background

In today's business environment, it is imperative that organisations continuously improve their processes to ensure they maintain their competitive advantage and remain sustainable for the foreseeable future (Prashar, 2016). Sabet, Adams & Yazdani (2016) argue that manufacturing sectors are wealth-producing while service sectors are wealth consuming. Manufacturing that thrives is important for driving sustainable growth (Rodseth, 2016).This is especially relevant for efficiency-driven economies such as China, South Africa, Chile and Costa Rica (Global competitiveness report, 2017).

Gupta & Snyder (2009) and Demchuk & Baitsar (2013) state that viable and distinct manufacturing improvement philosophies have been developed since the early 1980's with the main methodologies being Lean manufacturing, Six Sigma and the Theory of Constraints (TOC) which are typically used separately to improve organisational performance and competitiveness. The method followed to create improvement can either be regular small changes which is more aligned to Lean manufacturing and Six Sigma or by radical changes like capacity or technology upgrades which is synonymous with to TOC (Filho & Uzsoy, 2014). TOC is also a structured approach to process improvement, which identifies areas requiring improvement using constraint removal (Filho & Uzsoy, 2014).

These three production optimisation methodologies have very different approaches and aims:

- Lean manufacturing focusses on eliminating all types of waste within the process
- Six Sigma reduces process variability and errors
- TOC identifies, exploits and elevates system constraints (van Tonder, 2011)

According to Woeppel (2015), in the 2000's, 70% of industry managers were using Lean manufacturing, 34% Total quality management (TQM), 29% Six Sigma and 14% Theory of constraints (TOC). Katz's (2007) survey, the most recent found data, had the breakdown as 40.5% Lean manufacturing, 9.9% TQM, 3.1% Six Sigma and 3% TOC.

Mclean, Anthony & Dahlgaard (2017) stated that the most prominent improvement methodologies are Lean manufacturing, Six Sigma and a combination of the two while Näslund (2008) state Lean production has become the go to improvement methodology.

Anthony et al. (2017) and Cheng (2017) agreed with Mclean et al. (2017) that Lean Six Sigma is one of the most popular and recognised improvement methodologies to improve business performance, quality and productivity.

These surveys were done a long time ago and have very inconsistent data. With Lean manufacturing being the most popular, the fact is that still only 2% of Lean programmes reach their anticipated results (Liker & Franz, 2011). According to Pirasteh & Farah (2006), each manager uses an improvement methodology for which they have had success in the past or with which they feel more at ease. This might not be the most applicable and necessary improvement methodology for the organisation.

Improvement impact can be achieved more effectively and efficiently by utilising a combined and comprehensive approach (Demchuk and Baitsar, 2015). Prioritising different improvement projects has not been studied extensively and there are both similarities and differences among these philosophies (Voss, 2005). The problem is that currently not a lot is known about which improvement methodology is most used in the manufacturing industry, what the inhibitors to implementation of process improvement are and how to combine improvement methodologies into a hybrid methodology. Each improvement approach has its virtues, but it would be more valuable to combine them in a simple yet rigorous process (Prashar, 2016).

Three requirements needed for organisations to be competitive are flow, focus and stability (Hudson, 2017). This is why this study's main focus was on Lean manufacturing, Six Sigma and TOC improvement philosophies. The integration of improvement methodologies would create great synergy for continuous improvement techniques as no single approach can be the remedy for all business problems (Hudson, 2017; Patil & Mishar, 2014). Companies and their managers generally implement more than one improvement methodology, executed by different teams. These teams rarely converse and they don't collaborate, resulting in them competing with each other for company resources and management support (Ehie & Sheu, 2005). The study aimed to provide a combined approached to continuous improvement methodologies, which needs to overcome these obstacles.

Blanchard (2007) stated that according to the 2007 IW/MPI Census of Manufacturers that cost reduction strategies are increasing. This indicates why Lean manufacturing is the most popular improvement methodology of choice as its focus is to reduce waste. Improved quality strategies are also on the increase according to Blanchard (2007) which again links to TQM and Six Sigma being the second and third most popular improvement methodologies.

1.2. Research Aim

The aim of this research was to develop an integrated improvement methodology framework that can be used by the manufacturing industry to improve their processes in order to become more efficient, effective and to attain their company goals. The framework utilised Lean manufacturing, Six Sigma and TOC as the main constructs. By combining these improvement methodologies comprehensively, better results can be achieved (Demchuk and Baitsar, 2015; Gupta & Snyder, 2009). The aim of this research was also to identify inhibitors that need to be managed to improve improvement methodology implementation. The reason a focus is placed on managing the inhibitors prior to implementation is that altering the effects post implementation is cumbersome (Yadav & Desai, 2017).

1.3. Problem statement

The problem is that, although there seems to be merit in combining Lean manufacturing, Six Sigma and TOC, there is a gap in the literature around the congruence between all three of the continuous improvement methodologies. Woeppel (2015), Nave (2002), Demchuck & Baitsar (2013), Spector (2006), Smith (2013), de Jesus Pacheco (2015) and Van Tonder (2011) have speculated that industry would welcome a combined approach, but there is uncertainty as to how the combined approach would be welcomed. Furthermore, this study determined what inhibitors needs to be managed to enable improvement methodology success.

Recent data on what theories are used in industry are not currently available (Katz, 2007). This study also determined if the chosen improvement methodology is aligned with the goal of the organisation and if the stated benefit of the chosen improvement philosophy was effective. The study determined the main strategy and focus area of the organisation's improvement methodology.

Through the results from the respondents, recent data will be known for improvement theories used in industry, if improvement methodology is aligned with the goals of the organisation and if the chosen improvement methodology achieved success. The findings also showed how to combine improvement theories.

This study also explored the inhibitors to implementation of improvement methodologies in the manufacturing industry. These management of these inhibitors will be included in the integrated improvement methodology in order to improve its effectiveness.

1.4. Scope of Research

The scope of this research was to create a framework for continuous improvement using improvement methodologies that have generally been used independently. It incorporated numerous process improvement practitioners from various industries using different methodologies. The process improvement practitioners that were included was senior managers or head of departments, middle or unit managers, junior managers, engineers or practitioners responsible for process improvement. The industries that were incorporated in the study was alcoholic beverages, automotive, cereals, chemical manufacturing, confectionery, dairy products, electrical, electronics or optical products, food, grains and wheat, machinery and equipment, meat and fish, metal or metal fabricated products, mining equipment, non-alcoholic beverages, non-metallic mineral products (cement, glass, ceramics, etc.), oil and gas, other transport equipment, personal care or toiletries (hygiene, cosmetics, etc.), pharmaceutical, printing, pulp, paper, publishing and printing, rubber and plastic products, textiles and textile products, tobacco, vegetables and fruit, wood and wood products.

The three main improvement theories' (Lean manufacturing, Six Sigma and TOC) principles, assumptions, effects and the arguments for and against each theory was compared. Combinations of improvement theories and shortcomings of a hybrid improvement theory was also be investigated. The scope of this research did not include leadership and organisation adoption and mind-set change for sustainable implementation. The research was conducted in South Africa.

Implementation of continuous improvement processes such as Lean manufacturing hasn't been seen as successful in the western world (European union countries, Americas, Israel, Australia, New Zealand and in part of South Africa) due the lack of understanding of cultural dimensions and it takes certain societal culture to promote these processes (Pakdil & Leonard, 2015). These cultural dimensions and their effects on implementation of continuous improvement processes was not be included in the scope of this research.

1.5. Significance of research

Achieving EBITDA results, reducing costs and increasing revenues has proven to be difficult in spite of extensive implementation and prolonged implementation of Lean manufacturing (the most widely used methodology) (Netland & Ferdows, 2016). Poor results persist and many organisations struggle with their operational excellence and continuous improvement efforts (Woeppel, 2015). This research is important due to substantial resources being spent on improvement programs in business. The effectiveness of said improvement programs will aid in business and organisation sustainability (Pepper & Spedding, 2010). It will also create value for managers responsible for continuous improvement, helping them to be more efficient and effective (Woeppel, 2015)

1.6. Purpose

The purpose of the research was to determine the breakdown of each improvement theories used in industry, if the benefits stated by the improvement theory actualise and how to structure the combined approach. A Lean manufacturing, Six Sigma and TOC congruency model was developed from these insights.

Chapter 2: Literature Review

Red queen theory postulates that long-term success isn't guaranteed by performance, but rather that it is obtained when improvements are done quicker and better than the organisation's competitors (Chakravorty & Hales, 2016). Red queen theory or the Red queen effect has its origins from Lewis Carrolls' "Through the Looking Glass" where the queen answers Alice that it takes all the running she can do to remain in the same place and that if she wants to get anywhere that she must run twice as fast. The proposition is therefore that, if organisations want to improve, they must do so more rapidly than their competitors in their environment if they want to maintain or improve their position (Chakravorty & Hales, 2016; Sabet et al., 2016).

Manufacturing is still an important area of modern civilisation and involves material, labour, energy, financial and intellectual resources. An efficient organisation requires that all activities, actions and decisions be aimed at the formation, effective functioning and continuous development of production structures. Due to the complexity of the modern conditions, obtaining this efficiency proves to be difficult (Demchuck & Baitsar, 2013).

Continuous improvement has been defined differently by various authors as a philosophy, methodology or a process. (Mora, 2014). For the purpose of this research it will be referred to it as a methodology. Continuous improvement has been defined as particular bundle of routines which help an organisation improve on what it currently does (Bessant, Caffyn & Gallagher, 2001). Another definition is that it is an initiative that applies bundles of practises such as sequencing of steps and sets of tools to execute the initiative (Anand, Kemmis, McTaggard & Zuber-Skerritt, 2009). Lahy & Found (2015) stated that continuous improvement is: "Any and all co-ordinated efforts designed to accelerate the achievement of specified organisational objectives through change, learning and innovation". For this research this definition will be used.

In order to create the competitive edge for a company various improvement methodologies have been used. Examples of these methodologies include Agile management, Design of experiments, Hoshin Planning or Hoshin Kanri, Just-In-Time, Kaizen, Lean manufacturing, Lean Six Sigma, Poka-Yoke, Process excellence, Re-engineering, Six Sigma, TQM and TOC (Gershon, 2010). Katz (2007) and Woeppel (2015) states that TQM, Lean manufacturing, Six sigma and TOC are the four most used improvement philosophies used in industry and all promote their approach as the go to methodology for process improvement success. These methodologies are often applied to value chain management that aims to convert market demand into profit by accelerating the velocity of the transactions or processes up and down the value chain (Rippenhagen, 2002).

According to Kumar, Maiti and Gunasekaran (2018), there have been various quality management principles used over the years which include Lean manufacturing, ISO 9001 Quality standards, Six Sigma, TOC, Total productive maintenance (TPM) and TQM. Although Kumar, et al. (2018) refer to these as Quality Management (QM) systems, for the purpose of this study, it will be referred to as improvement methodologies. The oldest methodology in this study is TQM and therefore was explored first.

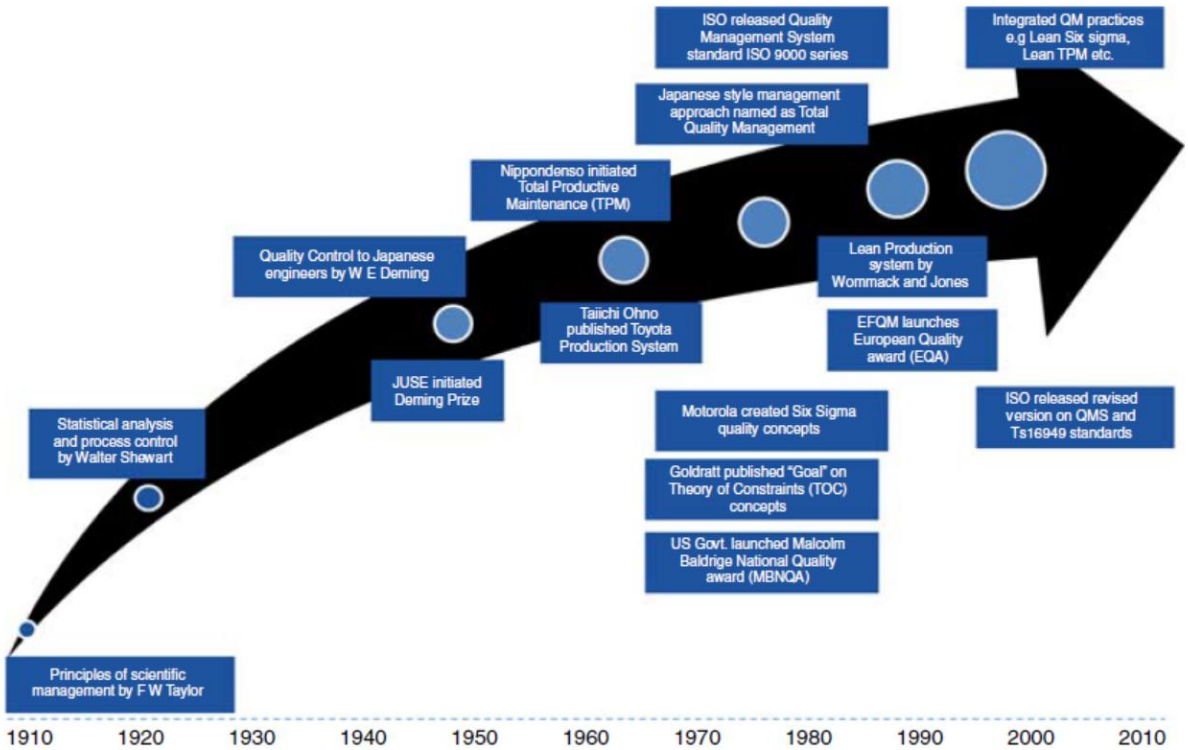

Figure 1. Evolution of Quality management systems (Kumar, et al, 2018)

2.1. TQM

TQM originated in 1951, but really took off as a process improvement methodology used in the 1970's and 1980's which aimed to make the entire company aware of the need for process improvement so as to improve the efficiency of the process, the quality of the throughput, customer satisfaction and ultimately lead to a more profitable organisation (Taylor, n.d.; Anthony et al., 2017; Banuro, Ntiri-Ampomah & Banuro, 2017; Kumar, et al., 2018). The problem with this methodology is that there were no standards in place and strategies are unclear (Taylor, n.d.; Harnesk & Abrahamson, 2007). TQM's shortfalls according to Black & Revere (2006) is that root causes of problems aren't being found while Dahlgaard-Park (2011) stated that TQM's shortfall as lack of agreement on its definition and the correct implementation by some organisations.

Gershon (2010), Taylor (n.d.), McLean et al. (2017) and Sabet et al. (2016) all agreed that TQM requires management support, a culture change to continuous improvement or a prescriptive methodology that allows for reproducibility. Ng, Rungtusanatham, Zhao & Ivanova (2015) agreed that culture and external environments needs to considered during TQM implementation. It is not in the scope of this research to investigate culture.

Kearney (1991) concluded that TQM has a failure rate of 80% and that it misses the mark in bringing about financial improvements. Youssef & Youssef (2018) stated that competiveness, inventory management, performance that is time-based, managing of inventory and management of quality is imperative for a manufacturing organisation to achieve world class manufacturing status. TQM does manage quality but is lacking in the other areas.

Gershon (2010) argued that TQM is the mother of all process improvement methodologies while Taylor (n.d.) stated that TQM was more of an idea, with many inconsistent management practices, that did not allow reproducibility. Kumar, et al. (2018) and Banuro et al. (2017) agreed that there is scarcity of formal TQM systems or frameworks and that there are many different models developed by different institutions. In order for a methodology to be reproducible, it requires a framework to be implemented. Thus the focus of this research will be Lean manufacturing, Six Sigma and TOC.

It can also be argued that TQM is not a sought after improvement methodology, due to TQM's slow implementation timeline of 3-4 years as compared to TOC, Lean manufacturing and Six Sigma which is ordinarily 1-2 years (Kumar, et al., 2018). The ISO 9001 Quality management system has also been linked to TQM and a lot of industries utilise ISO 9001 Quality Management (QM).

Askey and Dele (1994) argued that ISO9001 QM system (ISO 9000 during that period) is the logical next step from TQM while Poksinska, Jörn Dahlgaard & Antoni (2002) argued that ISO 9001 QM system is rather a subset of TQM. Youssef & Youssef (2018) argued that TQM and ISO9001 QM system are not substitutes and should be treated as different methodologies. In 1999, Terziovski, Sohal & Moss already found that TQM popularity has decreased while ISO 9001 certification has increased. Therefore, ISO 9001 QM system was examined separately.

2.2. ISO 9001 QM system

The largest standards developing organisation is ISO (International standards organisation) and started in 1946 when representatives from 25 countries convened to create an establishment that facilitates the coordination and unification of industrial standards (Rokke & Prakash Yadav, 2012)

This study agreed with Hammar (n.d.) that ISO 9001 doesn't explain how to implement or maintain improvement although it advocates that improvement is a requirement. Hence, ISO 9001 QM system is not an actionable improvement methodology. Kumar, et al. (2018) stated that the effectiveness measures are customer complaints, internal rejections and non-conformities which are reactive measures as opposed to Six Sigma which monitors process capability variations which is a pro-active approach. Cauchick Miguel & Celso Sobreiro Dias (2009) agreed that ISO 9001 QM system is reactive in that it cannot guarantee product quality but instead assesses the quality of operations. Six Sigma has a higher value adding contribution quantification of cost savings and project orientation focus as opposed to the ISO 9001 QM system that distinguishes its value add by Standard Operating Procedures (SOP's), internal audits and management reviews (Kumar, et al., 2018).

Wu & Chen (2011) argued that ISO-certified manufacturing companies show considerably higher performance in all areas than uncertified ones. In contrast, Kumar (2018) stated there is a positive impact on an organisation's performance that have implemented TQM, TPM and Lean, but it is not the case for an ISO 9001 QM system. The ISO 9001 QM system is a good assurance tool to suppliers, customers and stakeholders if you want to demonstrate quality control in an organisation through being certified (Hammar, n.d.). It is however a management system as opposed to an improvement methodology.

The ISO 9001 QM system is generally accepted as a requirement for prosperous global trade according to Denton & Maatgi (2016) and the process can be seen in Figure 2 below. Poksinska et al. (2002) and Denton & Maatgi (2016) further stated that ISO 9001 QM system benefits are to build customer confidence, improve the ability to bid on tenders, are mostly used as a marketing tool or it might be due to government requirements. These do not align to the requirements for an improvement methodology to enhance sustainability and increase its competitive advantage. Briscoe, Fawcett & Todd (2005) however stated that there is little difference between certified and non-certified companies and that the certified companies do not yield expected quality, profitability and productivity improvements. There is also an increase to quality costs (Briscoe et al., 2005). Figure 2 below indicates the ISO 9000/9001 improvement process.

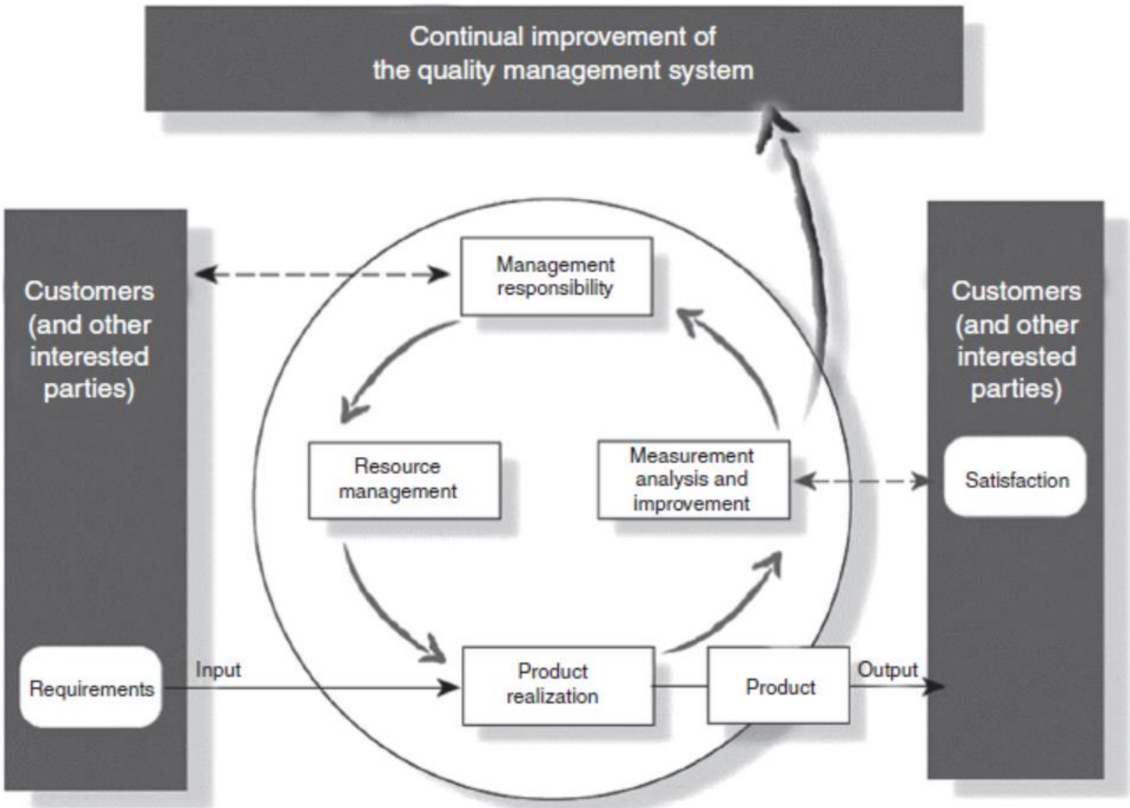

Figure 2. The ISO 9000/9001 process (Denton & Maatgi, 2016)

Kuo, Chang, Hung & Lin (2009) further stated that companies have had mixed success in using use of the ISO 9000 QM system for improvement. Barnes (2000) state that instead of companies pursuing quality, they pursue certificates which is not the intent for an improvement methodology.

The Manufacturing Performance Institute (MPI) also do not see the ISO 9001 QM system as an improvement methodology and define them as certifications (The MPI Group, 2014). The ISO 9001 QM system is has not significantly improved product quality and was not design as an enhancement or improvement program (Quazi, Hong & Meng, 2002). ISO 9001 does not detect quality issues and it is a collection of standards that govern documentation regarding a quality systems and is very inflexible (Krajewski & Ritzman, 1999; Pfeifer, Reissiger & Canales, 2004). The Manufacturing Performance

Institute (MPI) does however see Lean manufacturing as an improvement methodology and therefore it was investigated (The MPI Group, 2014).

2.3. Lean manufacturing

Lean manufacturing is the brainchild of Toyota production systems (TPS) and focusses on eliminating losses and increasing profits. Lean's strategic intent is to reduce waste and create a smooth flow between production processes (Antony, Kumar & Madu, 2005; van der Krogth, Gerathy, Salman & Little, 2010). Similar to the Theory of Constraints, Lean manufacturing advocates the improvement of fast flow of material (Moore & Scheinkopf, 1998; Anthony, Snee & Hoerl, 2017).

The National Institute of Standards and Technology (NIST)'s Manufacturing Extension Partner (MEP) defines Lean manufacturing as follows: "A systematic approach to identifying and eliminating waste through continuous improvement; flowing the product at the pull of the customer in pursuit of perfection" (NIST, 2003).

The seven types of waste, called Seven Muda in Japanese, was identified by Taiichi Ohno (the father of Toyota Production Systems) in 1988 and is abbreviated as TIMWOOD to recall it easily (Chan & Tay, 2018) . TIMWOOD refers to transport, inventory, movement, waiting, over-processing, over-production and defect wastes. (Spector, 2006; Chan & Tay, 2018). When the Toyota Production System was adopted in the Western world and when Lean Six Sigma was brought together, the 8th waste namely skills or also known as unutilised talent was introduced (Skhmot, 2017; Munk, 2015; Smekens & Zeelenberg, 2015).

An advantage of Lean manufacturing is that by eliminating waste you can also decrease processing time (Bentley, 2011). On the other hand it does not allow for the system to be analysed as a whole, but instead depends on many small improvements at various processes (Bentley, 2011).

Figure 3 below depicts all 8 waste types. The reason the "S" for skills was included is due Potdar, Routroy & Behera (2017) stating that employees' improper knowledge of work activities are inhibitors to improvement. Pirasteh & Kannappan (2013) suggested in their iTLS framework, which will be discussed later, also include training at each step of their process.

Figure 3. 8 Wastes of Lean manufacturing (TIMWOODS) (Skhmot, 2017)

Lean manufacturing also places activities into the following categories (Van Tonder, 2011):

- Value adding (A change in the features, nature or form of a product by a process aligned to customer requirements)
- Non-value adding (A process that doesn't increase product value but is necessary)
- Waste (Activities can be eliminated immediately because they that do not increase product value and are non-essential.

In Figure 4 below, the Lean manufacturing temple as created by Toyota can be seen. The foundation is built on an organised workplace, visual performance measures, standard operating procedures, problem solving and Total productive maintenance (TPM) where everybody inspects, cleans and maintains equipment (Liker, 2004). TPM however is not considered as an improvement methodology itself as it focussed on autonomous and planned maintenance activities requiring involvement from shop-floor workers (Kumar et al., 2018). It is not only a pillar of Lean manufacturing, but can also be complimentary to other improvement theories like TQM with lower improvement maturity (Stamm, Neitzert & Singh, 2009)

The pillars of the house is Just-in-time (JIT) and Build in quality. JIT refers to materials being delivered as they are needed and Built in quality refers to poor quality work not being transferred to the next station enabling capacity to be unlocked (van Tonder, 2011).

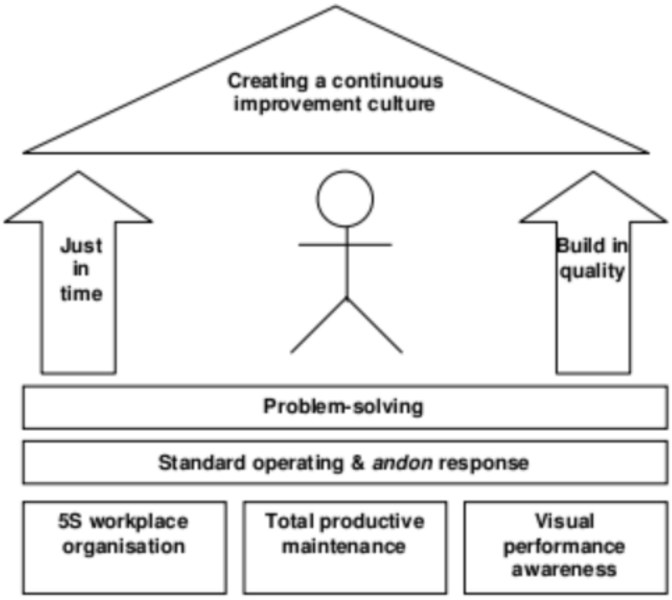

Figure 4. The Lean manufacturing temple (van Tonder, 2011)

In contrast to the Theory of Constraints, Lean manufacturing advocates a balanced plant. According to Bhamu & Singh Sangwan (2014), supplier integration and distribution systems have found it difficult to implement Lean manufacturing techniques due to conflict between it and the production pull signals to variable market demand. This is where TOC is beneficial. Stoll (2011) argued that Lean principles isn't applied where it can give companies most bang for their buck and Lean programs are often viewed a checklist of do's and don'ts. TOC can assist to provide this focus but cannot do so alone if not embraced as a strategic initiative supported by the business.

While there are many examples of radical achievements through Lean manufacturing, companies have challenges staying on track and 36% of Lean practitioners stated that backsliding to old ways of work is the main challenge (Spector, 2006). This might be due to it being mostly used in a companywide which makes change difficult (Cheng, 2017). It is however still considered as the go to improvement methodology in industry (Netland & Ferdows, 2016). This might be due to Lean manufacturing and IT (information technology) being closely linked because to reduce costs firms have turned to IT (Pinho & Mendes, 2017).

According to Ghobakhloo & Azar (2018) there are variations in Lean manufacturing's performance and benefits, I has also been costly to implement and has also been time consuming. According to Boyd & Gupta (2004), Lean manufacturing and TOC focusses on matching demand, but TOC's difference is it aware that production flow is restricted by the constraint. Lean manufacturing is also closely related to TQM in that companies often employ both, but the criticism is that they aren't targeted where their effects will have the most impact but a blanket approach is used (Boyd & Gupta, 2004). Another criticism of Lean manufacturing it is not good at resolving complex problems requiring statistics and data analysis (Anthony et al., 2017). This is where Six Sigma can support Lean manufacturing.

Lean manufacturing philosophy can be seen in Table 1. Although most of the philosophies points are worth striving for, they do not all hold true in any manufacturing environment. Lean manufacturing's low inventory causes a sense of urgency and other processes are also affected when one process stops (Van Tonder, 2011). The idea is management will be forced to resolve the problem and find the root cause due to the business hurting (Van Tonder, 2011). This is however not a sustainable approach as continued losses which the business isn't buffered against can cause it to shut down.

Table 1

Lean Manufacturing Philosophy

Quality doesn't increase costs	The workers are the experts
Mistakes leads to process improvement	Inventory hides problems
Small lot sizes	No work-in-progress queues
Automate	Reduce variation
Pull material	Contract lead times
Labour should always add value	Labour is a fixed cost
Machines should be slow and steady	Procure from single supplier
Don't expedite work	

Note. Adapted from Schmenner (2012)

Agile Manufacturing uses concepts from Lean manufacturing and therefore had to be included in the literature review.

2.4. Agile manufacturing

An organisation's ability to rapidly respond to changes in a dynamic and turbulent market, be flexible and accurately meet aggressive customer needs are referred to as Agile Manufacturing (Abdallah & Nabass, 2018).

Abdallah & Nabass (2018) were of the opinion that Agile Manufacturing will lead to Lean Manufacturing and significant affect operational performance. Lean manufacturing should form the foundation of Agile Manufacturing due to the latter borrowing some of its concepts (Potdar et al., 2017; Gurahoo, 2015). Potdar et al. (2017) argued that cost reduction is vital in manufacturing and Agile Manufacturing does not focus on this objective but rather on responsiveness. In contrast, Iqbal, Huq & Bhutta (2018) stated that Lean manufacturing and Agile manufacturing pursue the same objectives namely lead-time improvement, quality and cost competitiveness.

Lean manufacturing contain all the elements of Agile manufacturing and they are deeply interconnected (Iqbal et al., 2018; Bortolotti, Danese, Flynn, & Romano, 2015; Inman, Sale, Green & Whitten, 2011; Gunasekaran, Lai & Cheng, 2008; Ramesh & Devadasan, 2007). Agile and Lean manufacturing strategies are mutually supportive (Bhamu & Singh Sangwan, 2014). Hence the argument is proceed with employing Lean manufacturing directly.

Lean manufacturing and Agile manufacturing have been criticised for not utilising statistical analysis which is Six Sigma’s primary strength and therefore Six Sigma was studied.

2.5. Six Sigma

Six Sigma is a method for process improvement through reduction in variability and was first introduced at Motorola in mid-to-late 1980s (Hayler & Nichols, 2007; Pyzdek, 2003; Anthony et al., 2017). Its strategic intent is to stabilise. In statistics, sigma (σ) measures the intrinsic variability of a process which is called the standard deviation. A low standard deviation should improve process quality and performance as well as lowering the possibility of failure (Cheng, 2017).

Chiarini (2013) stated that TQM and Six Sigma can exist side-by-side in an organisation. In contrast, Sabet et al. (2016) as well as Näslund (2008) argue that it Six Sigma should rather be built on a TQM foundation and that Six Sigma is a further development of TQM. Gershon (2010), Antony et al. (2005) and Pande, Neuman & Cavanagh (2000) stated that Six Sigma overcomes the shortfalls and is an improved version of TQM. Pande et al. (2000) also stated that Six Sigma is now frequently used in organisations due to improvement and maintenance of quality of processes being imperative in any business. Six sigma is seen as TQM 2.0. It aims to achieve an error free business and is driven by disciplined use of facts, data and statistical analysis (Gershon, 2010).

Six Sigma's systematic and structured methodology has obtained widespread industry recognition due to it advocating focus on customer requirements and its bottom line impact. Measurement system statistical and quality control analysis has been one of the several techniques and tools developed (Prashar, 2016). According to Stamm et al. (2009), TQM and Lean manufacturing is not as orientated on fast and tangible results and doesn't give clear adjustment of structure when compared to Six Sigma.

An advantage of Six Sigma is that reducing variation in the process creates uniformity in the output (Bentley, 2011). This is important as continuously improving a system that has a lot of variability or is unstable is challenging (Hudson, 2017). As with Lean manufacturing, Six Sigma does not allow for the system to be analysed as a whole, but instead looks at various process steps independently. Also, interactions between the various steps are not generally considered (Bentley, 2011). Pull systems like TOC and Lean manufacturing can reduce the disruptions that inventory excess can cause especially when variations in quality and throughput have been reduced (Schmenner, 2012). This is where Six Sigma can assist TOC and Lean manufacturing.

Six Sigma requires graduate level understanding of applied statistics whereas Lean manufacturing requires only basic math operations (additions, subtraction, multiplication and division) (Bentley, 2011). This might explain why Lean manufacturing is more popular than Six Sigma and why Six Sigma is seen as more of a prestigious qualification. Prashar (2016) and Anthony et al. (2017) stated that the limitations of Six Sigma are that it needs incorporation into the existing management systems, it requires a theoretical foundation, it is subjective in improvement project selection, it takes too long for data analysis, lack of action and then it is also cut off from the business strategy.

The main differences between Six Sigma and Lean manufacturing is that the former's focus is to reduce defects, it is based on statistical formulas and is data driven where the latter is focussed on reducing non-value add processes, best practises and is observation driven. Both require a change of mind-set of leadership and employees (Lean Six Sigma experts, n.d.; Banuro et al., 2017). The Six Sigma Framework can be seen in Figure 5 below:

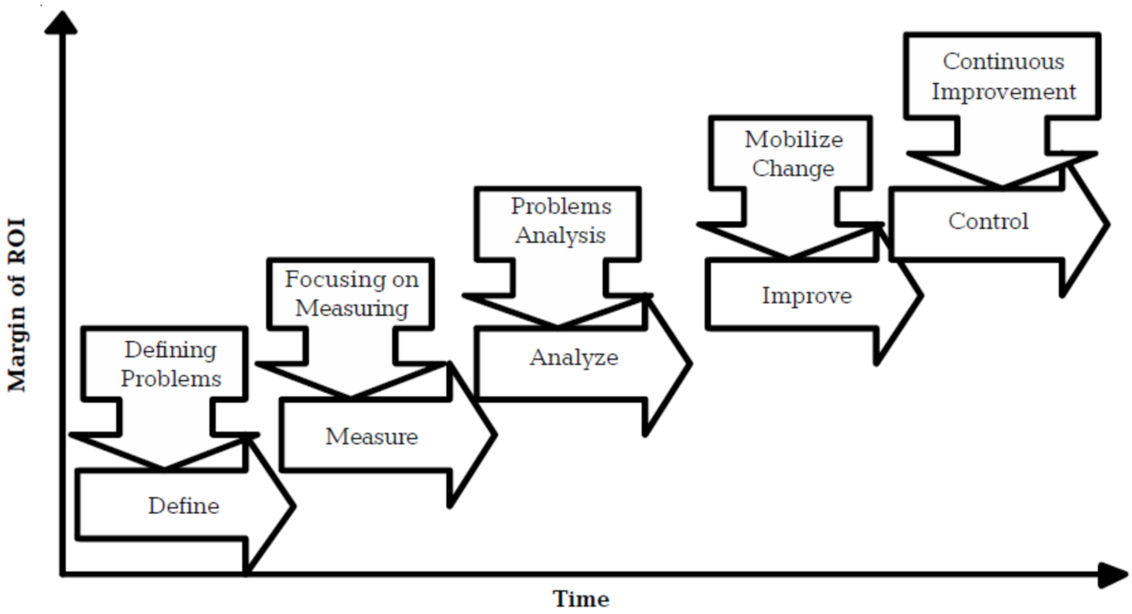

Figure 5. Six Sigma DMAIC framework (Cheng, 2017)

Even though Lean manufacturing and Six Sigma each produced results, they had their own limitations, therefore combing the methodologies seem logical (Anthony et al., 2017). Which lead to the formation of the Lean Six Sigma improvement methodology.

2.6. Lean Six Sigma

Anthony et al. (2017) and Bhuiyan & Baghel (2005) argued that Lean Six Sigma (LSS) has become one of the preferred and recognised business process improvement methodologies. Albliwi, Anthony & Lim (2015) stated that implementing LSS ensures that a company stays in competition and increase customer satisfaction, it improves product quality and manufacturing operations, it increase bottom line savings and top line growth and also reduces poor quality costs. In manufacturing LSS however still has the following limitations: a sustainable framework, lack of standardised programmes, no globally accepted standards, lack of a blueprint and not a lot of published case studies (Anthony et al., 2017).

Sig Sigma techniques require and organisation to be as Lean as possible (Pepper & Spedding, 2010). The challenge with this adoption is the ideal Lean manufacturing state is extremely difficult. But if it was focussed at the bottleneck, it is a lot more achievable. Stamm et al. (2009) argue that Lean focusses on process interconnection, speed and flow while Six Sigma's DMAIC provides big picture view and process stability.

Although Anthony et al. (2017) still argued that LSS must be used for comprehensive improvement, they further state that LSS needs to be improved to focus on mission critical problems. Patil & Mishra (2014) agreed that this methodology needs improvement as 60% of Lean Six Sigma initiatives fail and automakers are still unable to copy the success of Toyota due to the need for an integrated approach. This is where TOC can assist.

Assumptions from Lean manufacturing is business performance will automatically improve if waste is reduced and Six Sigma assumes overall the system will improve should variability be reduced everywhere (Spector, 2006). Again, the high failure rate of these initiatives might be due to there being too many projects, and the ones that can provide the greatest impact, aren't getting the most attention.

Timans, Ahaus, van Solingen, Kumar & Antony (2016) proposed the framework in Figure 6 below for implementation of a Lean Six Sigma program. These steps can be incorporated into a combined framework to enhance its implementation success rate.

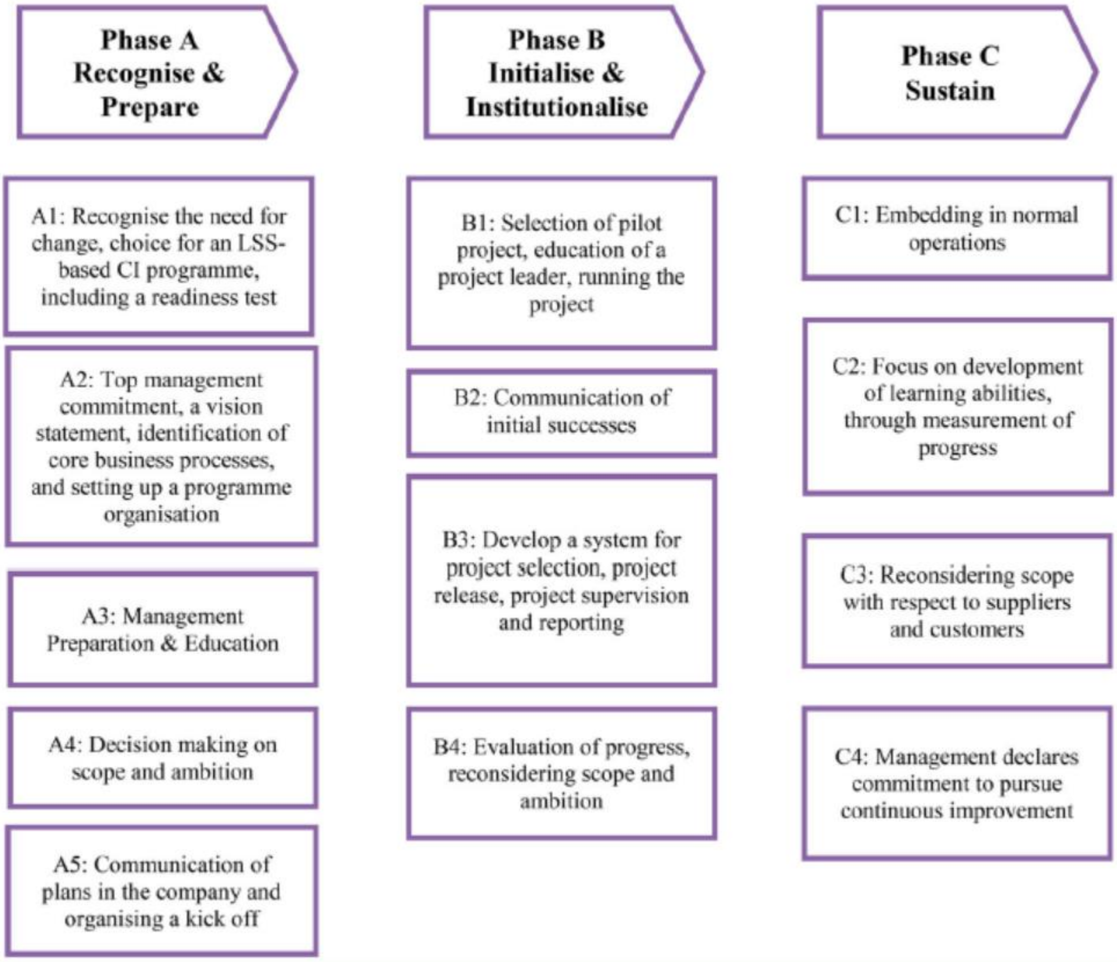

Figure 6. Lean Six Sigma implementation framework (Timans et al., 2016)

The key to enhancing business performance through Six Sigma is the DMAIC process (Cheng, 2017). The reason this study focussed on the DMAIC process is due to 80% of Six Sigma improvements coming from this approach (Hudson, 2017). The improvement framework of LSS and can be seen in Figure 7 below:

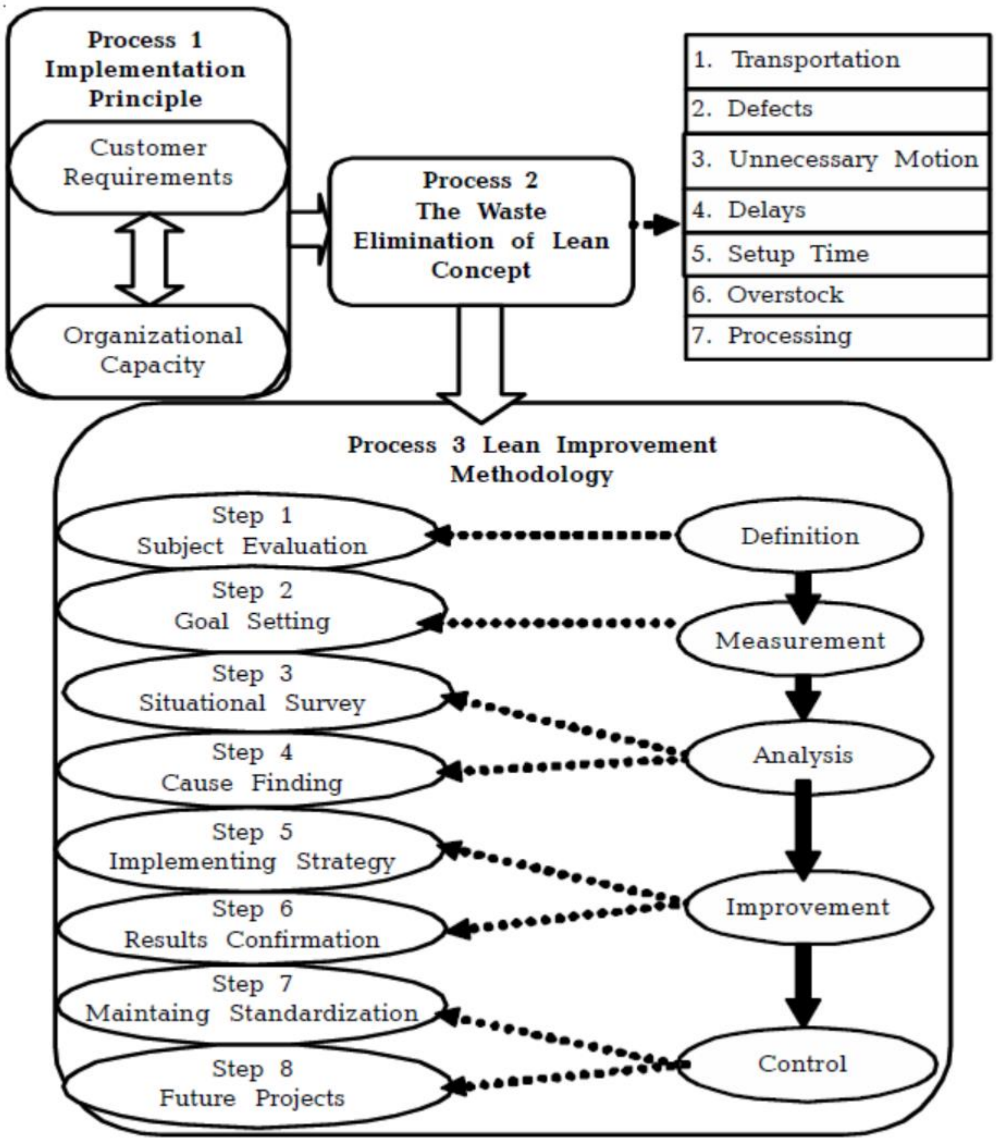

Figure 7. LSS framework (Cheng, 2017)

Arnheiter & Maleyeff (2005) stated that an organisation that implements Lean Six Sigma would be able to make best use of its operations by ensuring it is value-adding, favours global instead of local optimisation, makes customer centric and data-driven decisions and minimises quality variation. As seen in Figure 8 below, Arnheiter & Maleyeff (2005) and Pepper & Spedding (2010) stated that Lean Six Sigma provides a good producer-customer balance.

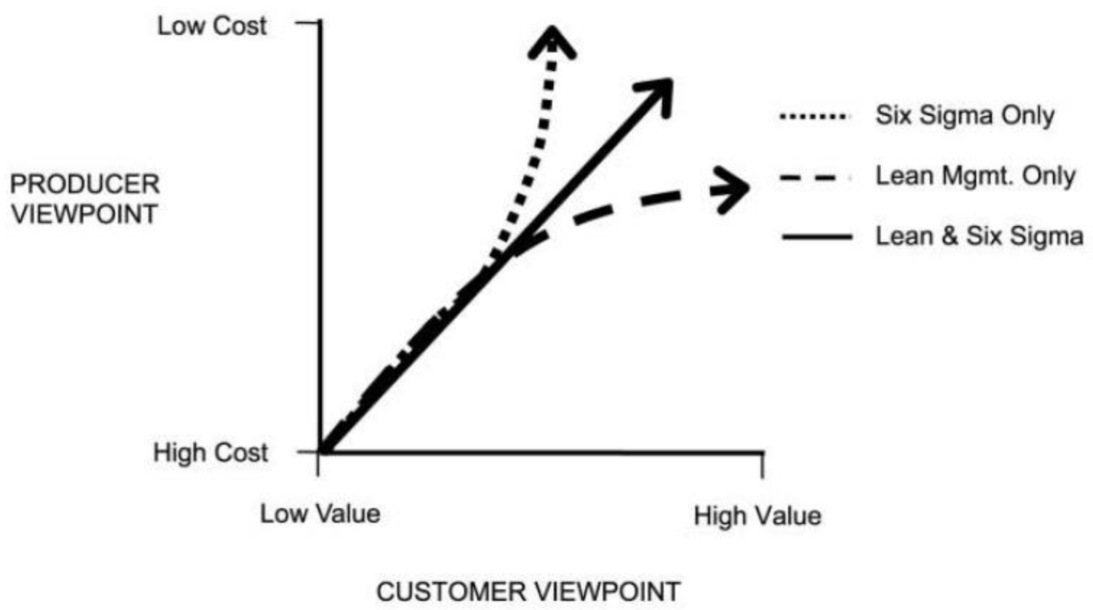

Figure 8. Lean Six Sigma competitive advantage (Arnheiter & Maleyeff, 2005)

Byrne & Blitz (2007) state that Lean Six Sigma concerns itself with not only doing better things but also doing things better. The challenges is it does not answer where to do this. TOC can assist in where to find this leverage point.

2.7. Theory of constraints (TOC)

Theory of constraints (TOC) was first conceptualised by Eliyahu Goldratt in the 1980's and its focus is on managing constraints and generating gains (Coman & Ronen, 1995). TOC's strategic intent is to synchronise the plant. Because production processes are dependant, it breaks this dependency by placing an input buffer to the constraint (Mabin & Baldersone, 2003). In contrast, Lean manufacturing states inventory or buffers hide problems and doesn't allow them to surface while in conjunction costing you money to carry and space (Schmenner, 2012).

TOC mimics Liebig's law (in agricultural studies) in that the scarcest resource or limit factor limits growth (or in the manufacturing industry throughput) and not the amount of total resources available (Stamm et al., 2009). According to Cook (1994) and Sabet et al. (2014), TOC has proved to be highly effective and successful, it has a wider application than Lean manufacturing does and has been promoted to have higher flow yields (Cook, 1994). Moore & Scheinkopf (1998) stated however that Lean manufacturing implementations are useful, but even more so if applied at the organisations inhibiting aspects.

Three fundamental questions are required by TOC with relation to an organisation's ongoing process improvements (Gupta & Snyder, 2009):

1. What needs to change or how do organisations define their weakest link?
2. What must the weakest link change to? What good and practical solutions must be used to strengthen the weakest link?
3. How should the change be brought about or how should the solutions be implemented?

An advantage of TOC is that by identifying the bottleneck in the production process and addressing this, the business achieves a faster throughput and produce bottom line results. (Bentley, 2011; Creasy, 2014). TOC seems to be the only independent origin improvement methodology which creates a new manufacturing paradigm evolution and indicates superiority when combined with other improvement methodologies (Stamm et al., 2009).

Boyd & Gupta (2004) suggested that for TOC to work and be fully implemented, an organisation must shift in decision making, measurement systems related to performance and the organisation's mind-set as seen in Figure 9 below. Although, TOC focuses on the constraints, it does require the whole organisation to be orientated towards throughput maximisation through constraints management (Boyd & Gupta, 2004).

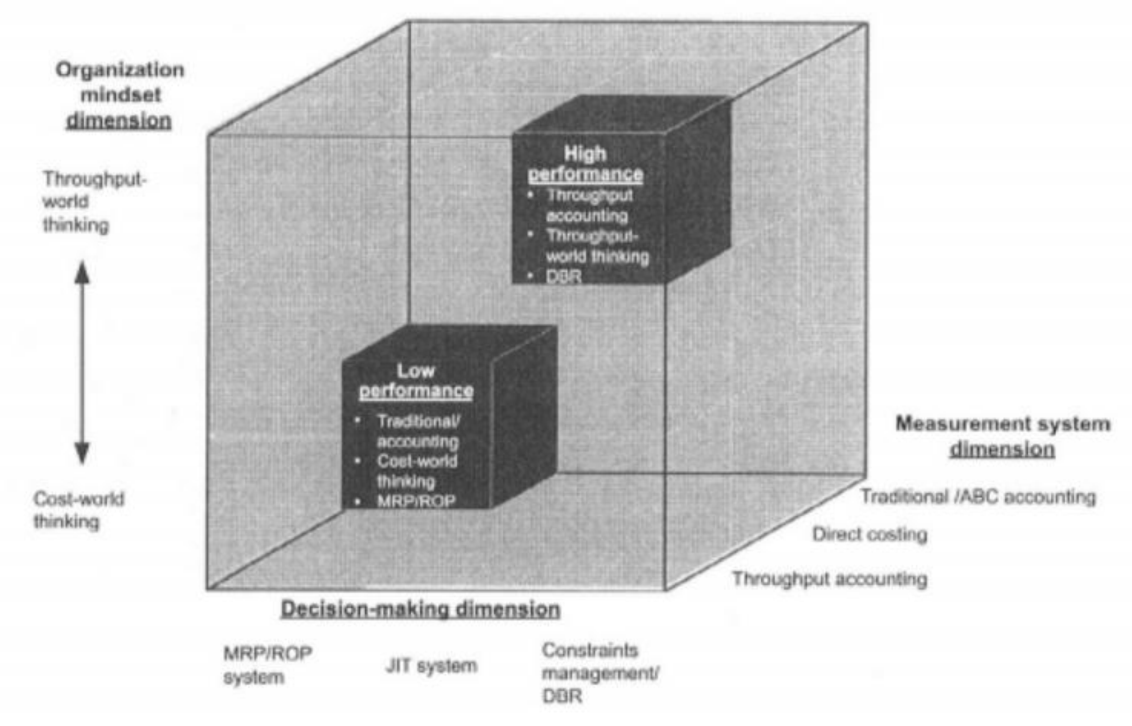

Figure 9. Three dimensional throughput oriented thinking (Boyd & Gupta, 2004).

Some criticisms of TOC are that data analysis is not as valued compared to Six Sigma. Also minimal input from workers is considered (Bentley, 2011). Another criticism of TOC is that in some cases the constraint process is affected by variability of non-constrained processes and its performance is limited due to it not looking at these variabilities of non-constrained processes (Filho & Uzsoy, 2014).

Furthermore, other criticisms of TOC is that there is no real clarity on the best constraint location, additionally its inability to deal with non-physical bottlenecks and finally that there is no clear green light on when to move to the next step (Pretorius, 2014).

TOC advocates have criticised that Material Resource Planning (MRP) is not an improvement methodology but that it requires accurate records of inventory, bill of materials and orders (Boyd & Gupta, 2004). MRP is important but it is a non-value adding process (Lean manufacturing comes to mind), it does not increase product value but is necessary.

Compared to Lean manufacturing's goal of seeking perfection, TOC might not be as glamourous by reducing constraints, but due to the complexity of today's organisation the leverage point need to be established (Moore & Scheinkopf, 1998).

Figure 10 indicates the five TOC focussing steps with in between decision stages as developed by Pretorius (2014) which will form the basis of an integrated process improvement model utilising TOC. There has been no change made to the initial step. A decision point has been created between step 1 and 2. The argument is that initially the constraint will be obvious and physical, but as the process has gone through a couple of iterations, the constraints can become non-physical Pretorius (2014).

Pretorius (2014) has not changed the process between step 2 and 3, but after step 3, a couple of in between decision points have been created. Step B verifies that the right constraint was chosen (Pretorius, 2014). Subordination will not be possible if the wrong constraint is chosen (Pretorius, 2014). Step C1 determines if the non-constraints are to be broken. In contrast to Lean manufacturing, TOC does not advocate a balanced plant as this will destroy flow according to Pretorius (2014). A balanced plant through dependent events and statistical fluctuations decreases throughput and increases inventory (Goldratt & Cox, 2016).

Decision point D comes into effect if performance is satisfactory which creates a cycling loop between step 2 and 3 Pretorius (2014). Step E deals with ideal constraint location and in some cases it might not be desirable to move the constraint (Pretorius (2014). The rest of the process follows the standard TOC process.

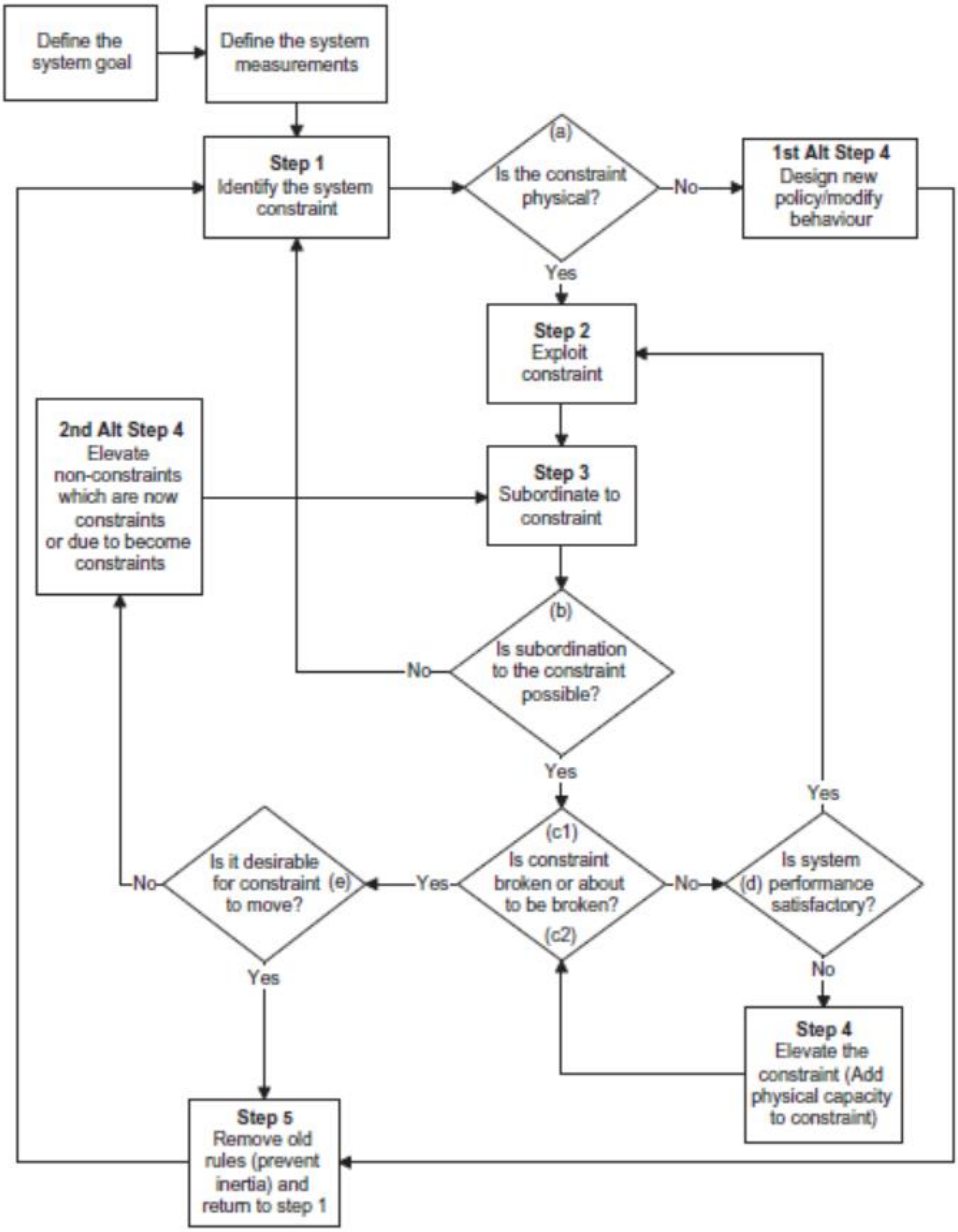

Figure 10. In between decision stages to the five TOC focusing steps (Pretorius, 2014)

Lean manufacturing, Six Sigma and TOC often seem to be in conflict with each other creating confusion between their differences, effects and similarities (Nave, 2002). Therefore a comparison was made between the theories.

2.8. Comparisons

The traditional approach to improve the manufacturing process is an additive approach which basically targets each problem as it is identified in the manufacturing process and then aims to correct these problems (Woeppel, 2015). Whereas the systems approach aims to identify a so-called “leverage point” in the process (Woeppel, 2015). In other words, not every problem that is identified and corrected will improve the system as a whole, one has to take a focused approach to identify the leverage point which will improve the system as a whole (Woeppel, 2015).

The problems with the traditional approach is that managers become frustrated with the continuous projects and after a time tend to stop supporting the projects, as many of these projects don’t achieve their expected outcomes (Woeppel, 2015). Many of these projects don’t improve overall company performance, which also tends to decrease the support for these improvement projects (Woeppel, 2015). According to Cook (1994), each improvement methodology, whether it be Lean manufacturing or TOC, require discipline and can’t each be seen as the solution to all difficulties.

Figure 11 below shows an historical development of manufacturing improvement methodologies, their needs, evolution and timelines.

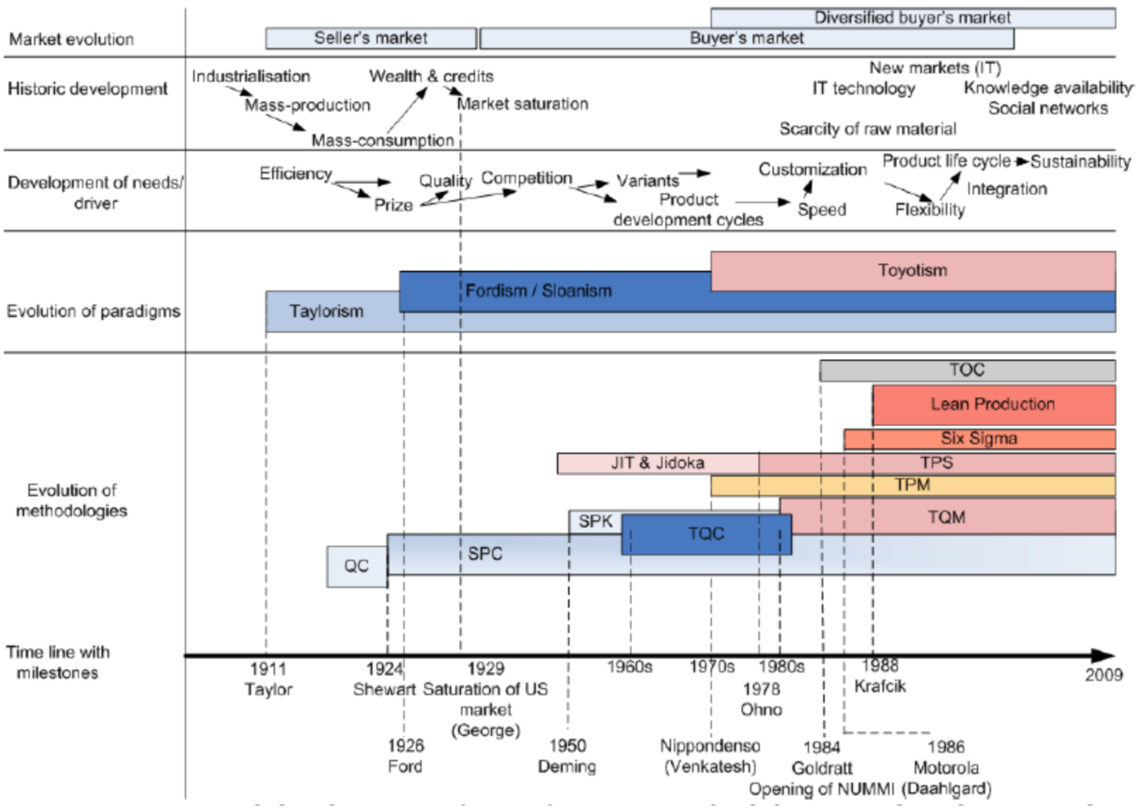

Figure 11. Historical progress of manufacturing methodologies (Stamm et al., 2009)

In conclusion, TOC focuses on constraints in the system, Lean focuses on production flow and Six Sigma is problem focused (Nave, 2002). Nave's thinking is flawed however as he states that improvement methodology adoption should be dictated by what is valued not what is necessary for the business or what the customer requires.

Ras & Visser (2015) stated that more than 70% of Lean manufacturing, Six Sigma and TOC are successful but organisations would still welcome a combined approach. Mclean, et al., (2017) stated in contrast that continuous improvement initiatives have a high failure rate. The main reasons continuous improvement programs fail according to Woeppel (2015), is due to continuous improvement teams advocating tool adoption and not achieving business goals, cost savings not being geared toward EBIDTA (cost savings are a mirage) and poor focus on what needs to be leveraged.

A combination of process improvement methodologies will lead to the production of better quality outputs, a decrease in inventory, increase in profits and an improvement powerhouse (Stamm et al., 2009; Nave, 2002; Creasy, 2014; Sproul, 2009). According to Patil & Mishra (2014), 30% of organisations have implemented a combination of improvement frameworks and practises which points to the need for an integrated framework. A comparison between improvement theories can be seen in Table 2 below.

Table 2

Improvement Theory Comparisons

Program	**Lean manufacturing**	**Six Sigma**	**Theory of Constraints**
First mentioned	1988	Late 1980	1984
Theory	Remove waste	Reduce variability	Manage constraints
5 Basic principles	1. Identify value 2. Identify value stream 3. Flow 4. Pull 5. Perfect	1. Define 2. Measure 3. Analyse 4. Improve 5. Control	1. Identify 2. Exploit 3. Subordinate 4. Elevate 5. Review
Primary objective	Value creation	Cost reduction	Profit maximisation
Main focus area	Flow or product or service	Problem solving	System constraints

Program (cont.)	Lean thinking (cont.)	Six Sigma (cont.)	Theory of Constraints (cont.)
Assumptions made by theory	Removal of waste will improve business performance	System output improves if variation of all processes are reduced	Processes are interdependent. A constraint exists either internally or in the market. Speed and volume are important. Existing systems can be used
Primary effect	Reduced flow time and increased efficiencies	Uniform process output or effectiveness and reduced quality variation	Throughput improvements or productivity
Secondary effects	Reduced variation and inventory. Quality improvement	Reduction in waste and inventory and increased throughput	Inventory and waste reduction. Quality improvement. Performance management system
Arguments against theory	Statistical or system analysis not valued	System interaction not considered and processes looked at independently	Data analysis not valued. Worker input is minimal
Process used	Any process	Repetitive processes	Any process
Topics	• Value stream maps • Pull systems • Cell-like structures operations	• Variation • FMEA (Failure mode and effects analysis)	• Critical chains • Evaporating clouds • Prerequisite Tree • Throughput accounting

	• Reducing setup times • Little's law • 5S (Sort, Set in order, Shine, Standardise and Sustain) • Team Leadership • One piece flow • Process grouping • SMED (Single minute exchange of dies) • Kanban systems • Visual factory • Just-in-time • Takt Time • Balancing of workflow • Lean scheduling • Heijunka (levelling) scheduling • Poke Yoke (mistake-proofing)	• Experiments design • Inferential statistics • Simulation • Measurement systems analysis • Histograms • DMAIC (Define, Measure, Analyse, Improve and Control) • Capability calculations • Descriptive statistics • Quality cost • Reliability • Control Charts • DFSS (Design for Six Sigma) • Goodness of fit testing • Software applications • Team leadership • Regression & Correlation	• The thinking process • FMEA • Transition tree • Adequate and essential conditions • Drum buffer rope (DBR) • Future and current reality trees • Constraint identification

Note. Adapted from Nave, 2002; Stamm et al., 2009; Bentley, 2011; Cheng, 2017; Kumar et al., 2018)

According to de Jesus Pacheco (2015) there is more similarity between methodologies than exclusion. From the comparison there is some but not concise overlap between

Lean manufacturing, Six Sigma and TOC. Therefore an integrated framework called TLS was studied.

2.9. TLS (TOC, Lean and Six Sigma)

Figure 12. Integrated TLS model (Woeppel, 2015)

Van Tonder (2011) argued the starting point for any organisation is value creation for the target market, society and the economy and performance measure incorporate this to enable alignment. Demchuck & Baitsar (2015) stated that TOC, Lean manufacturing and Six Sigma methodologies are complimentary and that an integrated methodology would provide systematic and a focussed approach for improvements. The benefits are (Demchuck & Baitsar, 2015):

- Organisation wide improvement benefits
- Better return on investment and profits
- Improved strategic target success through reduced process variability
- The methodology doesn't need to change every time there is lack of success but just the implementation and deployment thereof

TOC, Lean manufacturing and Six Sigma have many overlapping elements and an integrated approach will not only enhance competitiveness but is one of the most promising improvement methodology combinations (de Jesus Pacheco, 2015; Demchuk & Baitsar, 2013). Demchuck & Baitsar (2015) suggested that, from a quality assurance perspective, TOC should be used first, followed by Lean manufacturing tools and then the last phase should be Six Sigma.

Lean manufacturing and Six Sigma should be prioritised according to Spector (2006). If a constraint is internal, Lean manufacturing should be prioritised (to reduce waste and improve flow) and if it is external, Six Sigma should be prioritised (to make offerings more attractive) (Spector, 2006). The challenge with adapting the framework too often once constraints get eliminated is that it could cause the workforce to start getting confused regarding the benefits of the methodology used and make them resistant to change. Pirasteh & Kannappan (2013) proposed the framework as depicted in Figure 13 to implement its iTLS approach to process improvement.

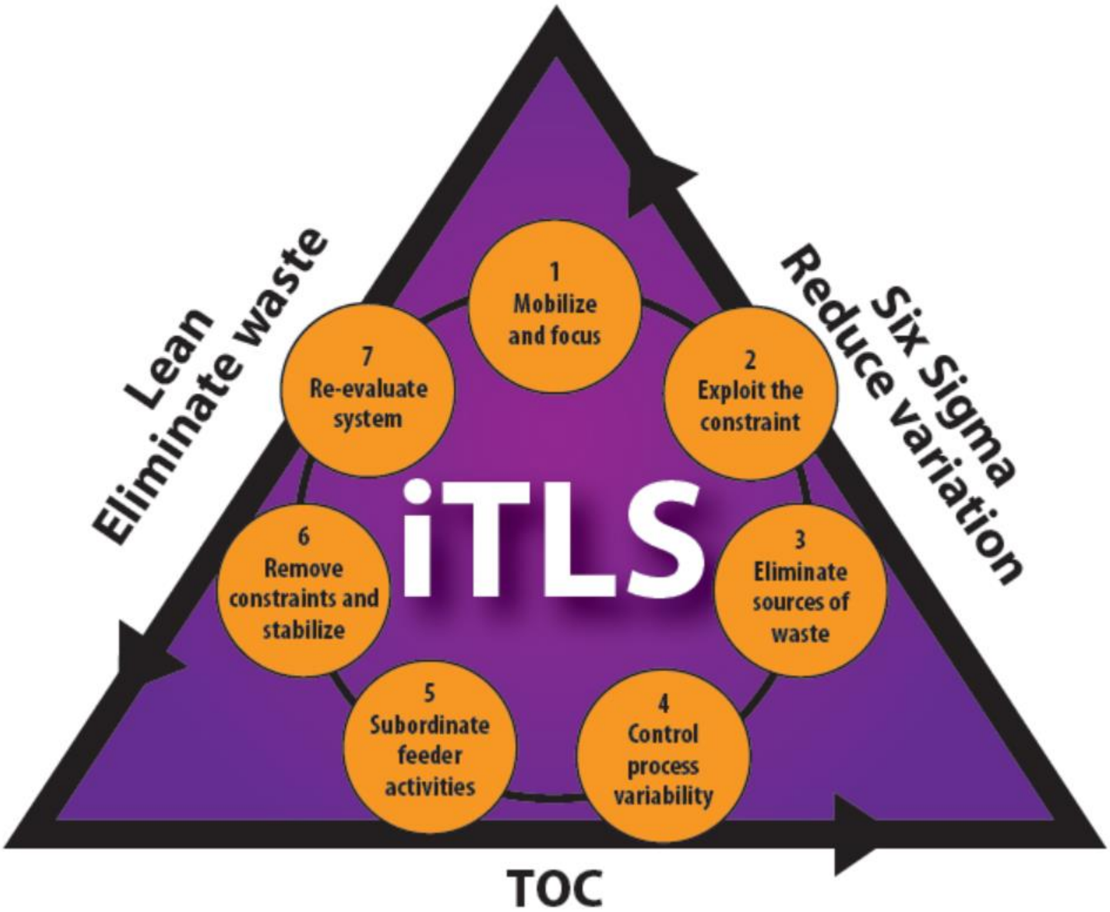

Figure 13. iTLS framework (Pirasteh & Kannappan, 2013)

Benefits versus efforts regarding improvement methodologies have always been a contentious issue (Pirasteh & Kannappan, 2013). Pirasteh & Kannappan (2013) suggested that the three methodologies (TOC, Lean manufacturing and Six Sigma) be combined in a 7 step process. The first is process is to mobilise and focus. The idea in this step is to align the organisation to ensure all the mission, objectives, scope of work and timelines are aligned to the constraint. Importantly the problem and the constraint needs to be identified. Any discrepancy in this step will send the process off course.

The second step is similar to the normal TOC process where we look at exploiting the constraint. The only difference is utilising Lean principles of value steam mapping, 5S, Takt management, work cycle efficiencies and metrics (Pirasteh & Kannappan, 2013). The third step is an overlap between Lean manufacturing and Six Sigma by eliminating waste through analysis of sources of waste and conducting an FMEA (Failure modes and effect analysis) on the bottleneck. It does still link back to TOC that a buffer needs to be placed in front of the constraint. (Pirasteh & Kannappan, 2013).

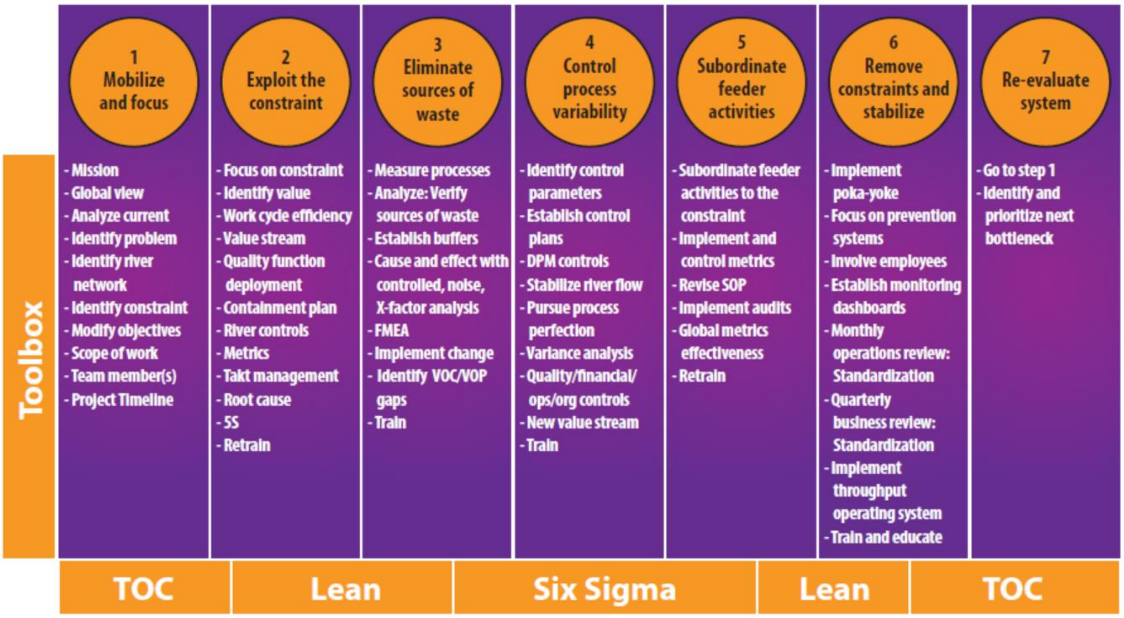

Figure 14. Seven iTLS steps with underlying with potential toos and underlying methodologies (Pirasteh & Kannappan, 2013)

The fourth step is to start controlling process variability in the bottleneck. (Pirasteh & Kannappan, 2013). This is important due to the bottleneck effectively dictating company output. This is done by control parameters being identified and process perfection being persued. The fifth step is to subordinate to feeder activities to ensure they are controlled. This is to ensure the bottleneck is never starved (Pirasteh & Kannappan, 2013).

The sixth step is to look at removing the constraint and stabilising the process. This is done by frequent reviews and dashboards to ensure business alignment. The final step is to re-valuate the constraint as it might have shifted (Pirasteh & Kannappan, 2013).

Pirasteh & Kannappan's (2013) model did not include the elevate constraint step as per the TOC improvement model. This step is vital as in can unlock additional capacity by ensuring the constraint's time isn't wasted on processing poor quality parts and parts that can be processed by non-constraints (van Tonder, 2011). In most steps Pirasteh & Kannappan (2013) suggested training. This study will rather look at key enablers to improve the adoption of the process improvement methodology.

Woeppel (2015) suggested the following method as shown in Figure 14 below. Woeppel’s (2015) method on face value seems much simpler than Pirasteh & Kannappan’s (2013) model.

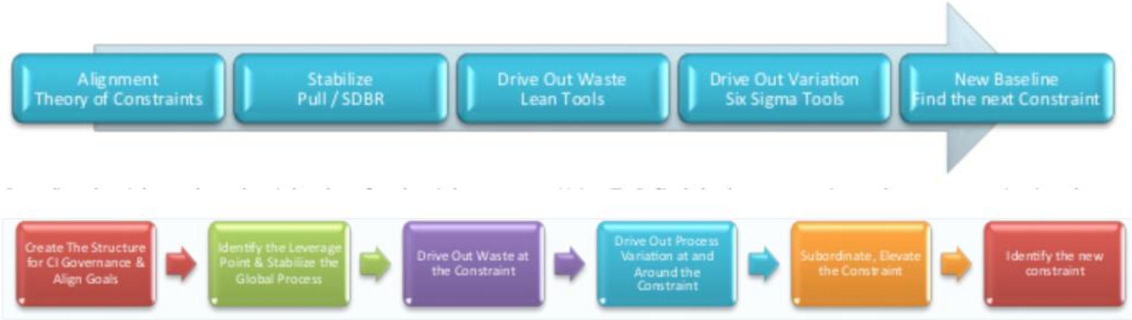

Figure 15. TLS process (Woeppel, 2015)

The benefits of using Woeppel’s (2015) is that current Lean, Six Sigma and TOC principles can be directly applied to the model as opposed to Pirasteh & Kannappan’s (2013) model that requires modification of these current practises, unlearning and relearning. Therefore, there is a larger likelihood of the adoption of Woeppel’s (2015) model. It will form the basis of the proposed TLS model of this study.

The first step is to create a structure to improve processes ensuring governance, reporting structures, organisation’s goals and initiatives are aligned (Woeppel, 2015).. The second step is to stabilise basic processes according to TOC and identify the leverage point in the process for improvement (Woeppel, 2015).

The third step is using Lean tools to drive out waste at the bottleneck and the fourth step is to use Six Sigma tools to drive our variation in the bottleneck (Woeppel, 2015). The sixth step is to subordinate and then elevate the constraint. The last step is to review the process to ensure the bottleneck hasn’t move due to improvements that have been accomplished and sustained (Woeppel, 2015).

The organisation can be steered away from what it wants to achieve if Lean manufacturing be implemented first, before TOC (van Tonder, 2011). Faster or stronger processes become faster and stronger and slower or weaker processes (which are the constraints) become slower and weaker (van Tonder, 2011). This is why improvement methodologies like 6TOC as suggested by Creasy (2014) was not considered.

To summarise the TLS model: TOC tells us what needs to be fixed, Lean tells us how to fix it and Six Sigma keeps the process optimal (Pirasteh & Farah, 2006). Other inhibitors to implementing the process improvement methodology do need to be considered.

2.10. Inhibitors to process improvement methodology implementation

Top management commitment, an educated workforce, willingness to change and discipline is required when implementing an improvement methodology (Cook, 1994). Näslund (2008) agreed that top management support, information and communication are required as critical success factors (CSF) for improvement methodologies. Furthermore, a clear business plan, project management, organisational culture, organisational structure and performance measurements have been identified as CSF (Näslund, 2008).

Mclean et al. (2017) agreed with Näslund, (2008) that process improvement initiatives fail due to organisational culture and project management. Other reasons stated for failure of process improvement initiatives were motives and expectations, management leadership, implementation approach, training, employee involvement and feedback and results (Mclean et al., 2017). Motives speak to the need for change and management leadership also includes commitment from management (Mclean et al., 2017).

A lot of research has been done on why TQM process improvement fails. According to Hietschold, Reinhardt & Gurtner (2014) TQM has 11 CSF, namely benchmarking, customer centeredness and satisfaction, information and data analysis, top management commitment and leadership, process management, supplier partnership, social and environment, strategic quality planning, culture and communication, teamwork and recognition as well as training and learning.

According to Rokke & Prakash Yadav (2010) TQM process improvement inhibitors are dynamic customer focus, human resource inclusion and transformation organisation culture. Lack of top management commitment did not feature as an inhibitor (Rokke & Prakash Yadav, 2010).

According to Bhasin (2015), Lean manufacturing also fails due to culture, but added change management and HR to the inhibitors. This study will aim to reduce these factors into a few that need to be managed. This is due to managing too many inhibiting factors can make implementation of process improvement methodologies too complex and result in desired outcomes not being achieved.

Throughout the review of literature the common theme remains that improvement theories have been established to create progress and there is no best theory. Each improvement methodology performs differently and it is important to assess where each improvement methodology’s strength can be utilised.

Chapter 3: Research questions, Hypotheses and Propositions

The aim of this research is to determine the breakdown in improvement theories used in the manufacturing industry, what the main objective is of the improvement methodology, which strategy has been most beneficial and if the chosen methodology has obtained the desired company results.

The main inhibitors for the improvement methodology implementation difficulty will also be determined. Finally, in developing a hybrid improvement methodology model, it will be determined in what order industry would prefer that this methodology be applied.

52.1 Research question/hypothesis 1

The main continuous improvement methodologies adapted in today's business context is Lean manufacturing, followed by Lean Six Sigma, then TQM and so forth as outlined in the study done by Katz (2007) as seen in Table 3 below

Table 3

Improvement theory breakdown

Continuous improvement method implemented	Percentage of respondents
Lean manufacturing	40.5%
Lean and Six Sigma	12.4%
Total Quality Management	9.9%
Agile manufacturing	3.8%
Toyota Production System	3.1%
Six Sigma	3.1%
Theory of Constraints	3.0%
Other	5.2%
No methodology	19.1%

Note. Reprinted from Katz (2007)

As stated the survey was done a long time ago an there is uncertainty if the information still holds true, therefore

Nul Hypothesis (Ho): The distribution according to Katz (2007) is correct

Alternative Hypothesis (H1): The distribution according to Katz (2007) is incorrect

3.2 Research question 2

Demchuck & Baitsar (2015) as well as Woeppel (2015) suggested that, in an integrated improvement methodology, TOC should be used first, followed by Lean manufacturing tools and then the last phase should be Six Sigma.

Research question 2's purpose was to determine how industry suggests these improvement theories be combined.

3.3 Research question/hypothesis 3

Change management, culture, top management support and training has emerged as common themes regarding process improvement difficulty (Cook, 1994; Näslund, 2008; Mclean et al., 2017; Hietschold et al., 2014; Rokke & Prakash Yadav, 2010; Bhasin, 2015).

The third research question this study aimed to answer was, what factors inhibit process improvement implementation. These factors can then be built into the TLS improvement model, managed, and in so doing, improve success rate.

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3.4 Research question/hypothesis 4

Each improvement theory state a primary objective. For Lean manufacturing it is value creation, increased production and efficiencies (van Tonder, 2011). For Six Sigma it is cost reduction and problem solving (van Tonder, 2011). And for Theory of Constraints it is profit maximisation and reduction in bottlenecks or constraints (van Tonder, 2011).

Nul Hypothesis (Ho): Each improvement theory only focusses on its main focus area with little overlap

Alternative Hypothesis (H1): Each improvement theory does not only focus on its main focus area and there is overlap

3.5 Research question/hypothesis 5

Improvement theories are implemented for various strategic reasons. It is expected that Lean manufacturing is implemented to save costs, Lean Six Sigma to save costs and reduce quality errors, Six Sigma to reduce quality errors and TOC to increase production with very little overlap (Nave, 2002; Stamm et al., 2009; Bentley, 2011; Cheng, 2017; Kumar et al., 2018).

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Nul Hypothesis (Ho): Each improvement theory only focusses on its strategic objective with little overlap

Alternative Hypothesis (H1): Each improvement theory does not only focus on its strategic objective and there is overlap

Chapter 4: Research methodology and Design

4.1 Philosophy

Research questions and objectives determine the research philosophy (Saunders & Lewis, 2012). The research philosophy was pragmatism. The reason for choosing this philosophy is due to our research objectives and questions being the most important elements (Saunders & Lewis, 2012). It was expected that a certain balance of benefits have or haven't emerged from implementing an improvement theory. It was expected that the interviewee would be interested in adopting a combined approach of improvement theories to improve the impact it has on their organisation.

4.2 Approach

A deductive approach was followed. This is relevant to this study because research strategy has been designed to test a theoretical proposition (Saunders & Lewis, 2012). Another reason a deductive approach was used is due to there being a wealth of literature compared to inductive research, due to the limited time frame and to avoid risk of not meeting the proposed timelines. Inductive research is time consuming and often there is a risk that no theory will emerge at all (Dudovskiy, 2017). Research questions was defined from general theories of improvement and answers to these questions was pursued. Questions was also operationalised. (Saunders & Lewis, 2012). From the feedback of the respondents, Nave (2002); Stamm, Neitzert & Singh (2009); Bentley (2011); Cheng (2017) and Kumar, et al. (2018) statements was analysed to determine if they are valid. The aim was to confirm the original overall theory (related to each improvement theory and TLS) or to adjust it in the view of the new findings (Saunders & Lewis, 2012).

4.3 Methodological choices

Due to this being a quantitative study, a mono-method was used (Saunders & Lewis, 2012). This is relevant for this study because the data collected for the study was ordinal or ranked and categorical (Saunders & Lewis, 2012). A mono-method methodological choice can either be qualitative or quantitative (Azorín & Cameron, 2010). Ideally a mixed-method would be used to create triangulation which gives a balanced picture of the situation under study but this makes the research design too complex and time consuming. (Altrichter, Kemmis, McTaggart & Zuber-Skerritt, 2002). The combined use of qualitative and quantitative methods in the same study is considered to be mixed-method (Azorín & Cameron, 2010). Therefore, due to the timing constraints on this study, a mono-method was followed.

4.4 Purpose of research design

The research design was descriptive due to the sampling method and it being a means to an end (Saunders & Lewis, 2012). Descriptive research is intended to yield the true picture of the situation and requires quantitative responses (Saunders & Lewis, 2012). This is also aligned to the use of questionnaire surveys (Saunders & Lewis, 2012).

The answers to the questions provided insight to what improvement methodology has been chosen and why that specific improvement methodology has been chosen. The reason exploratory research was not chosen is due to these studies generating qualitative data that needs to be interpreted (Dudovskiy, 2017).

4.5 Strategy

The strategy followed for this research was a survey due to it being beneficial in descriptive research (Saunders & Lewis, 2012). The strategic aim was cost-effectiveness and to enable the researcher to collect data about the same things from a large number of people. The other advantage was that it will be better equipped to manage time utilising a survey strategy (Saunders & Lewis, 2012). An experiment research strategy on the other hand tends to be longitudinal as opposed to cross-sectional and they are often more costly to execute. Experimental research is also more expensive and involves large sample sizes (Neelankavil, 2015). Experimental research aims to establish causal links to variables by manipulating an independent variable which does not resonate with this study to be conducted (Saunders & Lewis, 2012).

4.6 Time horizon

A cross-sectional research design was employed due to time constraints (Saunders & Lewis, 2012). The results captured a snapshot at the given time of what is happening in the industry. The proposed study does not aim to see what changes in improvement theories have occurred over time and what the reason was for the change. No secondary data produced by longitudinal research has been found. This confirms the decision to do cross-sectional research.

4.7 Techniques and procedures

Self-completed questionnaires was used to collect data. The use of a survey as opposed to a semi-structured or unstructured interviews allowed the researcher to distribute questions faster, allows a larger sample size, it was less time consuming for both parties and had fewer possible ethical problems (Dale, Arber & Procter, 1988). Utilising observations in order to determine why an improvement theory has not been as effective would be valuable. However, due to the many companies and their accessibility as well as time constraints, this would not be feasible. This also applies to focus groups and why they would not be feasible to use.

4.8 Population

The target population will be the manufacturing industry. This industry is well known for utilising improvement initiatives to build a competitive edge due to the changing market dynamics. It has always had fierce competition between competitors, many of them are global and are competing in an international arena. Consumers have a lot of information available about their products. Due to this need, industries have formalised improvement initiatives and are thus a suitable population to target (Novkov, 2016).

4.9 Unit of analysis

The unit of analysis will be the individual responsible for driving continuous improvement or any individual in management, including the Six Sigma, Lean manufacturing, or TOC champion in the business or the continuous improvement engineer. These individuals would most likely be the most knowledgeable about improvement methodologies and would be able to provide the best insight regarding combined approach as they're responsible for driving business excellence and continuous improvement (Woeppel, 2015).

4.10 Sampling method and size

The sampling method chosen was non-probability snowball sampling and the target responses was 150. This sampling methodology is the only possible approach due to a sampling frame not being readily available. This was be done by requesting a panel of volunteers to complete an online survey that may fall into the following categories: Alcoholic beverages; Automotive; Cereals; Dairy products; Electrical, Electronics or

Optical products; Grains and wheat; Machinery and equipment; Meat and fish; Metal or metal fabricated products; Non-alcoholic beverages; Non-metallic mineral products (Cement, glass, ceramics, etc.); Oil and Gas; Personal care or toiletries (Hygiene, cosmetics, etc.) and Vegetables & fruit. (Statsa, 2001; KPMG, 2016;). These industries were chosen from literature but the questionnaire also enabled the addition of other industries.

4.11 Measurement instrument

The measurement instrument was a questionnaire and to improve usability a month was allowed for completion due to the proposed timeline. A short definition of each improvement theory was be given before the questions are asked about that theory to ensure there is no confusion regarding interpretation or own understanding of said theory. The questionnaire was reviewed by the supervisor and peers to ensure there isn't confusion and the questions are clear (Barnum & Dragga, 2001). The questionnaire can be seen in Appendix A.

Internal validity was utilised in this study. The findings from the sample populations should be an accurate sample of the population due to organisations with similar products often utilising similar improvement strategies. There was a low risk for the following factors to render the findings invalid: subject selection, mortality, testing and ambiguity about causal direction. There was a medium risk for history to impact validity as the failure of an improvement process might resonate with the volunteer influencing their answers to the questionnaire.

In terms of reliability, should the same methodology be followed, it was expected that similar results will be achieved and confidence levels were high that the thread between conclusions and the data collected will be seen. There was low risk for observer error and bias as well as subject error due to the survey being taken at a time convenient for the volunteer. There was no researchers asking questions in different ways and researchers will not be interpreting data differently. There was a medium risk for subject bias, as volunteers responsible for improvement processes might not want to admit that its implementation has not been effective.

4.12 Data gathering process

The questionnaire was distributed to volunteers that was found by utilising LinkedIn® as a network due to it having professional members of more than 175 million in over 200 countries (Claybaugh & Haseman, 2013). Using a snowball technique, the aim was to locate the individual, ask them if they would volunteer to complete a survey and also if they can connect us to an acquaintance meeting the unit of analysis criteria. Google Forms® was utilised to distribute and gather data from the intended sample population. The advantages of using this method was that it is cost-effective, uncomplicated, needs little planning compared to other sampling techniques and chain referrals allows us to reach difficult-to-sample populations (Explorable, 2009). The MPI (Manufacturing Performance Institute) was also contacted to enable the distribution of questionnaires but unfortunately this was unsuccessful.

4.13 Analysis approach

The first step to data analysis was to check data for errors or any incomplete data in Microsoft Excel. Initially, Turkey's (1977) exploratory data analysis approach was be used due to it using diagrams to explore and understand the data received (Saunders, Lewis & Thornhill, 2007). This allows flexibility to respond to possible new findings keeping in mind the research questions and objectives. The mean, median and mode was calculated from data where applicable. The standard deviation was calculated to describe dispersion of data.

Reliability, normality and validity statistical tests was done. Exploratory factor analysis was done to determine the inhibitors to process improvement. An independent t-test and ANOVA test was done to test for differences between selected groups. All of the statistical analysis was completed by making use of Microsoft Excel 2013 Professional Plus and IBM SPSS® statistics software.

After the research analysis was completed, the results showed recent data for improvement theories used in industry, if improvement methodology is aligned with the goals of the organisation and if the chosen improvement philosophy actualised. The findings also showed if a combined approached was welcomed by industry and how to combine the approach.

This research will be beneficial to the business and academic environment in that it will have useful tools and techniques to successfully materialise continuous improvement and academics to contribute to the knowledge of operations and production management.

4.14 Limitations

Limitation exist in all research studies. The research will not be generalisable to all populations in manufacturing but only to the companies that completed the survey in the industry. Due snowball sampling initiated in South Africa, the questionnaires were most likely completed by a majority of South Africans and therefore it may be that improvement strategies for South African divisions are different from those of the international divisions of the business.

Some industries was left out of the sampling population due to the specified sample size. The possibility existed for an overrepresentation of some industries and underrepresentation of others.

Owing to the focus being deliberately applied to the manufacturing sector only due to methodological reasons, the framework might not be transferrable to other industries or to the service sector. It is advisable to determine if our research can be expanded to these industries.

Because snow ball sampling has been chosen, there is not a lot of control over the method, representativeness of the sample is not guaranteed, there is a concern over sampling bias and determination of sampling error is difficult. (Explorable, 2009; Sharma, 2017)

Continuous improvement sustainability is reliant on culture change to achieve business excellence (Patil & Mishra, 2014) and attitude and style of plant managers are reflected in the company (Schmenner, 2012). Nave (2002) argues that the culture of the organisation or what is valued must dictate the improvement methodology used. This can assist to reduce resistance to change but often what the company needs to improve business performance is not aligned with the current culture and improvement methodology to facilitate this change. What the organisation needs and what they value can be very different.

This study did not address the need for culture transformation required for successful implementation of a hybrid improvement framework.

Chapter 5: Results

5.1 Descriptive statistics

A pilot test was done to verify the questionnaire is accessible, all questions are answerable and data integrity is maintained. The pilot test results did not form part of the results of this study. To obtain respondents, the researcher used immediate networks to distribute the questionnaire on LinkedIn® and WhatsApp as a first wave. Due to the low response level of only 34 participants, the researcher posted the link to their survey on Facebook and presented an article on LinkedIn® as a second attempt to obtain participants. This increased their response rate to 53. Finally the researcher proceeded with looking for individuals in the manufacturing industry on LinkedIn® and sent them the survey individually, requesting that they also send it to their networks in the industry. Finally, 183 response were obtained.

Data transformations were needed. Three did not consent to the research and 15 did not work in the manufacturing industry which lead to only 165 useful responses for data analysis. All of the remaining respondents completed the surveys in full.

Below in Table 4 and Figure 16 we can see a breakdown of the respondent's number of employees in the organisation. Interestingly most of the respondents were from large manufacturing organisations with more than a 1000 employees. The organisations with 51 – 250, 251 – 500 and 501 – 1000 had equal representation of respondents.

Table 4

Number of employees in the organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 10	5	3.0	3.0	3.0
	10 – 50	15	9.1	9.1	12.1
	51 – 250	28	17.0	17.0	29.1
	251 – 500	29	17.6	17.6	46.7
	501 – 1000	26	15.8	15.8	62.4
	More than a 1000	62	37.6	37.6	100.0
	Total	165	100.0	100.0	

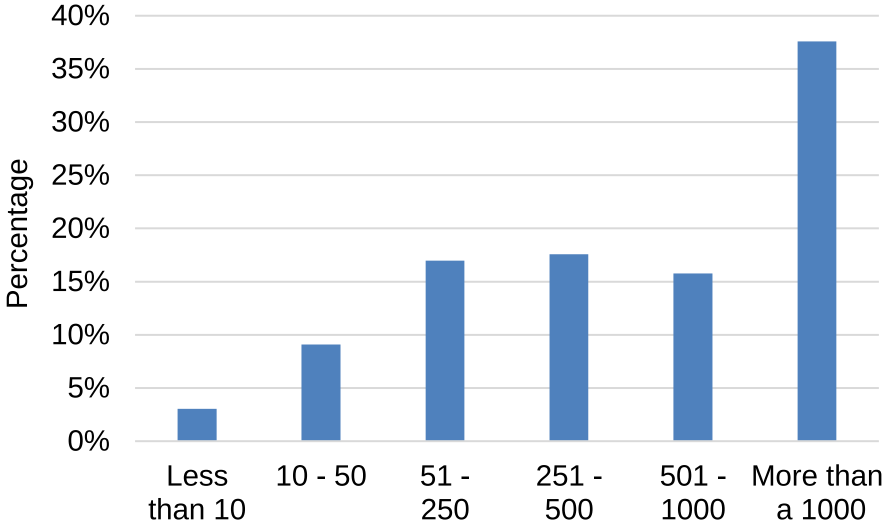


Figure 16. Number of employees in the organisation

A breakdown of the position held by the respondents are depicted in Table 5 and Figure 17 below. More than a third of the respondents were senior managers (68 responses) or head of departments with middle managers being a fifth (33 responses). Process improvement respondents were only 16.4% of the respondents.

Table 5

Position held in the organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Junior manager	8	4.8	4.8	4.8
	Process improvement	27	16.4	16.4	21.2
	Engineer	29	17.6	17.6	38.8
	Middle or unit manager	33	20.0	20.0	58.8
	Senior manager or Head of department	68	41.2	41.2	100.0
	Total	165	100.0	100.0	

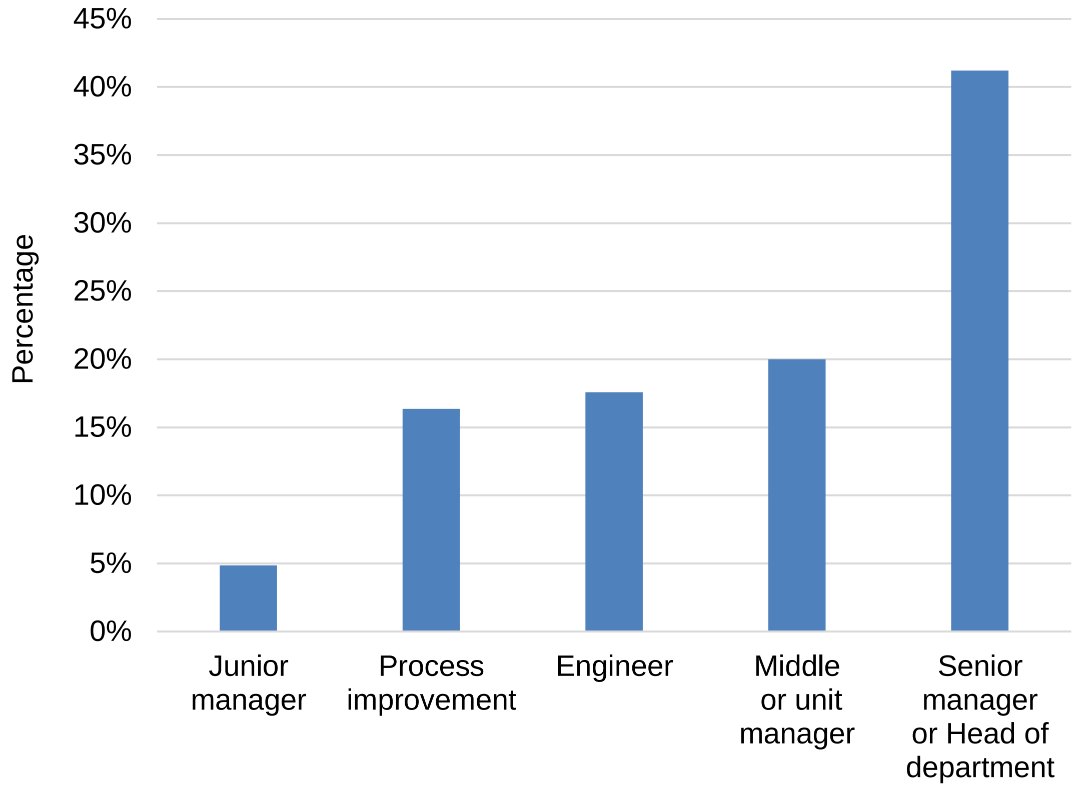


Figure 17. Position of respondent working in the manufacturing industry

Table 6 and Figure 18 depicts the experience within the manufacturing industry of the respondents. Experience of 6 – 10 years' experience within the manufacturing industry accounted for 38% (63 respondents) with the least being in the less than two years (8.5%) and more than 25 years' experience (6.7%). Respondents with 11 – 15 years' experience and 16 – 25 years' experience had equal representation.

Table 6

Experience within manufacturing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 2 years	14	8.5	8.5	8.5
	2 – 5 years	33	20.0	20.0	28.5
	6 – 10 years	63	38.2	38.2	66.7
	11 – 15 years	22	13.3	13.3	80.0
	16 – 25 years	22	13.3	13.3	93.3
	More than 25 years	11	6.7	6.7	100.0
	Total	165	100.0	100.0	

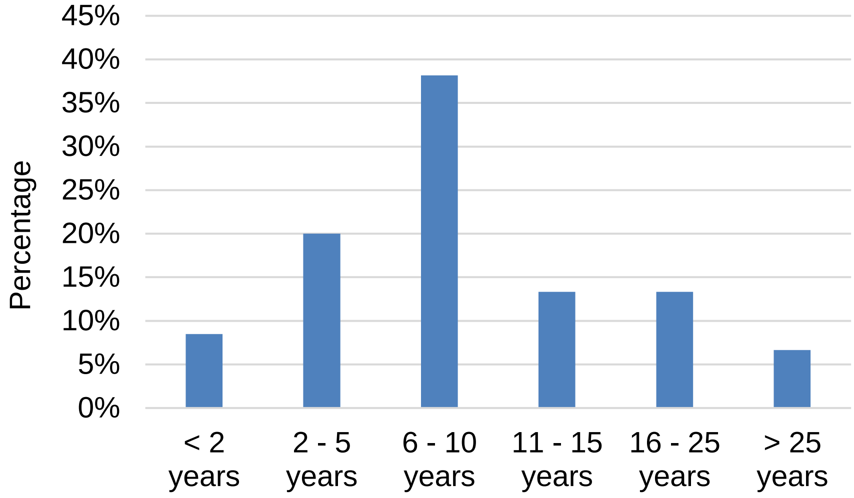


Figure 18. Experience within the manufacturing industry of the respondents

The manufacturing industry breakdown of respondents can be seen in Figure 19. Most respondents were from the Oil and Gas industry followed by an equal amount in the Metal or metal fabricated products and the Electrical, Electronics or Optical products category. A broad range of industries were represented in the sample. Other included respondents that work in multiple industries that couldn't be classified into a single industry.

More than 23 different industries participated in this research, the majority contributors from Oil and Gas with 10.3% of the responses. Electrical, Electronics or Optical products and Metal or metal fabricated products had the second highest responses each at 9.3%. This was followed by the automotive industry with 7.3% of the participants. Food; Pulp, Paper, Publishing and Printing; Personal care or toiletries; Machinery and equipment and Pharmaceutical had relatively the same responses with 5.5%, 5.5, 4.8%, 4.8% and 4.2% respectively.

Industries not well represented in this study were Printing (specifically security printing), Confectionery, Wood and wood products, Vegetables and fruit, Non-alcoholic beverages, Tobacco, Rubber and plastic products, Grains and wheat and Textiles and textile products, with less than 2% of respondents.

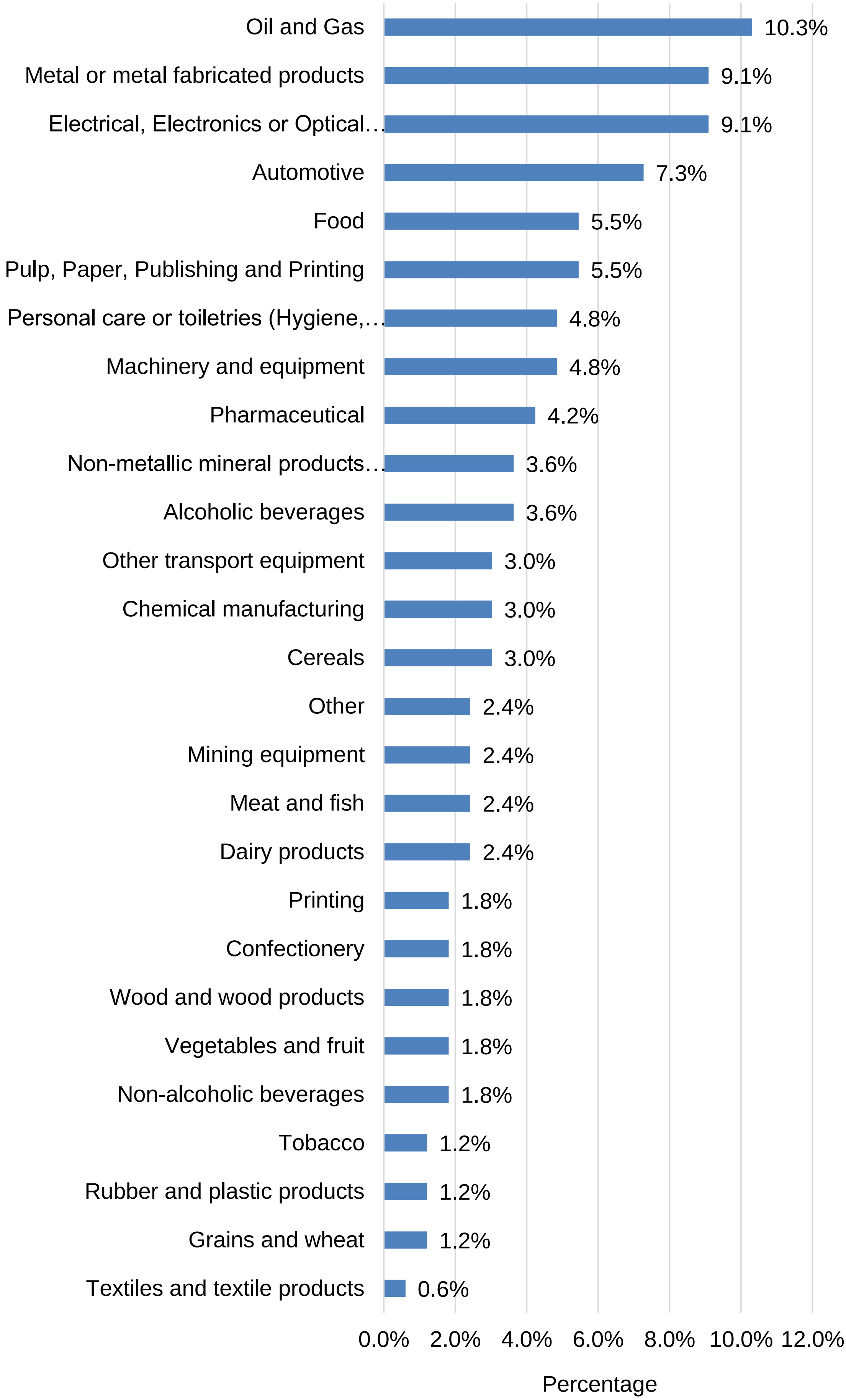


Figure 19. Manufacturing industry sector of respondents

As indicated in Figure 20 below, majority of respondents indicated that their company has an improvement methodology, cost saving or related exercise (147 respondents).

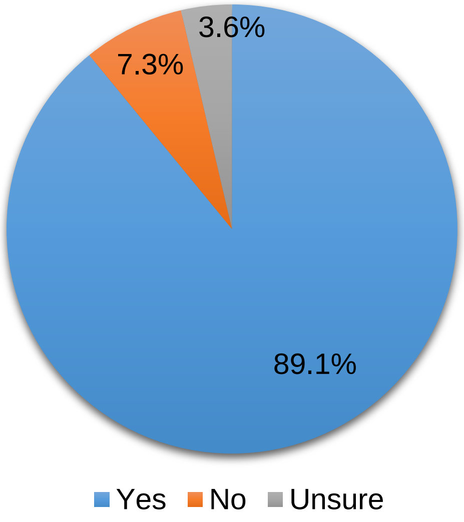


Figure 20. Companies with an improvement methodology, cost saving or related exercise

The main focus area of the operations, quality improvement methodology or approach that respondents selected can be seen from Table 7 and Figure 21. Improving efficiency had the most responses (40). Increase production or flow, Remove or reduce bottlenecks or constraints and Remove problems and/or reduce variability had similar responses.

The Other category included a combination of the focus areas or all of the focus areas. It also included a combination of the focus areas with other elements like safety, process improvement, profitability improvement, balancing flow via takt time, quality, increase productivity or their focus area changing over time.

Table 7

The Main Focus Area of the Operations, Quality Improvement Methodology or Approach

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Improve efficiency	40	24.2	24.2	24.2
	Reduce total cost	34	20.6	20.6	44.8
	Increase production or flow	27	16.4	16.4	61.2
	Remove problems and or reduce variability	24	14.5	14.5	75.8
	Remove or reduce bottlenecks or constraints in the system	24	14.5	14.5	90.3
	Improve revenue	4	2.4	2.4	92.7
	Other	12	7.3	7.3	100.0
	Total	165	100.0	100.0	

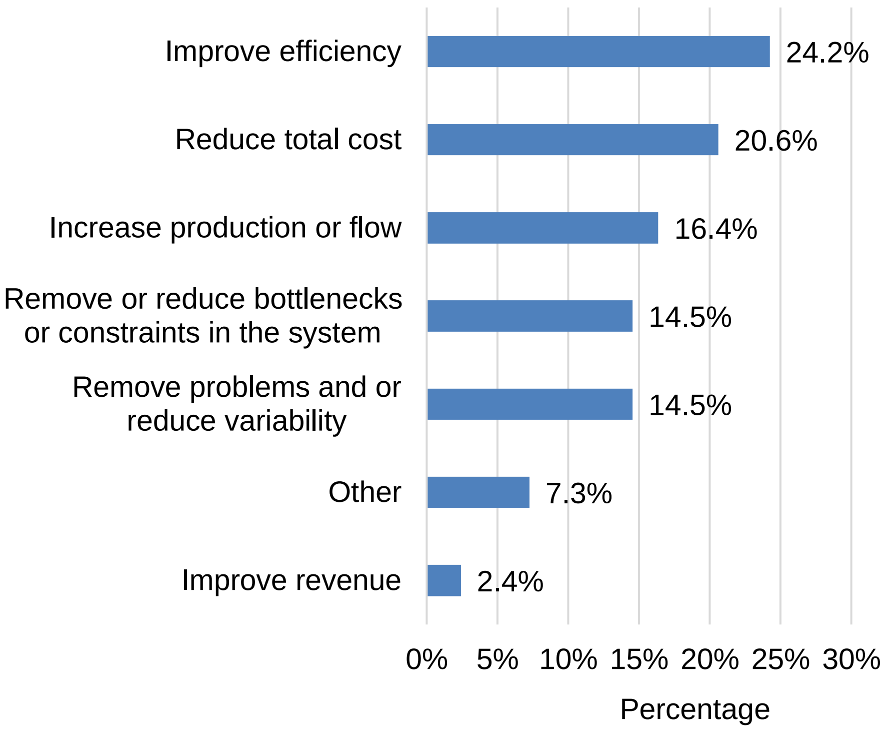


Figure 21. The main focus area of the operations, quality improvement methodology or approach

The response to if the chosen operations, quality improvement methodology or approach has achieved the desired company results, can be seen in Table 8 and Figure 22 below.

Strongly agree was coded as 1, Agree as 2, Neutral 3, Disagree 4 and Strongly disagree as 5. Strongly agree an Agree composed 73.9% of the total responses

Table 8

The Chosen Operations, Quality Improvement Methodology or Approach has Achieved the Desired Company Results

N						
Valid	Missing	Mean	Median	Mode	Std. Deviation	Minimum
165	0	2.10	2.00	2	0.895	1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly agree	41	24.8	24.8	24.8
	Agree	81	49.1	49.1	73.9
	Neutral	30	18.2	18.2	92.1
	Disagree	11	6.7	6.7	98.8
	Strongly disagree	2	1.2	1.2	100.0
	Total	165	100.0	100.0	

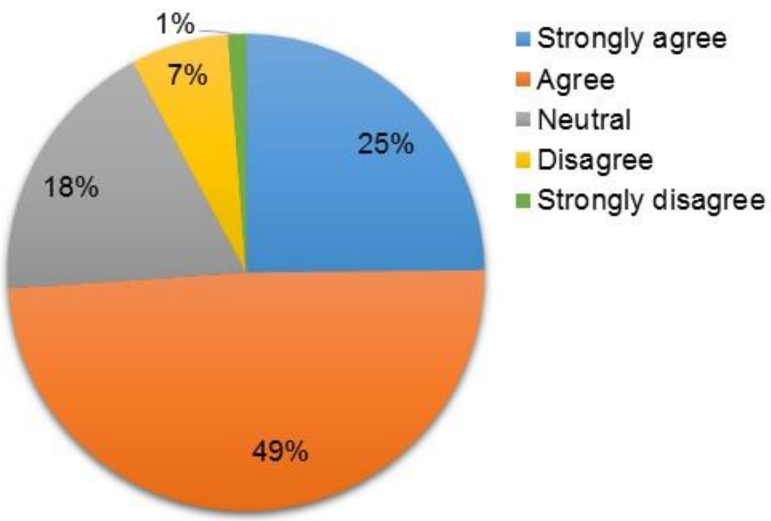


Figure 22. The chosen operations, quality improvement methodology or approach has achieved the desired company results

Table 9 and Figure 23 indicates improvement methodology implementation responsibility. Most respondents stated it is all employees followed by a large part a specialised team. Very few stated and individual is responsible for implementation.

Table 9

Improvement Methodology Implementation Responsibility

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	All employees	86	52.1	52.1	52.1
	Specialised team	69	41.8	41.8	93.9
	Individual	10	6.1	6.1	100.0
	Total	165	100.0	100.0	

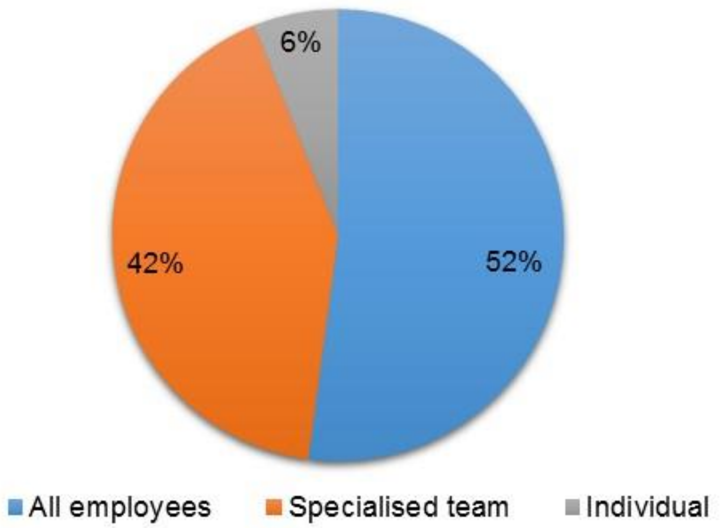


Figure 23. Responsible persons for implementing the improvement methodology

Table 10 and Figure 24 indicates the Implementation duration of improvement methodology used. Most were still in their infancy between 0 - 5 years (65.5%) followed by 15.8% that stated that they didn't know. Only 1.2% and 5.5% stated that the improvement methodology has been implemented 11 - 15 years and more than 15 years respectively.

Table 10

Implementation Duration of Improvement Methodology

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't know	26	15.8	15.8	15.8
	0 - 5 years	108	65.5	65.5	81.2
	6 - 10 years	20	12.1	12.1	93.3
	11 - 15 years	2	1.2	1.2	94.5
	More than 15 years	9	5.5	5.5	100.0
	Total	165	100.0	100.0	

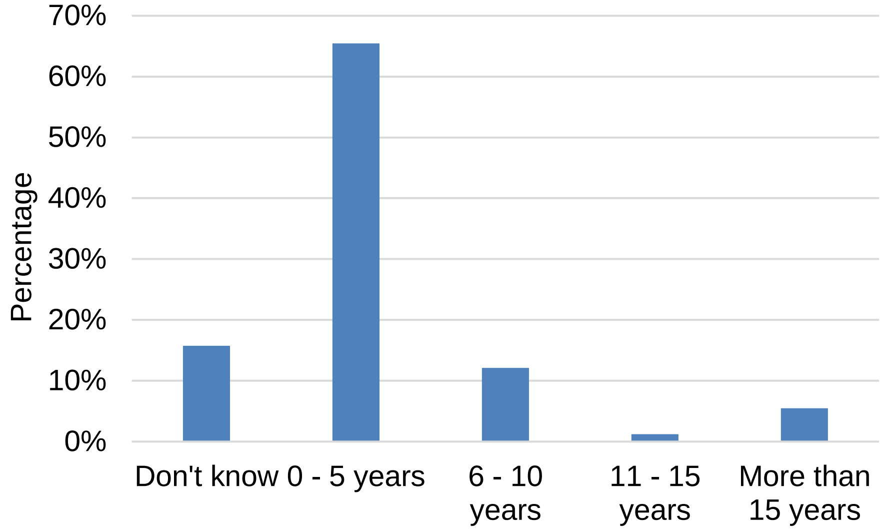


Figure 24. Implementation duration of improvement methodology

The strategy most beneficial for the company results can be seen in Figure 25 below. Remarkably, most respondents stated that their most beneficial strategy was cost savings (33.3%) and reduced quality errors (32.1%). The least beneficial strategy was decreased work in progress with a response rate of only 6.7%.

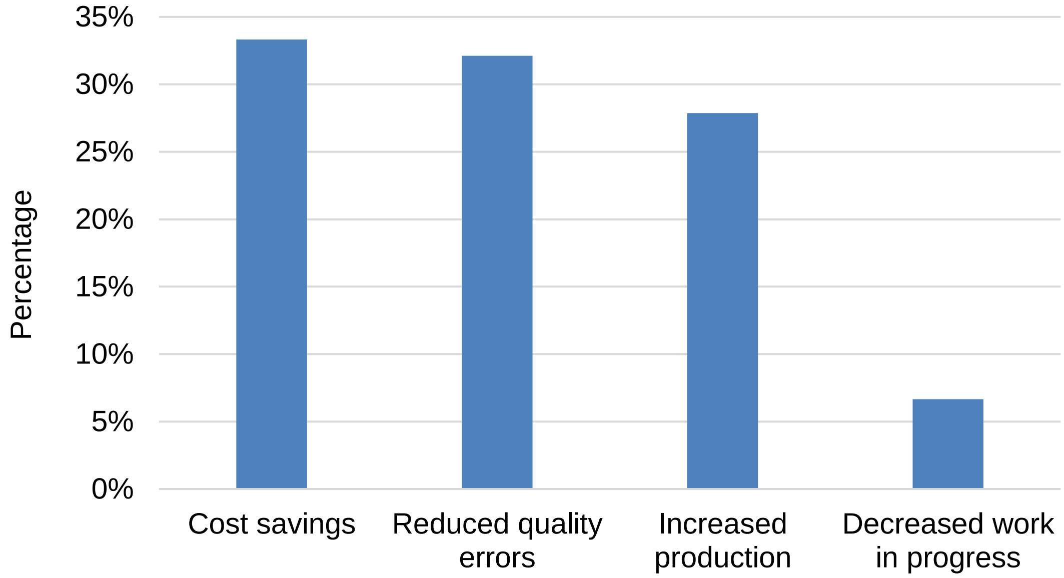


Figure 25. Strategy most beneficial for the company

Table 11 indicates the level of agreement as to why the improvement theory implemented at your company has been difficult. Again, Strongly agree was coded as 1, Agree as 2, Neutral 3, Disagree 4 and Strongly disagree as 5.

Table 11

The Level of Agreement as to Why the Improvement Theory Implemented at the Company Has Been Difficult

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Q16a Lack of commitment from management	Count	20	54	31	40	20	2.92	3.00	2	1.242	1	5
	Row N %	12.1%	32.7%	18.8%	24.2%	12.1%						
Q16b Lack of improvement methodology's technical knowledge	Count	18	73	29	35	10	2.67	2.00	2	1.111	1	5
	Row N %	10.9%	44.2%	17.6%	21.2%	6.1%						
Q16c Lack of understanding benefits	Count	24	64	24	41	12	2.72	2.00	2	1.199	1	5
	Row N %	14.5%	38.8%	14.5%	24.8%	7.3%						
Q16d Does not fit company's culture	Count	18	44	29	53	21	3.09	3.00	4	1.239	1	5
	Row N %	10.9%	26.7%	17.6%	32.1%	12.7%						
Q16e Management resistance to change	Count	23	46	28	45	23	2.99	3.00	2	1.295	1	5
	Row N %	13.9%	27.9%	17.0%	27.3%	13.9%						
Q16f Employees resistance to change	Count	29	80	27	22	7	2.38	2.00	2	1.056	1	5
	Row N %	17.6%	48.5%	16.4%	13.3%	4.2%						
Q16g The improvement methodology is a gimmick	Count	4	21	41	57	42	3.68	4.00	4	1.065	1	5
	Row N %	2.4%	12.7%	24.8%	34.5%	25.5%						
Q16h The improvement theory is not sustainable	Count	3	24	29	79	30	3.66	4.00	4	0.997	1	5
	Row N %	1.8%	14.5%	17.6%	47.9%	18.2%						
Q16i High cost of investment	Count	9	38	35	62	21	3.29	4.00	4	1.121	1	5
	Row N %	5.5%	23.0%	21.2%	37.6%	12.7%						
Q16j The improvement theory has failed previously	Count	4	41	32	62	26	3.39	4.00	4	1.097	1	5
	Row N %	2.4%	24.8%	19.4%	37.6%	15.8%						
Q16k Takes up too much time	Count	10	51	30	51	23	3.16	3.00	2[a]	1.184	1	5
	Row N %	6.1%	30.9%	18.2%	30.9%	13.9%						
Q16l The company does not value statistical or system analysis	Count	17	35	29	60	24	3.24	4.00	4	1.234	1	5
	Row N %	10.3%	21.2%	17.6%	36.4%	14.5%						
Q16m The company does not look at how process interaction and looks at them independently	Count	27	63	21	38	16	2.72	2.00	2	1.258	1	5
	Row N %	16.4%	38.2%	12.7%	23.0%	9.7%						
Q16n The company does not value data analysis and/or worker input is minimal	Count	16	53	31	45	20	3.00	3.00	2	1.215	1	5
	Row N %	9.7%	32.1%	18.8%	27.3%	12.1%						

a. Multiple modes exist. The smallest value is shown

In order to determine if industry size have an impact on implementation difficluty of an improvement methodology, data transformations were done to which resulted in two groups, 500 employees or less which can be classified as small and medium organisations and more than 500 employees which can be classified as large organsations. This was done to ensure sample sizes are large enough to obtain sensible statistical results. The two groups can be seen in Table 12 below.

Table 12 *Number of Employees in the Organisation Recoded*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	500 or less	77	46.7	46.7	46.7
	More than 500	88	53.3	53.3	100.0
	Total	165	100.0	100.0	

Further data transformations were done utilising the International Standard Industrial Classification of All Economic Activities (ISIC) as seen in Table 13 below. It is United Nations industry classification of all economic activities and is the most systematic and complete industrial classification made by them (United Nations, 2008). This was done to improve statistical analysis.

Table 13

Industry Grouping Utilising ISIC Codes

Industry grouping	Selected or stated industry as per questionnaire	Frequency	ISIC code
Food products and beverages			
	Alcoholic beverages	6	11
	Cereals	5	10
	Confectionery	3	10
	Dairy products	4	10
	Food	9	10
	Grains and wheat	2	10
	Meat and fish	4	10
	Non-alcoholic beverages	3	11
	Vegetables and fruit	3	10
	Total	39	
Automotive, electronic or optical equipment and other			
	Automotive	12	29
	Electrical, Electronics or Optical products	15	26
	Other	4	
	Total	31	
Machinery, transport and fabricated metal equipment or products			
	Machinery and equipment	8	28
	Metal or metal fabricated products	15	25
	Mining equipment	4	28
	Other transport equipment	5	30
	Total	32	
Non-metallic mineral and chemical products			
	Non-metallic mineral products (Cement, glass, ceramics, etc.)	6	23

	Chemical manufacturing	5	20
	Rubber and plastic products	2	20
	Personal care or toiletries (Hygiene, cosmetics, etc.)	8	20
	Pharmaceutical	7	21
	Total	28	
Refined petroleum products, tobacco, textiles, paper, wood products and printing			
	Oil and Gas	17	19
	Pulp, Paper, Publishing and Printing	9	17
	Textiles and textile products	1	13
	Tobacco	2	12
	Wood and wood products	3	16
	Printing	3	18
	Total	35	

The codebook for the questionnaire data can be seen in Appendix B. The codebook for data transformations or recoded questions can be seen in Appendix C

5.2 Current operations, quality improvement methodology or approach of respondents

Table 14 and Figure 26 below indicates the current operations, quality improvement methodology or approach of respondents. True lean and lean principles which the company has optimised into their own methodology were classified under Lean manufacturing.

Almost a quarter of respondents stated Lean manufacturing is their improvement methodology. The second highest was Lean Six Sigma. ISO 9001 as an improvement methodology was third while TLS was the least used methodology

Table 14

Current Operations, Quality Improvement Methodology or Approach

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Lean manufacturing	40	24.2	24.2	24.2
	Lean Six Sigma	28	17.0	17.0	41.2
	Six Sigma	6	3.6	3.6	44.8
	Theory of constraints	12	7.3	7.3	52.1
	Total quality management	17	10.3	10.3	62.4
	ISO 9001	21	12.7	12.7	75.2
	Cost saving	20	12.1	12.1	87.3
	WCM	4	2.4	2.4	89.7
	TLS	2	1.2	1.2	90.9
	Other	9	5.5	5.5	96.4
	No operations and/or quality improvement approach used	6	3.6	3.6	100.0
	Total	165	100.0	100.0	

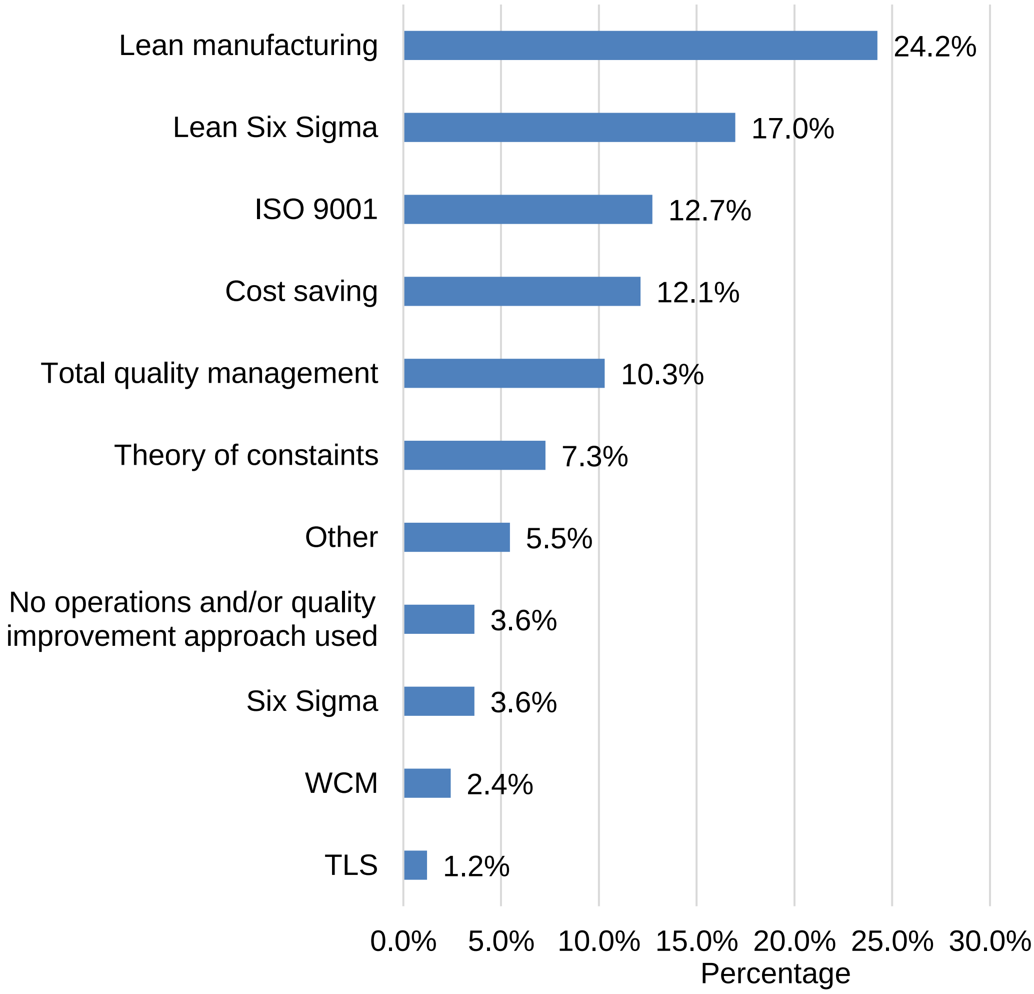


Figure 26. Current operations, quality improvement methodology or approach used

The “Other” category includes respondents that stated they used all of the above or a combination of the above improvement theories. It also included respondents that stated they used Demand Driven Manufacturing (DDM), Total Productive Management (TPM), in-house or own QMS processes and respondents which stated they are agile and take pieces of whichever processes are useful.

5.3 Improvement Methodologies Implementation order

The combination of how to apply improvement theories can be seen in Table 15 and Figure 27 below. 26.7% of participants stated TOC should be applied first followed by Lean manufacturing and then lastly Six Sigma. Interestingly, starting with Lean manufacturing and then TOC and lastly Six Sigma was second highest with 21.2%. Starting with Six Sigma, followed by TOC and then Lean manufacturing and Lean manufacturing, then Six Sigma, then TOC had the least amount of responses (10.9% respectively).

Table 15

Order of How Improvement Methodologies (Lean Manufacturing, Six Sigma and TOC) Should Be Applied

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	TOC then Lean manufacturing then Six Sigma	44	26.7	26.7	26.7
	Lean manufacturing then TOC then Six Sigma	35	21.2	21.2	47.9
	TOC then Six Sigma then Lean manufacturing	29	17.6	17.6	65.5
	Six Sigma then Lean manufacturing then TOC	21	12.7	12.7	78.2
	Lean manufacturing then Six Sigma then TOC	18	10.9	10.9	89.1
	Six Sigma then TOC then Lean manufacturing	18	10.9	10.9	100.0
	Total	165	100.0	100.0	

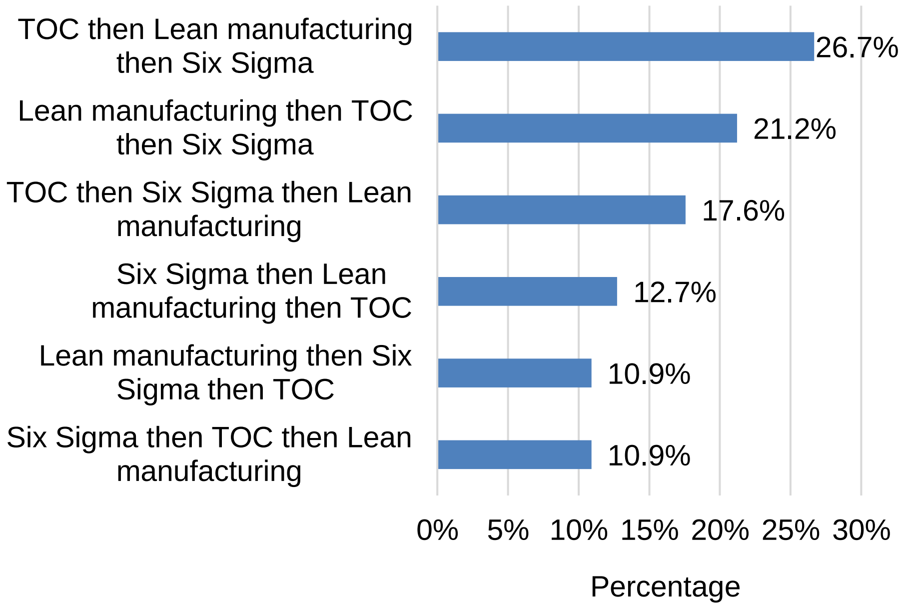


Figure 27. Combination of how improvement theories should be applied

5.4 Comparing improvement methodology to its main focus area: Cross tabulations

In order to complete the cross tabulations, all participants that respondent to with “Other” in question 8 and 9 were removed from the sample size. When comparing question 8 to 9, this reduced the sample size to from 165 to 148. When comparing question 8 to question 15, this reduced the sample size from 165 to 156.

The results of the cross tabulation of the companies’ improvement methodology or approach (question 8) and the main focus area of the operations or quality improvement methodology or approach (question 9) can be seen in Table 16.

Table 16

Cross Tabulation of Improvement Methodology (Question 8) and Its Main Focus Area (Question 9)

Crosstab

			Q9						
			Improve efficiency	Reduce total cost	Increase production or flow	Remove problems and or reduce variability	Remove or reduce bottlenecks or constraints in the system	Improve revenue	Total
Q8	Lean manufacturing	Count	9	8	8	5	8	0	38
		% within Q8	23.7%	21.1%	21.1%	13.2%	21.1%	0.0%	100.0%
	Lean Six Sigma	Count	6	6	3	5	5	0	25
		% within Q8	24.0%	24.0%	12.0%	20.0%	20.0%	0.0%	100.0%
	Six Sigma	Count	2	0	1	2	1	0	6
		% within Q8	33.3%	0.0%	16.7%	33.3%	16.7%	0.0%	100.0%
	Theory of constaints	Count	2	0	3	2	4	1	12
		% within Q8	16.7%	0.0%	25.0%	16.7%	33.3%	8.3%	100.0%
	Total quality management	Count	6	3	1	4	2	1	17
		% within Q8	35.3%	17.6%	5.9%	23.5%	11.8%	5.9%	100.0%
	ISO 9001	Count	7	1	6	5	2	0	21
		% within Q8	33.3%	4.8%	28.6%	23.8%	9.5%	0.0%	100.0%
	Cost saving	Count	4	10	3	0	2	1	20
		% within Q8	20.0%	50.0%	15.0%	0.0%	10.0%	5.0%	100.0%
	WCM	Count	1	1	0	0	0	0	2
		% within Q8	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	TLS	Count	0	0	1	0	0	0	1
		% within Q8	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
	No operations and/or quality improvement approach used	Count	1	3	1	0	0	1	6
		% within Q8	16.7%	50.0%	16.7%	0.0%	0.0%	16.7%	100.0%
Total		Count	38	32	27	23	24	4	148
		% within Q8	25.7%	21.6%	18.2%	15.5%	16.2%	2.7%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearso	50.915[a]	45	0.252
Likeliho	56.902	45	0.110
Linear-	1.156	1	0.282
N of	148		

a. 51 cells (85,0%) have expected count less than 5. The minimum expected count is ,03.

51 cells (85.0%) have an expected count less than 5 which is more than the 20% as recommended by Pallant (2007). No improvement methodologies could be group together to increase the count in each cell and enable the use of the statistical test. Therefore Pearson's Chi-Square rest and the p-value cannot be used and conclusions were made on the proportions in Chapter 6.

5.5 Comparing improvement methodology to most beneficial strategy: Cross tabulations

The results of the cross tabulation of the companies' improvement methodology or approach (question 8) and the strategy most beneficial for their company (question 15) can be seen in Table 17.

Table 17

Cross Tabulation of Improvement Methodology (Question 8) and the Most Beneficial Strategy (Question 15)

Crosstab

			Q15				
			Cost savings	Reduced quality errors	Increased production	Decreased work in progress	Total
Q8	Lean manufacturing	Count	14	9	15	2	40
		% within Q8	35.0%	22.5%	37.5%	5.0%	100.0%
	Lean Six Sigma	Count	13	4	10	1	28
		% within Q8	46.4%	14.3%	35.7%	3.6%	100.0%
	Six Sigma	Count	1	3	2	0	6
		% within Q8	16.7%	50.0%	33.3%	0.0%	100.0%
	Theory of constaints	Count	1	3	5	3	12
		% within Q8	8.3%	25.0%	41.7%	25.0%	100.0%
	Total quality management	Count	4	11	2	0	17
		% within Q8	23.5%	64.7%	11.8%	0.0%	100.0%
	ISO 9001	Count	4	13	2	2	21
		% within Q8	19.0%	61.9%	9.5%	9.5%	100.0%
	Cost saving	Count	12	2	4	2	20
		% within Q8	60.0%	10.0%	20.0%	10.0%	100.0%
	WCM	Count	2	0	2	0	4
		% within Q8	50.0%	0.0%	50.0%	0.0%	100.0%
	TLS	Count	0	1	1	0	2
		% within Q8	0.0%	50.0%	50.0%	0.0%	100.0%
	No operations and/or quality improvement approach used	Count	3	3	0	0	6
		% within Q8	50.0%	50.0%	0.0%	0.0%	100.0%
Total		Count	54	49	43	10	156
		% within Q8	34.6%	31.4%	27.6%	6.4%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearso	53.109[a]	27	0.002
Likeliho	56.459	27	0.001
Linear-	1.580	1	0.209
N of	156		

a. 26 cells (65,0%) have expected count less than 5. The minimum expected count is ,13.

26 cells (65.0%) have expected count less than 5 which is more than the recommended 20% (Pallant, 2007). No improvement methodologies could be group together to

increase the count in each cell and enable the use of the statistical test. Therefore Pearson's Chi-Square rest and the p-value cannot be used and conclusions were made in Chapter 6.

5.6 Inhibitors to process improvement implementation: Exploratory Factor Analysis

Question 16f and 16i was omitted from the factor analysis due to a low commonality of 0.154 and 0.153 respectively. Commonality should be above 0.3 (Pallant, 2007). The extraction method used was principle axis factoring (PAF) due to it being able to recover weak factors (De Winter & Dodou, 2012). Essential assumptions about distributions is not needed which especially useful in Likert scales (Tabachnick & Fidell, 2007). The first rotation method used was varimax rotation (giving a simplified structure) and the second order was direct oblimin rotation. The correlation matrix can be seen in Table 18 and 19. Most of the correlation were above 0.3 which is acceptable

Table 18

Correlation Matrix

Correlation Matrix

		Q16a	Q16b	Q16c	Q16d	Q16e	Q16g
Correlation	Q16a	1.000	0.320	0.471	0.231	0.572	0.224
	Q16b	0.320	1.000	0.530	0.305	0.342	0.261
	Q16c	0.471	0.530	1.000	0.309	0.388	0.238
	Q16d	0.231	0.305	0.309	1.000	0.396	0.193
	Q16e	0.572	0.342	0.388	0.396	1.000	0.268
	Q16g	0.224	0.261	0.238	0.193	0.268	1.000
	Q16h	0.164	0.285	0.215	0.129	0.083	0.574
	Q16j	0.159	0.166	0.146	0.126	0.113	0.333
	Q16k	0.158	0.308	0.169	0.190	0.172	0.393
	Q16l	0.375	0.346	0.334	0.381	0.409	0.225
	Q16m	0.379	0.417	0.395	0.291	0.463	0.304
	Q16n	0.327	0.330	0.289	0.227	0.337	0.330

Table 19 *Correlation Matrix (cont.)*

Correlation Matrix

		Q16h	Q16j	Q16k	Q16l	Q16m	Q16n
Correlation	Q16a	0.164	0.159	0.158	0.375	0.379	0.327
	Q16b	0.285	0.166	0.308	0.346	0.417	0.330
	Q16c	0.215	0.146	0.169	0.334	0.395	0.289
	Q16d	0.129	0.126	0.190	0.381	0.291	0.227
	Q16e	0.083	0.113	0.172	0.409	0.463	0.337
	Q16g	0.574	0.333	0.393	0.225	0.304	0.330
	Q16h	1.000	0.418	0.402	0.160	0.204	0.206
	Q16j	0.418	1.000	0.398	0.120	0.126	0.114
	Q16k	0.402	0.398	1.000	0.216	0.178	0.233
	Q16l	0.160	0.120	0.216	1.000	0.605	0.573
	Q16m	0.204	0.126	0.178	0.605	1.000	0.551
	Q16n	0.206	0.114	0.233	0.573	0.551	1.000

Table 20 indicates the KMO and Bartlett's test. The KMO is 0.829 which is acceptable as it is larger than 0.6 and the significance value is 0.00 which is lower than 0.05 which is also acceptable (Pallant, 2007). This supports the factorability of the correlation matrix (Pallant, 2007).

Table 20

KMO and Barlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.829
Bartlett's Test of Sphericity	Approx. Chi-Square	625.021
	df	66
	Sig.	0.000

All the MSA values for the anti-image correlations was larger than 0.7 which is more than the recommended value of 0.6 and can be seen in Appendix D. This indicates that there is no weak items that need to be omitted (Pallant, 2007). The commonalities can be seen in Table 21. All commonalities were between 0.226 and 0.632. Question 16d was kept due to it having an acceptable MSA value even though its value is below 0.3. This indicates our factor analysis is reliable and valid.

Table 21

Commonalities

	Initial	Extraction
Q16a	0.424	0.457
Q16b	0.389	0.382
Q16c	0.405	0.478
Q16d	0.250	0.226
Q16e	0.467	0.505
Q16g	0.427	0.484
Q16h	0.430	0.610
Q16j	0.249	0.307
Q16k	0.297	0.349
Q16l	0.499	0.632
Q16m	0.501	0.589
Q16n	0.427	0.539

Extraction Method: Principal Axis Factoring.

Total variance explained table can be seen below in Table 22 and in the scree plot in Figure 28. Three Eigen values are above 1.000 meaning 3 factors can be extracted. These values are also known as the Kaiser's criterion and are retained for further investigation (Pallant, 2007).

Table 22

Total variance explained

	Initial Eigenvalues			Loadings			Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**4.343**	36.194	36.194	3.831	31.928	31.928	2.041	17.012	17.012
2	**1.725**	14.372	50.566	1.203	10.026	41.954	1.816	15.132	32.145
3	**1.004**	8.366	**58.932**	0.522	4.349	46.303	1.699	14.158	**46.303**
4	0.829	6.911	65.843						
5	0.810	6.753	72.596						
6	0.698	5.814	78.410						
7	0.611	5.091	83.501						
8	0.482	4.013	87.514						
9	0.434	3.621	91.135						
10	0.412	3.430	94.564						
11	0.337	2.809	97.374						
12	0.315	2.626	100.000						

Extraction Method: Principal Axis Factoring.

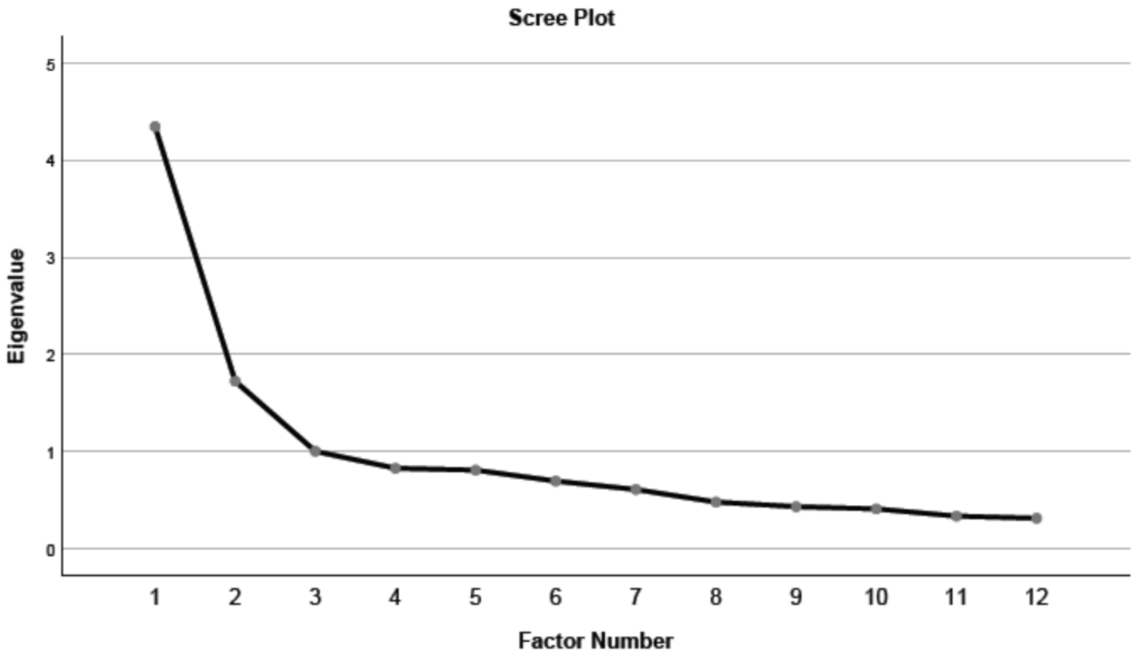


Figure 28. Total variance scree plot

Table 23 indicates the Rotated Factor Matrix. Values below 0.25 were suppressed. This indicates that the 3 factors were acceptable.

Table 23

Rotated Factor Matrix

	Factor		
	1	2	3
Q16c	**0.652**		
Q16e	**0.646**		0.289
Q16a	**0.635**		
Q16b	**0.502**	0.277	
Q16d	**0.390**		
Q16h		**0.773**	
Q16g		**0.640**	
Q16k		**0.558**	
Q16j		**0.543**	
Q16l	0.337		**0.713**
Q16n			**0.672**
Q16m	0.401		**0.639**

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 5 iterations.

A second order Factor analysis was done to condense the 3 factors into one factor as can be seen from Appendix E. This was not successful and the 3 factors remained as the main themes.

Reliability statistics were completed to ensure we can utilise the 3 factors. The factors were condensed into the themes and a summary of the reliability statistics can be seen in Table 24. The factors were also given names and the SPSS outputs are available in Appendix F. The Cronbach's Alpha for all the factors in more than 0.7 indicating the factors are reliable (Pallant, 2007).

Table 24

Summary of Reliability Statistics for Factors 1

Factor number	Theme name	Cronbach's Alpha
1	Change management	0.759
2	Time inhibitors and impressions	0.743
3	Analysis and interaction	0.803

.

The descriptive statistics for factors can be seen in Table 25 indicating the mean, median, mode and standard deviation.

Table 25

Descriptive Statistics for Factors Identified

	N							
	Valid	Missing	Mean	Median	Mode	Std. Deviation	Minimum	Maximum
Factor1 Management of Change	165	0	2.88	2.80	3	0.869	1	5
Factor2 Inhibitors and Impression	165	0	3.47	3.50	4	0.815	2	5
Factor3 Analysis and Interaction	165	0	2.98	3.00	2[a]	1.047	1	5

a. Multiple modes exist. The smallest value is shown

5.7 New research insight: Does organisation size impact inhibiting factors

5.7.1. Organisation size (Question 2 recoded) test for normality

Descriptive statistics were done on each of the factors of Question 2. SME's (Small and medium-sized enterprises) was defined as 500 employees and less and larges companies as more than 500. Question 2 was therefore recoded accordingly. The reason Levy's (1993) and Ghobadian & Gallear (1997) definition for small and medium-sized enterprises was used and not the European Union's definition of less than 250, was to enable the statistical test. The descriptive statistics can be seen in Appendix G

A Kolmogorov-Smirnov test was done to test for normality and due to each sample size being larger than 50 (Pallant, 2007). Table 26 indicates the p-values for each of the factors' recoded question 2. A p-value of less than 0.05 indicates that the sample is not normally distributed and more or equal to 0.05 indicates a normally distributed sample. All Factor samples were not normally distributed except for Factor 1 More than 500 and Factor 2, 500 or less.

Table 26

Test for Normality on Factors of Question 2 Recoded.

Kolmogorov-Smirnov[a]

rQ2		Statistic	df	Sig.
Factor1	500 or less	0.112	77	**0.018***
	More than 500	0.089	88	0.084
Factor2	500 or less	0.098	77	0.065
	More than 500	0.110	88	**0.011***
Factor3	500 or less	0.118	77	**0.009***
	More than 500	0.103	88	**0.021***

a. Lilliefors Significance Correction

Figure 29-31 shows box plot of each of the factors related to the organisation size of 500 or less or more than 500 employees.

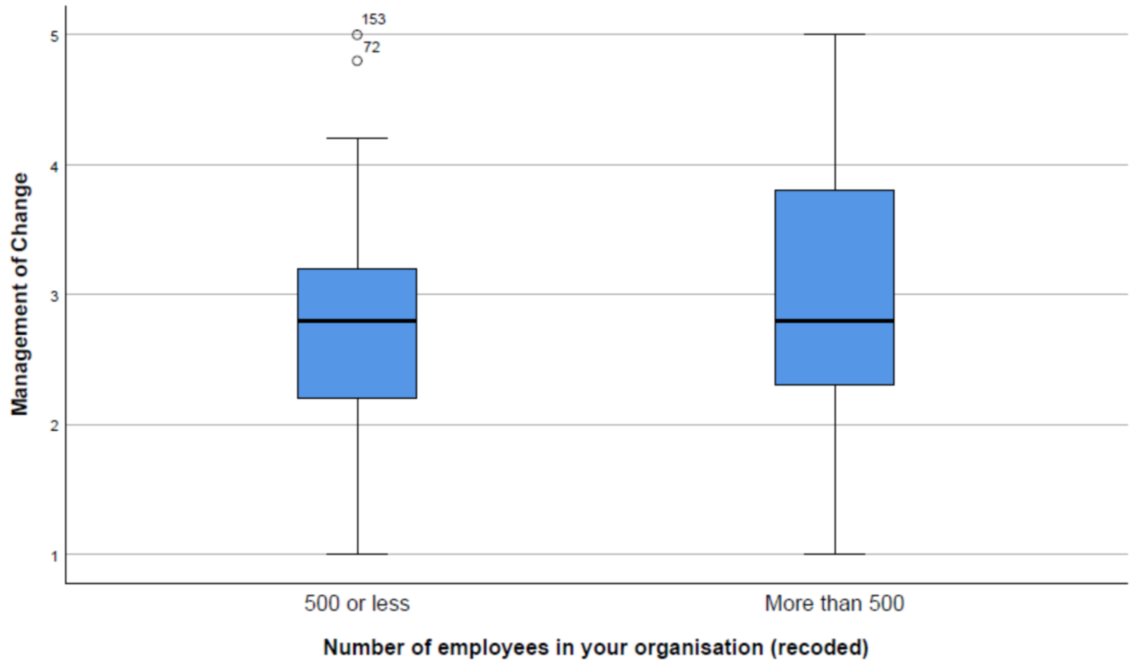


Figure 29. Management of change in different sized organisations

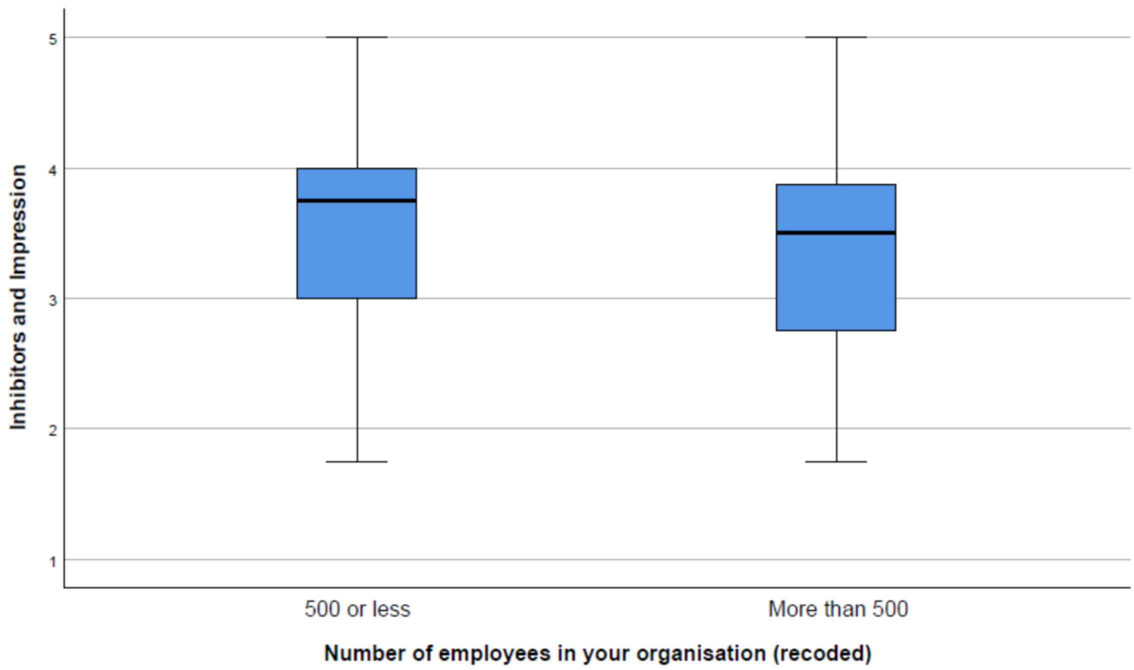


Figure 30. Inhibitors and impression in different sized organisations

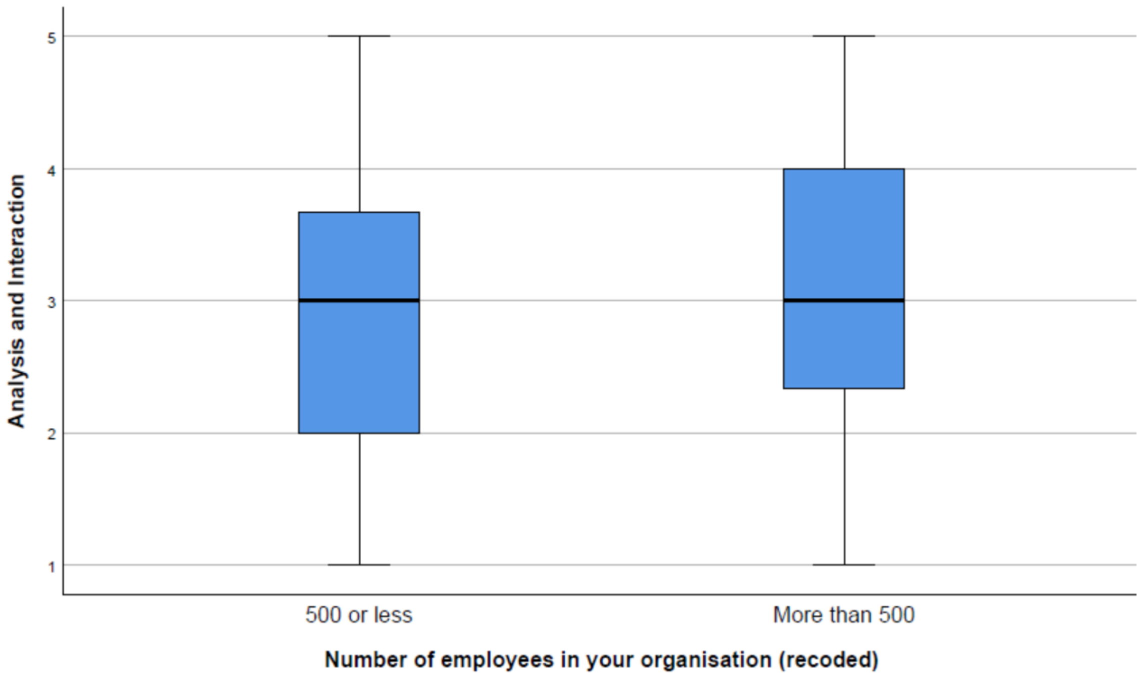


Figure 31. Analysis and interaction in different sized organisations

5.7.2. Comparisons between groups, test for differences in organisation size

Although most of the Factors were not normally distributed, am indecent t-test was done which is a parametric test assuming normality. This was done due to it being robust test, due to our sample sizes being larger than 20, to each participant not being present in both samples, due to the variance between groups not being too large and due to there not being extreme outliers. (Flom, 2017). Table 27 indicates the results for the independent t-test.

Table 27

Independent t-test for organisation size

Group Statistics

rQ2		N	Mean	Std. Deviation	Std. Error Mean
Factor1	500 or less	77	2.79	0.800	0.091
	More than 500	88	2.95	0.923	0.098
Factor2	500 or less	77	3.60	0.772	0.088
	More than 500	88	3.36	0.840	0.090
Factor3	500 or less	77	2.95	1.009	0.115
	More than 500	88	3.02	1.084	0.116

		Equality of Variances		t-test for Equality of Means						
									Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Factor1	Equal variances assumed	3.145	0.078	-1.182	163	0.239	-0.160	0.135	-0.428	0.107
	Equal variances not			-1.193	162.988	0.235	-0.160	0.134	-0.425	0.105
Factor2	Equal variances assumed	0.743	0.390	1.852	163	0.066	0.234	0.126	-0.015	0.483
	Equal variances not			1.863	162.596	0.064	0.234	0.126	-0.014	0.482
Factor3	Equal variances assumed	0.501	0.480	-0.410	163	0.683	-0.067	0.164	-0.390	0.256
	Equal variances not			-0.412	162.363	0.681	-0.067	0.163	-0.389	0.255

Equal variances were assumed for all Factors. The p-value for all groups were more or equal to 0.05 meaning there is no difference between small and medium companies and large companies regarding change management, time inhibitors and impressions as well as analysis and interaction.

5.8 New research insight: Does Industry impact inhibiting factors

5.8.1. Industry (Question 5 recoded) test for normality

Descriptive statistics were done on each of the factors of Question 5, which can be seen in Appendix H, and was recoded to into the following industry groupings:

- Food products and beverages
- Automotive, electronic or optical equipment and other
- Machinery, transport and fabricated metal equipment or products
- Non-metallic mineral and chemical products
- Refined petroleum products, tobacco, textiles, paper, wood products and printing

A Shapiro-Wilk test was done to test for normality and due to each sample size being smaller than 50 (Pallant, 2007). Table 28 indicates the p-values for each of the factors' recoded question 5. A p-value of less than 0.05 indicates that the sample is not normally distributed and more or equal to 0.05 indicates a normally distributed sample. All Factor samples were normally distributed except for Factor 1's and Factor 3's Machinery, transport and fabricated metal equipment or products.

Table 28 *Test for Normality on Factors of Question 5 Recoded.*

Shapiro-Wilk				
rQ5		Statistic	df	Sig.
Factor1	Food products and beverages	0.970	39	0.386
	Automotive, electronic or optical equipment and other	0.973	31	0.596
	Machinery, transport and fabricated metal equipment or products	0.890	32	**0.004***
	Non-metallic mineral and chemical products	0.984	28	0.934
	Refined petroleum products, tobacco, textiles, paper, wood products and printing	0.960	35	0.227
Factor2	Food products and beverages	0.964	39	0.235
	Automotive, electronic or optical equipment and other	0.960	31	0.295
	Machinery, transport and fabricated metal equipment or products	0.953	32	0.180
	Non-metallic mineral and chemical products	0.969	28	0.554
	Refined petroleum products, tobacco, textiles, paper, wood products and printing	0.977	35	0.658
Factor3	Food products and beverages	0.968	39	0.328
	Automotive, electronic or optical equipment and other	0.934	31	0.057
	Machinery, transport and fabricated metal equipment or products	0.929	32	**0.037***
	Non-metallic mineral and chemical products	0.933	28	0.074
	Refined petroleum products, tobacco, textiles, paper, wood products and printing	0.965	35	0.312

Figure 32-34 indicates the box plots for each of the factors related to the industry groupings.

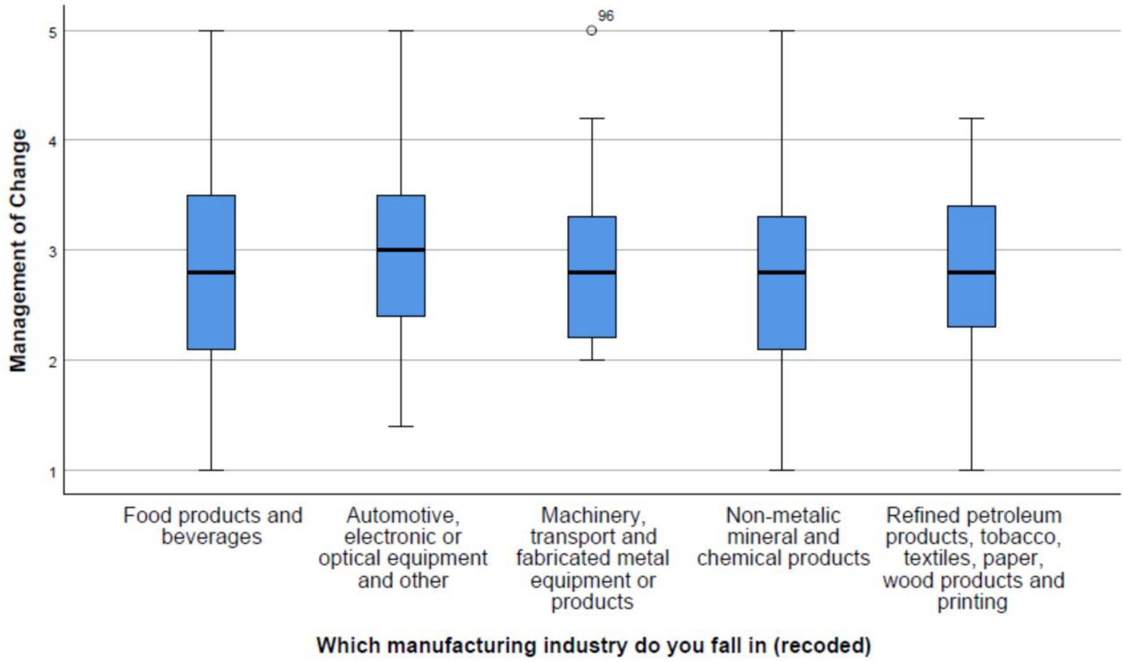


Figure 32. Management of change in different industries

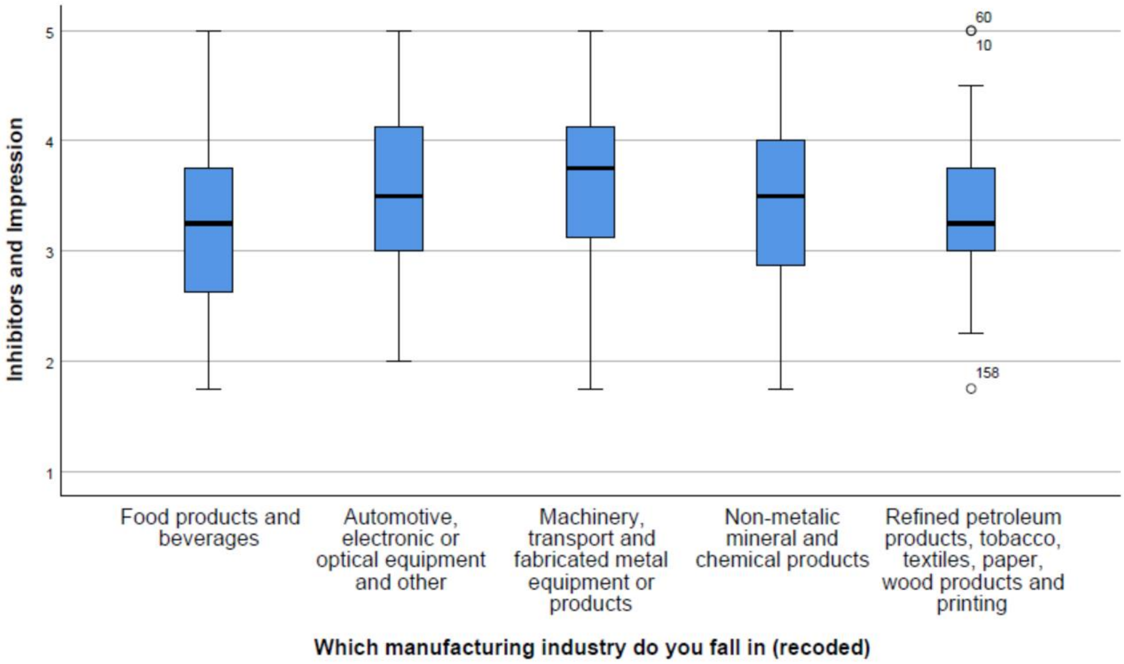


Figure 33. Inhibitors and impression in different industries

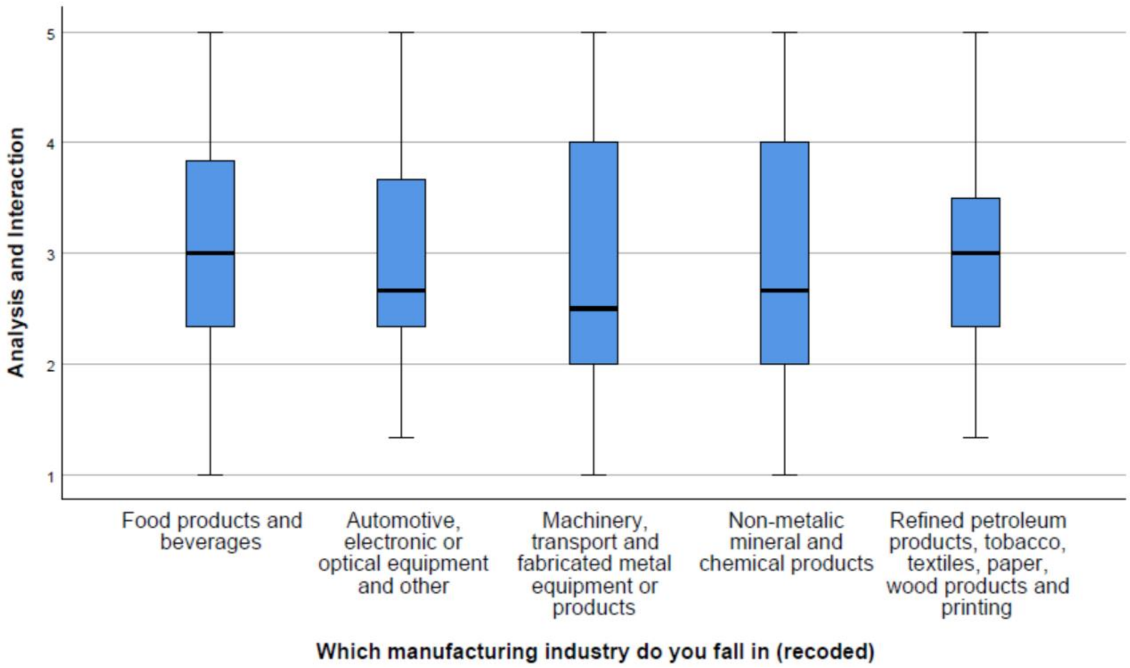


Figure 34. Analysis and interaction in industries

5.8.2. Comparisons between groups, test for differences in industry

Most of the Factors were normally distributed and an ANOVA test was done. The test can be seen in Table 29. All variances for all Factors were equal. All the p-values for all factors were greater or equal to 0.05. This means there is no difference between industries regarding change management, time inhibitors and impressions as well as analysis and interaction.

Table 29 *ANOVA test for Industry*

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Bound	Bound	Minimum	Maximum
Factor1	Food products and	39	2.94	1.015	0.162	2.61	3.27	1	5
	Automotive, electronic or	31	2.97	0.814	0.146	2.68	3.27	1	5
	Machinery, transport and	32	2.89	0.777	0.137	2.61	3.17	2	5
	Non-metalic mineral and	28	2.74	0.925	0.175	2.38	3.09	1	5
	Refined petroleum	35	2.83	0.803	0.136	2.55	3.10	1	4
	Total	165	2.88	0.869	0.068	2.74	3.01	1	5
Factor2	Food products and	39	3.28	0.874	0.140	3.00	3.57	2	5
	Automotive, electronic or	31	3.61	0.834	0.150	3.31	3.92	2	5
	Machinery, transport and	32	3.66	0.837	0.148	3.36	3.97	2	5
	Non-metalic mineral and	28	3.45	0.792	0.150	3.14	3.75	2	5
	Refined petroleum	35	3.41	0.707	0.120	3.16	3.65	2	5
	Total	165	3.47	0.815	0.063	3.35	3.60	2	5
Factor3	Food products and	39	3.09	0.991	0.159	2.77	3.42	1	5
	Automotive, electronic or	31	3.08	1.014	0.182	2.70	3.45	1	5
	Machinery, transport and	32	2.79	1.132	0.200	2.38	3.20	1	5
	Non-metalic mineral and	28	3.00	1.214	0.229	2.53	3.47	1	5
	Refined petroleum	35	2.94	0.941	0.159	2.62	3.27	1	5
	Total	165	2.98	1.047	0.081	2.82	3.14	1	5

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Factor1	Based on Mean	0.926	4	160	0.450
	Based on Median	0.925	4	160	0.451
	Based on Median and with adjusted df	0.925	4	153.710	0.451
	Based on trimmed mean	0.942	4	160	0.441
Factor2	Based on Mean	0.612	4	160	0.655
	Based on Median	0.608	4	160	0.658
	Based on Median and with adjusted df	0.608	4	157.480	0.658
	Based on trimmed mean	0.613	4	160	0.654
Factor3	Based on Mean	1.714	4	160	0.149
	Based on Median	1.244	4	160	0.295
	Based on Median and with adjusted df	1.244	4	153.740	0.295
	Based on trimmed mean	1.701	4	160	0.152

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Factor1	Between Groups	1.085	4	0.271	0.353	0.841
	Within Groups	122.802	160	0.768		
	Total	123.887	164			
Factor2	Between Groups	3.368	4	0.842	1.277	0.281
	Within Groups	105.509	160	0.659		
	Total	108.877	164			
Factor3	Between Groups	1.980	4	0.495	0.446	0.775
	Within Groups	177.754	160	1.111		
	Total	179.735	164			

Chapter 6: Discussion

6.1 Introduction and study participant detail

183 responses were obtained from the survey conducted but only 165 were useful. Most participants (37.6%) were from large manufacturing industries with more than a 1000 employees. Less than 10 employees (3.0% of participants) and 10-15 employees (9.1% of participants) were the least responses received. The remainder of the participants in categories 51- 250, 251-500 and 501-1000 were more or less equal (17.0%, 17.6% and 15.8% respectively). It would be expected that due to the participants being from mostly large manufacturing companies, failure rate will be higher than the norm.

From literature, many authors stated that process improvement methodologies fail. Kearney (1991) stated 80% of TQM initiatives fail, Liker & Franz (2011) stated 2% of Lean manufacturing programmes achieve results and Patil & Mishra (2014) stated 60% of Lean Six Sigma initiatives fail. Mclean, et al. (2017) also stated that continuous improvement initiatives have a high failure rate.

From the research, 73.9% of participants either agreed or strongly agreed that their quality improvement methodology or approach has achieved the desired company results. 18% of participants remained neutral and only 7.9% of participants either stated that they strongly disagree or disagree that their company's improvement methodology failed to achieve its desired outcomes.

Therefore, this study agrees with Ras & Visser (2015) in that more than 70% of Lean manufacturing, Six Sigma and TOC are successful.

Most participants (41.2%) were also senior managers or heads of departments and only 4.8% were junior managers. Participants responsible for process improvement, engineers and middle or unit managers were relatively equal in number with responses of 16.4%, 17.6% and 20% respectively.

The experience level of participants was suggestive of a normal distribution in that 38.2% stated that they had 6-10 years of experience within the manufacturing industry. The second highest were the 20% of participants who had 2-5 years' experience. Participants with 11-15 years' experience and 16-25 years' experience each totalled 13.3%. Lastly 8.5% of respondents had less than 2 years' experience and only 6.7% had more than 25 years' experience.

This study included various manufacturing industries. More than 23 different industries participated in this research, the majority contributors from Oil and Gas with 10.3% of the responses. Electrical, Electronics or Optical products and Metal or metal fabricated products had the second highest responses each at 9.3%. This was followed by the automotive industry with 7.3% of the participants. Food; Pulp, Paper, Publishing and Printing; Personal care or toiletries; Machinery and equipment and Pharmaceutical had relatively the same responses with 5.5%, 5.5, 4.8%, 4.8% and 4.2% respectively.

Industries not well represented in this study were Printing (specifically security printing), Confectionery, Wood and wood products, Vegetables and fruit, Non-alcoholic beverages, Tobacco, Rubber and plastic products, Grains and wheat and Textiles and textile products, with less than 2% of respondents.

From the participants in this study, 89.1% stated that their company had an improvement methodology, cost saving or related exercise, with 7.3% stating that their company didn't. The rest stated that they were unsure.

52.1% of respondents stated that improvement methodology implementation responsibility was the duty of all employees with 41.8% stating it was the responsibility of a specialised team. Only 6.1% stated it was an individual's responsibility. The high success rate of improvement methodologies from the respondents in this study therefore suggests that a combination of specialised teams as well as a companywide initiative should be used for process improvement.

Most improvement methodologies were created in the 1980's (Nave, 2002; Stamm et al., 2009; Bentley, 2011; Cheng, 2017; Kumar et al., 2018). In this study however, the implementation duration of most improvement methodologies has only been 0-5 years (65.5% of respondents). Other respondents either stated that they didn't know (15.8%) or that it has been 6-10 years (12.1%). 6.7% of respondents stated that it has been more than 11 years.

6.1. Research question 1: Improvement methodologies currently used in industry

Woeppel (2015) stated that in the 2000's that of the top four improvement methodologies used in industry, 70% were using Lean manufacturing, 34% Total quality management (TQM), 29% Six Sigma and 14% Theory of constraints (TOC). Katz (2007) had the top four improvement methodologies as Lean manufacturing, Lean Six Sigma, TQM and Agile manufacturing. As previously stated, Katz (2007) was the most recent found data.

In Figure 34 below, a comparision can be seen between Katz (2007) improvement theory breakdown and the findings from this study.

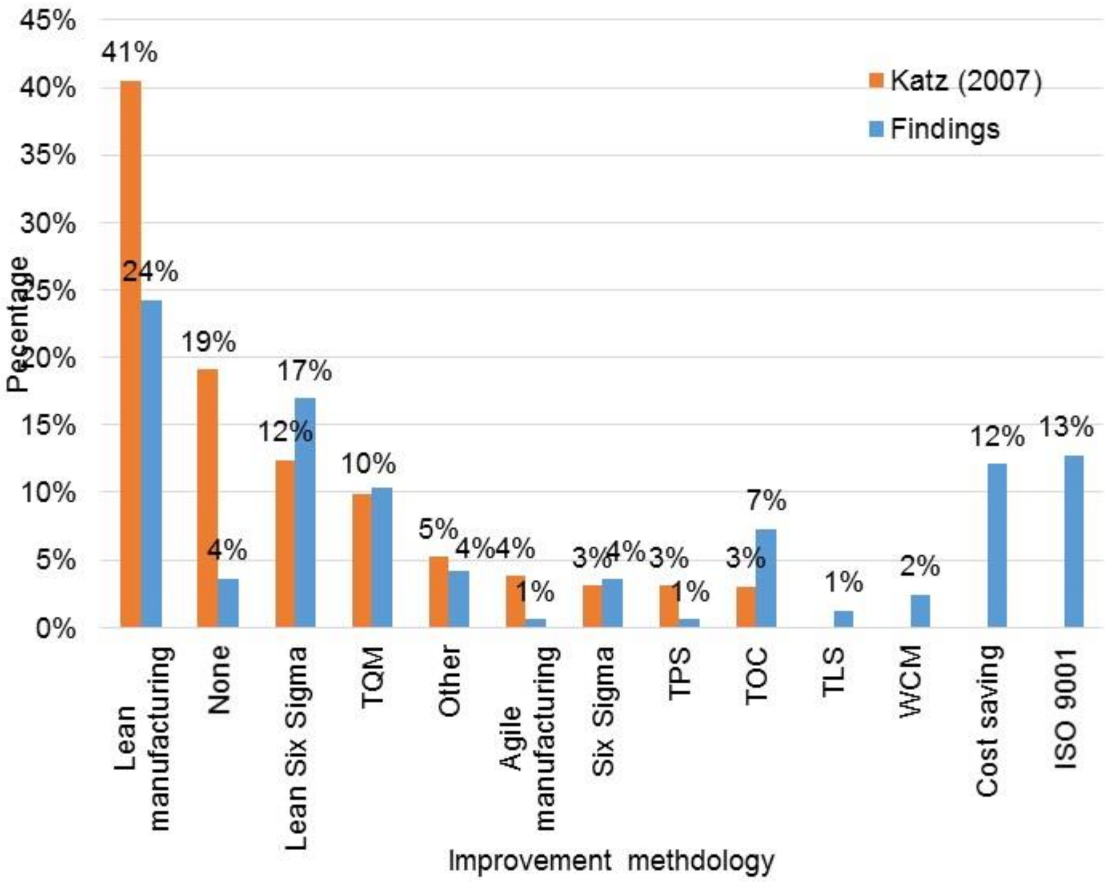


Figure 35. Improvement methodology comparison between Katz (2007) and study findings

From Figure 34 we can see there has been a significant decrease in Lean manufacturing as an improvement methodology as stated by Katz (2007) and Woeppel (2015). It is still however the leading improvement methodology. A possible explanation for the decline in Lean manufacturing as an improvement methodology is only the principles to do with cost savings is being applied. More manufacturing industries are also adopting improvement methodologies as seen in the drop from 19% to 4% in “None”. The use of Agile manufacturing and TPS has also decreased slightly.

The use of Lean Six Sigma has increased from 12% to 17% and TOC from 3% to 7%. TQM and Six Sigma have remained relatively unchanged. New improvement methodologies such as WCM and TLS has emerged but uptake is slow. There is a possibility these improvement theories was classified under “Other” in the survey done by Katz (2007). The same possibility exists for cost savings and ISO9001.

TQM in manufacturing remained largely unchanged at 10%, while 13% of respondents indicated that they use ISO 9001. Therefore, the statements made by Poksinska et al. (2002) and Youssef & Youssef (2018) indicate that indeed ISO 9001 should rather be considered a subset of TQM and not a substitute of TQM.

There are large discrepancies between this study’s findings when compared to Katz (2007) and Woeppel (2015). ISO 9001 and Cost savings has also emerged as an improvement methodology. The implication of these findings is that due to the decrease of the Lean manufacturing as a dominant theory and the increase in uptake of other improvement methodologies, an integrated improvement methodology would likely be welcomed by industry. Also, although ISO 9001 was not considered as an improvement methodology, the findings indicate that it should be incorporated in an integrated improvement methodology

6.2. Research question 2: Improvement theory combination

This study set out to determine how Lean manufacturing, Six Sigma and TOC should be combined into an integrated improvement methodology.

Demchuck & Baitsar (2015) suggested that, from a quality assurance perspective, TOC should be used first, followed by Lean manufacturing tools and then the last phase should be Six Sigma. Pirasteh & Kannappan (2013) agreed to this implementation sequence.

The study found that 26.7% suggest the implementation of TLS as an improvement methodology sequence, although it is not overwhelmingly so. The fact that 21.2% suggest the sequence should be Lean manufacturing, TOC and then Six Sigma indicates that there might be a strong notion towards use Lean manufacturing first for its cost saving capabilities. A strong argument exists to start with TOC as 17.6% suggest the sequence should be TOC, Six Sigma and then Lean manufacturing. The decision not to investigate improvement methodologies like 6TOC as suggested by Creasy (2014) was a good one as only 10.9% of participants suggested Six Sigma should be instituted first followed by TOC and then Lean manufacturing. Ras & Visser (2015) stated even through process improvement methodologies like Lean manufacturing, Six Sigma and TOC are successful, organisations would still welcome a combined approach.

The findings support the literature and therefore creates the opportunity for TLS to be the next improvement methodology breakthrough.

6.3. Research question 3: Factors inhibiting process improvement

Factors inhibiting process improvement implementation were investigated in this study with the aim to incorporate them into an integrated improvement methodology so as to improve the success rate of said improvement methodology. The factors were condensed into three themes and can be seen in Table 30 below:

Table 30 *Main factors inhibiting process improvement*

Factor number	Factor
1	Change management
2	Time inhibitors and impressions
3	Analysis and interaction

6.3.1. Change management

Willingness to change, the need for change or change management was identified by Cook (1994), Bhasin (2015) and Mclean et al. (2017) as an inhibitor that needs to be managed effectively to enable improvement methodology implementation.

Employee’s resistance to change was found to be the biggest reason in this study as to why improvement methodology implementation is difficult. Resistance to change is strongest at the start of a new process. Due to the majority of participants (65.5%) stating that they have only implemented their methodology over 0-5 years, it can explain why employees’ resistance to change has made implementation difficult. Furthermore, respondents also indicated that lack of understanding the benefits of the improvement methodology is one of the top four reasons why implementation has been challenging. This can also point to poor change management.

This study therefore agrees with Cook (1994), Bhasin (2015) and Mclean et al. (2017) that change management is an inhibitor to process improvement methodology implementation.

An educated workforce, training and learning was stated by Cook (1994) and Mclean et al. (2017) as a CSF to process improvement. Although technical knowledge and training formed part of the change management main construct, respondents felt that inadequate management thereof would make improvement methodology implementation difficult.

6.3.2. Time inhibitors and impressions

Implementation time and the impression of an improvement methodology was found to be an inhibitor in literature. Spector (2006) did indicate that 36% of Lean practitioners stated that their main challenge was backsliding to old ways of work. Ghobakhloo & Azar (2018) furthermore stated Lean manufacturing implementation is time consuming. Woeppel (2015) indicated that managers become frustrated with the continuous improvement projects and after a time stop supporting them due to them not delivering expected outcomes. 41.2% of respondents indicated that they utilise Lean manufacturing or Lean Six Sigma and therefore a comparison was made to literature.

This study found that respondents disagreed that their improvement methodology was a gimmick, that their improvement methodology was not sustainable and that their improvement methodology failed previously. Participants responded relatively neutrally to the statement that improvement methodologies take up too much time.

This can be explained by most respondents (73.9%) indicating that their chosen operations, quality improvement methodology or approach has achieved the desired company results and that most of the improvement methodologies (65.5%) implementation has been between 0 to 5 years.

The conclusion therefore is that time inhibitors and impression are an important inhibitor to the implementation of the improvement methodology, however the statistics from these findings cannot conclusively confirm this. This factor should thus be included as an inhibitor in the integrated improvement methodology framework to manage and the management thereof will likely be company dependant.

6.3.3. Analysis and interaction

Bentley (2011) stated that Lean manufacturing and Six Sigma do not allow for the system to be analysed as a whole and generally process interaction is not considered. Six Sigma's main criticism has been that it does not consider system interdependence. Nave (2002), Stamm et al., (2009), Bentley (2011), Cheng (2017) and Kumar et al., (2018) have further stated that statistical, system or complex analysis in Lean manufacturing and data analysis in TOC is not valued. Anthoney et al. (2017) not only stated that Lean manufacturing is not good at resolving complex problems but also stated that Six Sigma takes too long for data analysis. Hietschold, et al., (2014) also named data analysis as a CSF for TQM implementation success.

A summary of the answers given by respondents are given in Table 31 below. The means in red and orange indicate the statements that were agreed with by respondents while the means in green indicate the statements disagreed with by respondents.

Table 31

The Level of Agreement as to Why the Improvement Theory Implemented at the Company Has Been Difficult

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	Median	Mode	Std. Deviation
Lack of commitment from management	20	54	31	40	20	2.92	3	2	1.242
	12.1%	32.7%	18.8%	24.2%	12.1%				
Lack of improvement methodology's technical knowledge	18	73	29	35	10	2.67	2	2	1.111
	10.9%	44.2%	17.6%	21.2%	6.1%				
Lack of understanding benefits	24	64	24	41	12	2.72	2	2	1.199
	14.5%	38.8%	14.5%	24.8%	7.3%				
Does not fit company's culture	18	44	29	53	21	3.09	3	4	1.239
	10.9%	26.7%	17.6%	32.1%	12.7%				
Management resistance to change	23	46	28	45	23	2.99	3	2	1.295
	13.9%	27.9%	17.0%	27.3%	13.9%				
Employees resistance to change	29	80	27	22	7	2.38	2	2	1.056
	17.6%	48.5%	16.4%	13.3%	4.2%				
The improvement methodology is a gimmick	4	21	41	57	42	3.68	4	4	1.065
	2.4%	12.7%	24.8%	34.5%	25.5%				
The improvement theory is not sustainable	3	24	29	79	30	3.66	4	4	0.997
	1.8%	14.5%	17.6%	47.9%	18.2%				
High cost of investment	9	38	35	62	21	3.29	4	4	1.121
	5.5%	23.0%	21.2%	37.6%	12.7%				
The improvement theory has failed previously	4	41	32	62	26	3.39	4	4	1.097
	2.4%	24.8%	19.4%	37.6%	15.8%				
Takes up too much time	10	51	30	51	23	3.16	3	2[a]	1.184
	6.1%	30.9%	18.2%	30.9%	13.9%				
The company does not value statistical or system analysis	17	35	29	60	24	3.24	4	4	1.234
	10.3%	21.2%	17.6%	36.4%	14.5%				
The company does not look at how process interaction and looks at them independently	27	63	21	38	16	2.72	2	2	1.258
	16.4%	38.2%	12.7%	23.0%	9.7%				
The company does not value data analysis and/or worker input is minimal	16	53	31	45	20	3.00	3	2	1.215
	9.7%	32.1%	18.8%	27.3%	12.1%				

a. Multiple modes exist. The smallest value is shown

This study found process analysis and interaction as the third inhibitor. The participants stated that the company does not look at process interaction but looks at each process independently.

This study therefore agrees with literature that data analysis, statistical or system analysis and process interaction be managed to improve the success rate of the integrated improvement methodology approach.

6.3.4. Top management commitment

Cook (1994), Näslund (2008), Mclean et al. (2017) and Hietschold et al. (2014) stated that top management commitment is a requirement of process improvement implementation success. Rokke & Prakash Yadav (2010), in contrary stated top management commitment did not feature as a success factor.

In this study top management commitment did feature as an inhibitor and is part of the change management factor that need to be managed. Therefore agrees with Cook (1994), Näslund (2008), Mclean et al. (2017) and Hietschold et al. (2014) that top management commitment is a critical success factor.

The study concluded that Change management; Time inhibitors and impressions as well as Analysis and interaction are the reason for improvement methodology implementation difficulty. These factors were included in the integrated TLS improvement methodology model.

6.4. Research question 4: Overlap of Main focus area of improvement methodologies

In the manufacturing industry winning market share is still important and the focus is not only on cost saving but on entering new geographic markets. (Gates, Mayor & Gampenrieder, 2016). Lean manufacturing, Six Sigma and TOC have many overlapping elements and there are similarities between these philosophies (de Jesus Pacheco, 2015; Demchuk & Baitsar, 2013; Voss, 2005).

Although the statistical test could not be done, there is a lot of overlap between improvement theories. The focus area of Lean manufacturing, Lean Six Sigma, Six Sigma, ISO 9001, TQM and World Class Manufacturing (WCM) is to improve efficiency as opposed to the expectation that each improvement methodology would focus on its own strength.

Another overlap between improvement methodologies is the focus on reducing total cost. Interestingly, if companies have a choice to focus on improving revenue or reducing cost through improvement theories, they chose the latter. Reducing cost ranks high in Lean manufacturing, Lean Six Sigma and TQM as a focus area. International investments primary driver is to reduce costs. (Gates et al., 2016). Which can explain why 21.6% of participants indicated that the main focus area of their process improvement methodology is to reduce total cost

Interestingly, ISO 9001 featured as an improvement methodology indicating manufacturing industries value certification as an enabler of business and a value proposition to customers. Lean Six Sigma is favoured over Six Sigma but not Lean manufacturing.

This confirms literature and the impact thereof is it enables the creation of an integrated improvement methodology due to minimal conflict regarding focus areas of improvement methodologies

6.5 Research question 5: Overlap of beneficial strategies of improvement methodologies

The most beneficial strategy for the manufacturing industry is cost savings, followed closely by reduced quality errors. It is therefore expected that most companies would utilise Six Sigma, as its primary objective is cost reduction and its primary effect is reduced quality variation (Nave, 2002; Stamm, et al., 2009; Bentley, 2011; Cheng, 2017; Kumar et al., 2018)

This study however revealed that industries rather utilise Lean manufacturing, TQM and even ISO 9001 to fulfil this strategy. Six Sigma is not as popular as Lean Six Sigma which indicates that Six Sigma is being discarded in favour of Lean Six Sigma. Although it could not be proven statistically, it is clear that a lot of overlap exists regarding improvement methodologies’ strategic intent.

The findings therefore contradict the literature that Six Sigma is the simplest solution to reducing cost and quality errors. The implication thereof for management is to utilise an integrated improvement methodology, as a combination of methodologies will lead to the most beneficial outcome.

6.6 New insight: Organisation size and industry adaptation of improvement methodologies

No mention of organisation size relative to improvement theories were found in the literature. There was also no mention of improvement theories only specific to certain manufacturing industries.

This study found that there is no difference between small and medium companies, and large companies regarding change management, time inhibitors and impressions as well as analysis and interaction. Subsequently, there was also no difference between industries regarding change management, time inhibitors and impressions as well as analysis and interaction.

This means the development of an integrated TLS improvement model does not need to cater for organisational size or industry. This greatly reduces the complexity of the model.

Chapter 7: Conclusion

7.1 Principal findings

The principal finding of this study is an integrated improvement methodology framework should be used in the manufacturing industry. This was done through investigating the focus area of improvement methodologies and the most beneficial strategies that companies used. Organisational size and industry impact on the improvement framework was also investigated. Furthermore, this research aimed to identify inhibitors to process improvement.

Due to the methodology not discarding any progress made or current standalone methodologies like Lean manufacturing, Six Sigma or TOC, the expectation is that resistance to change will be minimised. By leveraging the strength of each methodology, each methodology can contribute its value and therefore help the organisation improve. Organisations can utilise current practises in the new DaMi-TLS improvement framework, which can be seen in Figure 35 below.

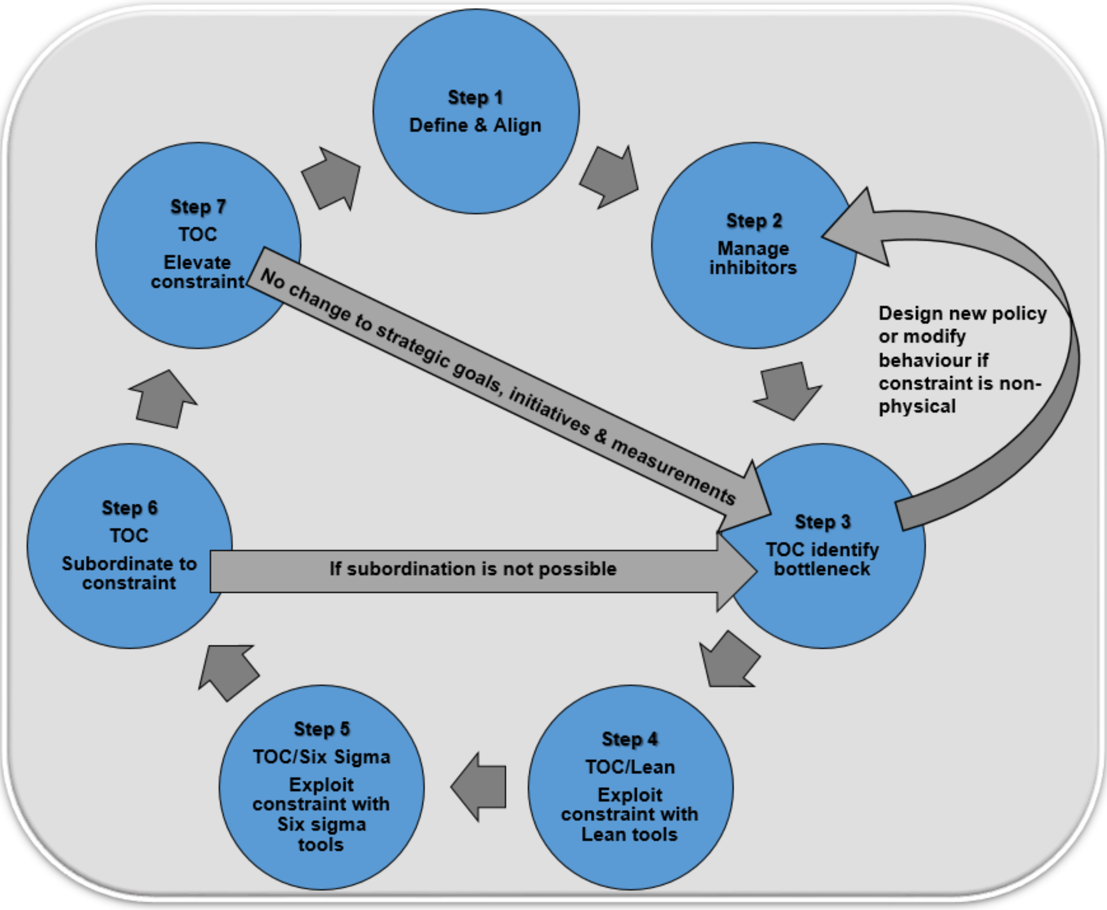
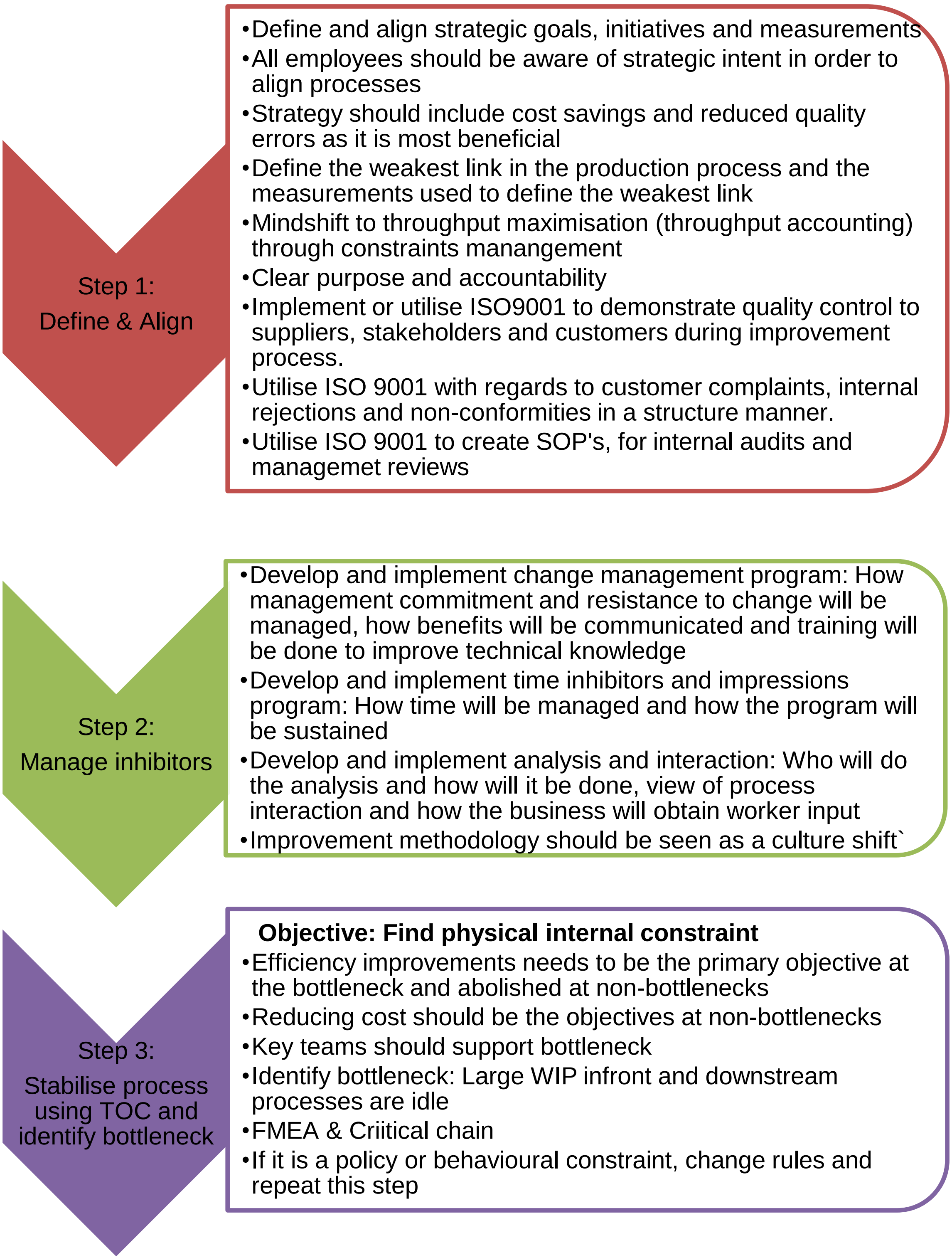
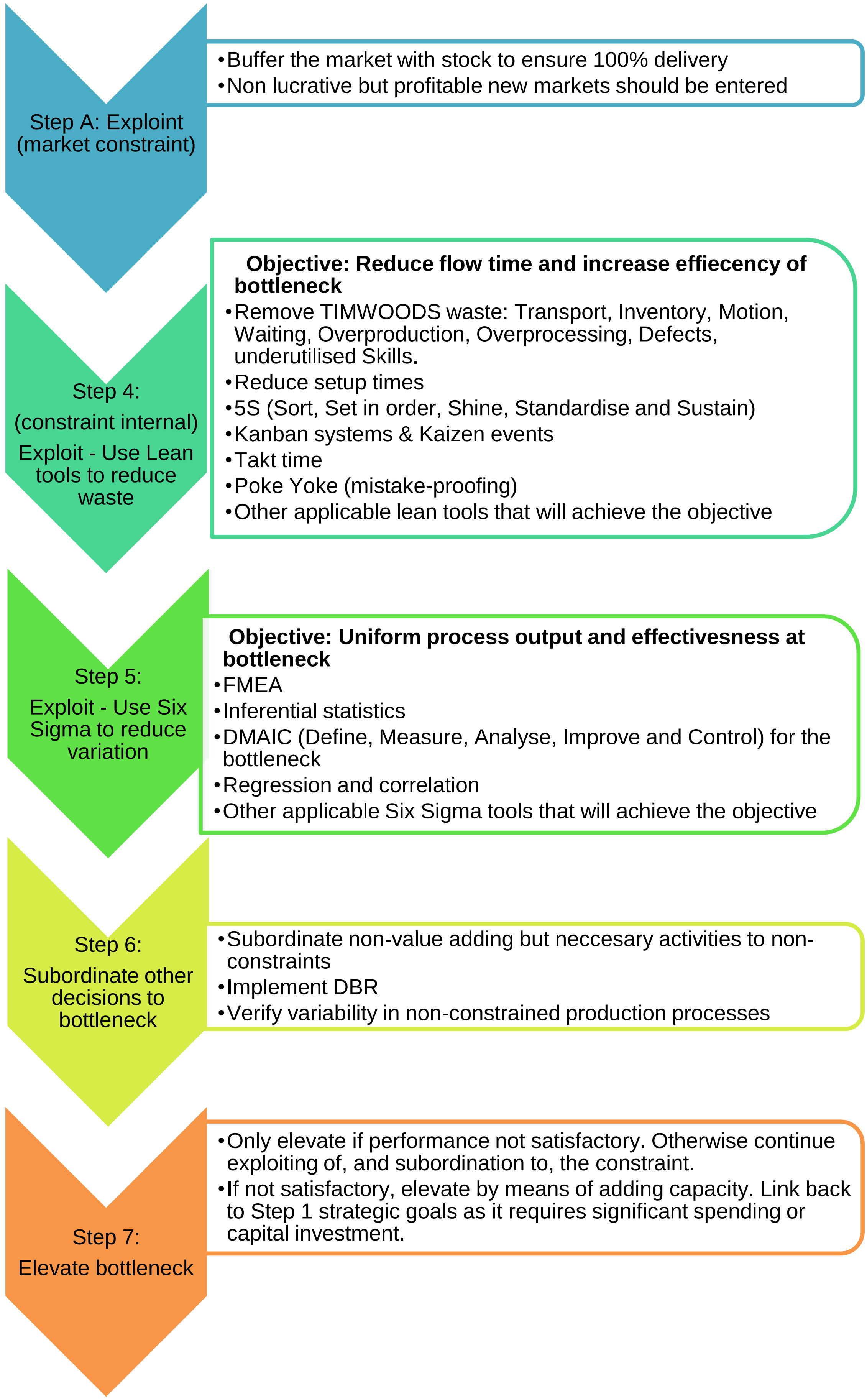


Figure 36. DaMi-TLS improvement theory framework

Figure 37 below explains the DaMi-TLS improvement theory framework in more detail and can be used as a more detailed roadmap for process improvement




Step A: Exploint (market constraint)
•Buffer the market with stock to ensure 100% delivery
•Non lucrative but profitable new markets should be entered
Step 4: (constraint internal) Exploit - Use Lean tools to reduce waste
Objective: Reduce flow time and increase effiecency of bottleneck
•Remove TIMWOODS waste: Transport, Inventory, Motion, Waiting, Overproduction, Overprocessing, Defects, underutilised Skills.
•Reduce setup times
•5S (Sort, Set in order, Shine, Standardise and Sustain)
•Kanban systems & Kaizen events
•Takt time
•Poke Yoke (mistake-proofing)
•Other applicable lean tools that will achieve the objective
Step 5: Exploit - Use Six Sigma to reduce variation
Objective: Uniform process output and effectivesness at bottleneck
•FMEA
•Inferential statistics
•DMAIC (Define, Measure, Analyse, Improve and Control) for the bottleneck
•Regression and correlation
•Other applicable Six Sigma tools that will achieve the objective
Step 6: Subordinate other decisions to bottleneck
•Subordinate non-value adding but neccesary activities to non-constraints
•Implement DBR
•Verify variability in non-constrained production processes
Step 7: Elevate bottleneck
•Only elevate if performance not satisfactory. Otherwise continue exploiting of, and subordination to, the constraint.
•If not satisfactory, elevate by means of adding capacity. Link back to Step 1 strategic goals as it requires significant spending or capital investment.

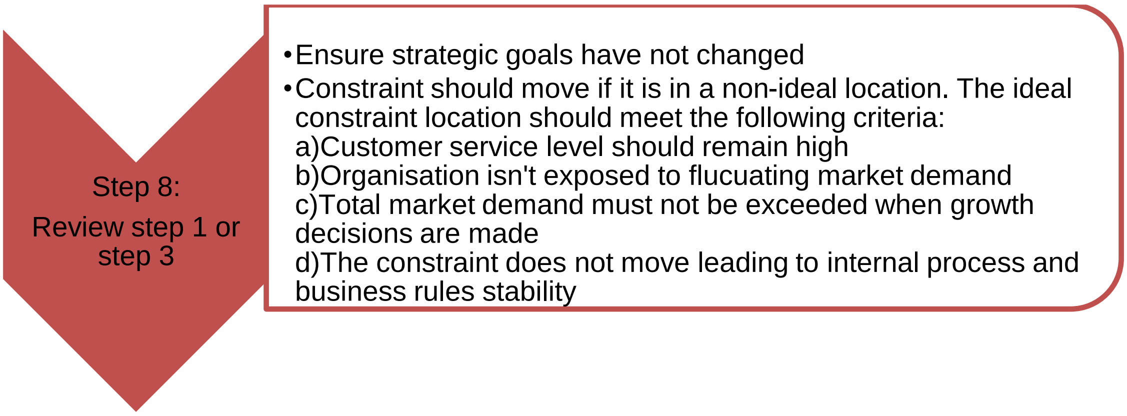


Figure 37: Detailed DaMi-TLS improvement theory roadmap

(Skhmot, 2017; van Tonder, 2011; Cheng, 2017; Timans et al., 2016; Pretorius, 2014; Nave, 2002; Stamm et al., 2009; Bentley, 2011; Kumar et al., 2018; Woeppel, 2015; Pirasteh & Kannappan, 2013)

The benefits to the improvement methodology is that is not limited to a specific manufacturing industry or organisational size. If we combine industries using Lean manufacturing, Lean Six Sigma, Six Sigma, TOC and TLS, there is an opportunity that 53% of industry would be keen to adopt the DaMi-TLS methodology as it utilises the techniques they're already familiar with. The incorporation of ISO 9001 into the improvement process is beneficial in that it signals to suppliers, customers and stakeholders that the business has good quality control processes.

The model indicates a relationship between five components namely TOC, Lean manufacturing, Six Sigma, ISO 9001 QM and process improvement inhibitors.

7.2 Implications for management

A substantial amount of resources are spent on improvement efforts and utilising the DaMi-TLS improvement framework can significantly increase the return on the spent resources. The framework can assist in reducing cost and improving quality which are heretofore the strategies most implemented in the manufacturing industry.

The DaMi-TLS improvement framework assists organisations to rapidly improve in order to maintain or improve their position in a competitive environment as manufacturing is still an important sector in today's world economy. It will also help navigate the complexity of modern manufacturing conditions as it creates focus and alignment in the organisation in order to coordinate efforts towards improvement.

By utilising the DaMi-TLS improvement framework, current skills and expertise in the organisation can be utilised. This aligns with Lean manufacturing's 8th step to not waste skills in an organisation. Staff with extensive Lean experience, Six Sigma certifications or TOC champions will embrace the methodology as it does not contradict what they know, but instead enables them to use their expertise more effectively.

As much as the DaMi-TLS framework has detailed steps, improvements in the fields of Lean manufacturing, Six Sigma or TOC can be incorporated into the framework making it both robust and agile.

The other benefit of the framework is it seeks to strengthen the weakest link in the production chain. Should the variation reduce and uniform output be delivered at the leverage point, the throughput and resultant profit of the whole business improves as well. The framework will be able to give fast, tangible results with clear structure for adjustments. Data analysis is also simpler as it does not require analysis of the whole supply chain but only the bottleneck. It is also directly linked to business strategy.

The use of the DaMi-TLS framework reduces poor quality costs, improves top line growth and bottom line savings, it improves manufacturing operations and ensures the company remains competitive with enhanced customer satisfaction.

7.3. Limitations of the research

This study contributed significant findings but is not without limitations from a practical and theoretical perspective. Industry variety was a limitation. Although different manufacturing industries were targeted, the fact that Oil and Gas had the majority of the responses might have affected the results.

The scope of this research did not include culture considerations, leadership aspects and the mind-set change needed for sustainable implementation. The reason for this is due to the complexity this adds to the study.

This study did not account for the characteristics of the market, manufacturing location, operating conditions, the complexity of the production process or the attributes of the products manufactured which can have an impact on the results obtained.

A qualitative study was not done in order to verify the quantitative results and therefore enable triangulation of findings.

This research did not distinguish between IT intensive plants, machinery intensive plants or labour intensive plants which can have an impact on the results.

Due to 41.2% of respondents being senior management or head of departments, there is a possibility that a bias exists in that these managers do not want to admit failure of process improvement methodologies.

7.4 Suggestions for future research

It is recommended that this research be expanded to include more respondents from other industries. A lot of different classification or taxonomies of industry also exists. It is recommended that the ISIC be used in future studies.

A study should be done filling each stratum of manufacturing industries with enough respondents to do a comparison between industries regarding each industry’s process improvement methodology used, their focus area, their most beneficial strategy, their success rate and their implementation difficulty.

There was difficulty obtaining data on recent improvement methodologies. The MPI (Manufacturing Performance Institute) provides a benchmark toolkit for future research. Although contact with them was unsuccessful, it is recommended that the questions from this study be included in the IW/MPI Census of Manufacturers for a more comprehensive study as they have global reach and more widespread questions.

Change management, Time inhibitors and impressions as well as Analysis and interaction have been identified as inhibitors to the implementation of process improvement. Although this study identified these inhibitors, its purpose was not to state how to manage them. It is recommended that research be conducted on how to overcome these inhibitors and this be integrated in the DaMi-TLS framework.

Manufacturing industries was the only focus of this study. Therefore, it is recommended to expand research to other industries outside manufacturing such as the non-profit sector or to the service sector.

It is recommended the sample size be increased to meet the minimum sample size to run appropriate statistical tests of cross tabulations concerning the main focus area and most beneficial strategy of companies. This will enable improved conclusions. The sample size can also be increased to verify the outcomes of this study.

Culture has emerged as one of the most important factors that needs to be considered during implementation and sustainability of process improvement. Although culture was not considered in this study, it is recommended that research be conducted on how to effectively design and change company culture to support process improvement and building it into the DaMi-TLS framework as an enabler.

Improvement methods cannot be developed only in theory. It needs to be tested practically. It is suggested that real life cases be used to test and improve the framework. Testing and validating the framework on complex manufacturing systems will not only provide assessment on the robustness of the framework, but can also provide great insights to further expand the model. The framework testing and validation should also cover various industries.

A common theme across most improvement methodologies is the need for education and training whether individual, team based or organisation wide. Future research can determine how, what and where to train within the organisation to enable improvement methodology success. The argument is to have a learning organisation.

7.5 Conclusion

This study has contributed to the process improvement body of knowledge and has provided other insightful concepts. It also led to the creation of an integrated framework that can be utilised in the manufacturing industry immediately. Indeed, there are no best process improvement methodologies and managers should leverage the strength of each to enable the change they need instead of wasting energy on debating why their methodology is best. The tools in this framework provide the platform to enable process improvement success through its valuable models, techniques and ideas. The challenge will not be in utilising the tools but also effectively managing this change process. It is the belief that this framework will bring about improved results faster.

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Appendix A

<table>
<tr><td colspan="2">The research project will focus on various improvement methodologies used in the manufacturing industry, in order to determine if they have been successful and if there is a need from the industry to utilise a hybrid improvement framework. This aid the business community in understanding which improvement theory is most used, if the improvement theory has achieved the desired results, what the purpose of implementation is and why it has proven to be difficult to implement. Your participation is anonymous and only aggregated data will be reported. You can withdraw at any time without penalty. The questionnaire should not take longer than 10min to complete. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact my supervisor or me. Our details are provided below.

Researcher name
Paul Eloff

Research Supervisor
Suzanne Myburgh</td></tr>
<tr><td>1. Do you work in the manufacturing industry or support the industry either by consulting or similar?</td><td>☐ Yes
☐ No</td></tr>
<tr><td>2. Number of employees in you organisation</td><td>☐ Less than 10
☐ 10 – 50
☐ 51 – 250
☐ 251 – 500
☐ 501 – 1000
☐ More than a 1000</td></tr>
<tr><td>3. What is your position</td><td>☐ Senior manager or Head of department
☐ Middle or unit manager
☐ Junior manager
☐ Engineer
☐ Process improvement</td></tr>
</table>

4. Experience within manufacturing	☐ Less than 2 years ☐ 2 – 5 years ☐ 6 – 10 years ☐ 11 – 15 years ☐ 16 – 25 years ☐ More than 25 years
5. Which manufacturing industry do you fall in	☐ Alcoholic beverages ☐ Automotive ☐ Cereals ☐ Dairy products ☐ Electrical, Electronics or Optical products ☐ Grains and wheat ☐ Machinery and equipment ☐ Meat and fish ☐ Metal or metal fabricated products ☐ Non-alcoholic beverages ☐ Non-metallic mineral products (Cement, glass, ceramics, etc.) ☐ Oil and Gas ☐ Personal care or toiletries (Hygiene, cosmetics, etc.) Vegetables & fruit ☐ Pharmaceutical ☐ Pulp, Paper, Publishing and Printing ☐ Rubber and plastic products ☐ Textiles and textile products ☐ Tobacco ☐ Vegetables and fruit ☐ Wood and wood products
6. If "Other" was selected in question 5, please specify	☐ ________

7. Does your company have an improvement methodology, cost saving or related exercise?	☐ Yes ☐ No ☐ Unsure
8. What is your current operations or quality improvement methodology or approach?	☐ Lean manufacturing ☐ Six Sigma ☐ Lean Six Sigma ☐ Total quality management ☐ Theory of constraints ☐ No operations and/or quality improvement approach used ☐ Cost saving ☐ ISO 9001 ☐ Other
8. If you selected "Other" in question 8, please describe	☐ ______________________
9. What was the main focus area of the operations or quality improvement methodology or approach?	☐ Increase production or flow ☐ Remove problems and or reduce variability ☐ Remove or reduce bottlenecks or constraints in the system ☐ Improve revenue ☐ Improve efficiency ☐ Reduce total cost ☐ Other
10. If you selected other in question 9, please describe	☐ ______________________
11. The chosen operations, quality improvement methodology or approach as answered in question 9 achieved the desired company results	☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

12. Companies often use Theory of constraints (TOC), Six sigma and Lean manufacturing to improve their business. If you would combine these improvement methodologies, what order should they be applied? • Theory of constraints (TOC) manages constraints (Identify, exploit, subordinate, elevate, review) • Six sigma reduces variability (define, measure, analyse, improve, control) • Lean manufacturing reduces waste (identify value, identify value stream, flow, pull, perfect)	☐ TOC then Lean manufacturing then Six Sigma ☐ TOC then Six Sigma then Lean manufacturing ☐ Six Sigma then TOC then Lean manufacturing ☐ Six Sigma then Lean manufacturing then TOC ☐ Lean manufacturing then TOC then Six Sigma ☐ Lean manufacturing then Six Sigma then TOC
13. Who is responsible for implementing the improvement methodology? No names will be reported and data will be stored without identifiers	☐ Individual ☐ Specialised team ☐ All employees
14. How long has the improvement methodology been implemented	☐ Don't know ☐ 0 – 5 years ☐ 6 – 10 years ☐ 11 – 15 years ☐ More than 15 years
15. Which strategy has been the most beneficial for your company	☐ Cost savings ☐ Reduced quality errors ☐ Increased production ☐ Decreased work in progress
16. State the level of agreement as to why the improvement theory implemented at your company has been difficult:	

16.a. Lack of commitment from management	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.b. Lack of improvement methodology's technical knowledge	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.c. Lack of understanding benefits	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.d. Does not fit company's culture	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.e. Management resistance to change	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.f. Employees resistance to change	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

16.g.The improvement methodology is a gimmick	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.h. The improvement theory is not sustainable	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.i.High cost of investment	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.j.The improvement theory has failed previously	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.k.Takes up too much time	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.i.The company does not value statistical or system analysis	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

16.m.The company does not look at how process interaction and looks at them independently	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree
16.n.The company does not value data analysis and/or worker input is minimal	☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

Appendix B

Table 32

Codebook for original data

	Item	*Code*
2. Number of employees in you organisation	Less than 10	1
	10 – 50	2
	51 – 250	3
	251 – 500	4
	501 – 1000	5
	More than a 1000	6
3. What is your position	Senior manager or Head of department	1
	Middle or unit manager	2
	Junior manager	3
	Engineer	4
	Process improvement	5
4. Experience within manufacturing	Less than 2 years	1
	2- 5 years	2
	6 – 10 years	3
	11 – 15 years	4
	16 – 25 years	5
	More than 25 years	6
5. Which manufacturing industry do you fall in	Alcoholic beverages	1
	Automotive	2
	Cereals	3
	Dairy products	4

	Electrical, Electronics or Optical products	5
	Grains and wheat	6
	Machinery and equipment	7
	Meat and fish	8
	Metal or metal fabricated products	9
	Non-alcoholic beverages	10
	Non-metallic mineral products (Cement, glass, ceramics, etc.)	11
	Oil and Gas	12
	Personal care or toiletries (Hygiene, cosmetics, etc.)	13
	Pharmaceutical	14
	Pulp, Paper, Publishing and Printing	15
	Rubber and plastic products	16
	Textiles and textile products	17
	Tobacco	18
	Vegetables and fruit	19
	Wood and wood products	20
	Other: Food	21
	Other: Chemical manufacturing	22
	Other: Confectionary	23
	Other: Printing	24
	Other: Transport equipment	25
	Other: Mining equipment	26
	Other	27
	Yes	1

7. Does your company have an improvement methodology, cost saving or related exercise?	No	2
	Unsure	3
8. What is your current operations or quality improvement methodology or approach?	Lean manufacturing	1
	Lean Six Sigma	2
	Six Sigma	3
	Theory of constraints	4
	Total quality management	5
	ISO 9001	6
	Cost saving	7
	Other: WCM	8
	Other: TLS	9
	Other	10
	No operations and/or quality improvement approach used	11
9. What was the main focus area of the operations or quality improvement methodology or approach?	Improve efficiency	1
	Reduce total cost	2
	Increase production or flow	3
	Remove problems and or reduce variability	4
	Remove or reduce bottlenecks or constraints in the system	5
	Improve revenue	6
	Other	7
11. The chosen operations, quality improvement methodology or approach as answered in question 9 achieved the desired company results	Strongly agree	1
	Agree	2
	Neutral	3
	Disagree	4

	Strongly disagree	5
12. Companies often use Theory of constraints (TOC), Six sigma and Lean manufacturing to improve their business. If you would combine these improvement methodologies, what order should they be applied?	TOC then Lean manufacturing then Six Sigma	1
	Lean manufacturing then TOC then Six Sigma	2
	TOC then Six Sigma then Lean manufacturing	3
	Six Sigma then Lean manufacturing then TOC	4
	Lean manufacturing then Six Sigma then TOC	5
	Six Sigma then TOC then Lean manufacturing	6
13. Who is responsible for implementing the improvement methodology? No names will be reported and data will be stored without identifiers	Individual	1
	Specialised team	2
	All employees	3
14. How long has the improvement methodology been implemented	Don't know	1
	0 – 5 years	2
	6 – 10 years	3
	11 – 15 years	4
	More than 15 years	5
15. Which strategy has been the most beneficial for your company	Cost savings	1
	Reduced quality errors	2
	Increased production	3
	Decreased work in progress	4
	Strongly agree	1

16. State the level of agreement as to why the improvement theory implemented at your company has been difficult:	Agree	2
	Neutral	3
	Disagree	4
	Strongly disagree	5

Appendix C

Table 33

Recoded data

	Item	*Code*
Recoded Question 2. Number of employees in you organisation	500 or less	1
	More than a 500	2
Recoded Question 5. Which manufacturing industry do you fall in	Food products and beverages	1
	Automotive, electronic or optical equipment and other	2
	Machinery, transport and fabricated metal equipment or products	3
	Non-metallic mineral and chemical products	4
	Refined petroleum products, tobacco, textiles, paper, wood products and printing	5

Appendix D

Anti-image Correlation

	Q16a	Q16b	Q16c	Q16d	Q16e	Q16g	Q16h	Q16j
Q16a	.809[a]	.019	-.278	.092	-.427	.025	-.052	-.062
Q16b	.019	.855[a]	-.368	-.083	-.058	.045	-.118	.031
Q16c	-.278	-.368	.840[a]	-.109	-.018	-.028	-.032	-.015
Q16d	.092	-.083	-.109	.849[a]	-.241	-.026	.001	-.028
Q16e	-.427	-.058	-.018	-.241	.807[a]	-.146	.164	.005
Q16g	.025	.045	-.028	-.026	-.146	.794[a]	-.453	-.066
Q16h	-.052	-.118	-.032	.001	.164	-.453	.746[a]	-.236
Q16j	-.062	.031	-.015	-.028	.005	-.066	-.236	.817[a]
Q16k	.012	-.173	.059	-.047	-.022	-.151	-.136	-.254
Q16l	-.094	-.007	-.006	-.218	-.031	.073	-7.580E-5	-.001
Q16m	.007	-.140	-.087	.033	-.184	-.076	-.026	-.003
Q16n	-.063	-.055	.012	.048	.007	-.156	.016	.045

Anti-image Correlation

	Q16k	Q16l	Q16m	Q16n
Q16a	.012	-.094	.007	-.063
Q16b	-.173	-.007	-.140	-.055
Q16c	.059	-.006	-.087	.012
Q16d	-.047	-.218	.033	.048
Q16e	-.022	-.031	-.184	.007
Q16g	-.151	.073	-.076	-.156
Q16h	-.136	-7.580E-5	-.026	.016
Q16j	-.254	-.001	-.003	.045
Q16k	.841[a]	-.064	.076	-.061
Q16l	-.064	.838[a]	-.339	-.335
Q16m	.076	-.339	.867[a]	-.242
Q16n	-.061	-.335	-.242	.862[a]

a. Measures of Sampling Adequacy(MSA)

Appendix E

Correlation Matrix

		Factor1	Factor2	Factor3
Correlation	Factor1	1.000	.349	.585
	Factor2	.349	1.000	.316
	Factor3	.585	.316	1.000

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.616
Bartlett's Test of Sphericity	Approx. Chi-Square	92.625
	df	3
	Sig.	.000

Anti-image Matrices

Anti-image Correlation

	Factor1	Factor2	Factor3
Factor1	.584[a]	-.213	-.534
Factor2	-.213	.768[a]	-.148
Factor3	-.534	-.148	.590[a]

a. Measures of Sampling Adequacy(MSA)

Communalities

	Initial	Extraction
Factor1	.372	.639
Factor2	.141	.189
Factor3	.357	.536

Extraction Method: Principal Axis Factoring.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**1.847**	61.555	**61.555**	1.364	45.451	45.451
2	.740	24.665	86.221			
3	.413	13.779	100.000			

Extraction Method: Principal Axis Factoring.

Factor Matrix[a]

	Factor
	1
Factor1	.799
Factor3	.732
Factor2	.434

Extraction Method: Principal Axis Factoring.

a. 1 factors extracted. 16 iterations required.

Appendix F

Scale: Question 16 - Factor 1

Case Processing Summary

		N	%
Cases	Valid	165	100.0
	Excluded[a]	0	.0
	Total	165	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.759	.759	5

Scale: Question 16 - Factor 2

Case Processing Summary

		N	%
Cases	Valid	165	100.0
	Excluded[a]	0	.0
	Total	165	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.739	.743	4

Scale: Question 16 - Factor 3

Case Processing Summary

		N	%
Cases	Valid	165	100.0
	Excluded[a]	0	.0
	Total	165	100.0

a. Listwise deletion based on all variables in the procedure

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.803	.803	3

Appendix G

Table 34

Descriptive statistics for Question 2 recoded

	rQ2			Statistic	Std. Error
Factor1	500 or less	Mean		2.792	.091
		95% Confidence Interval for Mean	Lower Bound	2.611	
			Upper Bound	2.974	
		5% Trimmed Mean		2.777	
		Median		2.800	
		Variance		.640	
		Std. Deviation		.800	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		1.000	
		Skewness		.389	.274
		Kurtosis		.292	.541
	More than 500	Mean		2.952	.098
		95% Confidence Interval for Mean	Lower Bound	2.757	
			Upper Bound	3.148	
		5% Trimmed Mean		2.934	
		Median		2.800	
		Variance		.852	
		Std. Deviation		.923	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		1.550	
		Skewness		.265	.257
		Kurtosis		-.414	.508
Factor2	500 or less	Mean		3.597	.088
		95% Confidence Interval for Mean	Lower Bound	3.422	
			Upper Bound	3.773	
		5% Trimmed Mean		3.606	
		Median		3.750	
		Variance		.596	
		Std. Deviation		.772	
		Minimum		1.750	

rQ2				Statistic	Std. Error
		Maximum		5.000	
		Range		3.250	
		Interquartile Range		1.000	
		Skewness		-.121	.274
		Kurtosis		-.332	.541
	More than 500	Mean		3.364	.090
		95% Confidence Interval for Mean	Lower Bound	3.186	
			Upper Bound	3.542	
		5% Trimmed Mean		3.362	
		Median		3.500	
		Variance		.705	
		Std. Deviation		.840	
		Minimum		1.750	
		Maximum		5.000	
		Range		3.250	
		Interquartile Range		1.188	
		Skewness		-.104	.257
		Kurtosis		-.572	.508
Factor3	500 or less	Mean		2.948	.115
		95% Confidence Interval for Mean	Lower Bound	2.719	
			Upper Bound	3.177	
		5% Trimmed Mean		2.933	
		Median		3.000	
		Variance		1.018	
		Std. Deviation		1.009	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		1.667	
		Skewness		.282	.274
		Kurtosis		-.638	.541
	More than 500	Mean		3.015	.116
		95% Confidence Interval for Mean	Lower Bound	2.786	
			Upper Bound	3.245	
		5% Trimmed Mean		3.011	
		Median		3.000	
		Variance		1.175	
		Std. Deviation		1.084	

Appendix H

Table 35

Descriptive statistics for Question 5 recoded

	rQ5			Statistic	Std. Error
		5% Trimmed Mean		3.399	
		Median		3.250	
		Variance		.500	
		Std. Deviation		.707	
		Minimum		1.750	
		Maximum		5.000	
		Range		3.250	
		Interquartile Range		.750	
		Skewness		.196	.398
		Kurtosis		.467	.778
Factor3	Food products and beverages	Mean		3.094	.159
		95% Confidence Interval for Mean	Lower Bound	2.773	
			Upper Bound	3.415	
		5% Trimmed Mean		3.096	
		Median		3.000	
		Variance		.982	
		Std. Deviation		.991	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		1.667	
		Skewness		.122	.378
		Kurtosis		-.332	.741
	Automotive, electronic or optical equipment and other	Mean		3.075	.182
		95% Confidence Interval for Mean	Lower Bound	2.703	
			Upper Bound	3.447	
		5% Trimmed Mean		3.059	
		Median		2.667	
		Variance		1.027	
		Std. Deviation		1.014	
		Minimum		1.333	
		Maximum		5.000	
		Range		3.667	
		Interquartile Range		1.333	
		Skewness		.561	.421
		Kurtosis		-.532	.821
	Machinery, transport and fabricated metal equipment or products	Mean		2.792	.200
		95% Confidence Interval for Mean	Lower Bound	2.384	
			Upper Bound	3.200	
		5% Trimmed Mean		2.762	
		Median		2.500	
		Variance		1.281	
		Std. Deviation		1.132	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		2.000	
		Skewness		.341	.414
		Kurtosis		-1.009	.809
	Non-metallic mineral and chemical products	Mean		3.000	.229
		95% Confidence Interval for Mean	Lower Bound	2.529	
			Upper Bound	3.471	
		5% Trimmed Mean		3.006	
		Median		2.667	
		Variance		1.473	
		Std. Deviation		1.214	
		Minimum		1.000	
		Maximum		5.000	
		Range		4.000	
		Interquartile Range		2.000	

rQ5				Statistic	Std. Error
		Skewness		-.025	.441
		Kurtosis		-1.145	.858
	Refined petroleum products, tobacco, textiles, paper, wood products and printing	Mean		2.943	.159
		95% Confidence Interval for Mean	Lower Bound	2.620	
			Upper Bound	3.266	
		5% Trimmed Mean		2.910	
		Median		3.000	
		Variance		.886	
		Std. Deviation		.941	
		Minimum		1.333	
		Maximum		5.000	
		Range		3.667	
		Interquartile Range		1.333	
		Skewness		.401	.398
		Kurtosis		-.292	.778

Appendix I

Gordon Institute of Business Science
University of Pretoria

23 July 2018

Eloff Paul

Dear Paul

Please be advised that your application for Ethical Clearance has been approved.

You are therefore allowed to continue collecting your data.

Please note that approval is granted based on the methodology and research instruments provided in the application. If there is any deviation change or addition to the research method or tools, a supplementary application for approval must be obtained

We wish you everything of the best for the rest of the project.

Kind Regards

GIBS MBA Research Ethical Clearance Committee

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